I. BACKGROUND AND QUALIFICATIONS

Q: Please state your name, business name and address.

A: My name is Peter A. Erickson. I am a Senior Scientist and the Climate Policy Program Director at Stockholm Environment Institute—U.S., a 501(c)(3) organization affiliated with Tufts University and based at 11 Curtis Avenue, Somerville, Massachusetts 02144. I work out of the Seattle office at 1402 Third Avenue, Suite 925, Seattle, Washington 98101.

Q: What is your educational background?

A: I received a Bachelor of Arts from Carleton College in 1998. My major field of study was Geology; I also studied mathematics extensively. In 2007, I took courses in intermediate microeconomics and macroeconomics at the University of Washington.

Q: Can you briefly describe your professional background and expertise?

A: I have worked in environmental research and consulting for over 20 years. During the last thirteen years, my professional focus has been on greenhouse gas (GHG) emissions accounting and the role of policy mechanisms in reducing GHG emissions. Specifically, I have conducted and led research projects on these topics on behalf of numerous partners and clients, including international institutions (e.g., the United Nations Framework Convention on Climate Change, the World Bank), the U.S. government (U.S. Environmental Protection Agency), state governments (e.g., State of Washington, State of Oregon), and local governments (e.g., City of Seattle). I have authored numerous peer-reviewed studies on how policies, actions, or infrastructure projects increase or decrease greenhouse gas emissions. These include studies about the GHG emissions implications of the proposed Keystone XL pipeline,[1] of the United States government's fossil fuel leasing

[1] Erickson, P., & Lazarus, M. (2014). Impact of the Keystone XL pipeline on global oil markets and greenhouse gas emissions. *Nature Climate Change*, 4(9), 778–781. https://doi.org/10.1038/nclimate2335

practices,[2] and of federal and state-level subsidies to US oil and gas production.[3] These and other projects are documented in my Curriculum Vitae, attached as Exhibit ELP-1 (PAE-1). In addition, I am an invited reviewer to the GHG emission reduction chapters in Working Group III of the Intergovernmental Panel on Climate Change's (IPCC) upcoming *Sixth Assessment Report.*

Q: Have you ever testified in front of the Michigan Public Service Commission?

A: No. Case No. U-20763 is my first time testifying in front of the Michigan Public Service Commission.

Q: Have you testified in other jurisdictions?

A: Yes. I have testified in front of the United States House Committee on Oversight and Reform, Subcommittee on Environment, on the topic of greenhouse gas emissions. I have also testified in front of the Pollution Control Hearings Board for The State of Washington on that topic.[4] I have submitted expert testimony to the United States District Court, District of Oregon,[5] and to the Shoreline Hearings Board for the State of Washington[6] regarding estimates of greenhouse gas emissions. I submitted an expert letter to the District Court of the Hague, Netherlands, regarding methods of estimating greenhouse gas emissions.[7] My

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[2] Erickson, P., & Lazarus, M. (2018). Would constraining US fossil fuel production affect global CO2 emissions? A case study of US leasing policy. *Climatic Change*, 150, 29–42. https://doi.org/10.1007/s10584-018-2152-z

[3] Achakulwisut, P., Erickson, P., & Koplow, D. (2021). Effect of subsidies and regulatory exemptions on 2020-2030 oil and gas production and profits in the United States. *Environmental Research Letters*.

[4] Advocates for a Cleaner Tacoma *et al. v.* Puget Sound Clean Air Agency, Puget Sound Energy. Pollution Control Hearings Board for the State of Washington. PCHB No. P19-087c.

[5] *Juliana et al. v. United States*, United States District Court, District of Oregon. Case No. 6:15-cv-01517-TC.

[6] Columbia Riverkeeper *et al. v.* Cowlitz County *et al.* Shoreline Hearings Board for the State of Washington. SHB No. 17-010c.

[7] At the request of the plaintiffs, I submitted a letter to the District Court of the Hague in *Vereniging Milieudefensie et al. v. Royal Dutch Shell* (Case Number C/09/571932 / HA ZA 19-379) regarding methods of estimating greenhouse gas emissions associated with oil production. The letter is available at: https://www.sei.org/publications/climate-case-shell-sei-letter-court/

work on estimating greenhouse gas emissions has been directly cited by the United States Court of Appeals for the Ninth Circuit[8] and by the United States District Court of Alaska.[9]

Q: On whose behalf are you submitting this testimony?

A: I am submitting this testimony on behalf of the Environmental Law & Policy Center and the Michigan Climate Action Network.

Q: Are you sponsoring any exhibits?

A: Yes. I am sponsoring the following exhibits:

- ELP-1 (PAE-1) – Curriculum Vitae of Peter A. Erickson
- ELP-2 (PAE-2) – IPCC (2021), Summary for Policymakers. *In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*
- ELP-3 (PAE-3) – Angel, J. R., et al (2018). *Chapter 21: Midwest. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program
- ELP-4 (PAE-4) – Burger and Wentz (2019), "*Evaluating the Effects of Fossil Fuel Supply Projects on Greenhouse Gas Emissions and Climate Change under NEPA*"
- ELP-5 (PAE-5) –Heyes et al (2018), "*The Economics of Canadian Oil Sands*"
- ELP-6 (PAE-6) – Erickson et al (2014), "*Impact of the Keystone XL pipeline on global oil markets and greenhouse gas emissions*"

[8] *Ctr. for Biological Diversity v. Bernhardt*, 982 F.3d 723, 738 (9th Cir. 2020).
[9] Sovereign Inupiat for a Living Arctic v. Bureau of Land Mgmt., No. 3:20-CV-00290-SLG, 2021 WL 3667986, at *20 n. 201 (D. Alaska Aug. 18, 2021)).

- ELP-7 (PAE-7) –Achakulwisut, Erickson, and Koplow (2021), "Effect of subsidies and regulatory exemptions on 2020–2030 oil and gas production and profits in the United States"

Q: What materials did you review in preparing this testimony?

A: I reviewed relevant portions of Enbridge's application and testimony, Enbridge and Commission reports and websites, discovery responses from Enbridge, and other party responses to requests for discovery from Enbridge. I also reviewed and relied upon a variety of scientific and economic journal articles, reports, and other literature, and publicly available data and analysis in forming my opinions. Where I explicitly rely upon a source in forming my opinion, I cite to it in my testimony.

II. OVERVIEW OF TESTIMONY

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to estimate, quantify, and explain the level of greenhouse gas emissions associated with Enbridge's Proposed Project. This will include both the greenhouse gas emissions resulting from the construction and operation of the Proposed Project, as well as the greenhouse gases contained in or associated with the oil and natural gas liquids ("NGL") fuel carried by the pipeline. I will also estimate the change in global greenhouse gas emissions that would arise as a consequence of the Proposed Project, as measured relative to a no-action scenario, where Enbridge discontinues use of the existing pipeline in the Straits of Mackinac, but does not construct the Proposed Project. This latter approach evaluates likely differences in global oil supply and consumption when comparing the no-action scenario to the Proposed Project being built.

Q: Please describe the project for which Enbridge seeks approval.

A: Enbridge Energy, Limited Partnership ("Enbridge") currently operates an oil pipeline called Line 5, which transports oil and Natural Gas Liquids ("NGL") from western Canada to eastern Canada. A portion of Line 5 currently consists of two 20-inch diameter pipelines that run through the Straits of Mackinac in Michigan. In this case, Enbridge is seeking approval to build an underground tunnel, and to replace and relocate into that tunnel the portion of the Line 5 petroleum pipeline that currently sits on the bottom of the Straits (the "Proposed Project").

Q: What methods did you use to estimate the greenhouse gas emissions associated with the Proposed Project?

A: I use standard greenhouse gas emissions accounting practices, consistent with those laid out in guidance by the Greenhouse Gas Protocol initiative,[10] and report my results in standard units of millions of metric tons of carbon-dioxide equivalent (CO_2e). In brief, with respect to the construction of the Proposed Project, these methods involve estimating what activities occur in association with the Proposed Project (for example, the use of a machine to bore the tunnel under the Straits of Mackinac), how much energy is used by each activity (for example, how much electricity is used by the tunnel-boring machine), and how much greenhouse gas emissions are associated with each unit of energy (for example, how much carbon dioxide is released by the power plants that make the electricity for the tunnel-boring machine). I use similar methods to estimate the greenhouse gas emissions associated with the operation of the Proposed Project, and also when estimating the greenhouse gas

[10] For example, the GHG Protocol's *Corporate Accounting and Reporting Standard*, their *Project Accounting* standard, and their *Policy and Action Standard* lay out methods for estimating GHG emissions associated with specific projects, including procedures for assessing emissions relative to a counterfactual, no-action baseline.

emissions associated with the oil and NGL that will be transported through the Proposed Project after completion.

Q: Are these methods commonly used by experts when estimating greenhouse gas emissions from oil pipelines?

A: Yes. My methods are consistent with those used in other greenhouse gas assessments of oil pipelines, such as the Keystone XL pipeline, and indeed I check my work against those other estimates, as well as against the peer-reviewed, scientific literature and against standards for life-cycle assessment (LCA) and oil market analysis. All data sources I rely upon directly are cited here in this document.

Q: Can you summarize your conclusions?

A: I reach three main conclusions that I describe in my testimony.

- First, I estimate that the Proposed Project is associated with about 87 million metric tons carbon-dioxide equivalent (CO_2e) annually.
- Second, I conclude that, when compared to a scenario in which the existing Line 5 pipeline no longer operates, construction and operation of the Proposed Project would lead to an *increase* of about 27 million metric tons CO_2e annually in global greenhouse gas emissions from the production and combustion of oil.
- Third, by enabling the continued, long-term production and combustion of oil, construction of the project would work against, and therefore be inconsistent with, the goals of the global Paris Agreement and Michigan's Healthy Climate Plan.

Q: Does your analysis include an estimate of the greenhouse gas emissions from the existing dual pipelines Enbridge operates in the Straits of Mackinac?

A: No. I am aware that the Governor of Michigan and the Director of the Michigan Department of Natural Resources notified Enbridge on November 13, 2020, that the state revoked and terminated the 1953 Easement which allows Line 5 to operate in the Straits. My understanding is that this revocation and termination would require Line 5 to discontinue operation. However, I also discuss below why it is appropriate to consider a "no-action" scenario even in the absence of the Governor's actions. As a result, my analysis includes a scenario where I assume that if the Proposed Project is not completed, Line 5 will no longer operate.

III. OVERVIEW OF CLIMATE CHANGE AND THE NEED FOR GREENHOUSE GAS EMISSIONS CUTS

Q: How does the current understanding about the effects of climate change inform your discussion of GHG emissions and Enbridge's Proposed Project?

A: To provide some context, here I first provide some basic information about the state of climate science and the need for rapid and steep cuts in GHG emissions over the coming decades. Around the world, with just 1.1 degree Celsius (C) of warming experienced to date, we are already seeing serious harms that include increasing flooding, wildfires, droughts, heat waves, expanded impacts of pests and pathogens, and other effects. As addressed in more detail by other testifying experts in this case, these types of events are all plausibly linked to climate change.[11] For example, three "five-hundred year" floods occurred in Houston, Texas in just three years, with one storm – Hurricane Harvey –

[11] For an additional summary of these effects, see: Holdren, J. P. (2018, September). The Science & Policy of Climate Change: An Update on the Challenge and the Opportunity. Presented at the Low-emissions Solutions Conference, San Francisco, CA. (https://lowemissions.solutions/static/uploads/180911_GCAS_Holdren.pdf)

producing rainfall that "likely exceeded that of any known historical storm in the continental United States."[12] In many areas of the world and the country, increasing summer temperatures are already making working outdoors dangerous. A scientific review of the effects of climate change on health has concluded, "[t]he life of every child born today will be profoundly affected by climate change. Without accelerated intervention, this new era will come to define the health of people at every stage of their lives."[13] In the new, most recent assessment of the science behind climate change, the Intergovernmental Panel on Climate Change described the observed rate of climate change as both "unprecedented" and "unequivocally" caused by human activities.[14]

Q: Are there similar impacts as a result of climate change in the Midwest region or Michigan in particular?

A: In the Midwest of the United States, climate change will lead to increased temperatures and precipitation that will reduce agricultural productivity, erode soils, and lead to pest outbreaks, while also leading to poor air quality, substantial loss of life, and worsening economic conditions for people.[15]

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[12] Hayhoe, K., Wuebbles, D. J., Easterling, D. R., Fahey, D. W., Doherty, S., Kossin, J. P., … Wehner, M. F. (2018). Chapter 2: Our Changing Climate. *Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*.

[13] Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Boykoff, M., … Montgomery, H. (2019). The 2019 report of The Lancet Countdown on health and climate change: Ensuring that the health of a child born today is not defined by a changing climate. *The Lancet*. https://doi.org/10.1016/S0140-6736(19)32596-6

[14] IPCC. (2021). Summary for Policymakers, attached as Exhibit ELP-2 (PAE-2). *In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

[15] Angel, J. R., Swanson, C., Boustead, B. M., Conlon, K., Hall, K. R., Jorns, J. L., Kunkel, K. E., Lemos, M. C., Lofgren, B. M., Ontl, T., Posey, J., Stone, K., Takle, E., & Todey, D. (2018). Chapter 21: Midwest. Impacts, Risks, and Adaptation in the United States: *The Fourth National Climate Assessment, Volume II.* U.S. Global Change Research Program, attached as Exhibit ELP-3 (PAE-3). https://doi.org/10.7930/NCA4.2018.CH21

Q: Do GHG emissions need to be reduced to limit the impacts of climate change?

A: Yes. GHG emissions need to be substantially reduced to limit the impacts of climate change. For example, the U.S. Government's *Fourth National Climate Assessment* describes, consistent with the findings of the international scientific community, that climate risks can only be adequately addressed with "substantial and sustained reductions in global greenhouse gas emissions."[16] As the report notes, "[f]uture risks from climate change depend primarily on decisions made today."[17]

More broadly, guidance on how quickly GHG emissions need to be reduced can be found in international agreements such as the United Nations Framework Convention on Climate Change (UNFCCC), through which nations have been working collectively to address the risks of climate change throughout the world. The most recent landmark agreement of countries that are party to the UNFCCC, including the United States, is the Paris Agreement of 2015. The Paris Agreement commits countries to "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels." In adopting the Paris Agreement, countries also asked the Intergovernmental Panel on Climate Change (IPCC) to produce a report on what emissions levels would be needed to achieve the 1.5 °C limit.[18]

[16] Reidmiller, D. R., Avery, C. W., Easterling, D. R., Kunkel, K. E., Lewis, K. L. M., Maycock, T. K., & Stewart, B. C. (2018). *Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II.* U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018. Page 25.
[17] *Ibid*, page 26.
[18] UNFCCC. (2015). Decision 1/CP.21: Adoption of the Paris Agreement. Retrieved from United Nations Framework Convention on Climate Change website: http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf

Q: What level of reductions did the IPCC conclude would be necessary to achieve the 1.5 °C limit?

A: The IPCC, in its special report, *Global Warming of 1.5 °C,* describes that net global carbon dioxide (CO_2) emissions must reach zero to halt warming, and specifically that emissions levels must reach zero by about the year 2050 in order to meet the 1.5 °C with no or "limited" overshoot (exceedance) of the temperature limit. Even *if* other means of removing CO_2 are developed and applied at large scale, the IPCC found that, between 2020 and 2050, gross global CO_2 emissions from fossil fuel combustion and industry would need to decline by about 70%.[19] These findings were broadly re-affirmed by the IPCC in its recent report *Climate Change 2021: The Physical Science Basis*, even as their new report on GHG emission reduction scenarios is not due until early 2022.[20]

Q: How must fossil-fuel based energy systems change to meet the 1.5 °C limit?

A: Use and production of all three major fossil fuels – coal, gas, and oil – must decline dramatically to meet the 1.5 °C limit. Over the next three decades (through 2050), the IPCC finds that, to attain the 1.5 °C limit with no or limited temperature overshoot, coal use must decline by an average of 6% annually (for a total of 82% between 2020 and 2050), gas use by an average of 2% annually (for a total of 43%), and oil use by an average of 3% annually (for a total of 65%).[21] Further, one of the longstanding principles of the international negotiations, termed "common but differentiated responsibilities," is that reductions in the U.S. and other highly developed countries must proceed faster than these global averages,

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[19] Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., … Vilariño, M. V. (2018). *Mitigation pathways compatible with 1.5°C in the context of sustainable development. In Special Report on the impacts of global warming of 1.5 °C.* Retrieved from http://www.ipcc.ch/report/sr15/ Figure 2.6, page 117 and Table 2.4, page 119.

[20] IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

[21] Rogelj et al 2018, Table 2.6, page 132.

on account of our historic responsibility for climate change and our relatively high capacity to financially support solutions.

IV. GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE PROPOSED PROJECT

Q: Are there GHG emissions associated with the Proposed Project?

A: Yes. For the Proposed Project, Enbridge would build a tunnel and replace and relocate into that tunnel the portion of the Line 5 petroleum pipeline that currently sits on the bottom of the Straits of Mackinac. There are two main ways in which the Proposed Project will result in GHG emissions. First, GHG emissions will be released by the equipment used to build and operate the tunnel. Second, the Proposed Project will handle and transport petroleum that, once combusted, releases even greater quantities of GHG emissions than from Project construction or operation.

Q: Let's take those two sources of GHG emissions in turn. First, what is your estimate of the GHG emissions associated with the construction and operation of the pipeline for this Proposed Project?

A: I estimate the GHG emissions associated with construction of the pipeline to be about 87,000 metric tons carbon dioxide equivalent (CO_2e). I estimate that operation of the pipeline will result in about 520 metric tons CO_2e annually.

Q: What is CO_2e?

A: Emissions from different greenhouse gases, each of which causes different amounts of warming, are often combined into a single metric of CO_2 *equivalent* by using the concept of global warming potential (GWP). For example, a ton of methane causes many times more warming than a ton of carbon dioxide, and this ratio is called the GWP of methane. In the IPCC's latest *Sixth Assessment Report*, the GWP of fossil methane is reported as

29.8 over a 100-year timeframe. One metric ton of methane is therefore 29.8 metric tons CO_2*e* over 100 years according to the IPCC. Throughout my testimony, I focus my own calculations mainly on CO_2; in making these calculations, I include other, non-CO_2 GHGs like methane (CH_4) indirectly and only to the extent that they were calculated by primary sources, such as by the US EPA's eGrid tool (on a CO_2e basis, and inheriting any GWP assumptions made by each primary source). Further, any time I refer to a ton, I mean a metric ton unless stated otherwise, and which I may occasionally abbreviate as just the letter *t*.

Q: How did you arrive at 87,000 metric tons CO_2e as an estimate of the GHG emissions from construction of the Proposed Project?

A: I used standard GHG accounting practices to arrive at this estimate, using information provided by Enbridge and basic facts about the Proposed Project, and by relying on other published information about how much energy is used to carry out the proposed activities.

First, descriptions of the main activities and materials needed to construct the pipeline are readily available in project documents, e.g. the *Tunnel Design and Construction Report* dated December 23, 2020 (Exhibit A-13) and other documents provided by Enbridge. These activities include the use of a tunnel-boring machine, operation of other construction equipment, and the making and installation of key construction materials, including steel and concrete.

Second, I used published estimates about similar equipment, machinery, and materials to estimate how much energy is used for each activity.

Third, to complete the picture, I gathered basic data about how much GHG emissions are released from each unit of activity or energy.

Q: Is this typical of the methodology employed by experts in your field?

A: Yes. Together, these three steps – and their underlying data and assumptions – are, in my opinion, reasonable and consistent with assumptions in major government GHG inventories and assessments, such as the U.S. EPA's national GHG inventory and the US State Department's assessment of the Keystone XL pipeline.

Q: Can you summarize your estimates?

A: Yes. My estimates of the GHG emissions from the activities and materials needed to construct the Proposed Project are shown in Table 1 below. As shown, I estimate the total GHG emissions associated with construction to be about 87,000 metric tons carbon dioxide equivalent (CO_2e).

TABLE 1. EMISSIONS ASSOCIATED WITH CONSTRUCTION OF THE PROJECT

Source of construction-related emissions	**Emissions (metric tons CO_2e)[22]**	**Method notes and assumptions**
Equipment: tunnel boring machine (TBM) and related tunneling equipment (using electricity)	56,000	Based on electricity consumption during construction estimated by Enbridge for south side of the Straits
Equipment: other (electricity)	2,300	Based on electricity consumption during construction estimated by Enbridge for north side of the Straits
Equipment: other vehicles (diesel)	5,100	Includes excavators, grading equipment, loaders, dump trucks, and other vehicles
Materials: concrete for tunnel liner and roadway	19,000	Based on estimated cement content of Enbridge's estimated concrete usage
Materials: steel for pipeline	3,300	Based on 0.625-inch thick steel, 30-inch outer diameter pipeline, and average CO_2-intensity of US steel
Land-clearing	570	Estimated by Enbridge[23]
Estimated total construction emissions	**87,000**	(Individual figures may not add to total due to rounding)[22]

The estimate in Table 1 includes what I see as the major sources of emissions associated with project construction, but does not include several much-smaller sources of emissions associated with constructing the tunnel, such as for making the steel for electrical conduit

[22] All estimates here are rounded to two significant digits. As a result, the individual figures may not add to the total due to rounding.
[23] Enbridge Response to Michigan Public Service Commission Staff Discovery Request 6(8).

or rebar, or for making the grout that will occupy the annular space surrounding the concrete tunnel liner. Accordingly, I believe my estimate is conservative.

Q: Table 1 lists detailed assumptions about each major source of construction-related emissions. Can you describe these assumptions for the equipment used to construct the tunnel?

A: Yes. First, I assume that the tunnel excavator will, like other tunnel-boring machines, be operated using electricity. Enbridge has estimated the electricity usage during construction at the south terminus of the tunnel, where the tunnel boring machine (TBM) will be based, to be 66,184 megawatt-hours (MWh), and so I use this figure for the electricity used by the TBM and other, minor uses based at the south terminus. I then estimate the GHG emissions associated with each unit of electricity, using data specific to the Straits of Mackinac region from the US EPA, to be 0.851 metric tons of CO_2e per MWh of non-baseload electricity consumed; that figure is for electricity from the RFC Michigan eGrid regions, as derived from the US EPA's eGrid tool.[24]

Q: What assumptions did you use for the other equipment?

A: For equipment other than the tunnel-boring machine, such as other electric equipment at the north side of the Straits, and for loaders and dump trucks, my approach is similar. For electricity usage, I use estimates provided by Enbridge. For vehicles, I use published estimates about how much energy (here, diesel) was used for this kind of equipment from another, similar project, and then use data from the U.S. EPA about how much GHG emissions are released by combusting each unit of diesel.

[24] https://www.epa.gov/egrid/summary-data. A metric ton is 1,000 kilograms.

Q: What specific assumptions and calculations did you make about this other equipment?

A: I use an electricity estimate from Enbridge[25] for the north side to characterize other electrical equipment. For off- and on-road vehicles, such as loaders and grading equipment, used to excavate and grade material, I use an estimate of energy consumption of 0.25 million btu per cubic meter (mmbtu / m^3) for such equipment, based on another recent tunnel boring project (Parsons Brinckerhoff, 2011)[26] and apply that estimate to the 272,000 cubic meters of material I anticipate will be excavated for the Proposed Project (a 24.5-foot diameter bore for 20,350 feet, based on Enbridge's tunnel design documents[27]). I assume that energy for these vehicles is mostly diesel, with resulting CO_2 emissions of 74 kg CO_2 / mmbtu per Annex 2 of US EPA's national inventory (U.S. EPA, 2021).[28]

Q: Table 1 also lists detailed assumptions about the materials used to construct the tunnel. Can you describe these?

A: Yes. The two major materials used to construct the Proposed Project are concrete (for the tunnel lining and interior roadway) and steel (for the pipeline itself). Each of these materials is GHG-emissions-intensive to manufacture.

Q: How does the production and use of concrete result in GHG emissions?

A: For concrete, the main source of GHG emissions is CO_2 from making cement, which is the binding agent in concrete. Making cement relies on a substantial amount of heat, usually

[25] Enbridge Response to Michigan Public Service Commission Staff Discovery Request 6(9).
[26] Parsons Brinckerhoff. (2011). *Alaskan Way Viaduct Replacement Project: Final Environmental Impact Statement*. https://data.wsdot.wa.gov/publications/Viaduct/
[27] The 24.5 foot diameter bore assumes an inside tunnel diameter of 21 feet, a tunnel wall thickness of 15 inches, and an extra 6 inches of bore space around the outside, all of which were published in Enbridge's *Tunnel Design and Construction Report for the Straits Line 5 Replacement Segment*. December 23, 2020, Exhibit A-13.
[28] US EPA (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/).

from burning coal or natural gas, and also relies on a chemical reaction, involving lime, which releases CO_2 directly. I use information provided by Enbridge to estimate how much cement is needed, and then information from an industry group – the Global Cement and Concrete Association – to estimate that making each ton of US-made cement releases 0.75 tons CO_2.

Q: What specific assumptions and calculations did you make about concrete used in the Proposed Project?

A: Enbridge's report "Tunnel Design and Construction Report for the Straits Line 5 Replacement Segment," dated December 23, 2020 (Exhibit A-13), reports the tunnel length at 20,350 feet, the tunnel inside diameter of 21 feet, and the tunnel wall thickness of 15 inches. This information implies a volume of concrete of about 66,000 cubic yards. This is very similar to the value reported by Enbridge[29] that 65,330 tons of reinforced concrete will be needed. Because the numbers are so close, I rely here on the 65,330 tons reported by Enbridge. Further, additional project specifications report an average cement content of about 800 pounds of cementitious materials per cubic yard of concrete.[30] Together, this implies the need for about 24,000 tons of cement for the tunnel walls. Additional cement would be needed for the roadway inside the tunnel; I calculate that separately.

Q: How does the production and use of steel result in GHG emissions?

A: For steel, similarly, emissions are released both from making heat (e.g., from burning coal or other fossil fuels) and from chemical reactions inherent in the steel-making process.

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[29] Enbridge Response to Environmental Law & Policy Center and Michigan Climate Action Network Discovery Request 1.

[30] "Cementitious" materials are primarily cement, but may include amounts of cement alternatives, such as fly ash. I calculated the 800 figure as the average of minimum 611 and maximum 1000 pounds of cementitious material per cubic yard, per page 317416 – 17 of the precast concrete tunnel specs in the following document: https://www.michigan.gov/documents/mdot/Enbridge_Submittal_-_Jointly_Developed_Project_Specs_715739_7.pdf).

Similar to my methodology for cement, I estimate the quantity and type of steel needed to make the pipeline that is part of the Project based on information provided by Enbridge and the GHG emissions associated with each unit of US-made steel provided by a research study.

Q: What specific assumptions and calculations did you make about steel used in the Proposed Project?

A: Information provided by Enbridge (Exhibit A-14), provides specifications for the steel pipeline, including the outside diameter of 30 inches and the wall thickness of 0.625. From this and the 20,350 ft length, I estimated the need for about 14 million cubic inches of steel. API 5L steel has a density of about 0.28 pounds per cubic inch (calculated from Table 4 of the American Petroleum Institute's *Specification for Line Pipe*),[31] implying the need for about 2,000 short tons of steel, or 1,800 metric tons. The average CO_2-intensity of blast-furnace steel in the U.S. is 1.83 t CO_2 / t of crude steel.[32] I use the GHG-emissions intensity of blast-furnace steel, not electric-arc steel, because the quantity of steel made by electric arc furnaces is constrained by how much scrap steel is available, so it is more plausible that the marginal source of steel is instead from blast furnaces.

Q: Are there also GHG emissions associated with the operation of the Proposed Project?

A: Yes. After the Proposed Project is constructed, there are GHG emissions associated with operating the tunnel, such as electricity to operate lighting and ventilation systems, and the electric service vehicles that would travel inside the tunnel. I estimate that GHG emissions associated with operating the tunnel itself would be approximately 520 metric tons CO_2e

[31] Available at https://law.resource.org/pub/us/cfr/ibr/002/api.5l.2004.pdf.

[32] See Figure 16 of Hasanbeigi, A., & Springer, C. (2019). How Clean is the US Steel Industry? An International Benchmarking of Energy and CO_2 intensities. Global Efficiency Intelligence.

annually. This does not include any emissions associated with operating the existing Line 5 Mackinaw City Pump Station.

Q: Can you explain how you arrived at the 520 metric tons CO2e annually associated with the operation of the Proposed Project?

A: Ongoing operation of the Proposed Project will involve energy and associated greenhouse gas emissions for the tunnel's ventilation fans, for the sump pump inside the tunnel, for the tunnel service vehicle that operates inside the tunnel, and for lighting, all for many years into the future. Based on electricity usage for these items at other similar tunnels, I estimate that GHG emissions associated with operating the tunnel would be approximately 520 metric tons CO_2e annually. More specifically, I estimate the tunnel itself would use about 600 megawatt-hours (MWh) of electricity per year,[33] which is a conservative estimate compared to confidential information provided by Enbridge in discovery and not cited here. At the US EPA's reported GHG-intensity of electricity in the Straits of Mackinac region of 0.87 tons CO_2e/MWh,[34] 600 MWh of electricity consumption translates into about 520 t CO_2e.

Q: Now that you have discussed estimated GHG emissions from construction and operation of the project, let's turn to the second source of GHG emissions you referenced above. Are there GHG emissions associated with the oil and NGL products that will be shipped through the Proposed Project?

[33] Based on average annual electricity consumption of 193 kWh/m for TBM tunnel types (Peeling, J., Wayman, M., Mocanu, I., Nitsche, P., Rands, J., & Potter, J. (2016). Energy Efficient Tunnel Solutions. Transportation Research Procedia, 14, 1472–1481. https://doi.org/10.1016/j.trpro.2016.05.221), discounted by 50% for lighting electricity since the Proposed Project would not normally be lit.

[34] This is the average GHG intensity for electricity consumed from the RFC Michigan and RFC West regions, which each border the Straits, in EPA's eGrid tool.

A: Yes, there are GHG emissions associated with the oil and NGL that will be transported using the pipeline contained in Enbridge's Proposed Project. I estimate that the GHG emissions associated with the crude oil and NGLs handled by the Proposed Project will be 87,000,000 metric tons CO_2e annually.

Q: Please explain how you arrived at 87,000,000 metric tons CO_2e annually.

A: The Proposed Project will also be associated with greenhouse gas emissions from the petroleum (oil and NGL) handled by the project. The Proposed Project is expected to handle 540,000 barrels per day (b/d) of liquid, comprising about 450,000 b/d of crude oil, and 90,000 b/d of natural gas liquids,[35] chiefly propane and butane,[36] again all for many years into the future. GHG emissions are released at each stage of producing, processing, and combusting petroleum, and so I estimate the total emissions by splitting the "life cycle" of a barrel of crude oil or NGL into stages, which are typically referred to in this type of analysis as the "upstream" and "downstream" stages.

Q: What are the upstream stages?

A: Here, I use the term *upstream* to refer to all stages that happen before, or upstream, of final combustion. So, *upstream* refers to the initial extraction and processing of petroleum, such as the operation of oil wells and any other equipment needed to process or handle the oil, as well as for oil refining (oil refining is sometimes considered *midstream*, but for my purposes here I will include it under upstream).

[35] Liquid volumes carried by the pipeline are taken from page 2-2 of Dynamic Risk Assessment Systems. (2017). *Alternatives Analysis for the Straits Pipelines.*

[36] I estimate the propane and butane fractions based on Muse Stancil. (2019). Review of the Report "Assessment of Alternative Methods of Supplying Propane to Michigan in the Absence of Line 5" for Enbridge, provided by Enbridge in response to Michigan Environmental Council, Grand Traverse Band of Ottawa and Chippewa Indians, Tip of the Mitt Watershed Council, and National Wildlife Federation Discovery Request 21.

Q: How do you estimate GHG emissions from the upstream stages?

A: For the upstream stages, I rely on research that estimated how much emissions are released for production and processing of petroleum from Western Canada and the Bakken formation in North Dakota and Montana in the United States, since these regions would be the source of the petroleum carried by the pipeline.

Q: What do you conclude about GHG emissions from upstream stages based on your review of available literature?

A: According to research by Stanford University and colleagues for the Oil-Climate Index, producing light oil from these formations in Western Canada and North Dakota releases about 55 kg CO_2e per barrel. Refining them releases an additional 18 kg CO_2e per barrel. I calculate these numbers as the average of the flare and no-flare case for the US Bakken formation in the Oil-Climate Index (Oil Climate Index, 2016).[37]

Q: **What is the downstream stage?**

A: By downstream, I mean combustion at point of end use.

Q: How do you estimate emissions from the downstream stage?

A: For the downstream stage I estimate emissions based on how much carbon is contained in a barrel of crude oil. According to the United States Environmental Protection Agency, a barrel of crude oil (or its derivatives) releases an average of 432 kg CO_2 once combusted.[38] A barrel of propane and butane releases 236 and 282 kg CO_2, respectively. These figures are derived from combining energy content (mmbtu/barrel) from Tables A-39 and A-41

[37] Oil Climate Index Webtool—Phase II. Carnegie Endowment for International Peace. http://oci.carnegieendowment.org/#total-emissions).

[38] This value of 432 kg CO_2 per barrel from the US EPA is nearly identical to the value of 429 kg CO_2e produced by the Oil-Climate index for Bakken oil. I use the EPA value since the EPA also provides values for propane and butane, and so I can use a consistent source for the largest (combustion) source of emissions across all three liquids.

and carbon contents (t C / mmbtu) from Table A-29 of Annex 2 of the US EPA's national GHG inventory (U.S. EPA, 2021).[39]

Q: What do you do next?

A: The last step in quantifying the emissions associated with petroleum handled by the Project is to estimate what, if any, of the petroleum handled would not ultimately be combusted or otherwise oxidized to CO_2, and for which the emission factors above would therefore not apply. I estimate that 8% of the petroleum handled would ultimately not be combusted or otherwise be oxidized, since it would end up underground as long-term storage, e.g. as plastics buried in landfills that no longer release CO_2. Accordingly, I reduce the per-barrel emissions estimates listed above for the "downstream" stage by 8%.

Q: What do you base that assumed reduction on?

A: I base it on a peer-reviewed study that is the most detailed assessment I am aware of that investigates what fraction of North American oil production is not ultimately combusted.[40] That article evaluates what fraction of oil is used for non-energy uses such as petrochemicals, lubricants, and other industrial uses, as well as what fraction of these otherwise "non-energy uses" are indeed ultimately combusted, such as when plastics are burned at waste-to-energy plants or tires are burned at cement kilns, and concludes that 8.02% of petroleum liquids end up as net carbon storage.

Q: What is the end result of this process?

[39] U.S. EPA. (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/).

[40] Heede, R. Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. *Climatic Change* **122,** 229–241 (2014). https://doi.org/10.1007/s10584-013-0986-y

A: In total, using the individual assumptions above, I estimate that the GHG emissions associated with the crude oil and NGLs handled by the Proposed Project will be 87,000,000 metric tons of CO_2e annually.

Q: Based on your analysis in this testimony, do you have any observations about the GHG emissions associated with the construction and operation of the Proposed Project as compared to the GHG emissions linked to the crude oil and NGL?

A: Yes. These emissions associated with the crude oil and NGLs handled by the Proposed Project are much larger than emissions associated with constructing and operating the Proposed Project itself. The following table compares all emissions using a common unit of time: one year. To do this, I amortize the emissions associated with construction over the planned 99-year life of the pipeline. I chose a 99-year amortization period because Enbridge refers to a design life of "no less than 99 years" for the tunnel (*Tunnel Design and Construction Report,* page 5).

TABLE 2. SUMMARY OF GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE PROPOSED PROJECT

GHG emissions category	**Average annual emissions (metric tons CO_2e)**	**Notes**
Tunnel construction	870	Amortized over 99 year lifetime
Tunnel operation	520	
Liquids (crude oil and NGL) handled	87,000,000	

V. INCREMENTAL GREENHOUSE GAS (GHG) EMISSIONS CAUSED BY THE PROPOSED PROJECT

Q: Have you estimated the GHG emissions associated with the Proposed Project in any other way?

A: Yes. I also estimated the incremental GHG emissions associated with the Project relative to a no-action scenario.

Q: What is a "no-action" scenario?

A: A no-action scenario is a scenario in which the Proposed Project does not go forward. In light of the Governor's actions, described above, if the Proposed Project does not go forward, Line 5 will no longer operate.

Q: Does your analysis depend on the Governor's actions being upheld in the courts?

A: No. Even if the Governor had not revoked the 1953 Easement, it still would make sense to consider a "no-action" scenario. Enbridge's stated purpose for the Proposed Project is to remove an environmental threat to the Straits of Mackinac caused by the location of the existing pipeline. Irrespective of the Governor's actions, it would be appropriate to consider whether Enbridge could achieve its stated purpose by shutting down the existing pipeline without constructing the Proposed Project.

Q: What are "incremental" GHG emissions, and how are they different from your analysis above?

A: My estimates of GHG emissions above included the major, "gross" sources of GHG emissions reasonably *attributable* to the Proposed Project. A different way of looking at the GHG emissions is instead to estimate what emissions are caused by, or a consequence of, the Project – what could be termed the "net" or "incremental" emissions. This type of estimate relies on assessing how GHG emissions would change with the Proposed Project, compared to a no-action scenario where the Project does not go forward. This *consequential* view can therefore be useful for decision-makers interested in how any given project, such as the Proposed Project, will incrementally increase GHG emissions.

Q: Why are consequential emissions different from those attributable to the Proposed Project?

A: Because if the Proposed Project were not built, some of the GHG emissions I estimated above would still occur. Some of the oil and NGL products that would have been transported through the Proposed Project would still be transported by other methods, and still consumed. However, for the reasons I explain below, fewer oil and NGL products would be transported and consumed if the Proposed Project were not built, resulting in lower overall GHG emissions.

Q: Is this a common approach in the field of estimating greenhouse gas emissions?

A: Yes. Estimating incremental GHG emissions is a common feature of many GHG emissions estimation methods, including those discussed in the GHG Protocol's *Policy and Action Standard* and those reviewed in Burger and Wentz (2020), "Evaluating the Effects of Fossil Fuel Supply Projects on Greenhouse Gas Emissions and Climate Change under NEPA". The approach here is sometimes termed a *consequential* life-cycle assessment, whereas the approach in the prior section is sometimes termed an *attributional* life-cycle assessment. These terms and approaches are a common methodology used in the field of life cycle assessment, and are discussed in peer-reviewed papers often relied upon in my field, such as Brander, M., & Ascui, F. (2015).[41]

[41] The Attributional-Consequential Distinction and Its Applicability to Corporate Carbon Accounting. In *Corporate Carbon and Climate Accounting* (pp. 99–120). Springer, Cham. https://doi.org/10.1007/978-3-319-27718-9_5

Q: What do you estimate incremental GHG emissions to be?

A: Below I estimate the incremental GHG emissions associated with the Project to be about 27,000,000 metric tons CO_2e annually. This is lower than my estimate of all emissions associated with the Project of 87,000,000 metric tons CO_2e annually because, in my estimation, some of those emissions would occur even if the Proposed Project does not proceed.

Q: How did you estimate incremental GHG emissions associated with the Proposed Project?

A: To quantify the incremental GHG emissions of an energy project or action, one must first describe how that project or action will change the energy market. In the case of the Proposed Project, the availability of oil pipelines, including Line 5, affects global GHG emissions because pipelines help increase the supply of oil. Evaluation of these dynamics is a typical methodology for analyzing incremental GHG emissions of an energy infrastructure project. An overview of such approaches can be found in Section IV of the peer-reviewed paper by Burger and Wentz (2020), "Evaluating the Effects of Fossil Fuel Supply Projects on Greenhouse Gas Emissions and Climate Change under NEPA," attached as Exhibit ELP-4 (PAE-4).[42] The oil market is well-connected globally, and there is a straight-forward connection between oil supply and oil consumption. The more oil is available (and at lower cost), the lower the global price of oil, and the more oil is consumed. And, the more oil is consumed, the higher are GHG emissions from producing and burning oil.

[42] Burger, M., & Wentz, J. (2020). Evaluating the Effects of Fossil Fuel Supply Projects on Greenhouse Gas Emissions and Climate Change under NEPA. *William & Mary Environmental Law and Policy Review*, 44(2), 423–530.

Q: How do pipelines impact global markets for oil?

A: Pipelines increase the supply of oil by providing transport of oil to market when other options do not exist or are higher cost. This is widely understood, and is nicely summarized for Canadian oil in the peer-reviewed article, Heyes et al (2018), "The Economics of Canadian Oil Sands" – attached as Exhibit ELP-5 (PAE-5).[43] That article focuses on oil sands, but with principles that also apply to light oil. Further, when oil supply is greater, prices are lower, an effect which is summarized in my own peer-reviewed work: Erickson, P., & Lazarus, M. (2014), attached here as Exhibit ELP-6 (PAE-6). Impact of the Keystone XL pipeline on global oil markets and greenhouse gas emissions. *Nature Climate Change,* 4(9), 778–781.[44] As these peer-reviewed articles demonstrate, the effects of shifts in oil supply can be quantified using economic principles and models, which is what I do here.

Q: Why do you compare the Proposed Project to a "no-action" scenario?

A: Estimating the effect of the Proposed Project on oil supply requires clearly articulating what would happen in a "no-action" scenario, so that the effect of the Proposed Project can be compared to that, and the incremental effect of the Proposed Project can be quantified. Given that the State of Michigan is revoking and terminating the 1953 Easement that allows Line 5 to operate under the Straits, it is reasonable to consider the no-action scenario to be one in which the Line 5 pipeline is not operational. Even if the 1953 Easement remained valid, it would be appropriate to consider a no-action scenario in which Enbridge shuts down the existing Line 5 and does not replace it with a new segment of pipeline. Enbridge's stated purpose for the project is to "alleviate an environmental concern to the Great Lakes

[43] Heyes, A., Leach, A., & Mason, C. F. (2018). The economics of Canadian oil sands. *Review of Environmental Economics and Policy*, 12(2), 242–263. https://doi.org/10.1093/reep/rey006
[44] Also available at https://doi.org/10.1038/nclimate2335

raised by the State of Michigan relating to the approximate four miles of Enbridge's Line 5 that currently crosses the Straits of Mackinac."[45] One way to achieve that purpose would be to remove Line 5 from the Straits and decommission the pipeline.

Q: What would happen if the existing dual pipelines in the Straits of Mackinac were shut down, and the Proposed Project was not built?

A: In such a case, where the Line 5 pipeline through the Straits of Mackinac is not replaced, more of the oil from Montana, North Dakota, and Western Canada would likely be transported by rail, which is generally more expensive than pipelines for transporting petroleum. The key difference of the scenario *with* the Proposed Project and the scenario *without* the Project is therefore the cost of transporting oil out of these regions of North America. I will refer to these regions as the greater Williston Basin, which includes both the Bakken and Duvernay formations. This is what I analyze in more detail below.

Q: What are the main differences between moving oil by rail as compared to pipeline that affect the incremental GHG emissions associated with the Proposed Project?

A: Studies have found that the added cost for moving light crude oil by rail, as compared to by pipeline, is about USD $6 per barrel more expensive than pipelines. Different studies have found values somewhat above or below this value, but in my opinion, $6 per barrel is a reasonable, midrange estimate. However, I will discuss how my results could be lower or higher if the actual cost premium were different.

[45] Application at ¶2.

Q: Did you do an independent analysis of what the various alternatives to transporting oil and NGL via Line 5 would be?

A: No. I understand that a number of alternative analyses have been undertaken by various experts and groups. However, such a detailed analysis is not necessary for purposes of my analysis of GHG emissions. Rather, I rely on a regional average estimate of how constraints on pipeline capacity can increase the costs for moving oil, based on review of a number of sources.

Q: What sources did you consult to estimate the range of increase in costs for transporting oil from the greater Williston Basin by rail instead of by pipeline?

A: I consulted several sources. One was a statistical analysis of actual pipeline and rail crude oil tariffs, conducted by researchers at the University of Waterloo in Canada.[46] An analysis by university economists, Heyes *et al*. (2018), cited previously, report a range between $3 per barrel (which they attribute to the US State Department) and $9 per barrel (which they attribute to the TransCanada corporation).[47] A banking and financial services company, Scotiabank, also estimated that insufficient pipeline capacity would lead to an increase in costs of oil from Alberta about $6 per barrel.[48] Lastly, Alternative 3 of the Dynamic Risk report *Alternatives Analysis for the Straits Pipeline*, though it was addressing a specific rail path from Superior, Wisconsin to Sarnia, Michigan (and not the system-wide average cost

[46] Morrison, A., Bachmann, C., & Saccomanno, F. (2018). Developing an Empirical Pipeline and Rail Crude Oil Mode Split and Route Assignment Model. *Transportation Research Record,* 2672(9), 261–272. Available at https://doi.org/10.1177/0361198118801350.

[47] Heyes, A., Leach, A., & Mason, C. F. (2018). The economics of Canadian oil sands. *Review of Environmental Economics and Policy*, 12(2), 242–263. https://doi.org/10.1093/reep/rey006

[48] Based on the difference between the MSW (light crude) discounts in the "healthy pipeline" ($3/bbl discount) versus "base case" case ($9/bbl discount) in Chart 1 of Scotiabank (2018). Shut in? Assessing the merits of government supply intervention in the Alberta oil industry. Available at https://www.scotiabank.com/content/dam/scotiabank/sub-brands/scotiabank-economics/english/documents/commodity-note/shut-in-government-intervention-assessment_2018-11-21.pdf.

premium of moving oil by rail from the Greater Williston Basin, which is my focus here), also found a rail cost premium of about $6 per barrel. The key point for my analysis is that the added cost of alternative transport can make it more costly to supply oil and therefore decrease oil consumption, as I describe in more detail below.

Q: Are there greenhouse gas emissions from alternative methods of transporting oil?

A: Yes. The other factor that relates to GHG emissions is that the GHG emissions associated with moving oil by rail are, like cost, also slightly higher. The increase is small, about 6 kg CO_2e per barrel transported by rail instead of by pipeline, which is just 1% of the total GHG emissions associated with a barrel of oil.[49] However, this difference must also be accounted for, as I do below.

Q: Have you quantified how oil supply from the greater Williston Basin would be affected in the no-action scenario, where the existing line stops operating and the Proposed Project is not built?

A: Yes. In the absence of the Line 5 pipeline, some oil fields in the greater Williston Basin may not be able to afford an added cost of $6 per barrel for transporting their oil by rail, since that extra charge would erase any profit that would be expected by oil-field developers. In such a case, prospective new oil fields may not be developed, and so less oil would be supplied to the global oil market compared to the scenario where the Proposed Project is constructed.

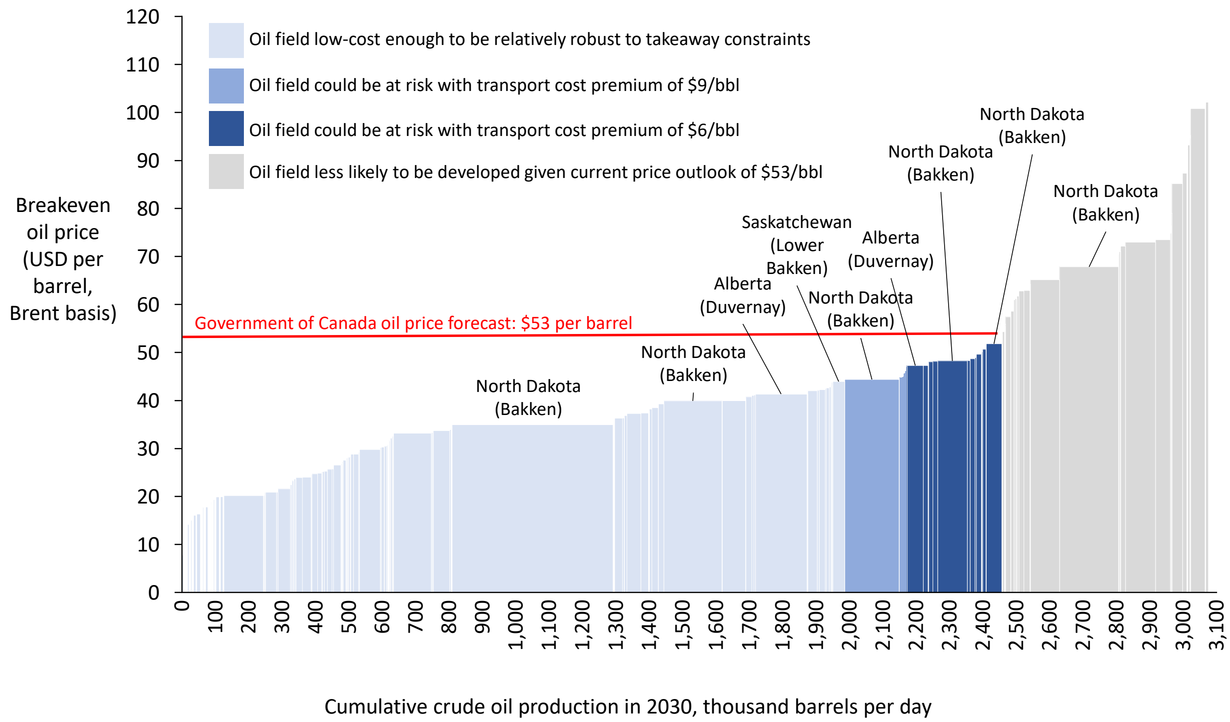
Indeed, the economics of oil in the greater Williston Basin may be challenging in the years ahead. The Government of Canada currently foresees crude oil prices to gradually

[49] Source: Nimana, B., Verma, A., Di Lullo, G., Rahman, Md. M., Canter, C. E., Olateju, B., Zhang, H., & Kumar, A. (2017). Life Cycle Analysis of Bitumen Transportation to Refineries by Rail and Pipeline. *Environmental Science & Technology*, 51(1), 680–691. https://doi.org/10.1021/acs.est.6b02889.

drift downwards towards $53 per barrel by the end of this decade (2030).[50] Oil fields that are only profitable ("break even") at prices just below this level – namely, between $53 per barrel and $47 per barrel ($53 minus the $6 extra for rail transportation) – would therefore not be able to afford an added $6 cost per barrel of transporting their oil to markets. A substantial number of oil projects in the greater Williston Basin are expected to break even in this range of $47 to $53 per barrel, and would therefore be put at risk by the added $6 per barrel in transportation costs. Figure 1, below, shows the sources of light crude oil production in the Canadian provinces of Alberta, British Columbia, Manitoba, and Saskatchewan, and US States of Montana and North Dakota that could potentially feed into the Enbridge mainline pipeline system, including Line 5. The oil fields colored in dark blue are the ones that would be put at risk by a transport cost premium of $6 per barrel. These are new oil fields, for example, in the Bakken formation of North Dakota and the Duvernay formation in Alberta. In total, the quantity of oil that would be put at risk, and ultimately stranded (not developed) by an added $6 per barrel in transportation costs (and assuming an oil price outlook of $53 per barrel) is 290,000 barrels per day. For reference, this is equivalent to about 64% of Line 5's expected crude oil throughput of 450,000 barrels per day.

[50] Canada Energy Regulator. (2021). *Energy Futures 2021: Consultation on Preliminary Results*.

FIGURE 1. CRUDE OIL COST CURVE FOR GREATER WILLISTON BASIN LIGHT CRUDE[51]



Therefore, were the Proposed Project not constructed and Line 5 not to be re-started, I estimate that about 290,000 barrels per day of greater Williston Basin light crude oil production would not be developed, due to the resulting increase in system-wide transportation costs. Note, however, that the actual amount of oil production at risk could actually be larger.

Q: In the no-action scenario, where the existing line stops operating and the Proposed Project is not built, could more than 290,000 barrels per day of oil supply be stranded?

A: My estimate of 290,000 barrels per day put at risk in the no-action scenario assumes that sufficient rail capacity exists to transport the oil carried by Line 5, and that it costs $6 per

[51] Source of cost curve: Rystad Energy. (2021). Cube Browser, Version 2.2. https://www.rystadenergy.com/Products/EnP-Solutions/UCube

barrel more than transporting oil by pipeline. However, when the capacity to move oil from oil fields to markets (whether by rail or pipeline) is constrained, firms that operate pipelines or rail lines can (and do) exert market power and increase their transportation charges or tariffs to capture additional profit. When they have done this in the recent past, the added cost of crude transportation compared to normal, average pipeline costs grows beyond the $6 per barrel difference in costs assumed here, to between roughly $9 per barrel and, in rare circumstances, as much as $27 per barrel on a temporary basis.[52]

Takeaway capacity for crude oil from the greater Williston Basin has been constrained in the past, and likely will be constrained in the coming years. Recent draft forecasts by the Canadian Energy Regulator, a government body, show that, even *with* the Line 5 pipeline (450,000 bpd crude capacity) *and* Line 3 pipeline (full capacity: 760,000 bpd, expanded from current capacity of 390,000 bpd), Western Canada will have only about 100,000 bpd of spare capacity in the system by 2030.[53] However, if *either* of those pipelines is not operational (and assuming continued delays in the Trans Mountain Pipeline expansion project to Vancouver, B.C.) oil transportation capacity would be insufficient. In that case, it is reasonable to expect that the no-action scenario could lead to added transportation charges of around $9 per barrel on a long-term basis.

An added charge of $9 per barrel for rail transport, instead of $6 per barrel, would have an even greater effect on oil supply. As shown in Figure 1, at a transport cost premium

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[52] The low end of this is taken from the following source: Heyes, A., Leach, A., & Mason, C. F. (2018). The economics of Canadian oil sands. Review of Environmental Economics and Policy, 12(2), 242–263. https://doi.org/10.1093/reep/rey006. The authors describe a discount for diluted bitumen, a heavier grade of oil, of $9 per barrel at the Hardisty hub, but that the difference between rail and pipeline shipping costs for bitumen is *less* than for other grades of oil, e.g. light crude, that do not require diluent. Therefore, a $9 per barrel up-charge is likely on the low end. Alternatively, the high end is calculated as the difference between the "healthy pipeline" and "persistent distressed discounts" case for MSW (light crude) in Chart 1 of Scotiabank (2018).
[53] Takeaway capacity from western Canada is described on slide 10 of: Canada Energy Regulator. (2021). Energy Futures 2021: Consultation on Preliminary Results.

of $9, and again assuming an oil price outlook of about $53 per barrel, much more oil is at risk (the added oil that becomes at-risk at $9 per barrel, as compared to $6 per barrel, is shown in a medium blue): about 450,000 bpd of crude oil production. In other words, it is conceivable that the full crude oil capacity of the Line 5 pipeline, 450,000 bpd, could be left undeveloped if Line 5 is not re-started.

Q: In the no-action scenario, where the existing line stops operating and the Proposed Project is not built, could fewer than 290,000 barrels per day of oil supply be stranded?

A: Yes, as I explain above, my central estimate is that 290,000 barrels per day will be stranded, but the figure could also be lower. One way that less oil could be stranded is if the long-term price of oil was expected to be much higher than the $53 per barrel figure I used here. I used that estimate, because, in my opinion, the Government of Canada's recent analysis of oil prices is the most up-to-date and relevant for the greater Williston Basin. A forecast of $53 per barrel is also similar to the outlook of oil consultancy Rystad Energy, which foresees the oil price at about $50 per barrel in the latter half of this decade. However, if the long-term outlook for the price of oil was to increase dramatically, e.g. to $100 per barrel, then differences of about $6 per barrel in transportation costs may not matter as much to how much oil is supplied in Figure 1, and so much less oil could be stranded. Or, if the no-action scenario were to lead to much less than a $6 per barrel increase in transportation cost, the amount of oil stranded could also be less.

Note, however, that less-extreme increases in the outlook for oil prices may not have much effect on my estimate of how much oil would be at risk. For example, the U.S.

Energy Information Administration has forecast oil prices to be about $73 per barrel, [54] which is higher than the $53 forecast from the Canada Energy Regulator. But while a price outlook of $73 would shift *which* exact oil fields are at risk (shifting up the cost curve in Figure 1), the same *number* of barrels – about 290,000 barrels – would be at risk.

Q: Are your estimates of additional rail costs the same as what Michigan oil producers would expect to see if they were no longer able to use Line 5 to get their oil to market?

A: No. These estimates of rail costs reflect the cost of transporting crude oil from the greater Williston Basin to markets. I have no reason to believe they would reflect the additional cost to Michigan producers who would no longer be able to use Line 5 and instead used rail transport to get their product to market, since that is a much smaller quantity of oil in a much more localized transportation market.

Q: How much would the added cost of oil from the greater Williston Basin affect global GHG emissions?

A: Put simply, shutting down the existing dual pipelines in the Straits and not building the Proposed Project would lead to less, and more costly, oil supplied from the greater Williston Basin over the long term. This outcome would affect global oil markets and consumption levels, because the long-term global price of oil is directly affected by how much it costs to develop the oil fields that will provide the added, or marginal, sources of supply at a given level of expected demand.[55] Since new sources of oil would be more costly than previously anticipated, the long-term oil price would rise, and oil consumers

[54] Brent crude oil price forecast in real dollars for 2030 from US EIA. (2021). *Annual Energy Outlook 2021*. U.S. Energy Information Administration. http://www.eia.gov/forecasts/aeo/

[55] For a discussion of these dynamics, see page 7 of Fattouh, B., Poudineh, R., & West, R. (2019). Energy transition, uncertainty, and the implications of change in the risk preferences of fossil fuels investors. The Oxford Institute for Energy Studies, or Erickson, P., van Asselt, H., Koplow, D., Lazarus, M., Newell, P., Oreskes, N., & Supran, G. (2020). Why fossil fuel producer subsidies matter. *Nature*, 578(7793), E1–E4. https://doi.org/10.1038/s41586-019-1920-x

would respond to the higher expected price by using less oil, such as by switching to other forms of lower-carbon transportation or by using more efficient vehicles. The effect of reductions in oil supply on oil price and consumption is well-established, even as it is also the subject of ongoing research and debate, as discussed in Hamilton (2009) and Caldara et al (2019).[56]

Q: Why are the costs of oil from the greater Williston Basin so important?

A: The costs of oil from the greater Williston Basin are especially important because this region is expected to be one of the major sources of the new, added supplies of oil in the years to come. In particular, the crude oil from these regions is expected to comprise at least 7% of the marginal, new sources of oil, based on my analysis of the costs and volumes of world oil supply in Rystad Energy's Ucube database.[57] An increase in the cost of oil from the greater Williston Basin would therefore have a proportional effect on the global marginal cost of supplying oil: namely, a $6 per barrel increase in the cost of oil from this region could increase the average *global* marginal cost of supplying oil by about $0.40 per barrel. (An increase of $6 per barrel in 7% of the marginal cost translates, via simple multiplication, to an average increase of $0.40 per barrel). That, in turn, would translate into an increase in global oil prices of about $0.29 per barrel.

Q: Will that increase in oil prices have a significant impact on customers in Michigan?

A: I have not conducted that analysis here, but it in my opinion it is unlikely that the effects of the price increase would be locally significant. Rather, the impacts of the per barrel price

[56] Hamilton, J. D. (2009). Understanding crude oil prices. *The Energy Journal*, 30(2), 179–206. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol30-No2-9; Caldara, D., Cavallo, M., & Iacoviello, M. (2019). Oil price elasticities and oil price fluctuations. *Journal of Monetary Economics*, 103, 1–20. https://doi.org/10.1016/j.jmoneco.2018.08.004

[57] Rystad Energy. (2021). Cube Browser, Version 2.2. https://www.rystadenergy.com/Products/EnP-Solutions/UCube

increase would have global impacts. Even though the increase is small on the individual level ($0.29 per barrel of oil is less than 1 cent per gallon), that added cost would add up to globally significant effects on consumer behavior and oil consumption around the world, since it would lead to changes in how (and how many) people and goods are transported using oil.

Q: If the Proposed Project were built, what is your overall estimate of the incremental GHG emissions compared to the no-action alternative?

A: In total, assuming a $6 per barrel increase in transportation costs associated with rail transport of petroleum, I estimate that, compared to the no-action scenario, where the existing line stops operating and the Proposed Project is not built, building the Proposed Project would lead to a net, incremental increase in annual global oil consumption of about 150,000 bpd, equivalent to 27,000,000 metric tons CO_2e per year from burning and producing that oil. Nearly all of this increase in oil consumption and GHG emissions would occur outside Michigan.

Q: How did you calculate this estimate?

A: This change in global oil price and oil consumption is calculated using a simple oil market model, parameterized by elasticities (long-run elasticity of crude oil supply of 0.6, long-run elasticity of crude oil demand of -0.3), a model that is described in more detail in my peer-reviewed, scientific work, including, most recently: Achakulwisut, P., Erickson, P., & Koplow, D. (2021). Effect of subsidies and regulatory exemptions on 2020–2030 oil and gas production and profits in the United States. *Environmental Research Letters*, 16(8), 084023, which is attached here as Exhibit ELP-7 (PAE-7).[58] I convert this change in oil

[58] Available at https://doi.org/10.1088/1748-9326/ac0a10 .

consumption to a change in GHG emissions from burning oil by assuming a global, reference GHG-intensity of crude oil of 502 kg CO_2e per barrel, while also assuming that any oil now carried by rail instead of pipeline does so at an added GHG-intensity of 6 kg CO_2e per barrel.

"Long-run" elasticities are intended to gauge effects over a period of time in which producers and consumers have time to make changes in their equipment or investment decisions, such as the decision of what kind of car to buy or whether or not to drill a new oil field. Over this time period – the next several years – the flexibility of decisions is greater than in the "short run," and hence the effects of a change in price are greater. The long-run elasticities of supply (0.6) and demand (-0.3) that I use here are the same as in my most recent peer-reviewed research. An elasticity of supply of 0.6 is consistent with a fairly "flat" oil supply curve characteristic of the current oil price outlook. (Were oil price outlooks to be much higher, e.g. over $100, the supply curve would be steeper, and the elasticity of supply lower.)

A long-run elasticity of demand, -0.3, is higher (in absolute value) than some prior reviews: Hamilton (2009) reported a range of -0.2 to -0.3. A higher value like -0.3, is commonly believed to be more consistent with the greater current availability of electric vehicles, and is still lower than an alternative, commonly used value of -0.5 as reported by Raimi (2019).[59]

Q: What is the source of your assumption about the elasticity of supply and demand?

A: My source for the elasticity of supply estimate of 0.6 is taken directly from the slope of the oil supply curve, as assembled by oil industry consultancy Rystad Energy, for prices in the

[59] Raimi, D. (2019). The Greenhouse Gas Impacts of Increased US Oil and Gas Production [Working Paper 19-03]. http://www.rff.org

$50 per barrel to $70 per barrel range, as described in Erickson *et al.* 2020. My source for the elasticity of demand is taken from Hamilton (2009).

Q: Why did you choose these specific values and not others in the literature?

A: The values I am using represent my expert judgment as to most reasonable values for the present situation, given current oil price outlooks and the expanding alternatives to oil in the transport sector, which is by far the largest sector using oil. These values are also well within the ranges used in other studies, and therefore represent mid-range values that should yield reasonable results for decision-makers. It would also be possible to use different values to get a sense of how the results could change.

Q: Did you calculate the results using different values?

A: Yes. I did a sensitivity analysis in which I varied elasticities of supply and demand to see how the results could vary. In the table below, I display how very different assumptions about elasticities of supply and demand could make my estimate of 27 million metric tons CO_2e higher or lower. While I present this to show a wide range of potential outcomes, I find the lower elasticity of supply value of 0.1 to be extraordinarily unlikely, as that implies a very steep supply curve in which oil producers are very insensitive to price, a situation that only arises if long-term oil forecasts are very high, e.g. over $100 per barrel. In the more likely scenario – with higher elasticity of supply -- the incremental GHG emissions remain over 20 million metric tons CO_2e even where assumptions regarding the elasticity of demand change.

TABLE 3. INCREMENTAL GLOBAL GHG EMISSIONS (MILLION TONS CO_2E) RESULTING FROM THE PROPOSED PROJECT, USING DIFFERENT ELASTICITIES OF SUPPLY AND DEMAND

		Long-run elasticity of global crude oil supply		
		0.1	**0.6** (best estimate)	1
Long-run elasticity of global crude oil demand	-0.2	4.2 million t CO_2e	20 million t CO_2e	27 million t CO_2e
	-0.3 (best estimate)	4.8 million t CO_2e	**27 million t CO_2e**	38 million t CO_2e
	-0.5	5.4 million t CO_2e	37 million t CO_2e	55 million t CO_2e

Values in **bold** are best estimates used in this testimony

Q: Does this mean that your estimate of incremental GHG emissions could be lower?

A: Yes, of course. As indicated in Table 3 above, my estimate of incremental emissions could be much lower if the elasticity of supply of oil was much lower, a situation that could arise if oil demand were to outpace oil supply in the years ahead and oil prices were to rise substantially, e.g. to well over $100 per barrel. I consider this outcome unlikely and, also, not very consistent with global goals to decarbonize the economy, the attainment of which would instead yield greatly reduced oil demand and, in turn, lower oil prices. As explained in my testimony above, my estimate could also be somewhat lower if the absence of Line 5 had less of an effect on oil transportation costs than in my central estimate.

Q: Are there any other ways your estimate of incremental GHG emissions could be lower?

A: Yes. Another way my estimate could be affected is if consumers, in response to slightly lower oil prices resulting from the Proposed Project (compared to the no-action scenario), were to increase their oil consumption at the expense of other fossil-based sources of energy, such as coal or gas-based electricity. I have not evaluated those effects, termed "cross-price" or substitution effects in the economic literature, because they involve different fuels than what would be handled by the Proposed Project and so are secondary considerations. These effects could reduce my incremental estimate of 27 million metric tons CO_2e somewhat; however, as the global energy transition accelerates, the marginal source of the main substitute for oil – electricity – is no longer mainly fossil fuels, but instead primarily very low-carbon renewable power. This strong trend towards renewable power suggests that any shift away from electricity would have relatively minor effects on my incremental GHG emissions estimate.

Q: How could your estimate of incremental GHG emissions be higher?

A: My estimate of incremental GHG emissions could be somewhat greater if consumers were even more sensitive to oil prices in the future than they have been in the past (i.e., an elasticity of demand of -0.5 or more, as in Table 3) or if, as described above, the rail and pipeline takeaway capacity from the greater Williston Basin is even more constrained than I assume here (e.g., if either the Line 3 or Trans Mountain pipeline projects currently underway are not completed).

Q: If the estimate could change, why should it be relied upon here?

A: I believe my central estimate of 27,000,000 metric tons CO_2e is a reasonable approximation of the incremental effect of the Proposed Project on global GHG emissions based on available information regarding supply and demand elasticities. The methods used above use standard GHG emissions accounting principles, and my specific approaches regarding pipelines and oil markets have been successfully scrutinized by the scientific peer review process several times for other projects. Furthermore, I have considered several possible uncertainties. Finally, in other contexts involving estimations of GHG emissions, courts have concluded that the inherent uncertainties in these types of estimations is no justification for failing to quantify these effects.[60]

Q: What about the possibility that, if the Proposed Project is not built, the "no action" scenario is not the closing of Line 5, but instead that the existing, dual pipelines continue to operate for some limited amount of time?

A: In such a case, then the concept of incremental emissions described above still applies, but the effect is essentially postponed by however many years the existing dual pipelines could continue to operate.

Q: Have you estimated how this decrease in the quantity of oil consumed would impact customers in Michigan?

A: No. My focus is on the global GHG emissions effect of the Line 5 pipeline. Michigan represents only about one-half of 1% of global oil consumption, so the GHG emissions effects inside Michigan are a small part of the overall GHG emissions effects of the Line 5 pipeline. Of course, the impact on Michigan's natural resources, as the result of all global GHG emissions, is significant, as discussed by other expert witnesses in this case.

Q: Have you estimated changes in price, consumption, or incremental GHG emissions associated with the propane or butane handled by the Proposed Project?

A: No. In contrast to the incremental emissions from increased consumption of crude oil that would result from constructing the Proposed Project (relative to the no-action scenario), which are driven by effects global markets, any incremental emissions from changes in propane and ethane markets would likely be more local, due to propane and ethane markets in the Eastern U.S. and Canada, including in Michigan.

[60] *See Ctr. for Biological Diversity v. Bernhardt*, 982 F.3d 723, 739–40 (9th Cir. 2020).

These effects are likely much smaller than for crude oil for three reasons: (1) the quantity of these NGLs handled by the pipeline is only 20% the volume of crude; (2) NGLs contain at least 35% less carbon per barrel than crude; and (3) the propensity for end-markets to increase their consumption of NGLs (relative to the no-action scenario) may be less than for crude oil, as consumers do not make as frequent decisions regarding home heating (a key source of propane use) as they do about how often and what kind of vehicle to drive.

For these reasons, I do not estimate the changes to price, consumption, or incremental GHG emissions associated with NGLs. I do note that the same fundamental market principles would apply as for oil: proceeding with the Proposed Project would, relative to the no-action scenario, would mean lower costs of producing NGLs from the greater Williston Basin, lower prices for these liquids, and therefore a (proportionally smaller) increase (again, relative to the no-action scenario) in their consumption.[61]

Q: Have you estimated how the incremental GHG emissions caused by the Proposed Project would affect climate change, including in Michigan?

A: No. Consistent with section III of this testimony ("Overview of climate change and the need for greenhouse gas emissions cuts"), the intent of global climate change policy is that substantial emission reductions are needed in all regions of the world and in all sectors. Accordingly, the change in warming or climate impacts that would result from actions in Michigan should be viewed in that context and not as isolated (and proportionally smaller) effects on global temperature.

[61] Lower-carbon alternatives to propane (e.g. for heating or for industrial equipment) and butane (e.g. for petrochemicals and plastic manufacturing) are becoming available.

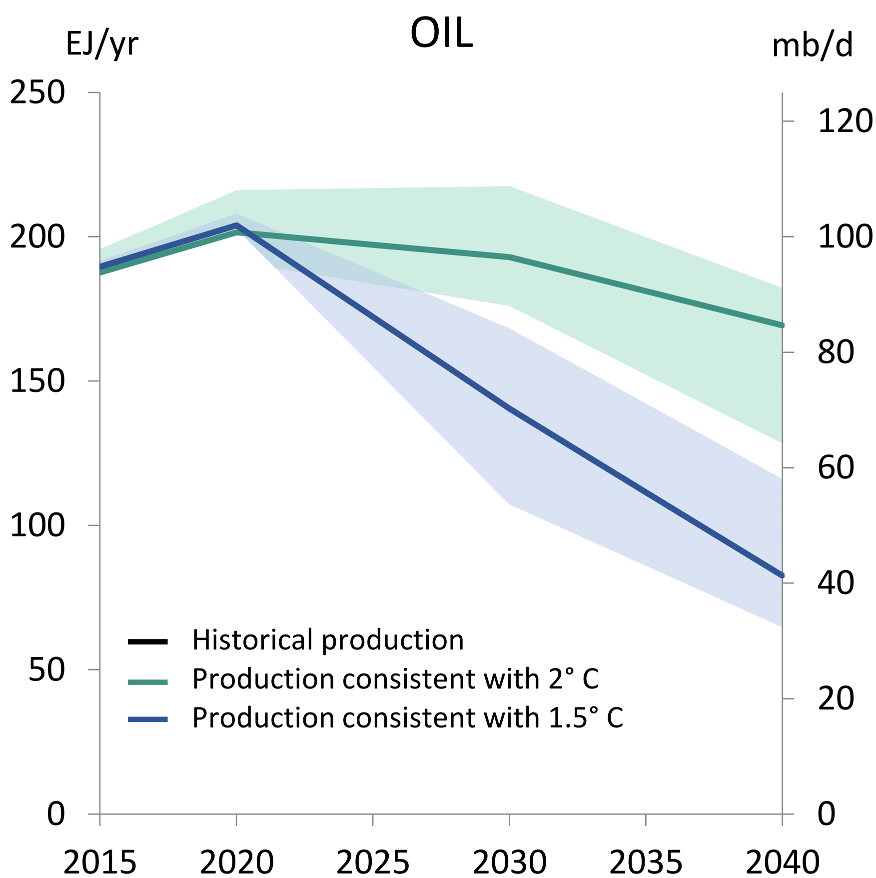
VI. INCONSISTENCY OF THE PROPOSED PROJECT WITH INTERNATIONALLY AGREED CLIMATE LIMITS

Q: Is Enbridge's Proposed Project generally consistent with international, national and state climate goals?

A: No. Michigan's Governor Gretchen Whitmer has initiated the MI Healthy Climate Plan aimed at protecting public health and the environment, and helping to develop new clean energy jobs, by putting Michigan on a path towards becoming carbon-neutral, meaning net zero greenhouse gas emissions, by 2050. Further, the Governor has committed the State of Michigan to advance the goals of the Paris Agreement. As described in section III of this testimony, one of the goals of the Paris Agreement is "pursuing efforts" to limit global warming to 1.5°C above pre-industrial levels. To meet that goal with no or "limited" overshoot (exceedance) of the temperature limit, the Intergovernmental Panel on Climate Change (IPCC) has found that global emissions must reach zero by about the year 2050. Further, the IPCC has found that oil production and use must fall by an average of about 3% annually (for a total of 65%) between 2020 and 2050.

Analysis by international research organizations of the IPCC's emission-reduction pathways, published in partnership with the United Nations' Environment Program, has found that oil production needs to decline under both the 1.5 °C and 2 °C limits, as shown in Figure 2.

FIGURE 2. OIL PRODUCTION AND USE CONSISTENT WITH 1.5 °C AND 2 °C LIMITS[62]



By contrast, maintaining oil production at recent levels for the next several decades is not consistent with meeting the warming goals of the Paris Agreement. Constructing long-lived oil infrastructure, such as pipelines, that helps lower the cost and investment risk of oil production – increasing oil use and emissions (as demonstrated in Section V of this testimony) is therefore at odds with the temperature and emissions goals of the Paris Agreement.

[62] Figure adapted from SEI, IISD, ODI, E3G, & UNEP. (2020). The Production Gap: Special Report 2020. http://productiongap.org/2020report. Green and blue bands show inter-quartile ranges across all scenarios analyzed by the Production Gap Report authors.

Q: Besides the IPCC and the UN Environment Program, are there any other major international institutions that have pointed out the disconnect between further oil-related development and climate goals?

A: Yes, the International Energy Agency (IEA), an intergovernmental organization, has similarly found that expanding oil production is inconsistent with reaching zero emissions by mid-century and limiting warming to 1.5°C. In its recent *Net Zero by 2050* report, the IEA found that there is "no need for investment in new fossil fuel supply" in their net-zero pathway.[63] More specifically, the IEA stated that "no new oil and natural gas fields are needed," which helps lead to a "contraction of oil and natural gas production."[64]

Constructing the Proposed Project and re-starting Line 5 would provide added certainty and low-cost takeaway capacity for new oil fields in the Bakken and Duvernay formations in Alberta, British Columbia, and Saskatchewan provinces of Canada, and in the states of North Dakota and Montana in the U.S. (*See* Figure 1). Developing new oil fields in these regions would be inconsistent with both the IPCC scenarios and the IEA's road map for reaching net zero by 2050, and would thus also be inconsistent with Michigan Governor Whitmer's commitment to align the state's policies with the Paris Agreement and with net zero emissions by 2050.

<u>SUMMARY OF TESTIMONY/CONCLUSIONS</u>

Q: Please summarize your conclusions.

A: My testimony has three main conclusions.

[63] Source: page 21 of IEA. (2021). *Net Zero by 2050: A Roadmap for the Global Energy Sector*. International Energy Agency. https://www.iea.org/reports/net-zero-by-2050

[64] Source: page 23 of IEA (2021).

First, as described in section IV of this testimony, the Proposed Project is associated with about 87 million metric tons carbon-dioxide equivalent (CO_2e) annually, the overwhelming majority of which are from the use, or combustion, of the oil and natural gas liquids transported by the Line 5 pipeline.

Second, as described in section V, compared to a no-action scenario, where the Line 5 pipeline no longer operates in the Straits, the Proposed Project would lead to an *increase* of about 27 million metric tons CO_2e in global greenhouse gas emissions from the production and combustion of oil.

Third, as described in section VI, by enabling the continued, long-term production and combustion of oil, construction of the project would work against, and therefore be inconsistent with, the goals of the global Paris Agreement and Michigan's Healthy Climate Plan.

Q: Does this conclude your testimony?

A: Yes.

STATE OF MICHIGAN
MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of **ENBRIDGE ENERGY, LIMITED PARTNERSHIP** application for the Authority to Replace and Relocate the Segment of Line 5 Crossing the Straits of Mackinac into a Tunnel Beneath the Straits of Mackinac, if Approval is Required Pursuant to 1929 PA 16; MCL 483.1 et seq. and Rule 447 of the Michigan Public Service Commission's Rules of Practice and Procedure, R 792.10447, or the Grant of other Appropriate Relief	)))))))))))	Case No. U-20763

DIRECT TESTIMONY OF DR. PETER HOWARD

ON BEHALF OF

THE ENVIRONMENTAL LAW & POLICY CENTER
AND THE MICHIGAN CLIMATE ACTION NETWORK

September 14, 2021

Q. Please state your name, business name and address.

A. My name is Dr. Peter Howard. I am the economics director at the Institute for Policy Integrity at the New York University School of Law.[1] Our offices are located at 139 MacDougal Street, Wilf Hall, 3rd Floor, New York, NY 10012. Policy Integrity is a non-partisan think tank dedicated to improving the quality of government decisionmaking through advocacy and scholarship in the fields of administrative law, economics, and public policy.

Q. What is the purpose of your testimony?

A. My testimony applies a widely-accepted economic methodology, known as the Social Cost of Greenhouse Gases, to monetize the incremental climate costs from the emissions from construction and operation of the proposed Line 5 project, as well as the lifecycle emissions from the oil and natural gas products that would be transported by that Proposed Project. Specifically, based on the best available quantitative data and conservative valuations, the Proposed Project will generate a present value of $41 billion (in 2020 USD) or more in net monetized climate costs from 2027 to 2070 as compared to the no-action alternative—in other words, the Proposed Project will generate average annual monetized climate costs of approximately $1 billion each year over this period, plus significant unmonetized climate effects and other unquantified pollution costs to human health and the environment. This $41 billion figure represents real-world, concrete climate damages to Michigan, the United States, and the world, in the form of energy system disruptions, human health effects from air quality impacts and extreme temperatures, water quality and water scarcity impacts, agricultural productivity losses, property damage, biodiversity losses, and costs to other

[1] No part of this testimony purports to present the views, if any, of New York University or its School of Law.

climate-vulnerable market sectors and natural resources[2] that matter to the people of Michigan. Translating these damages into dollar figures helps to contextualize how the pollution from the Proposed Project will concretely impair the air, water, natural resources, and public trust. These results further demonstrate the prudence of the no-action alternative by putting the Proposed Project's incremental climate costs into terms that can more readily be compared against the Proposed Project's alleged benefits and so reveal the Proposed Project to be, on net, detrimental to society.

Q. What is your educational background?

A. I hold a Ph.D. in Agricultural and Resource Economics from the University of California, Davis, where my research focused on climate change, environmental policy, and agricultural policy. I also hold a Bachelor of Arts from Bard College, where I majored in economics.

Q. Can you briefly describe your professional background?

A. After graduating with my Ph.D. in 2012, I started my academic career as an economic fellow at the Institute for Policy Integrity at New York University School of Law. During this time, my research focused primarily on the social cost of carbon. In 2015, I accepted my current position as the Economics Director at Policy Integrity, where the primary focus of my work remains on the social cost of carbon and related climate economic issues, though my work and expertise has expanded to include several related topics, including resource extraction. Over the last decade, my climate economics work has been published in various prestigious environmental economics, legal, and policy journals. My work has

[2] *See* Climate Impacts Reflected in the SCC Estimates, https://costofcarbon.org/scc-climate-impacts (last visited Aug. 26, 2021) (detailing which climate impacts are included or partially included in the current estimates of the social cost of greenhouse gases).

been cited by the federal government (e.g., the Interagency Working Group on the Social Cost of Greenhouse Gases, 2016; 2021) and researchers (National Academy of Sciences, 2017). My 2017 paper with Thomas Sterner on climate damages formed the basis of Nobel Prize recipient William Nordhaus's alternative damage function that he published in 2019. My Curriculum Vitae is attached as Exhibit ELP-8 (PH-1).

Q. Have you ever testified in front of the Michigan Public Service Commission?

A. No.

Q. Have you testified in other jurisdictions?

A. Yes. I have testified on the value of using the social cost of greenhouse gases before: the New Jersey legislature, the Colorado Air Quality Control Commission, the U.S. District Court for the District of Montana, the National Academies of Sciences Committee on Assessing Approaches to Updating the Social Cost of Carbon, the U.S. Office of Information and Regulatory Affairs, and the U.S. Interagency Working Group on the Social Cost of Greenhouse Gases.

Q. On whose behalf are you submitting this testimony?

A. I am submitting this testimony on behalf of the Environmental Law & Policy Center and the Michigan Climate Action Network.

Q. Are you sponsoring any exhibits?

A. Yes. I am sponsoring the following exhibits:

ELP-8 (PH-1) – Curriculum Vitae of Dr. Peter Howard.PDF

ELP-9 (PH-2) – SCC Calculations for Line 5

ELP-10 (PH-3) – Extrapolation Code

Q. Can you summarize your conclusions?

A. By applying a widely-accepted economic methodology, known as the Social Cost of Carbon, to monetize the relative climate benefits of a "no-action scenario" compared to the Proposed Project, based on the available data, it is very likely that the no-action scenario will generate tens, if not hundreds, of billions of dollars of net climate benefits. Our main net present estimate of $41 billion (2020 USD) as the Proposed Project's incremental climate costs from construction, operation, and lifecycle emissions from transported products, is certainly a conservative underestimate for several reasons. First, the available estimates of the social cost of carbon dioxide are conservative lower bounds because multiple highly significant climate damages—such as wildfires, flooding and mortality from inland extreme weather, groundwater overexploitation, habitat modifications, and invasive species—are not currently quantified, among other reasons.[3] Second, our $41 billion estimate applies a social cost of carbon dioxide calculated using a conservative discount rate of 3%, even though overwhelming evidence now supports decreasing the discount rate to 2% or lower, which would increase the social cost of carbon dioxide values substantially.[4] Third, the $41 billion figure reflects the net present value of the Proposed Project's climate impacts only through the year 2070, because the federal government's

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[3] *See* Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014) (co-authored with Nobel Laureate Kenneth Arrow, among others); *see also* Climate Impacts Reflected in the SCC Estimates, *supra* note 2 (listing omitted damage categories).

[4] *See* Peter Howard & Jason A. Schwartz, *About Time: Recalibrating the Discount Rate for the Social Cost of Greenhouse Gases* (Policy Integrity Report 2021), https://policyintegrity.org/files/publications/About_Time.pdf (summarizing the economics literature and arguments); *see also* Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates under Executive Order 13990 at 19-21 (2021), https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf [hereinafter 2021 TSD] (conceding the updated evidence); Council of Economic Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate* (Issue Brief, Jan. 2017), https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701_cea_discounting_issue_brief.pdf (arguing to lower the consumption-based discount rate to 2%).

estimates of the social cost of carbon currently end in 2070. But the Proposed Project could continue to have climate impacts through at least 2127, and additional values of the social cost of carbon can be extrapolated from 2071 through 2127. Accounting for the latter two adjustments (using a 2% discount rate and extrapolating damages through 2127) would likely increase the estimate of the Proposed Project's net monetized climate damages by approximately four-fold, up to roughly $160 billion. Even this figure could underestimate the Proposed Project's climate damage, because it omits key damage categories and may not fully account for the risk of catastrophic impacts.

Q. What is your understanding of the project for which Enbridge seeks approval?

A. Enbridge Energy is proposing to build a tunnel beneath the Straits of Mackinac to house a segment of its Line 5 oil and natural gas liquids pipeline (the "Proposed Project").

Q. Do you know whether Enbridge considered any alternatives?

A. Enbridge reports having examined two alternatives to its proposed tunnel: "(ii) a new pipe installed across the Straits using an open-cut method that includes secondary containment; or (iii) a new pipe installed below the Straits using the horizontal directional drilling (HDD) method." (Pastoor Direct at 15:.22-25).

Q. What would a no-action alternative entail?

A. A no-action alternative would entail allowing the existing pipeline to shut down, and not building a tunnel or installing any replacement pipelines. This would have the effect of decreasing the supply of oil and natural gas liquids. Basic economic principles of supply and demand dictate that with decreased supply, the quantity demanded will also drop in response to price signals. Decreased demand for oil and natural gas liquids will decrease the combustion of oil and natural gas liquids, which will decrease emissions of greenhouse gases and other harmful pollutants. The reductions in lifecycle emissions from the oil and gas products that the Proposed Project would otherwise transport, as well as avoided emissions from the construction and operation of any action alternative, can be monetized as the incremental benefits of selecting the no-action alternative (or, equivalently, as the incremental costs of selecting the Proposed Project). This testimony provides such a monetization of the greenhouse gas effects.

Q: Have you reviewed any analysis of the no-action alternative?

A: Yes, I have reviewed Peter A. Erickson's testimony.

Q: Do you rely on Mr. Erickson's calculations?

A: Yes. I rely on his finding of the Proposed Project's total greenhouse gas emissions from construction and operation, and the lifecycle emissions from the transported oil and gas products, as well as his calculation of the net greenhouse gas emissions compared to the no-action alternative. I use his calculations of quantified tons of greenhouse gas emissions to monetize the Proposed Project's climate costs.

Q. Why is monetization of environmental externalities important for evaluating how pollution from the Proposed Project impairs the air, water, natural resources, or public trust?

A. Monetization can help both decisionmakers and the public understand the nature of the Proposed Project's pollution and the impairment it causes. When environmental externalities are presented only qualitatively, decisionmakers and the public both will tend to overly discount the importance of the effects. In general, non-monetized effects are often irrationally treated as worthless.[5] This may be especially true if some effects (like capital

[5] Richard Revesz, *Quantifying Regulatory Benefits,* 102 Cal. L. Rev. 1424, 1434-35, 1442 (2014).

cost and operational costs) are monetized, while other effects (like climate and health benefits) are discussed only quantitatively or qualitatively.[6]

It also may be especially difficult for the public and decisionmakers to fully consider climate effects that are presented only quantitatively through estimates of emissions volumes. As the U.S. Environmental Protection Agency's website explains, "abstract measurements" of so many tons of greenhouse gases can be less useful for the public, unless "translat[ed] . . . into concrete terms you can understand."[7] In particular, it may be difficult for many members of the public—and even for some decisionmakers otherwise well-versed in climate change—to conceptualize how significant emissions of 27 million tons per year of greenhouse gases actually are, let alone what concrete impacts those emissions will have to the air, water, natural resources, human health, economy, and public trust. Comparisons of tons of greenhouse gases emitted by the Proposed Project to statewide, national, or global totals of annual emissions may misleadingly make such quantitative figures appear small.[8] But in fact, even a "small portion of a gargantuan source of . . . pollution" may still "constitute[] a gargantuan source of . . . pollution on its own terms."[9] Monetization makes that clear. Specifically, while 27 million tons per year may

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[6] A well-documented mental heuristic called "salience bias" causes people to irrationally focus more on salient figures and ignore less salient figures. Because people are very familiar with money, but do not often encounter in their everyday lives statistics on the metric tons of greenhouse gas emissions, people are more likely to focus on costs and benefits presented in monetary terms, and less likely to focus on climate costs presented only quantitatively or qualitatively.

[7] EPA, Greenhouse Gas Equivalencies Calculator, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last updated Mar. 2021), *available at* https://perma.cc/UNX8-PQ3J.

[8] A well-documented mental heuristic called "probability neglect" causes people to irrationally reduce small probability risks entirely down to zero. Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L61, 63, 72 (2002) (drawing from the work of recent Nobel laureate economist Richard Thaler). Another well-document mental heuristic called "scope neglect" suggests that abstract volume estimates will fail to give people the required informational context to understand climate risks. Daniel Kahneman et al., *Economic Preferences or Attitude Expressions? An Analysis of Dollar Responses to Public Issues*, 19 J. Risk & Uncertainty 203, 212-213 (1999).

[9] Sw. Elec. Power Co. v. EPA, 920 F.3d 999, 1032 (5th Cir. 2019) (internal quotation marks omitted).

be hard to conceptualize, the monetized expected cost of the climate risks associated with those same emissions—about $1 billion per year according to the federal Interagency Working Group's central estimate of the social cost of carbon[10]—is a salient, relevant, and contextualized way of understanding the Proposed Project's pollution. (This type of calculation is explored in much greater detail later in this testimony.)

Moreover, monetization using the social cost of greenhouse gas methodology will help decisionmakers and the public understand the concrete impairment to air, water, natural resources, and the public trust caused by that pollution. Though the current best estimates of the social cost of greenhouse gases cannot yet capture all categories of climate damages, current estimates do at least partially reflect many key real-world impacts such as:[11]

- **energy system losses** and disruptions, including from temperature-related changes to the demand for cooling and heating;
- human health impacts, including cardiovascular and respiratory mortality from climate-induced **changes in air quality**, as well as from heat-related illnesses,

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[10] *See infra* and attached exhibits for more details on this calculation. To briefly summarize, the quantified metric tons of incremental carbon dioxide-equivalent emissions from the Proposed Project as compared to the no-action alternative (from Peter A. Erickson's testimony) are monetized by the relevant central estimate of the social cost of carbon dioxide published in February 2021 by the federal Interagency Working Group (2021 TSD, *supra*), and then discounted back to present value at a 3% rate. This $1 billion per year figure reflects that the total net present value of the incremental climate effects from 2027-2070 is conservatively estimated at $41 billion, and $41 billion over 44 years is nearly $1 billion per year. The actual present value figure varies each year.

[11] These impacts are all included to some degree in at least one of the three integrated assessment models (IAMs) used by the Interagency Working Group (namely, the DICE, FUND, and PAGE models), though some impacts are modeled incompletely or not represented in all three models, and many other important damage categories are currently omitted from these IAMs. *Compare* Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis* at 6-8, 29-33 (2010), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf [hereinafter IWG, *2010 TSD*]; *with* Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014), http://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf.

changing disease vectors like malaria and dengue fever, and **water-borne diseases**;

- **water supply losses** and disruptions, including changes in fresh water availability from extreme weather events and infrastructure impacts;
- lost productivity and other impacts to **agriculture, forestry, and fisheries**, due to alterations in temperature, precipitation, CO_2 fertilization, and other climate effects;
- **property lost** or damaged by coastal flooding, storms, other extreme weather events, as well as the cost of protecting vulnerable property and the cost of resettlement following property losses;
- some **biodiversity losses** and ecosystem service impacts;
- some impacts to **outdoor recreation** and other non-market amenities; and
- some **catastrophic impacts**, including the triggering of climate tipping point events and damages at very high temperatures.

By translating tons of emissions into dollars of real-world climate damages, applying the social cost of greenhouse gas metrics will help decisionmakers and the public understand the nature of the impairment caused by the Proposed Project's greenhouse gas pollution.

Q. Why is monetization of environmental externalities important for evaluating whether the no-action scenario is a feasible and prudent alternative to the Proposed Project?

A. Monetization can help decisionmakers and the public weigh climate costs against other costs and benefits of various alternatives, and so determine the relative prudence of the no-action alternative as compared to the Proposed Project. In order to ensure that environmental effects will be treated on par with other costs and benefits, those environmental externalities should, whenever feasible, be monetized. When all costs and benefits are translated into the common metric of money, the tradeoffs inherent in policy choices become apparent, and decisionmakers can more readily and more transparently compare society's preferences for competing priorities. Specifically, the fact that the Proposed Project will inflict an additional $41 billion or more in climate damages as compared to the no-action alternative is clearly relevant in weighing the prudence of the no-action alternative.

Q. Why is monetization appropriate for greenhouse gas emissions in particular, including the greenhouse gas emissions from the Proposed Project?

A. Greenhouse gas emissions are particularly suitable candidates for monetization, and the emissions from the Proposed Project can be readily monetized.

First, greenhouse gases are global pollutants, such that any ton of carbon dioxide emissions causes the same environmental harms regardless of the source of the emission. It does not matter what type of project caused the emission or where the emission originated geographically: any ton of carbon dioxide will become well-mixed in the global atmosphere, cause the same kind of additional radiative forcing and other atmospheric interactions over its long lifespan, contribute the same incremental temperature increase and other impacts to climate and weather, and so cause the same additional impairment to air, water, natural resources, human health, and the economy. (The measurement of such impacts through the application of integrated assessment models is discussed more below.) For this reason, we can calculate with reasonable certainty the climate costs imposed by the emissions from the Proposed Project.

The second reason why greenhouse gas emissions are particularly suited for monetization is that a widely accepted monetization tool exists. The federal Interagency Working Group's estimates of the Social Costs of Greenhouse Gases have been thoroughly vetted by economists, scientists, and the courts; have been widely adopted by a growing list of other U.S. states; and are freely available and easy to apply. (The development, vetting, and use of these estimates is detailed more below.)

The global nature of the climate effects of greenhouse gases also creates a third reason why monetization of greenhouse gas emissions is particularly appropriate: reciprocity. By using the metrics in its decisionmaking proceedings, Michigan can help build a precedent for other states to follow. As Michigan helps encourage other jurisdictions to likewise weigh the social cost of greenhouse gases in their decisions, Michigan will benefit as other jurisdictions' emissions are reduced. Because greenhouse gases do not stay within geographic borders, but rather mix in the earth's atmosphere and affect climate worldwide, greenhouse gases emitted outside Michigan contribute directly to climate damages in Michigan (just as Michigan's emissions contribute directly to climate damages outside Michigan). Michigan stands to benefit greatly as other U.S. states apply a global social cost of greenhouse gas value to their energy policy decisions and so weigh the externalities of their emissions that will fall on Michigan. It is therefore rational for Michigan to use the social cost of greenhouse gases in its own decisionmaking, because it will encourage other states to follow suit.[12]

[12] *See* Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columb. J. Envtl. L. 203 (2017); Jason A. Schwartz, *Strategically Estimating Climate Pollution Costs in a Global Environment* n.34 (Policy Integrity Report, June 2021), https://policyintegrity.org/files/publications/Strategically_Estimating_Climate_Pollution_Costs_in_a_Global_Environment.pdf (making the case for state-level reciprocity).

Several U.S. states already apply the federal Interagency Working Group's methodology in their energy policy decisions, including Colorado, Nevada, Minnesota, California, Washington, and others. (See *infra* for more on how other states are valuing the social cost of greenhouse gases.) Michigan should join those states as a leader in climate policy by considering the social cost of greenhouse gases in its decisionmaking, and so encourage additional states to follow suit—which in turn will benefit Michigan.

Q. How are climate effects monetized using the social cost of greenhouse gas methodology?

A. Economists monetize climate damages by linking together global climate models with global economic models, producing what are called integrated assessment models. These integrated assessment models can take a single additional unit of greenhouse gas emissions emitted from any source anywhere in the world (such as from burning oil or operating tunnel-boring equipment) and calculate the change in atmospheric greenhouse concentrations; translate that change in concentration into a change in temperature; and model how that temperature change and associated weather changes will cause economic damages. The resulting monetary estimate of how each additional unit of greenhouse gases will impact our health, our economic activity, our quality of life, and our overall well-being is called the social cost of greenhouse gases.

Q. Is there a consensus among scientists, economists, and other experts on the best methodology for monetizing climate damages from greenhouse gas emissions?

A. Yes. The methodology and estimates developed by the federal Interagency Working Group on the Social Cost of Greenhouse Gases, published most recently in February 2021, is widely considered to be the best available calculation of the social cost of greenhouse gases, even though it is also widely considered to be a conservative underestimate of true costs of climate change.[13]

In 2009, an Interagency Working Group assembled experts from a dozen federal agencies and White House offices to "estimate the monetized damages associated with an incremental increase in [greenhouse gas] emissions in a given year" based on "a defensible set of input assumptions that are grounded in the existing scientific and economic literature."[14] The estimates are based on the three most cited, most peer-reviewed models built to link physical impacts to the economic damages of each additional ton of greenhouse gas emissions. Those three leading integrated assessment models are DICE (by Nobel laureate William Nordhaus of Yale University), FUND (by Richard Tol and David Anthoff of Sussex University and University of California-Berkeley), and PAGE (by Chris Hope of Cambridge University). These models are able to estimate and monetize many[15] of the most important categories of climate damages, including, but not limited to: energy system losses and disruptions; air quality and water quality changes and associated impacts to human health; fresh water supply losses; impacts to forestry, fisheries, and agriculture; property damage; biodiversity losses and ecosystem service impacts; impacts to outdoor recreation and other non-market amenities; and catastrophic impacts.

The Working Group ran these models using inputs and reasonable assumptions drawn from the peer-reviewed literature, and the Working Group updated its estimates every few years—most recently in February 2021—to reflect the latest and best scientific

[13] *See* IWG, 2021 TSD, *supra* note 4, at 4 (admitting that its own estimates "likely underestimate societal damages from GHG emissions").

[14] IWG, 2010 TSD, *supra* note 11.

[15] *See supra* notes 2-3 & 11 and accompanying text for details on which categories are or are not currently included.

and economic data.[16] From early 2017 through January 2021, the Trump Administration disbanded the Working Group, and during that period some agencies developed much lower "interim" estimates of the social cost of greenhouse gases.[17] In 2020, a federal court found those "interim" estimates to be arbitrarily and illegally inconsistent with the best available science and economics;[18] a report by the U.S. Governmental Accountability Office (GAO) similarly concluded that those "interim" estimates had no process for ensuring consistency with the best available science and economics.[19] In 2021, the Biden Administration reconstituted the Working Group, which quickly readopted the prior values from 2016 (adjusting them for inflation into 2020$).[20] The Working Group expects to more thoroughly update the estimates by January 2022, and in particular has expressed a need to reexamine the selection of the discount rate.[21]

Q. What discount rates did the Working Group select, and what range of estimates has the Working Group issued?

A. For each greenhouse gas (i.e., carbon dioxide, methane, nitrous oxide), the Working Group has issued a "central estimate" of social costs per metric ton of emissions per year based on a 3% discount rate and taking the average from a probability distribution; a "high-impact estimate" based on the 95th percentile of that probability distribution calculated at a 3% discount rate; as well as additional estimates that explore the calculation's sensitivity to a

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[16] IWG, 2021 TSD, *supra* note 4.

[17] *See* Policy Integrity, *How the Trump Administration Is Obscuring the Costs of Climate Change* (2018), https://policyintegrity.org/files/publications/Obscuring_Costs_of_Climage_Change_Issue_Brief.pdf.

[18] California v. Bernhardt, 472 F.Supp.3d 573, 611-14 (N.D.Cal. 2020).

[19] GAO, GAO-20-254, *Social Cost of Carbon: Identifying a Federal Entity to address the National Academies' Recommendations Could Strengthen Regulatory Analysis* 29 (2020) (concluding that the "interim" estimates "may not be well positioned to ensure agencies' future regulatory analyses are using the best available science").

[20] IWG, 2021 TSD, *supra* note 4.

[21] *Id.*

lower (2.5%) or higher (5%) discount rate.[22] Discount rates are important because of the nature of greenhouse gases and climate change. Once emitted, greenhouse gases can linger in the atmosphere for centuries, building up the concentration of radiative-forcing pollution and affecting the climate in cumulative, non-linear ways.[23] The integrated assessment models project future climate damages over roughly a 300-year timescale. However, society tends to value economic effects today more than future effects.[24] A discount rate is used to take all the marginal climate damages that an additional ton of emissions emitted in the near future will inflict over the next 300 years, and translate those future damages back into present-day values.

Since its founding in 2009 through its most recent updated guidance, the Working Group has chosen a 3% discount rate for its central estimate based on available data and historical precedents on federal agencies' default choice of discount rates.

Q. Is the Working Group's choice of discount rates appropriate, and should other discount rates be considered?

A. Though the choice of a 3% central discount rate was appropriate as a conservative selection a decade ago, more recently updated market data on U.S. Treasury rates, consumer saving rates, and economic forecasts—as well as updated economic literature on uncertainty, correlations between climate damages and economic growth, preferences for inter-

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[22] *See generally* 2010 TSD, *supra* note 11. The 5% discount rate was selected as an "upper value" to reflect "possibility that climate damages are positively correlated with market returns," *id.* at 23, while the 2.5% rate was used to reflect the fact that "interest rates are highly uncertain over time," *id.*

[23] Carbon dioxide also has cumulative effects on ocean acidification, in addition to cumulative radiative-forcing.

[24] However, many experts on climate policy and economics believe that a non-zero rate of time preference is inappropriate in the context of long-term climate change, because society really does not or should not care less about the welfare of future generations. *See* Richard Revesz & Matthew Shahabian, *Climate Change and Future Generations*, 84 S. Cal. L. Rev. 1097 (2011).

generational equity, expert elicitations, and other technical concepts[25]—all point strongly in the direction of a lower discount rate being more appropriate. Based on such economic and ethical considerations, New York has already moved to estimates based on a 2% discount rate (calculated through a methodology otherwise based on and consistent with the Working Group's estimates), and Washington and Colorado have adopted the Working Group's estimates at 2.5%.[26] In February 2021, the Working Group expressed that a rate of 2.5% *or lower* may be appropriate, and the Working Group will revisit its choice of discount rates when it updates its values in January 2022.[27] For that reason, this testimony shows both the Working Group's estimates at the 3% and 2.5% discount rates, but cautions that even the 2.5% estimates are likely conservative underestimates because the most appropriate discount rate is likely at or below 2%.[28] To further address this potential source of underestimation, we also ran the analysis using New York State's valuations of the social cost of carbon dioxide at a 2% discount rate, though these estimates are available only through the year 2050.

Q. What are the values of the social cost of carbon dioxide over time?

A. The social cost of greenhouse gases increases over time, because an additional ton of emissions will inflict greater damages in the future as emissions accumulate in the atmosphere and climate and economic systems become increasingly stressed. The following table shows the Interagency Working Group's estimates for the social cost of

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[25] Howard & Schwartz, *About Time*, *supra* note 4.

[26] N.Y. Dep't of Envtl. Conserv., Establishing a Value of Carbon: Guidelines for Use by State Agencies 18 (2020; revised 2021), https://www.dec.ny.gov/docs/administration_pdf/vocguidrev.pdf; Wash. Dept. of Commerce, *Recommendation for Standardizing the Social Cost of Carbon When Used for Public Decision-Making Processes* (2014) http://www.commerce.wa.gov/wp-content/uploads/2015/11/Energy-EV-Planning-Social-Cost-of-Carbon-Sept-2014.pdf; Colo. H.B. 21-1238 (2021).

[27] 2021 TSD, *supra* note 4, at 21, 35.

[28] *See* Howard & Schwartz About Time, *supra* note 4.

carbon, by year of emissions, calculated at both the 3% and 2.5% discount rates, as well as corresponding social cost of carbon dioxide estimates calculated at the 2% rate by New York State in a manner consistent with the Working Group's method.

Importantly, the Working Group's central estimate omits key categories of climate damages—like many of the risks of catastrophic and irreversible consequences, including environmental and social "tipping points." The Working Group developed a set of high-impact estimates (calculated at the 95th-percentile of the probability distribution for the 3% discount rate estimates), which serve as a partial proxy for, among other things, omitted catastrophic damages, risk aversion, and other uncertainties.[29] Policy decisions should therefore be informed by the Working Group's full range of estimates, and the high-impact estimates are provided in the following table as well.

The Working Group's most recent set of estimates, published in February 2021, run through year 2050. Recently, in June 2021, the U.S. Environmental Protection Agency (EPA)—a key member of the Working Group—extended the Working Group's estimates from 2050 out through year 2070. New York's estimates are currently available only through year 2050.

[29] IWG, 2010 TSD, *supra* note 11, at 25, 30.

Table 1. Social Cost of Carbon Dioxide Estimates (in 2020$, per metric ton)[30]

Year	IWG/EPA's Central Estimates at a 3% Discount Rate	IWG/EPA's Estimates at a 2.5% Discount Rate	New York's Central Estimates at a 2.0% Discount Rate	IWG/EPA's High Impact Estimates (95th-percentile at a 3% discount rate)
2020	$51	$76	$121	$152
2025	$56	$83	$129	$169
2030	$62	$89	$137	$187
2035	$67	$96	$146	$206
2040	$73	$103	$154	$225
2045	$79	$110	$164	$242
2050	$85	$116	$172	$260
2060	$94	$128	*not available*	$276
2070	$108	$144	*not available*	$328

Q. Have the Working Group's estimates been reviewed by third parties?

A. Yes, the Working Group's estimates have been repeatedly endorsed by reviewers. In 2014, the U.S. Government Accountability Office reviewed the Working Group's methodology and concluded that it had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information via public comments and updated research.[31] In 2016, the U.S. Court of Appeals for the Seventh Circuit held that estimates of the social cost of carbon used to date by agencies were reasonable.[32] In 2016 and 2017, the National Academies of Sciences issued two reports that, while recommending future improvements to the methodology,

[30] The table shows rounded figures. Unrounded values are available at https://www.whitehouse.gov/wp-content/uploads/2021/02/tsd_2021_annual_unrounded.csv. *See* IWG, 2021 TSD, *supra* note 4; EPA, *Social Cost of Greenhouse Gases (SC-GHGs) Unrounded Annual Estimates through 2070*, June 2021 https://www.regulations.gov/document/EPA-HQ-OAR-2021-0208-0161; N.Y. Dep't of Envtl. Conserv., *supra* note 26.

[31] Gov't Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* 12-19 (2014).

[32] Zero Zone, Inc. v. Dep't of Energy, 832 F.3d 654, 679 (7th Cir. 2016).

supported the continued use of the existing Working Group estimates.[33] In 2020, the U.S. District Court for the Northern District of California held that by breaking from the Working Group's estimates, the Trump Administration had ignored the best available science and economics.[34] It is, therefore, unsurprising that scores of economists and climate policy experts have endorsed the Working Group's values as the best available estimates, even while stressing that the estimates are conservative underestimates.[35] The Working Group's estimates have been used in well over 100 federal regulatory proceedings, and counting, each subject to a thorough public comment period.[36]

Q. Do other states use the Working Group's estimates for the social cost of greenhouse gases?

A. A number of states have recognized the importance of considering the social cost of carbon estimates and have begun using the federal Interagency Working Group's estimates or methodology to measure the harms from carbon dioxide emissions in their proceedings. States that consider the damage of carbon dioxide emissions in various energy and climate policy proceedings include Colorado, Minnesota, Nevada, Virginia, Washington, California, Illinois, Maine, New Jersey, New Mexico, and New York.[37] Notably, all states that have to date incorporated or are considering incorporating the social cost of greenhouse

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[33] Nat'l Acad. Sci., Eng. & Medicine, *Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide* 3 (2017); Nat'l Acad. Sci., Eng. & Medicine, *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update* 1 (2016).

[34] California v. Bernhardt, 472 F.Supp.3d at 611-14.

[35] *See, e.g.*, Joseph E. Aldy et al., *Keep Climate Policy Focused on the Social Cost of Carbon*, 373 SCIENCE 950 (2021); Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 655 (2017); Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 REV. ENVTL. ECON. & POL'Y 23, 42 (2013); Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014) (co-authored with Nobel Laureate Kenneth Arrow, among others).

[36] *See* Howard & Schwartz, *Think Global*, *supra* note 12, App. A (cataloguing uses in federal proceeding).

[37] *See* Cost of Carbon, States Using the SCC, https://costofcarbon.org/states.

gases into their electricity decisionmaking have relied at least in part—and, more often, exclusively—on the Interagency Working Group's numbers or methodology.

A few key examples are worth exploring in more detail. Several states have decided to focus on estimates that are greater than the Working Group's "central" estimates calculated at the 3% discount rate. As mentioned above, New York States has adapted the Working Group's methodology but applied a 2% discount rate, to be consistent with more recent economic data and also to help offset the fact that the social cost of greenhouse gases is underestimated because many significant categories of climate damages cannot currently be estimated due to data limitations.[38] Back in 2014, Washington decided to focus on the Working Group's estimates at the 2.5% discount rate for similar reasons, and to fulfill ethical obligations to future generations and maintain Washington's role as a leader on climate change.[39] Colorado also requires its gas and electricity utilities to focus on the 2.5% estimates.[40] Similarly, California's Public Utilities Commission requires consideration of the Working Group's high-impact estimates,[41] because many of the climate damage categories most relevant to the state's energy infrastructure and economy—such as wildfires, thermal efficiency decreases, and overheating of electricity system components—are not fully incorporated into the central estimates of the social cost of carbon.[42]

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[38] N.Y. Dep't of Envtl. Conserv., *supra* note 26, at 18-19.

[39] Wash. Dept. of Commerce, *supra* note 26, at 3-5.

[40] Colo. HB 21-1238, *supra* note 26.

[41] Before the Cal. PUC, 19-05-019, Decision Adopting Cost-Effectiveness Analysis Framework Policies for All Distributed Energy Resources at 42 (May 16, 2019), http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M293/K833/293833387.PDF.

[42] *See* Before the Cal. PUC, ALJ's Ruling Seeking Responses to Questions and Comment on Staff Amended Proposal on Societal Cost Test (Mar. 14, 2018), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M212/K023/212023660.PDF.

Michigan should join these states as a climate leader by considering the Working Group's estimates—including high-impact estimates and estimates at lower discount rates—as it weighs the impairment caused by the Proposed Project's pollution and the comparative prudence of the no-action alternative. As the Governor recently recognized in an Executive Directive, "Michigan must be a leader in this fight."[43]

Q. Why is a global perspective necessary and appropriate when valuing the social cost of greenhouse gas emissions?

A. Several reasons explain why a full accounting of climate costs requires a global estimate of the social cost of greenhouse gases. First, the principles of reciprocity discussed above dictate the need for a global perspective. Michigan cannot solve climate change on its own, and Michigan benefits tremendously when other states and other countries reduce their greenhouse gas emissions. In prioritizing the actions that Michigan should take to contribute to the global efforts to combat climate change, Michigan should think about the climate damages it inflicts on the rest of the world, just as Michigan would want the rest of the world to think about the damages their actions cause to Michigan's air, water, natural resources, and public trust. As Michigan recognized when joining the U.S. Climate Alliance:

> Smart, coordinated state action can ensure that the United States continues to contribute to the global effort to address climate change.…Alliance members are committed to supporting the international agreement, and are pursuing climate action to make progress toward its goals. It is time for Michigan to join the effort.[44]

To encourage other jurisdictions to continue to take account of the externalities of their emissions impose on Michigan, Michigan must likewise take account of the

[43] Gov. Gretchen Whitmer, Executive Directive 2020-10: Building a Carbon-Neutral Michigan (Sept. 23, 2020).
[44] Gov. Gretchen Whitmer, Executive Directive 2019-12: Responding to Climate Change (Feb. 4, 2019).

externalities of its emissions that fall outside state borders. The fragile tit-for-tat dynamic could fall apart in the face of too many jurisdictions turning a blind eye to their global externalities and considering only local effects. For example, soon after the Trump administration reversed course and developed its own, flawed, domestic-only "interim" values of the social cost of greenhouse gases, the country of Mexico also moved toward considering only domestic climate impacts in its regulatory analyses.[45] To secure the reciprocal level of efficient action of greenhouse gas emissions, Michigan should follow the lead of Colorado, Minnesota, Nevada, and other states, and use a global number.

Second, climate damages do not respect political borders. The people of Michigan have financial and personal interests in businesses and property located outside Michigan that may be affected by climate change. Michigan's businesses depend on non-local economies to buy their exports, sell imports, and fill their supply chains. If rising temperatures and rising seas cause climate refugees or infectious disease vectors to migrate toward or within the United States, Michigan will feel the impacts along with the rest of the country. Michigan's economy, public health, and security are all linked to globally interconnected systems. Because climate damages occurring outside Michigan borders can spill over and affect the people of Michigan, a global perspective on the social cost of greenhouse gases is required.[46] In fact, a federal judge recently found it was arbitrary and illegal to focus on climate effects occurring only within strict geographic borders given that effects occurring beyond those borders will spill back and inflict local economic, health, and security damages.[47]

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[45] *See* Schwartz, *Strategically Estimating Climate Pollution Costs in a Global Environment*, *supra* note 12, at n.38.

[46] *See id;* Howard & Schwartz, *Think Global*, *supra* note 12.

[47] California v. Bernhardt, 472 F.Supp.3d at 611-14.

Finally, no existing methodology can calculate accurately a domestic-only estimate. The models simply were not designed to produce such estimates: for example, the models do not account for any inter-regional spillover effects. Any approximate and speculative estimate based on factors like percentage of global GDP, or share of global coastline or landmass, will be inherently misleading, as they ignore inter-regional spillover effects and extraterritorial interests of citizens.[48] While many scientists can and do describe the impact of climate change on natural resources in Michigan,[49] and there is no question that specific natural resources in Michigan will be impacted in individual ways, there is no Michigan-only estimate of the social cost of greenhouse gases; only global estimates.[50]

Every state that has begun to incorporate the social cost of greenhouse gases is using a global damage estimate. Attempting to apply a Michigan-specific estimate would be akin to a homeowner throwing trash in her neighbor's yard without considering the odors and pests that will spill back to her own property, or how the neighbor might retaliate in kind.

Q. What quantitative figures do you use to monetize the climate damages from the Proposed Project's emissions?

A. We take as given Peter A. Erickson's quantitative estimates of the metric tons of carbon dioxide-equivalent[51] emissions that the Proposed Project's construction and operation will

[48] *See* Schwartz, *Strategically Estimating Climate Pollution Costs in a Global Environment*, *supra* note 12, at 29 (explaining, for example, that the coastline-based scaling would absurdly suggest that landlocked or non-coastal states have a zero valuation of the social cost of greenhouse gases).

[49] *See, e.g.,* Direct Testimony of Dr. Overpeck.

[50] *See e.g.,* Joint Comments to U.S. Forest Service on Use of Social Cost of Carbon in Colorado Roadless Rule, at 11-14 (Jan. 15, 2016), *available at* http://policyintegrity.org/documents/Forest_Service_SDEIS_comments.pdf (explaining, for example, that there is no national-, Colorado-, or forest-only estimate of the social cost of carbon).

[51] Erickson presents his quantitative figures in carbon dioxide-equivalent totals, using a relative global warming potential for methane as 29.8 over a 100-year timeframe. Considering the nearer-term relative potency of methane, however, puts methane's relative global warming potential much higher, at 82.5 over a 20-year timeframe. *See* IPCC, AR6: Chapter 7, at 7-125 (2021). Ultimately, because of different lifespans and other atmospheric interactions, it is

generate, and the lifecycle emissions from the oil and gas products transported by the Proposed Project relative to emissions under the no-action scenario. As Erickson's testimony explains, his figures could under- or over-estimate some emissions, and overall Erickson's testimony states that its results may be conservative.

Q. How did you monetize the climate costs from construction of the Proposed Project, and what assumptions did you make about the Proposed Project's construction timeline?

A. Because the social cost of carbon dioxide increases over time, we must place Erickson's quantitative estimates into specific calendar years. To do this, we assume that it could take about another six years from 2021 for the Proposed Project to clear the remaining environmental reviews and other procedures before construction could begin in 2027.[52] Then based on Enbridge's estimate of a two-year construction period,[53] we assume construction will be completed from 2027-2028, and we assume that Erickson's calculation of 87,000 metric tons of carbon dioxide-equivalent emissions from construction would be split equally between 2027 and 2028 (i.e., 43,500 metric tons per year). We then multiplied these annual construction emissions by the corresponding year's estimates of the social cost of carbon dioxide, considering the four sets of values defined above (3%, 2.5%, 2%, and high-impact). We then discounted these future damage estimates back to their present-

somewhat more accurate to directly estimate the social cost of methane rather than to convert tons of methane into carbon dioxide-equivalents using relative global warming potentials. The Working Group has developed estimates for the social cost of methane, which range from about 29-37 times greater than the social cost of carbon estimate for the corresponding year. IWG, 2021 TSD, *supra* note 4, at 5. However, given the tons of methane at stake here compared to the tons of carbon dioxide, using the social cost of methane would not be significantly different from using the global warming potential-adjusted figures here.

[52] *See* U.S. Council on Environmental Quality, *Environmental Impact Statement Timelines (2010-2018)* at 8 (2020), https://ceq.doe.gov/docs/nepa-practice/CEQ_EIS_Timeline_Report_2020-6-12.pdf (noting that U.S. Army Corps of Engineers-approved projects take about 6 years to complete environmental review).

[53] Enbridge, *Line 5 Straits of Mackinac Crossing* at 2, https://www.enbridge.com/~/media/Enb/Documents/Factsheets/FS_Line5_Straits_tunnel_project.pdf?la=en.

day value in the current year of 2021 using the discount rate that corresponds to the underlying rate used to calculate the relevant social cost of carbon values (i.e., a 2.5% discount rate is used when applying the social cost of carbon values calculated at a 2.5% rate).

Q. How did you monetize the climate costs from operation of the Proposed Project, including costs for emissions occurring after the year 2070?

A. Following Erickson's calculations, we assume that the Proposed Project's annual operating emissions are 520 metric tons of carbon dioxide-equivalents, and that the Proposed Project's lifespan was 99 years. Therefore, if we assume construction will end in 2028 and operations will begin in 2029, operations will continue through to at least 2127.

Neither the social cost of carbon dioxide estimates published by the federal government or those issued by New York are available through 2127. The federal Interagency Working Group's latest estimates run through 2050, though EPA has extended this analysis through to 2070. New York's estimates run through 2050.

However, estimates of the social cost of carbon dioxide grow at relatively stable rates over time. As such, we can extend the Working Group/EPA's estimates beyond 2070 to 2127 using linear extrapolation. We select linear extrapolation over other alternatives (such as polynomial and box-cox transformation) as these more flexible alternative functions are essentially linear for the average social cost of carbon estimates corresponding to the 3% and 2.5% discount rates, avoids overfitting the model based on its simplicity, and produces a lower-bound approximation. The projected, extrapolated values through 2127 are available in Exhibit PH-2 and the extrapolation code is available in Exhibit PH-3.

Given the different timeframes during which different estimates of the social cost of carbon dioxide are available, we have made calculations based on three separate time periods. Our central estimates are calculated for emissions occurring over the time period 2027-2070, using EPA's estimates of the social cost of carbon. However, we also calculate from 2027-2050, to limit the estimate to the Working Group's set of values. And we also calculate from 2027-2127, applying our extrapolation of social cost of carbon dioxide figures into the future.

Q: What is your estimate of the climate costs from the construction and operation of the Proposed Project?

A: From 2027 to 2070, the climate costs of the Proposed Project's emissions from the construction and operation of the pipeline equals $5.0 million dollars when applying the social cost of carbon values calculated at the 3% discount rate. 84% of these effects stem from the pipeline's construction. Using the 2.5% discount rate and the high-impact SCC estimate increases the joint GHG cost of construction and operation up to $7.6 million and $15.2 million, respectively. A longer timeline to 2127 slightly increases the GHG cost estimates, as does using a lower discount rate of 2%. Considering these issues jointly could increase these cost estimates to approximately $13 million. See the attached spreadsheet (Exhibit PH-2) for a more complete breakdown of climate costs associated with various emissions sources. However, as explained above, the per-ton monetized damages from carbon dioxide does not change depending on the source of emissions. From an economic perspective, it does not matter whether a ton of carbon dioxide is emitted by construction, operation, or downstream combustion of transported products—all those emissions will cause climate damages. Basic economic principles of supply and demand indicate that construction and operation of the Proposed Project will increase the net supply and demand of oil and gas products, and so increase net lifecycle emissions from the production, transport, and combustion of those oil and gas products. All those emissions can and should be monetized as well.

Q. Mr. Erickson also estimated incremental greenhouse gas emissions resulting from the transport of oil and NGL through the Proposed Project, as compared to a no-action alternative. How did you monetize the net climate costs from the products delivered by the Proposed Project, as compared to emissions under the no-action alternative?

A. Following Erickson's testimony, we assumed a net increase of 27 million metric tons of greenhouse gas emissions (CO_2e) annually from the fuel transported by the pipeline, as compared to emissions under the no-action alternative. As explained above for operational emissions, we assumed that the lifespan of the pipeline will be at least 99 years, such that the pipeline will begin transporting oil and gas in 2029, and run through at least 2127. Given those assumptions, the monetization of lifecycle emissions from the transported products is then identical to above.

Q. What are the total monetized climate costs of the Proposed Project's emissions from construction and operation and the lifecycle emissions from additional oil and gas products transported by the Proposed Project?

A. As explained above, we use the federal Interagency Working Group's estimates of the social cost of carbon calculated at a 3% discount rate, and extended by EPA through year 2070, for our main, conservative estimate. But we also test our calculation's sensitivity to using other social cost of carbon figures (specifically, estimates at the 2.5% and 2% discount rates, and the Working Group's high-impact estimates), as well as over different time periods (through 2050, or through 2127). In all cases, we discount future effects back to present value as of 2021. For undiscounted totals, estimates additional discount rates (0%, 1%, and 5%), and breakdowns of estimates by construction source or lifecycle stage, please see Exhibit PH-2.

Table 3. Total Value of the Proposed Project's Net Monetized Climate Costs (Present Value in 2021; in 2020$)

Time Period	Estimate of the Social Cost of Carbon Dioxide			
	IWG/EPA's Central 3% Estimates	IWG/EPA's 2.5% Estimates	New York's Central 2% Estimates	IWG/EPA's High Impact Estimates
2027-2050	$24.95 billion	$38.45 billion	$63.24 billion (154% higher than the 3% estimate)	$76.24 billion
2027-2070	**$41.02 billion**	$64.95 billion	*not directly available; an assumed 154% increase would total $104.00 billion*	$124.38 billion
2027-2127	$63.38 billion	$106.84 billion	*not directly available; an assumed 154% increase would total $160.68 billion*	$191.45 billion

Q. Is your monetization of the environmental costs of the Proposed Project a conservative estimate?

A. Yes, our estimate of $41 billion in net present value climate costs from the Proposed Project's emissions from 2027 through 2070, calculated using the 3% social cost of carbon figures, is a very conservative for several reasons.[54]

[54] Again, this analysis takes as given the quantified totals from Erickson's testimony. The monetized totals presented here may be under- or over-estimates to the extent those quantified totals are under- or over-estimates.

First, the pipeline is expected to have at least a 99-year lifespan, implying an end date of 2127, not 2070. Extrapolating and applying the 3% social cost of carbon estimates through 2127 would increase the net present value from $41 billion to $63 billion.

Second, as discussed above, considerable recent evidence strongly points to a discount rate below 3%, of 2% or lower. If the Working Group's 2.5% estimates are applied over the 2027-2070 period rather than the 3% figures, the net present value of climate costs would increase to almost $65 billion. Similarly, over the shorter 2027-2050 time period, moving from the 3% estimates to New York's estimates of the social cost of carbon at a 2% discount rate would increase the net present value of the project's climate costs by 154% (from $25 billion to $63 billion). If that same relative percentage increase holds true over the longer analysis period of 2027-2127, then we can predict that applying 2% social cost of carbon figures over the 2027-2127 period instead of the 3% figures would increase the net present total value to over $160 billion.[55] Even this may be a low estimate, as some recent evidence supports a discount rate below 2%.

Third, the methodology for calculating the social cost of greenhouse gases currently excludes many significant health, environmental, and welfare impacts due to data limitations, such as:

- Wildfires, including acreage burned, health impacts from smoke, property losses, and deaths;
- Agricultural impacts, including food price spikes and changes from heat and precipitation extremes;

[55] That is, a 154% increase of $63.38 billion = 63.38 billion * (1+1.54) = 160.65 billion.

- Death, injuries, and illnesses from omitted natural disasters and interruptions in the supply of water, food, sanitation, and shelter;
- Impacts on labor productivity from extreme heat and weather;
- Catastrophic impacts and tipping points, including rapid sea level rise and damages at very high temperatures;
- Ocean acidification and extreme weather effects on fisheries and coral reefs;
- Biodiversity and habitat loss, and species extinction;
- Changes in land and ocean transportation;
- National security impacts from regional conflict, including from refugee migration stemming from extreme weather and from food, water, and land scarcity;
- And many more categories.[56]

Consequently, while the Working Group's estimates remain among the best available for government decisionmakers to use, they are widely acknowledged to be underestimates, perhaps severely so.[57] To proxy for these omitted impacts, the Working Group has recommended considering its high-impact estimates. Over the 2027-2127

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[56] Howard, *Omitted Damages*, *supra* note 11. For more on wildfires specifically, see Peter H. Howard, *Flammable Planet: Wildfires and the Social Cost of Carbon* (Policy Integrity/Cost of Carbon Report, 2014), https://costofcarbon.org/files/Flammable_Planet__Wildfires_and_Social_Cost_of_Carbon.pdf. For other lists of actual climate effects, including air quality mortality, extreme temperature mortality, lost labor productivity, harmful algal blooms, spread of West Nile virus, damage to roads and other infrastructure, effects on urban drainage, damage to coastal property, electricity demand and supply effects, water supply and quality effects, inland flooding, lost winter recreation, effects on agriculture and fish, lost ecosystem services from coral reefs, and wildfires, *see* EPA, *Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment* (2017); U.S. Global Change Research Program, *Climate Science Special Report: Fourth National Climate Assessment* (2017); EPA, *Climate Change in the United States: Benefits of Global Action* (2015); Union of Concerned Scientists, *Underwater: Rising Seas, Chronic Floods, and the Implications for U.S. Coastal Real Estate* (2018).

[57] *See* Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 4.

timeframe, applying the high-impact estimates would calculate total net present climate damages as $194 billion. Note that this estimate would be even higher if the 95th percentile of the probability distribution associated with a 2% discount rate were taken, instead of the 95th percentile for the 3% rate's distribution that the Working Group used.

Finally, these estimates cover climate only damages from greenhouse gas emissions. But the construction and operation of the Proposed Project, as well as the production and combustion of products delivered by the Proposed Project, will emit a variety of other harmful air emissions and also have other impacts to water and natural resources. Some of those additional environmental impacts could be monetized with additional data collection and analysis; others cannot currently be quantified or monetized but may still be highly significant and should be considered. Their omission from this analysis further confirms that the estimate of $41 billion in damages is a conservative underestimate of the Proposed Project's environmental externalities.

Q. Does this conclude your testimony?

A. Yes.

STATE OF MICHIGAN
MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of **ENBRIDGE ENERGY, LIMITED PARTNERSHIP** application for the Authority to Replace and Relocate the Segment of Line 5 Crossing the Straits of Mackinac into a Tunnel Beneath the Straits of Mackinac, if Approval is Required Pursuant to 1929 PA 16; MCL 483.1 et seq. and Rule 447 of the Michigan Public Service Commission's Rules of Practice and Procedure, R 792.10447, or the Grant of other Appropriate Relief	)))))))))))	Case No. U-20763

DIRECT TESTIMONY OF DR. JONATHAN T. OVERPECK

ON BEHALF OF

THE ENVIRONMENTAL LAW & POLICY CENTER AND THE MICHIGAN CLIMATE ACTION NETWORK

September 14, 2021

Q: Please state your name, business name and address.

A: My name is Jonathan T. Overpeck. I am an interdisciplinary climate scientist and the Samuel A. Graham Dean of the School for Environment and Sustainability at the University of Michigan. My office is located at the University of Michigan, Samuel T. Dana Building, 440 Church Street Ann Arbor, MI 48109. I appear here in my capacity as an expert witness on behalf of the Environmental Law & Policy Center and the Michigan Climate Action Network.[1]

Q: Have you ever testified in front of the Michigan Public Service Commission?

A: No.

Q: Have you testified in other settings?

A: I have not testified in judicial proceedings, but I have testified before Congress on several occasions.

Q: On whose behalf are you submitting this testimony?

A: On behalf of the Environmental Law & Policy Center and the Michigan Climate Action Network.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to explain the impacts of greenhouse gas emissions to the atmosphere (e.g., due to the burning of fossil fuels) and climate change, from the scale of the globe down to regional, and with a particular focus on how climate change impacts natural resources in Michigan and the Great Lakes region.

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[1] This testimony contains my independent scientific opinion. It is being provided in my individual capacity, and no part of this testimony purports to present the views, if any, of the University of Michigan.

Q: Can you summarize how climate change will impact natural resources in Michigan and the Great Lakes region?

A: Yes. Climate change is manifesting both as changes in average climate, as well as in terms of the increasing frequency and severity of extremes around the planet. Higher temperatures, greater average precipitation and more intense precipitation are the three types of change that have become most troubling for Michigan and the Great Lakes region. There is a clear trend towards warmer conditions and greater farm runoff that are combining to yield increased occurrence and risk of algal blooms in lakes - blooms that are often toxic. Moreover, farms and infrastructure are starting to be overwhelmed by both increased average amounts of rain, and increased intensity of the rainfall. Paradoxically, the rapidly increasing average temperatures and temperature extremes mean more frequent and severe dry conditions in the region. Many farmers in Michigan are already moving to irrigation to help make sure the warmer temperatures don't reduce crop yield. Michigan has a history of drought, although generally Michigan droughts only last a season or two. However, just like everywhere else, warming temperatures will make the impacts of these droughts worse when the droughts occur in the future. These are just some of the serious impacts of climate change in Michigan and the Great Lakes region that I expand on later in my testimony. Continuing to add greenhouse gases to the atmosphere will make climate change impacts much worse in Michigan, the Great Lakes and the region.

Q: Are you sponsoring any exhibits?

A: Yes. I am sponsoring the following exhibits:

- ELP-11 (JTO-1) – Curriculum Vitae of Dr. Jonathan T. Overpeck

- ELP-12 (JTO-2) – IPPC Report on Climate Change 2014, Impacts, Adaptation, and Vulnerability. Chapter 4, *Terrestrial and Inland Water Systems*.
- ELP-13 (JTO-3) – IPPC Report on Climate Change 2014, Impacts, Adaptation, and Vulnerability. *Summary for Policymakers*.
- ELP-14 (JTO-4) – IPPC Report on Climate Change 2021, The Physical Science Basis.
- ELP-15 (JTO-5) – 2018 Fourth National Climate Assessment.
- ELP-16 (JTO-6) – New England Journal of Medicine, Call for emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health

Q: What is your educational background?

A: I received a PhD in Geological Sciences from Brown University in 1985. Prior to that, I received my Master of Science in Geological Sciences from Brown University in 1981 and a Bachelor of Arts in Geology from Hamilton College in 1979. I completed a postdoctoral fellowship sponsored by the NASA Goddard Institute for Space Studies (one of the nation's premier climate modeling centers) and Columbia University.

Q: Please summarize your professional experience and expertise in the field of climate and environmental sciences.

A: I have more than 40 years of experience studying climate change, climate impacts, vegetation change, environmental sciences and related fields. I am actively involved in a wide range of research and publications relating to climate and the environmental sciences across the United States and globally. I have written and published over 220 works on climate and the environmental sciences. I served as a Working Group 1 Coordinating Lead Author for the Nobel Prize-winning IPCC 4th Assessment (2007), and as a Working Group

2 Lead Author for the IPCC 5th Assessment (2014). I have conducted climate research programs on five continents, focused on understanding drought and megadrought dynamics (and risk) the world over, and I served as the lead investigator of Climate Assessment for the Southwest and the Southwest Climate Adaptation Science Center – two major programs focused on regional climate adaptation in the Southwest United States. Recently, I contributed as a member of the University of Michigan's President's Commission on Carbon Neutrality, and I currently serve on the State of Michigan's Council on Climate Solutions and on Ann Arbor's Energy Commission, focused largely on sustainable energy solutions. I have appeared and testified before Congress multiple times. I am a Fellow of the American Geophysical Union and the American Association for the Advancement of Science, and have received additional honors from the American Meteorological Society, the Department of Commerce, and the Quivira Coalition, among others. A detailed resume is attached as Exhibit ELP-11 (JTO-1).

Q: Do you have experience related to the impacts of climate change on natural resources?

A: Yes. I have published dozens of papers that focus on the relationship between climate and vegetation, the prevalence and risks of drought, and the impacts of climate change on freshwater resources and ecosystems. For example, I recently published: *Climate change and the aridification of North America* and *Southwestern fish and aquatic systems: the climate challenge. In: Standing between life and extinction: ethics and ecology of conserving aquatic species in the American Southwest*. I was also a lead author of Chapter 4, *Terrestrial and Inland Water Systems*, and a drafting author of *Summary for Policymakers*, in Climate Change 2014, Impacts, Adaptation, and Vulnerability, which is the most recent published IPCC climate change assessment focused on how climate change is affecting, and will impact, terrestrial vegetation, wildlife, inland waters and natural resources. I attach Chapter 4 as Exhibit ELP-12 (JTO-2) and the Summary for Policymakers as Exhibit ELP-13 (JTO-3).[2] I am very familiar with the extensive body of research that addresses the impacts of climate change on other natural resources.

Q: What are the scientific sources that you draw upon in this testimony?

A: My testimony draws on a variety of published and peer-reviewed sources, including recent reports of the Intergovernmental Panel on Climate Change (IPCC),[3] the most recent U.S. National Climate Assessment, and research published in peer-reviewed journals. Although they are lengthy, I have attached the full report of the recently released IPPC Report Climate Change 2021, The Physical Science Basis as Exhibit ELP-14 (JTO-4) and the 2018 Fourth National Climate Assessment as Exhibit ELP-15 (JTO-5). In this testimony, I synthesize this material to illustrate how climate change will, without strong intervention, have devastating impacts on the world and in particular on Michigan and the Great Lakes. While I cite to specific sources where I felt it would be helpful, due to the sheer volume of peer-reviewed research on climate change, it would not be possible to provide a comprehensive bibliography of all peer-reviewed articles relevant to the subject matter. However, the considerable literature on the topic is clear: our region will experience more moderate and manageable climate change impacts if greenhouse gas emissions are rapidly reduced. To avoid unmanageable climate impacts requires the rapid phase-out of fossil fuels and an end to construction of new fossil fuel infrastructure.

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[2] The full report is voluminous and publicly available at https://www.ipcc.ch/report/ar5/wg2/

[3] These reports are voluminous, but can be accessed in full at https://www.ipcc.ch/ under the tab named "REPORTS."

Q: How are humans impacting the global climate?

A: Climate warming over the past century is indisputably tied to human activity – specifically, activity that increases the heat-trapping or "greenhouse" capacity of the atmosphere. The warming itself is well documented by research at multiple independent laboratories; the global average surface air temperature has risen just over 1°C (1.8°F) since the 19th century. Each of the last 4 decades has been warmer than the previous, and the warmest 10 years of the past 140 have all occurred since 2005. Warmer air temperatures join many other lines of evidence, including warmer oceans, melting ice sheets and glaciers, less snow cover, less sea ice, and rising sea level, to paint an unmistakable picture of a warming planet.

Q: What is the cause of that warming?

A: The cause of the warming is clear. The greenhouse effect is not only theoretical: we can measure the heat-trapping properties of CO2, methane, nitrous oxide, and other greenhouse gases in the laboratory, and we know from the physics of radiation that greenhouse gases maintain the Earth's temperature above what the Sun's radiation alone would provide. Rising greenhouse gas concentrations are well documented from sites all over the globe and, prior to direct atmospheric measurements, from bubbles of air trapped in glacial ice. The modern concentration of CO2 has risen sharply from 280 to 415 parts per million since the Industrial Revolution[4] – a level not seen for millions of years. This rise stems primarily from the burning of fossil fuels – coal, oil, and gas. The CO2 in the atmosphere carries the chemical fingerprint of fossil fuels in its carbon isotopes, and the increase reflects the known combustion of over 18 trillion barrels of oil, 390 billion tonnes of coal, and 155

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[4] *See* the National Oceanic and Atmospheric Administration *Trends in Atmospheric Carbon Dioxide*, accessible at https://gml.noaa.gov/ccgg/trends/history.html and https://gml.noaa.gov/ccgg/trends/global.html, both updated monthly.

trillion cubic meters of natural gas over the past century,[5] all releasing CO2 into the atmosphere. Deforestation also adds CO2 to the atmosphere, but these emissions have been balanced by forest regrowth over the past 170 years.[6] The consensus among active climate scientists, that burning fossil fuels is warming the planet, is exceptionally strong - between 97-100% of scientists have reached this conclusion. [7]

Q: How much has the world warmed already?

A: According to the IPCC and multiple other sources, the world has warmed by just over 1°C and is on a path to warm several more degrees C unless greenhouse gas emissions are slashed quickly.[8] The summer of 2021 offers a preview of the consequences of such warming: heat waves, drought, floods, wildfires, more devastating hurricanes, sea level rise, human suffering and mortality. The science linking mean annual global warming – even just 1°C – with an increased range of extreme weather and climate conditions is clear.[9]

Q: Is that warming consistent across the globe?

A: Global warming is unevenly distributed. Land areas warm more than ocean; high latitudes warm more than the tropics and midlatitudes. On a smaller scale, weather systems create a patchwork of hot and cold conditions, and city dwellers suffer more heat than rural and suburban residents because human infrastructure (roads, buildings, parking lots, etc.)

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[5] *See* Interactive tool available at https://www.theguardian.com/environment/ng-interactive/2015/apr/10/how-much-fossil-fuel-are-we-using-right-now for an illustration of the magnitude of the extraction of gas, oil and coal.
[6] Friedlingstein,P. et al. (85 co-authors), *Global Carbon Budget 2020* (2020). Earth System Science Data, 12, 3269–3340. DOI: 10.5194/essd-12-3269-2020. Available at www.globalcarbonproject.org/carbonbudget
[7] *See* Powell, J. (2019), *Scientists Reach 100% Consensus on Anthropogenic Global Warming*, Bulletin of Science. Technology & Society. Vol. 37, Issue 4, 2017, 183 –184; Anderegg, William R L; Prall, James W.; Harold, Jacob; Schneider, Stephen H. (2010). *Expert credibility in climate change*, Proc. Natl. Acad. Sci. USA. 107 (27): 12107–9; Benestad, Rasmus E.; Nuccitelli, Dana; Lewandowsky, Stephan; Hayhoe, Katharine; Hygen, Hans Olav; van Dorland, Rob; Cook, John (1 November 2016). *Learning from mistakes in climate research*. Theoretical and Applied Climatology. 126 (3): 699–703.
[8] See IPPC Report, Climate Change 2021, Summary for Policymakers, Exhibit ELP-14 (JTO-4) at Figure 8.
[9] *See, e.g.,* IPPC Report, Climate Change 2021, The Physical Science Basis, Exhibit ELP-14 (JTO-4).

amplifies urban warming, and greenery generally reduces extreme heat. Regional mean annual warming of a degree or two has led to increases in extreme conditions as well. The frequency and severity of heat waves are increasing around the planet, with clear health consequences, especially for the elderly, those with chronic heart or lung ailments, outdoor workers, and those without air conditioning. Heat combined with humidity creates conditions that are literally not survivable, even for the healthy; these conditions are beginning to occur now and will become more common as warming proceeds.[10]

Q: What impacts is this warming having on the Earth?

A: As climate warms, other aspects of the Earth system respond. Precipitation is changing in many ways. First, air that is warmer can hold more moisture as water vapor. This fact creates a seeming paradox: warmer air draws more moisture from plants and soils, drying the land and vegetation, and creating drought. But when storms do develop, the higher atmospheric water vapor content provides more moisture for precipitation and creates stronger storms because of the energy released when vapor turns to liquid. As a result, we can expect more intense rainfall along with longer dry spells – i.e., intensified hydrologic extremes. These worsening trends have long been anticipated by climate scientists and climate models, and they are now being observed in real time. Second, in a warmer world, we expect – and observe – changes in the position of storm tracks that bring rainfall onto continents, and in the behavior of monsoon systems and other rainfall-related climate patterns. For example, the tropical belt is expanding, widening the wet region around the equatorial zones and shifting deserts poleward. Third, places that receive both snow and rainfall are seeing an increased fraction of their precipitation falling as rain, due to warming

[10] Mora, C. et al. (2017). *Global risk of deadly heat*. Nature Climate Change 7:501-506.

temperatures. This has tremendous implications for places that receive water from mountain snowpack, where runoff is peaking earlier and where summers (i.e., growing seasons) are experiencing reduced water availability. Combined with the loss of mountain glaciers, hydropower generation will also suffer. Finally, tropical hurricanes are expected to become stronger, carry more precipitation, and be able to reach further out of the tropics as ocean temperatures warm. The "hurricane season" in which storms develop is also likely to grow longer as temperature rises.

Q: Are these changes happening now?

A: Yes. These changes in climate are happening now, around the planet, and they are accelerating. They bring with them major global impacts on critical aspects of human well-being. Changing patterns of rainfall, increasing drought, and stronger storms pose significant challenges to agriculture, particularly in warm regions, and especially for smaller-scale and subsistence farmers with modest resources for adaptation. Warmth favors microbial growth and reproduction, posing a disease threat to crops as well as to human health and natural ecosystems. Insects also thrive in warm temperatures; the spread of disease-bearing insects will, unless strong public health measures are followed, expand the boundaries of "tropical" ailments such as dengue fever and malaria. A changing landscape of temperature and precipitation will alter the distribution and health of natural ecosystems. Where we have set aside protected lands to preserve notable ecosystems, we may find that the climate no longer allows that system to thrive there. In some cases, wildlife species are on the move or changing the seasonal timing of their migrations to avoid suboptimal conditions. Climate change is expected to increasingly drive a global biodiversity extinction crisis.

Q: Are the Earth's oceans impacted by climate change?

A: Yes. In the oceans, rising temperatures and the melting of land-based ice are causing an accelerating rate of sea level rise, the costs of which will be increasingly massive in terms of economic, human well-being, ecological, and cultural losses. The oceans are also experiencing chemical changes, as fossil-fuel carbon reacts with ocean chemistry to raise the acidity, and ocean oxygen levels drop as warmer waters can hold less oxygen. The warming of the tropical oceans is exceeding the tolerance of many species; coral reef ecosystems have declined by over half, and coral mortality across the full tropical belt has accelerated with record warm temperatures. These systems support the livelihoods and sustenance of hundreds of millions of people.

Q: Do you expect these impacts to be constant over time?

A: No. The impacts of climate change become stronger as the scale of the warming grows. Today, we are already struggling to adapt to the impacts of climate change. Recent events have left no doubt that even in wealthy nations, climate change can cause extensive human suffering and loss. Hundreds of people perished in the late-June 2021 heat wave that struck the Pacific Northwest and British Columbia;[11] fires in California during 2020 damaged or destroyed 10,488 homes, produced 1.2 million tonnes of fine particles that clouded the air nationwide, and killed 31 people.[12] As climate warms further, such events will intensify, and adapting to these changes will become even more difficult. To avoid massive costs in

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[11] *See* Nadja Popovich and Winston Choi-Schagrin, *Hidden Toll of the Northwest Heat Wave: Hundreds of Extra Deaths*, New York Times, August 11, 2021, available at https://www.nytimes.com/interactive/2021/08/11/climate/deaths-pacific-northwest-heat-wave.html

[12] *See California's 2020 fire siege: wildfires by the numbers*, available at https://calmatters.org/environment/2021/07/california-fires-2020/, and Cal Fire's *2020 Fire Siege Report*, available at https://www.fire.ca.gov/, ("The 2020 Fire Season will be counted among the most severe since the founding of our nation; only the 'Big Burn' of 1910 stands in grim comparison. Since 2015, the term 'unprecedented' has been used year over year as conditions have worsened, and the operational reality of a changing climate sets in.").

human suffering, economic resources, and ecological devastation, we need to address the root cause of climate change – the burning of fossil fuels.

Q: How is climate already changing in Michigan and the Great Lakes Region?

A: Human-driven climate change, caused by increases in greenhouse gas emissions, is already impacting every region of the globe, and the Great Lakes region is no exception. Most of the changes that have already been observed agree with those anticipated by climate scientists and climate modeling, and this gives us greater confidence in attributing these changes to human causes, as well as in projecting continued change into the future. Both temperature- and precipitation-related changes have been significant in the region, and are clearly linked to human-driven climate change. These changes, in turn, are having notable impacts on the Great Lakes themselves.

Q: Do you have a concrete example of how climate has impacted Michigan?

A; Surface air warming in Michigan and the Great Lakes region has been substantial in all seasons,[13] in agreement with what was expected and simulated by global climate models. In addition, this warming has accelerated since 1980, just as the magnitude of greenhouse gas emissions has accelerated has accelerated.[14] As annual and seasonal mean temperatures have increased, the incidence and magnitude of extreme hot temperatures and heat waves have also increased at the global scale, as well as across much of North America[15] The ability to attribute an increase in the *occurrence* of extreme temperatures and heat waves to human activities that emit greenhouse gases appears to be robust at the scale of North

[13] Data demonstrating this warming can be accessed at https://data.giss.nasa.gov/gistemp/maps/
[14] *See* Climate Change 2021, The Physical Science Basis, Exhibit ELP-14 (JTO-4) at Chapter 2.
[15] *See* Climate Change 2021, The Physical Science Basis, Exhibit ELP-14 (JTO-4) at Chapter 11.

America,[16] and emerging in the Great Lakes region;[17] there is also growing confidence that the *severity* of extreme hot temperatures and heat waves is linked to the human-driven warming of the region. As hot temperature extremes increase, there is also evidence that the incidence and intensity of cold extremes will decrease.[18] However, recent research on the linkages between climate change-caused rapid Arctic warming and winter-time cold air outbreaks in Eastern North America, including the Great Lakes region, suggest that extreme cold temperatures associated with "polar vortex" events will continue to plague Michigan and the Great Lakes, even as average winter-time temperatures warm.[19]

Q: Has climate change impacted precipitation in Michigan?

A: Yes. Human-driven climate change appears to be the cause of a significant increase in mean average precipitation, and particularly in winter and spring, across Michigan and the Great Lakes watershed. According to new research out of the University of Michigan, this is the primary cause of recent record high water levels in the Great Lakes,[20] and has also set the stage for more frequent flooding across the region. Flooding in the state and region has been made much worse, however, by another well-known result of global warming, the intensification of rainfall due to the fact that a warming atmosphere can hold – and release – increasing amounts of water vapor. The total annual precipitation falling in the

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[16] *Id*.
[17] *Id*.; *see also* Lopez, H., West, R., Dong, S. et al. *Early emergence of anthropogenically forced heat waves in the western United States and Great Lakes*. Nature Clim Change 8, 414–420 (2018). Available at https://doi.org/10.1038/s41558-018-0116-y
[18] *See* Climate Change 2021, The Physical Science Basis, Exhibit ELP-14 (JTO-4) at Chapter 11.
[19] Cohen et al., *Linking Arctic variability and change with extreme winter weather in the United States*, Science 373, 1116–1121 (2021).
[20] Gronewold, A. D., Do, H. X., Mei, Y., & Stow, C. A. (2021). *A tug-of-war within the hydrologic cycle of a continental freshwater basin*. Geophysical Research Letters, 48, e2020GL090374. Available at: https://doi.org/10.1029/2020GL090374

heaviest one percent of storm events has increased by more than 40% since the start of the 20th century in the Midwest U.S. region including Michigan.[21]

Q: Will we be able to predict these extreme weather events?

A: Unfortunately, a net result of on-going human-caused temperature and precipitation change in Michigan and the Great Lakes region is a loss of prediction skill for extreme *weather* events. It is difficult to anticipate the *exact timing* of record heat, cold, or rainfall events simply because the burning of fossil fuels and other human activities are pushing the Earth's climate system into uncharted territory. This means we need to learn, more than ever, to expect the unexpected.

Q: Michigan is the Great Lakes State. How is climate change impacting the Great Lakes?

A: The Great Lakes themselves have responded to human-caused climate change as already noted: levels in each of the lakes has experienced recent record highs due largely to the observed increase in precipitation. The Great Lakes, as well as smaller water bodies in the region, are all warming substantially, and the increase in average and extreme precipitation is also generating more runoff into the lakes. Collectively, human-driven climate changes are changing the lake environments in dramatic ways, altering the temperature, nutrient and oxygen gradients in the lakes. Moreover, the warming is reducing lake ice duration, coverage and thickness, which affects the lake's ecosystems and the region's climate. As noted above, extreme cold air outbreaks into the region are still common, and thus some years still have extensive lake ice coverage. There also appears to be an on-going increase

[21] *See* Exhibit ELP-15 (JTO-5), 2018 Fourth National Climate Assessment at Chapter 21.

in lake level variability, with both record low and high lake levels taking place in recent years.

Q: How will global climate change impact people and natural systems in the future?

A: If greenhouse gases continue to accumulate in the atmosphere and drive additional climate change, the impacts of climate change will continue to intensify. The largest uncertainty in projecting future climate change is estimating the future trajectory, year to year, of greenhouse gas emissions. If the current upward trends in greenhouse gas emissions continue, future climate change will be substantially larger, more dangerous, and more destructive.

Q: Is there a method for assessing future climate change that is generally accepted in the field of climate science?

A; Yes. The standard scientific approach to assessing future climate change is to rely on climate and Earth system models that have grown increasingly sophisticated and skilled at simulating observed patterns and trends in past and modern climate. Model performance and realism is assessed using agreement among models and with observed climate changes; all IPCC climate and Earth system models simulate warming as a response to increases in atmospheric greenhouse gas concentrations. Models have proven skillful in simulating many aspects of climate change, and the physics represented in the models are consistent with those observed in the real world. Since the exact future trajectory of future greenhouse gas emissions into the atmosphere is not known, climate scientists utilize a range of possible future emission scenarios. This, plus the use of dozens of different models, allow for quantitative projections of future climate change for any trajectory of future greenhouse gas emissions.

Q: What are some of these possible climate futures?

A: Based on the extensive scientific literature, the IPCC has identified a range of plausible climate futures for the 21st century. The most extreme widely used scenario which I refer to as a "continued fossil-fuel-rich scenario" (after the IPCC; this widely used scenario is also known as RCP8.5 or SSP5-8.5) posits a relatively slow move away from fossil fuels over this century, and results in a global temperature increase of 4.5°C (±1.2°C uncertainty) by 2100. In "low-emissions" scenarios that limit global warming to 1.5-2°C, greenhouse gas emissions must stabilize quickly, begin to drop by mid-decade, and reach zero between 2050-2075. The climate science community and the 195 signatory countries to the United Nations Paris Agreement have determined that it is critical to limit global warming to 1.5 to 2.0°C above pre-industrial levels to avoid dangerous interference with the climate system. For context, the last time the Earth experienced global warmth above 2.5°C was about 3 million years ago, when global vegetation patterns were much different from today, the Arctic was seasonally ice-free, the Greenland and Antarctic Ice Sheets were much smaller, and sea level was as much as 25m higher than today.[22] Seemingly small changes in global average temperatures have far-reaching and unevenly distributed consequences for the Earth's environment and regional habitability.

Q: Can you describe the relationship between a given amount of warming and impacts on the Earth and its natural resources?

A: The latest IPCC report documents clearly that the impacts of warming become more intense as warming increases. In other words, a 2°C warmer world is more perilous than one at 1.5°C warmer, and in a 4°C warmer world, massive losses from heat, drought, fires, storms,

[22] *See, e.g.*, Climate Change 2021, The Physical Science Basis, Exhibit ELP-14 (JTO-4).

and sea level change become the norm. This dependence of impacts on the degree of warming highlights the imperative to reduce emissions as much as possible, as fast as possible. Consistent with this observation, we are now experiencing increasing climate change impacts that are in agreement with IPCC projections and that are certain to intensify in a warmer world. As these impacts become more common and more extreme, they are also likely to co-occur and compound in ways that multiply their costs to humans, society, and natural systems. Moreover, warming beyond 1.5°C increases the likelihood of crossing one or more of many climate thresholds, or "tipping points," that would accelerate warming and/or its impacts beyond a point that is irreversible on human time scales.[23]

Q: What are some examples of one of these tipping points?

A: The *cryosphere* – the Earth's frozen water – will be profoundly affected by warmer temperatures. The Greenland and Antarctic ice sheets are losing mass at accelerating rates, amplifying sea level rise and the threats it poses to coastal communities around the planet. These include flooding, human casualties, groundwater salination, losses of infrastructure and structures, and the obliteration of whole island nations and coastal cultures, from the low-lying islands of the Pacific to the Mississippi River delta. Melting ice sheets represent a tipping element because reversing ice sheet melt is unlikely on century or shorter time scales. The cryosphere includes permafrost, which, as it melts, may release large amounts of additional greenhouse gases (CO2 and methane) – another potent climate tipping point that would add substantially to the atmosphere's greenhouse capacity. Finally, the melting of Arctic sea ice is well underway, and its future rate will depend on how fast the climate

[23] *See* Steffen, W., et al., (2018). *Trajectories of the Earth system in the Anthropocene*. Proceedings of the National Academy of Sciences of the United States of America. 115: 8252-8259; IPCC special report on Global Warming of 1.5º C (2018). Available at: https://www.ipcc.ch/sr15/

warms. Sea ice acts as a potent climate amplifier in that the loss of the reflective ice surface will increase radiation absorption. Ice loss also changes the gradient of temperature between high and mid-latitudes, thought to increase the "waviness" of the jet stream and thus accentuate climate variability across the midlatitudes (including more frigid "polar vortex" conditions across the Great Lakes).

Q: Do you have other examples of tipping points?

A: Yes. Future precipitation changes around the globe reflect an intensification of the hydrological cycle. Because warm air holds more moisture, both wet and dry extremes occur more frequently and become stronger. A day of extreme rainfall that would have happened once per decade in a climate without human influence can be expected to happen 1.7 times under 2°C warming and 2.7 times under 4°C; these events are 14% and 30% wetter, respectively. Similarly, a once-per-decade dry year for a natural climate state will become a once-per-4-years event under 2°C and an every-other-year event if climate warms to 4°C, with greater intensity as climate warms. These values represent global averages of regionally variable responses. Prolonged dry conditions can result in the wholesale transformation of a regional ecosystem, for example a huge expanse of forest shifting to grassland, which reduces that system's capacity to recycle moisture, absorb carbon, and provide key ecosystem services. Widespread severe wildfire may accompany such a vegetation shift from forest to non-forest, and this in turn would release a great deal of additional CO_2 to the atmosphere – CO_2 that is currently sequestered naturally in forest plants and soils. Ecosystem tipping points are major causes for concern, from tropical rainforests and coral reefs to Arctic sea ice-dependent communities.

Q: What happens when more than one effect of climate change happens at once?

A: Compound events pose substantial threats to human and natural systems in a warming world, more so if the warming is stronger. As an example, consider the interaction of precipitation and temperature in the Colorado River Basin, where the heavily managed river provides water and hydropower to a population of 40 million (and growing), along with protected areas, Native nations, and agricultural lands.[24] The Colorado River flow depends on snowpack in the Colorado Rocky Mountains. The fraction of precipitation falling as snow is declining as climate warms, and rain falling on snow-covered ground accelerates melting. Drought in the surrounding lowlands is creating dust (exacerbated by oil and gas development road-building) that darkens the alpine snowfields, further speeding their seasonal melt and reducing the water that they yield to the rivers. Peak runoff is occurring earlier in the year, and river flows are lower,[25] creating a longer summer dry season that compounds anthropogenic drought. Widespread forest mortality has resulted from the combination of hot drought and mortality from deadly insect pests, e.g., the pine bark beetle and spruce budworm, who are thriving in a warmer climate that allows a longer breeding season and reduces winter cold mortality. The abundance of dead trees and decades-long drought has fueled wildland fires that reduce air quality and visibility across the West. Fires strip the land of vegetation that stabilizes the soil and helps it retain moisture. Meanwhile, the reservoirs on the Colorado have not been full for 20 years, and this summer they dropped so low that the first-ever federal shortage declaration was made, cutting water promised to Arizona and Nevada. The western US is facing a perfect storm

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[24] *See* Colorado River Basin Fact Sheet. Available at: https://www.usbr.gov/climate/secure/docs/2021secure/factsheets/Colorado.pdf

[25] Udall, B. and J. Overpeck (2017). *The twenty-first century Colorado River hot drought and implications for the future*. Water Resources Research, 53, doi:10.1002/2016WR019638.

of heat, drought, dependence on a failing water system, and the loss of iconic and valuable ecosystems – what one writer has termed the "dust-bowlification" of the West.[26] All of these impacts are currently worsening, and they become even grimmer in a 4°C world, compared to one where warming is kept below 2°C.

Q: Could these types of compound events happen in Michigan and the Great Lakes?

Yes, in multiple ways. Increasing greenhouse gases in the atmosphere are causing warming and the intensification of the hydrological cycle in Michigan and the Great Lakes. This warming means more extreme warm temperatures and more severe drought conditions, coupled with more intense storms when rain does materialize. These pose significant challenges for agriculture: direct heat and water stress on plants, favorable conditions for pests and disease-causing organisms to infest stressed plants, and flooding that inhibits farmers' ability to plant, harvest, and manage their crops. More intense rainfall will translate to increased and more concentrated runoff of nutrient-laden water into the Great Lakes and other inland water bodies, where the increased nutrient loading will combine with warmer temperatures to favor more algal blooms, including blooms of harmful (toxic) blooms. Lake Erie is already plagued by such harmful algae blooms, and as climate warms, all of the Great Lakes will experience greater frequency and extent of such blooms, as will many smaller water bodies in the state and region. These blooms, in turn, can cause serious drinking water concerns (as happened in Toledo in 2014), adding to the water treatment challenges posed by more intense rainfall, flooding and sediment transport. Blooms have profound negative impacts on freshwater ecology of the Great Lakes and smaller water bodies, including depletion of oxygen that can reach lethal levels for fish and other aquatic

[26] Romm, J. *The next dust bowl*. Nature 478, 450–451 (2011). Available at: https://doi.org/10.1038/478450a

organisms. Lastly, we have recently learned that toxins produced by harmful algae can become airborne.[27] These toxins would add to other air quality threats likely to increase in a warmer, drier world (e.g., wildfire smoke, dust, ground-level ozone, and – if fossil fuel production and use continues – industrial and combustion byproducts.

Q: Are there concerns about a tipping point for the Earth's oceans?

A: Yes. The oceans will experience significant changes in their physical, chemical, and biological properties as a consequence of warming. Marine heatwaves are becoming longer and more frequent, extensive, and intense under warmer climate. In a 2°C warmer world, the number of marine heatwave days is expected to increase globally by a factor of 4; this factor rises to 12 in a 4°C world.[28] Marine heatwaves have devastating ecological and human consequences, including mass mortality of benthic species (e.g., coral), toxic algal blooms, and declines in fisheries and mariculture. In addition to warming, the oceans will experience chemical changes – rising CO2 inexorably lowers the ocean's pH, creating more acidic conditions that compromise the health of most marine biota. Rising temperatures lead directly to increased ocean stratification, which reduces the upward mixing of nutrients and allows the surface to warm more dramatically. The ocean's dissolved oxygen levels will drop as waters warm, reducing habitat favorability for most organisms. These trends contribute to expectations that the oceans primary productivity – the base of the ocean food chain – will decrease in the future, with greater impacts in a 4°C world than in a 2°C world.

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[27] Olson et al., *Harmful Algal Bloom Toxins in Aerosol Generated from Inland Lake Water*, Env. Sci. Technol. 2020, 54, 4769−4780.
[28] IPCC 2019 Special Report on the Ocean and Cryosphere in a Changing Climate, Technical Summary, Figure 3. Available at: https://www.ipcc.ch/srocc/chapter/technical-summary/ts-0-introduction/ipcc-srocc-ts_3/

Q: Will the Earth's ecosystems reach a tipping point?

A: Yes, such tipping points are a big risk if we don't rapidly slow greenhouse gas emissions. Valuable and cherished natural ecosystems are at risk from changing climate. These include coral reefs and tropical rainforests – among the most diverse ecosystems on Earth. The warming that has already killed half the world's coral will continue to exact a toll, greater with every degree of heating. In the Arctic, as temperatures rise, the hydrological cycle is being transformed, wildfires are becoming more extensive, and infrastructure and homes are being destabilized by melting permafrost. Across the globe, warming is shifting the preferred habitats of species, resulting in changed migration patterns, their altitudinal and latitudinal distributions, and interspecies interactions that maintain ecosystem resilience. Ecosystems will continue to reshuffle as climate warms, sometimes dramatically (e.g., through fire, marine heatwaves, and other major disturbances), with consequences for the humans who depend on these systems. Wildlife conservation areas, national parks, and marine protected areas may find themselves abandoned by the species they were designed to support. Global warming above 2°C will likely increase global extinction rates significantly, perhaps triggering the Earth's sixth major mass extinction event.

Q: Are there other impacts of climate change that you would like to discuss?

A: The impacts of global warming go beyond this summary and are described in reports from the IPCC, the U.S. National Climate Assessment, and many other reports and papers that emphasize particular regions or sectors. What is clear from this immense body of work, building on many decades of science, is that human-caused climate change is now having the impacts that climate science foresaw many years ago, and that these impacts will become more intense as warming continues. Most scientists seem to be surprised at the rapidity with which these projections of the future have materialized – if anything our predictions have been conservative. But if we can curb greenhouse gas emissions, we will limit the warming, and we can limit the damage and the suffering. Adapting to climate change – even if warming is kept to 2°C – is a formidable challenge, as the summer of 2021 demonstrated. If warming is allowed to reach 4°C or more, effective adaptation becomes largely wishful thinking.

Q: You testified earlier about how climate change is currently impacting Michigan and the Great Lakes. How do you anticipate climate change will impact Michigan and the Great Lakes in the future?

A: If global warming is limited to 1.5 to 2.0°C above pre-industrial levels (about 0.5 to 1.0°C above present-day, the "low-emissions" scenario), then the changes the state and region are already seeing, many of which I describe above, will likely worsen to a limited degree. However, if the current trajectory of climate change is allowed to continue, referred to here as a "continued fossil-fuel-rich scenario," the impacts on the climate of Michigan and the Great Lakes will become much more substantial.

Q: What is the "continued fossil-fuel-rich" scenario?

A: Because future human behavior is not yet predictable, the IPCC uses a range of greenhouse gas emission scenarios to put boundaries on the expected range of future climate change between now and 2100. Our current path is a high-emissions pattern, and the IPCC's most extreme warming scenario assumes that we will do very little to constrain our emissions in the near term (although emissions do plateau in 2080 in this scenario, which is called SSP5-8.5 in that report).[29] To evaluate the climate consequences of this emissions path, we use a

[29] See Climate Change 2021, The Physical Science Basis Summary for Policymakers, Exhibit ELP-14 (JTO-4) at Figure SPM4a.

greenhouse gas emissions scenario that captures a trajectory of emissions that assumes continued heavy use of fossil fuels into the future, and that postpones meaningful greenhouse gas emissions reductions into the future. I refer to this as a continued fossil-fuel-rich scenario because it largely represents what could happen if we continue a heavy reliance on fossil fuels and fossil fuel infrastructure.

Q: Is there a "low-emissions" scenario?

A: In contrast to the relative inaction on greenhouse gas emissions that is built into the continued fossil-fuel-rich scenario, I also draw upon "low-emissions" scenarios to highlight the climate change and impacts we will likely get if we act quickly on climate change in order to meet the goal of the Paris Agreement, that is to limit global warming to 1.5 to 2.0°C above pre-industrial levels. In this testimony, I am considering the IPCC's SSP1-1.9 and SSP1-2.6 scenarios to represent these lower risk, lower emission pathways.

Q: What impact will the "continued fossil-fuel-rich" scenario have on Michigan?

A: Continued fossil-fuel-rich greenhouse gas emissions have the potential to warm Michigan and the Great Lakes region by an additional 5°C or more by the end of the century, compared to the current level of warming of about 1°C, whereas a low-emissions warming scenario would increase temperatures in the state and region by a much more modest 0.5 to 1°C. Moreover, for Michigan continued fossil-fuel-rich warming would mean:

- Dramatic mean surface air warming in all seasons, with significantly higher daily maximum temperatures and daily minimum temperatures (i.e., hotter nights); peak annual maximum daily temperatures would increase by 5°C or more.

- Many more days with extreme heat. For example, southern Michigan could experience over 40 days a year with temperatures exceeding 100°F, which in many cases will be coupled with the high humidity; the risk of longer and hotter heat waves would continue to rise though the coming decades.[30]
- Warmer winter temperatures, and significantly diminished snow cover, although extremely cold "polar vortex" events could persist for some time into the future, creating variability that would challenge agricultural and natural systems.

Q: What are some other impacts on Michigan from continued fossil-fuel-rich greenhouse gas emissions?

A: Continued fossil-fuel-rich greenhouse gas emissions will continue to favor the on-going trend towards more mean annual precipitation in Michigan and the Great Lakes, with much of the increase occurring in the cooler part of the year. This change will be associated with a continued increase in the frequency and intensity of extreme precipitation events, and increased runoff and risk of river, urban and rural flooding. Intensification of precipitation compared to pre-industrial is very likely. In contrast, the low-emissions scenario suggests that rapid reductions in greenhouse gas emissions will mean a substantially smaller increase in the frequency and intensity of precipitation, as well as the associated runoff rates and flooding.

Warming under the continued fossil-fuel-rich scenario will likely also lead to more intense, hotter, droughts in Michigan and the Great Lakes region. What are now merely summer dry spells will have a substantially higher risk of becoming hot droughts, with

[30] *See* 2018 Fourth National Climate Assessment as Exhibit ELP-15 (JTO-5) at Chapter 21.

impactful decreases in soil moisture driven by hotter temperatures. Hotter temperatures and associated drier conditions will also give rise to increased wildfire weather of the type now widely occurring in the Western United States.

Severe warm season thunderstorms storms and windstorms in Michigan are also likely to increase under the larger warming scenario, whereas it is unclear if climate change associated with low emissions would yield significant changes to thunderstorms and windstorms. Similarly, given continued fossil-fuel-rich emissions, the Great Lakes and smaller bodies of water see much more dramatic continued warming (including lake heatwaves),[31] lake ice decline, increases in runoff, and circulation changes than if emissions are curbed in line with the low-emissions scenario. Water level variability in the Great Lakes is likely to increase more substantially, with both more high and low record levels likely if warming continues along a continued fossil-fuel-rich trajectory. This response results from the "tug-of-war" between stronger evaporation in a warmer world (driving lake levels down) and increasing precipitation (pushing them higher) – factors that explain the recent oscillations between high and low lake levels.[32]

Q: Do you have an understanding of how those effects of climate change will impact Michigan's natural resources?

A: Yes. Climate change greatly increases the risk of profound disruption of natural resources in Michigan and the Great Lakes region. Warming will cause large-scale shifts in forest tree species and other vegetation across the region, and the process by which this takes

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[31] Woolway et al. 2021, *Lake heatwaves under climate change*, Nature v589, Available at: https://doi.org/10.1038/s41586-020-03119-1

[32] Gronewold, A. D., Do, H. X., Mei, Y., & Stow, C. A. (2021). *A tug-of-war within the hydrologic cycle of a continental freshwater basin*. Geophysical Research Letters, 48, e2020GL090374. https://doi.org/10.1029/2020GL090374

place will involve greater tree mortality and disturbance due to climate and weather extremes – in other words, it will happen through abrupt disturbances such as fire or windthrow, followed by regrowth of species that can thrive under the new climate.[33] Increasing aridity by itself will hurt iconic tree species such as sugar maple.[34] Moreover, increasingly hot and dry spells (a.k.a. hot drought) will increase forest stresses due to invasive species, insect pests and plant disease, and increase the likelihood of severe wildfire - just as we're already seeing in the western United States.[35] The result is a decline in forest health, and in the ecosystem goods and services that forests currently provide. As the vegetation suffers, so will the wildlife that depends on the vegetation for food and habitat.

Aquatic natural resources will also be hit increasingly hard by continued climate change.[36] I've already described how warming, increased precipitation, and more intense rainfall are combining to increase the incidence of algal blooms – including toxic varieties – in all of the Great Lakes. Lake Erie is the poster child for this serious problem, where the toxic algae is creating lethal anoxic conditions, killing fish and repelling recreationalists. Toxic blooms threaten the drinking water of communities who rely on the lake for water. With continued fossil fuel emissions of greenhouse gases, similar algae problems could become much more widespread along many of the region's coasts and inland waters. Fish habitats are already being impacted by warming waters, and a weakened natural ecosystem creates opportunities for invasive species from warmer parts of the globe, which in turn

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[33] See Exhibit ELP-12 (JTO-2).
[34] Ibanez, I. et al., (2018). *Anthropogenic nitrogen deposition ameliorates the decline in tree growth caused by a drier climate*. Ecology 99: 411-420.
[35] See Exhibit ELP-15 (JTO-5).
[36] See Exhibit ELP-15 (JTO-5).

could mean more problems for native fish species. Tourism, recreation, water supplies, healthy natural resources and more are all at increasing risk in Michigan and the Great Lakes region as long as we permit greenhouse gas emissions to continue.

A notable increase in rainfall intensity has already occurred in the Midwest due to greenhouse gas emissions, and further emissions threaten our natural resources with a greater risk of flooding, erosion and degradation of waterway and coastal habitats.[37] Coastal impacts are compounded by the ongoing increase in Great Lakes water level extremes and variability, as well as the reduction in lake ice in winter. Based on trends that we already observe, Michigan and the Great Lakes are clearly sensitive to warming when it comes to extreme rainfall, algal blooms, water level variability, and the impacts on human and natural systems that accompany these changes. Further warming will amplify these effects, highlighting the need to keep future emissions to a minimum.

Q: **Do you have an understanding of how climate change will impact human health will impact people in Michigan?**

A: Yes, as I have testified above, extreme heat and heatwaves are already becoming a major human health challenge, both in urban and rural areas. Michigan and the Great Lakes region will likely see a large increase in extreme temperature-related premature deaths if greenhouse gas emissions are not halted quickly. Increased flooding, fueled by greenhouse gas emissions, will become even more lethal and increase health risks related to degraded water treatment, disease spread, and access to critical health services. Risks from disease are also made worse by climate change.[38] Warming temperatures have hastened the spread of tick-borne Lyme disease in Michigan, and has combined with increased precipitation

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[37] See Exhibit ELP-15 (JTO-5).
[38] See Exhibit ELP-15 (JTO-5).

and runoff to worsen the risk from harmful algae blooms in the Great Lakes; most recently, we are learning that the toxic algae can also become airborne and cause elevated health risks as the more prevalent toxic algae blows over land. The habitat of disease-carrying mosquitos is also expected to expand in Michigan and the Great Lakes if warming is not halted.

At present, air pollution in Michigan and the Great Lakes, often deemed unhealthy by public health officials, is a direct result of fossil fuel burning for industry and transportation in the region. Poor air quality has been implicated in significant numbers of premature deaths each year,[39] as well as a greater susceptibility to diseases including dementia,[40] asthma,[41] and COVID-19.[42] Continued use of fossil fuels means continued air pollution-related health problems, compounded by the additive effects of warming on smog production and the likely increase in smoke from wildfires, both nearby and remote. Conversely, a strong shift away from fossil fuel production and use could actually improve air and water quality in the Great Lakes region, particularly for those who are disproportionately impacted through their proximity to refineries, pipeline leaks, highways, and smokestacks.

Q: Are there any solutions to climate change?

A: The solutions to climate change fall into two major categories. The first is climate change adaptation where strategies are developed to live and cope with changes already happening,

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[39] Cohen A.J. et al. (2017). *Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015*. Lancet 2017; 389: 1907–18.
[40] Peeples, L. (2020). *How air pollution threatens brain health*. Proceedings of the National Academy of Sciences of the United States of America 117: 13856–13860.
[41] The Lancet Commission on pollution and health (2017). Published online October 19, 2017 http://dx.doi.org/10.1016/S0140-6736(17)32345-0.
[42] Zhou X. et al., (2021). *Excess of COVID-19 cases and deaths due to fine particulate matter exposure during the 2020 wildfires in the United States*. Science Advances 7: eabi8789

and expected to happen. The second broad category of solution is climate change mitigation, which includes all means to slow, and eventually halt climate change before the magnitude of global warming above pre-industrial levels reaches 1.5 to 2.0°C. A third proposed approach for dealing with climate change involves efforts to further geoengineer, or alter, the Earth's climate system, so that it cools in ways that may offset the impacts of continued fossil fuel use and greenhouse gases. However, no form of proposed geoengineering has yet proved to be effective, safe and not cost-prohibitive, despite increased focus by the scientific community.

Q: In your opinion, is climate change adaptation a reasonable solution to climate change?

A: No. Whereas climate change adaption strategies are already necessary and being increasingly deployed, the science has convincingly shown that adaptation is unlikely to be cost-effective or sufficient once global warming reaches 1.5 to 2.0°C. The loss of life and property from recent climate change disasters brutally illustrates how challenging adaptation is in practice, even at the current warming of 1°C. Beyond 1.5-2°C, there are many ways that adaption strategies will fall short of protecting key human and natural systems. For example, there would be a real risk of ice sheet collapse and the resulting global sea level rise of many meters would submerge huge swaths of coastlines, infrastructure, and communities around the world. Extreme heat and drought, and the associated disruption of water and food systems, would become overwhelming across significant regions of the globe. The stresses on ecosystems and biodiversity would increase the odds of triggering the sixth mass extinction in Earth history.[43] Human health

[43] Exhibit ELP-12 (JTO-2).

would likely be one of the biggest casualties. Over 200 medical journals teamed up in 2021 to publish a joint statement emphasizing that no temperature rise is "safe," and that allowing temperatures to increase more than 2°C above pre-industrial levels would be "a catastrophic outcome for [human] health and environmental stability."[44] The impacts of climate change on geopolitics, social stability, national security, and "climate refugee" movements have long been acknowledged by the US Department of Defense, the United Nations, and expert researchers. Climate change adaptation will simply be unable to address the scale and scope of the changes we expect, if fossil fuel and other greenhouse gas emissions continue on their current trajectory.

Q: What about climate change mitigation?

A: Climate change mitigation involves slowing or stopping climate change by deploying human interventions to reduce greenhouse gas emissions, or to enhance the sinks of greenhouse gases. The technologies to do this exist and are already being deployed, for example replacing fossil fuel-based energy generation with renewable energy plus energy storage, and internal combustion engine vehicles with electrified mobility. These technologies are already cost-effective relative to their fossil-fuel alternatives and continue to see cost declines. More energy efficient buildings and electrified heating and cooling also eliminate the need for fossil fuel, and reduce costs for heating and cooling.

A theoretical alternative to eliminating fossil fuel use is to capture CO2 from the atmosphere and sequester it in robust storage. At present, there are no realistic sinks for greenhouse gases that make it possible to continue the fossil-fuel-rich level of greenhouse gas emissions while limiting global warming to 1.5 to 2.0°C. Natural carbon sinks,

[44] *See* Exhibit ELP-16 (JTO-6).

including both the large ocean carbon sink and terrestrial vegetation sinks, are unlikely to help reduce greenhouse gas emissions beyond the role they now play. Even the current ability to serve as sinks is threated by climate change. In addition, no human technology has yet been developed to remove greenhouse gases from the atmosphere at scale, or in a cost-effective manner. This means that the only proven, cost-effective way to stop climate change from becoming dangerously large (i.e., more that 1.5 to 2.0°C global warming above pre-industrial levels) is to eliminate the existing and new emissions of greenhouse gases. Critical to achieving this goal, in turn, is leaving much of the available recoverable fossil fuels in the ground, and reducing oil and gas production steadily into the future.[45]

Q: Can you please summarize your conclusions?

A: Human-driven climate change, caused by increases in greenhouse gas emissions, is already impacting every region of the globe, and the Great Lakes region is no exception. If greenhouse gases continue to accumulate in the atmosphere and drive additional climate change, the impacts of climate change will continue to intensify. The impacts of warming become more intense as warming increases. Higher temperatures, greater average precipitation and more intense precipitation are the three types of change that have become most troubling for Michigan and the Great Lakes region. A notable increase in rainfall intensity has already occurred in the Midwest due to greenhouse gas emissions, and further emissions threaten our natural resources with a greater risk of flooding, erosion and degradation of waterway and coastal habitats. Increasing greenhouse gases in the atmosphere are causing warming and the intensification of the hydrological cycle in Michigan and the Great Lakes. This warming means more extreme warm temperatures

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[45] Welsby D. et al., (2021). *Unextractable fossil fuels in a 1.5 °C world*. Nature 597: 230 https://doi.org/10.1038/s41586-021-03821-8

and more severe drought conditions, coupled with more intense storms when rain does materialize. Climate change greatly increases the risk of profound disruption of natural resources and human health in Michigan and the Great Lakes region.

Q. Does this conclude your testimony?

A. Yes.

STATE OF MICHIGAN
MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of **ENBRIDGE ENERGY, LIMITED PARTNERSHIP** application for the Authority to Replace and Relocate the Segment of Line 5 Crossing the Straits of Mackinac into a Tunnel Beneath the Straits of Mackinac, if Approval is Required Pursuant to 1929 PA 16; MCL 483.1 et seq. and Rule 447 of the Michigan Public Service Commission's Rules of Practice and Procedure, R 792.10447, or the Grant of other Appropriate Relief	)))))))))))	Case No. U-20763

DIRECT TESTIMONY OF DR. ELIZABETH A. STANTON

ON BEHALF OF

THE ENVIRONMENTAL LAW & POLICY CENTER, THE MICHIGAN CLIMATE ACTION NETWORK, AND THE BAY MILLS INDIAN COMMUNITY

September 14, 2021

Q: Please state your name, business name and address.

A: My name is Elizabeth A. Stanton. I am the Director and a Senior Economist at the Applied Economics Clinic. Our offices are located at 1012 Massachusetts Avenue, Arlington MA, 02476.

Q: What is your educational background?

A: I received a PhD in Economics from the University of Massachusetts-Amherst in 2007. Prior to that, I received my Master of Arts in Economics from New Mexico State University in 2000 and a Bachelor of International Studies at the School for International Training in Brattleboro, Vermont.

Q: Can you briefly describe your professional background?

A: I am the founder and Director of the Applied Economics Clinic ("AEC"), a non-profit consulting group. AEC provides expert testimony, analysis, modeling, policy briefs, and reports for municipalities and other public interest groups on the topics of energy, environment, consumer protection, and equity. AEC also provides training to the next generation of expert technical witnesses and analysts through applied, on-the-job experience for graduate students in related fields and works proactively to enhance diversity among the people who do our jobs today and in the future. As a researcher and analyst with two decades of professional experience as a political and environmental economist, I have authored more than 155 reports, policy studies, white papers, journal articles, and book chapters as well as more than 45 expert comments and oral and written testimony in public proceedings on topics related to energy, the economy, the environment, and equity. My articles have been published in Ecological Economics, Climatic Change, Environmental and Resource Economics, Environmental Science & Technology, and other journals. I have also published books, including Climate Change and Global Equity

(Anthem Press, 2014) and Climate Economics: The State of the Art (Routledge, 2013), which I co-wrote with Frank Ackerman. I am also co-author of Environment for the People (Political Economy Research Institute, 2005, with James K. Boyce) and co-editor of Reclaiming Nature: Worldwide Strategies for Building Natural Assets (Anthem Press, 2007, with Boyce and Sunita Narain). My recent work includes review and analysis of electric and gas sector planning in several states, Integrated Resource Plan (IRP) and Demand-Side Management (DSM) planning review, analysis and testimony of state climate laws as they relate to proposed capacity additions, and other issues related to consumer and environmental protection in the electric and gas sectors. In my previous position as a Principal Economist at Synapse Energy Economics, I provided expert testimony in electric and gas sector dockets, and led studies examining environmental regulation, cost-benefit analyses, and the economics of energy efficiency and renewable energy. Prior to joining Synapse, I was a Senior Economist with the Stockholm Environment Institute's (SEI) Climate Economics Group, where I was responsible for leading the organization's work on the Consumption-Based Emissions Inventory (CBEI) model and on water issues and climate change in the western United States. While at SEI, I led domestic and international studies commissioned by the United Nations Development Programme, Friends of the Earth-U.K., and Environmental Defense Fund, among others. My Curriculum Vitae is attached as Exhibit ELP-17 (EAS-1).

Q: Have you ever testified in front of the Michigan Public Service Commission?

A: No.

Q: Have you testified in other jurisdictions?

A: Yes. I have testified in public utility and other related dockets in Massachusetts, New Hampshire, South Carolina, District of Columbia, Pennsylvania, Indiana, Minnesota, Louisiana, Florida, Illinois, Puerto Rico, and Vermont, and have submitted comments in several federal dockets, including in front of the U.S. EPA.

Q: On whose behalf are you submitting this testimony?

A: I am submitting this testimony on behalf of the Environmental Law & Policy Center, the Michigan Climate Action Network, and the Bay Mills Indian Community.

Q: Are you sponsoring any exhibits?

A: Yes. I am sponsoring the following exhibits:

- ELP-17 (EAS-1) – Curriculum Vitae of Dr. Elizabeth A. Stanton.
- ELP-18 (EAS-2) – Notice of Revocation and Termination of Easement.
- ELP-19 (EAS-3) – Governor Whitmer Executive Directive 2020-10.
- ELP-20 (EAS-4) – May 11, 2021, Letter from Governor Whitmer to Enbridge.
- ELP-21 (EAS-5) – Enbridge Response to Notification of Revocation and Termination.
- Exhibit ELP-22 (EAS-6) MPSC. 2021. *MI Propane Security Plan: Ensuring Resilience without Line 5.*
- Exhibit ELP-23 (EAS-7) Public Sector Consultants. 2020. *Analysis of Propane Supply Alternatives for Michigan.* Prepared for Michigan DEP and PSC.
- Exhibit ELP-24 (EAS-8) Dynamic Risk's 2017 *Alternatives Analysis for the Straits Pipelines*.
- Exhibit ELP-25 (EAS-9) Executive Order No. 2020-182.

Q: What materials did you review in preparing this testimony?

A: Any document upon which I relied directly is cited in my testimony.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to determine whether "no-action" was considered by Enbridge as an alternative that would meet the Company's stated purpose for the Proposed Project and whether such an alternative is feasible.

Q: Can you summarize your conclusions?

A: I conclude that Enbridge failed to consider a "no-action" alternative and that a "no-action" alternative is feasible here. As I describe more fully below, Enbridge's stated purpose is to remove the threat of an oil spill from the existing pipelines in the Mackinac Straits. Enbridge proposes shutting down the existing pipeline and considers three alternatives for replacing the pipeline. However, Enbridge does not consider a "no action" alternative. A "no action" alternative would be not constructing the tunnel and not continuing to operate the existing dual pipelines. Not continuing to operate the dual pipelines, i.e., "shutting down" Line 5, is a reasonable component of a no-action alternative because it is a likely outcome even if the project is not approved. It is likely because it has already been ordered by the State government, and also because it is another way to remove the threat of an oil spill. A no-action alternative is feasible because Michigan's energy needs can be met without propane through electrification. During a transition to heating with modern electric heat pumps, Governor Whitmer's Upper Peninsula Energy Task Force Committee's short- and long-term recommendations lay out steps to securing energy supplies in the event of a shutdown of Line 5.

II. <u>OVERVIEW OF ENBRIDGE'S PROPOSED PROJECT</u>

Q: Please describe the project for which Enbridge seeks approval under Act 16.

A: In Case No. U-20763, before the Michigan Public Service Commission ("MPSC" or the "Commission"), Enbridge Energy is proposing to build a tunnel beneath the Straits of Mackinac to house a new segment of its Line 5 oil and natural gas liquids pipeline (the

"Proposed Project"). This proposed segment would be a single 30-inch diameter pipeline to replace current dual-pipelines, each with 20-inch diameters.

Q: What is the purpose of the Proposed Project?

A: Enbridge states in the testimony supporting its application that the purpose of the Proposed Project is to alleviate environmental risk:

> The purpose of the Project is to alleviate an environmental concern to the Great Lakes raised by the State of Michigan relating to the approximate four miles of Enbridge's Line 5 that currently crosses the Straits of Mackinac ("Straits"). Line 5 is a fully operational 645-mile interstate pipeline, and the approximate four-mile segment that crosses the Straits -- which is known as the "Dual Pipelines" – lies on top of the lakebed with the exception of portions buried near each shoreline. (Pastoor Direct at 3:25-4:5).

Q. Who is Enbridge?

A. Enbridge is a Canadian fossil fuel pipeline transport company. According to the Company's website, "We operate across North America, fueling the economy and people's quality of life. We move about 25% of the crude oil produced in North America, we transport nearly 20% of the natural gas consumed in the U.S., and we operate North America's third-largest natural gas utility by consumer count."[1]

Q: Do you have an understanding of the environmental concerns to which Enbridge refers in its testimony?

A: Yes. According to Michigan Governor Gretchen Whitmer's November 2020 notice terminating Enbridge's Straits of Mackinac easement, the existing Line 5 pipeline is at risk of leaking oil and natural gas liquids into the Straits of Mackinac and from there into the Great Lakes:

> Enbridge's operation of the Straits Pipelines presents a substantial, inherent and unreasonable risk of an oil spill and such a spill would have grave ecological and economic consequences, severely impairing public rights in the Great Lakes and their public trust

[1] https://www.enbridge.com/about-us

> resources. While Enbridge has proposed to replace the existing Pipelines with a new pipeline to be constructed in a tunnel beneath the lakebed, that project is likely years away from completion at best. For all these reasons, the Governor and the Director of the Department of Natural Resources find that Enbridge's use of the Straits Pipelines is contrary to and in violation of the public trust.[2]

These environmental concerns are also referenced in a number of documents that are available on the Michigan Pipeline Safety Advisory Board website, which was created by Michigan's previous Governor, Rick Snyder.[3]

Q: Are you aware of any additional environmental concerns associated with the Proposed Project?

A: Yes. The existing pipeline transports hydrocarbons, which result in greenhouse gas emissions that contribute to climate change. Shutting down the existing pipelines resolves concerns about an oil spill in the Great Lakes, but it also reduces the emissions of greenhouse gases. Michigan's Executive Directive No. 2020-10 states that:

> The science is clear, and message urgent: the earth's climate is now changing faster than at any point in the history of modern civilization, and human activities are largely responsible for this change. Climate change already degrades Michigan's environment, hurts our economy, and threatens the health and well-being of our residents, with communities of color and low-income Michiganders suffering most. Inaction over the last half-century has already wrought devastating consequences for future generations, and absent immediate action, these harmful effects will only intensify. But we can avoid some of the worst harms by quickly reducing greenhouse gas emissions and adapting nimbly to our changing environment.[4]

Q: Does Enbridge take the negative environmental effects of greenhouse gas emissions from the Proposed Project into account in its application?

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[2] Exhibit ELP-18 (EAS-2), Notice of Revocation and Termination of Easement at 9.
[3] *See* https://mipetroleumpipelines.org/resources-reports
[4] See Exhibit ELP-19 (EAS-3), Governor Whitmer Executive Directive 2020-10.

A: No, Enbridge does not address greenhouse gas emissions in its application. However, I am aware that testimony from Expert Witness Pete Erickson discusses the greenhouse gas emissions associated with Enbridge's Proposed Project, and that Expert Witness Dr. Peter Howard applies the Social Cost of Greenhouse Gases to Mr. Erickson's estimates.

Q: Is Enbridge currently authorized to run the dual pipelines across the Straits?

A: No. Governor Whitmer revoked and terminated Enbridge's easement, requiring the pipelines across the Straits to be shut down.[5] I understand Enbridge has refused to terminate operation of the existing pipelines pursuant to the Governor's notice, and is challenging the revocation and termination of the 1953 easement in court.[6] I am further aware that Governor Whitmer has put Enbridge on notice that the State of Michigan considers the Company's continued operations in the Straits to be an intentional trespass.[7]

Q. Are you aware of any alternatives that Enbridge has considered to alleviate environmental risk instead of its proposed tunnel?

A. Enbridge examined three alternatives to operating the existing dual pipelines. The first alternative was the proposed tunnel, which is at issue in this case. The other two alternatives were: "(ii) a new pipe installed across the Straits using an open-cut method that includes secondary containment; or (iii) a new pipe installed below the Straits using the horizontal directional drilling (HDD) method." (Pastoor Direct at 15:22-25) All three alternatives involve transporting hydrocarbon in a pipeline across the Straits. Enbridge did not consider any alternative that involved not replacing the existing line, resulting in Line 5 ceasing operations.

[5] ELP-18 (EAS-2) "[t]he Easement is being revoked for violation of the public trust doctrine, and is being terminated based on Enbridge's longstanding, persistent, and incurable violations of the Easement's conditions and standard of due care." p.20.
[6] *See Michigan, State of et al v. Enbridge Energy, Limited Partnership et al*, 1:20CV01142
[7] ELP-20 (EAS-4) May 11, 2021, Letter from Governor Whitmer to Enbridge.

Q. Has Enbridge considered an appropriate range of alternatives?

A. No. Enbridge has artificially limited its analysis of alternatives to include only methods that involve (1) shutting down the existing dual pipelines, **and** (2) transporting hydrocarbon in a pipeline across the Straits, allowing for continued operation of Line 5. Enbridge has overlooked an essential alternative that would meet its stated purpose of alleviating environmental risks to the Great Lakes: (1) shutting down the existing dual pipelines, **and** (2) taking no action to replace the pipelines with a new segment.

Q. Is that overlooked alternative what you refer to as the "no-action alternative"?

A. Yes, although I recognize that this terminology can be somewhat awkward when applied. In my experience, when alternatives analyses are undertaken, considering a "no-action alternative" is best practice. The no-action alternative evaluates what would happen if the proposed action were not to be undertaken. Here, the proposed action is the construction of a tunnel. Enbridge should have included in its alternatives analysis an alternative in which the existing pipeline no longer operates, but is not replaced with a new pipeline. In short, the "no-action" alternative is to eliminate the environmental risk to the Great Lakes by shutting down the existing pipeline, but take "no action" to construct a new pipeline segment through the Straits.

Q. Is the shut-down of the existing pipeline a necessary component of every alternative in a proper alternatives analysis?

A: Yes. Not only has Enbridge been ordered by the State to shut down the existing dual pipeline segment in the Straits, the Company's stated purpose is eliminating the environmental threat of a spill from the existing dual pipelines. Continuing to operate the existing pipelines would not achieve Enbridge's stated purpose, and therefore cannot be considered as a component of an alternative here. It is important to consider the no-action alternative because, even if a tunnel reduced some of the threat of an oil spill in the Straits, it would not eliminate the threat, and, when compared to discontinuing operation of Line 5, would exacerbate the harm to natural resources caused by climate change.

Q: Is the shutdown of the existing line a certainty?

A: No. I understand that Enbridge is contesting the shutdown order and says that it will continue to operate the dual pipelines if it is not allowed to build the tunnel.[8] By refusing to comply with the Governor's order, Enbridge sets up a false choice between a pipeline within the tunnel and a pipeline without a tunnel, thus avoiding discussion of a true no action alternative.

Q: Why do you say Enbridge set up a false choice?

A: Enbridge has made clear that the purpose of the Proposed Project is to alleviate environmental harm by shutting down the existing pipeline and must consider all available alternatives that would serve this same purpose. Enbridge's testimony implies that the choice in front of the Commission is between different methods of transporting hydrocarbons across the Straits. But Enbridge has not presented the Commission with a true no action alternative. Taking "no action" would be not developing a new method by which to transport hydrocarbons across the Straits, regardless of the outcome of Enbridge's contestation of the Governor's order to shut down the line.

Q. Would it be feasible and prudent to shut down the existing line and not replace it with a new line, resulting in the shutdown of Line 5 in its entirety?

A: Yes.

Q. What do you understand feasible and prudent to mean?

[8] ELP-21 (EAS-5) Enbridge Response to Notification of Revocation and Termination.

A: My understanding is that the words "feasible" and "prudent" are not defined in the Michigan Environmental Protection Act. An acceptable method of determining intent is to refer to a dictionary for the common usage of the words.[9] A "feasible" alternative is one that is "capable of being put into effect or accomplished; practicable" or "capable of being successfully utilized; suitable."[10] "Prudent" is defined as "exercising sound judgment."[11]

Q: What is the basis for your opinion that it would be feasible and prudent to shut down the existing line and not replace it with a new line?

A. Shutting down the existing line and taking no action to replace it is practicable and represents the exercise of sound judgment.

<u>A no-action alternative is practicable</u>: Without Line 5 at the Straits of Mackinac current consumers of propane and related products would either purchase fuels transported in a different way (other pipelines, road and rail) or would switch to non-hydrocarbon fuels, likely electrification via modern heat pumps. Michiganders would still have access to the energy they need to heat their homes (see Section III). There are viable alternatives to heating with propane (see Section IV). Michigan agencies are obligated to create policies and incentives to reduce emissions, including in the building sector (see Section IV).

<u>A no-action alternative represents the exercise of sound judgment</u>: Taking no action to build a tunnel for Line 5 would shut down one of many sources of energy while achieving the express purpose of the Proposed Project: eliminating environmental risk to the Straits. In my opinion this course of action represents sound judgment because it simultaneously advances climate change goals established by the State of Michigan. Indeed, with Michigan's requirement to achieve a 28 percent reduction in emissions (from 2005 levels)

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[9] Nelson v. Grays, 209 Mich.App. 661, 664, 531 N.W.2d 826 (1995).
[10] Funk & Wagnalls Standard Dictionary (1980).
[11] Funk & Wagnalls Standard Dictionary (1980).

by 2025 and carbon neutrality no later than 2050, investments in propane heating (and the infrastructure to transport that propane) will become "stranded assets" by 2050 at the very latest. These investments will lose all value, regardless of the age or condition of the equipment. Investments that extend the life of propane heating and transmission equipment do not seem to represent sound judgment whether for households or for energy companies (see Section V).

III. IN A NO-ACTION ALTERNATIVE, MICHIGANDERS WOULD STILL BE ABLE TO HEAT THEIR HOMES

Q. Has there been any analysis of what Michigan consumers would do in the event that Enbridge's Line 5 supply were no longer available?

A. Yes. Governor Whitmer's Upper Peninsula Energy Task Force Committee ("UP Energy Task Force") published short- and long-term recommendations on securing energy supplies in the event of a shutdown (accidental or by policy) of Line 5. The UP Energy Task Force identified a number of policies that would mitigate the short-term energy supply disruptions including evaluating potential changes in supply and distribution, investing in the propane supply infrastructure, monitoring market conditions, addressing energy costs in the Upper Peninsula, enabling state contracting of propane, and instituting consumer protections. The UP Energy Task Force's longer-term recommendations focus on creating alternative supplies to meet consumer demand for heat. These policies include financing energy waste reduction, supporting development of renewables and energy storage options, promoting affordable electricity for consumers, and promoting environmental justice actions.

Q. How is propane currently used in Michigan?

A. According to the U.S. Energy Information Administration's (EIA) Residential Energy Consumption Survey most of Michigan's residential propane sales are used for space and water heating.[12]

According to the U.S. Census Bureau, eight percent of Michigan households use some form of bottled fuel to heat their homes. In Detroit, less than 1 percent of homes heat with propane while in the Upper Peninsula the share rises to 19 percent (see Table 1).[13] Three percent of homes in the Michigan region use propane to heat water.[14]

Table 1. Michigan home heating fuels

	MI		Detroit		UP	
	Homes	%	Homes	%	Homes	%
Bottled, tank, or LP gas	326,681	8%	2,168	1%	24,057	19%
Gas	3,006,749	76%	227,405	86%	71,353	57%
Electricity	385,768	10%	29,250	11%	12,947	10%
Fuel Oil	42,597	1%	641	0%	3,497	3%
Wood	116,756	3%	413	0%	11,281	9%
Other	37,784	1%	1,702	1%	1,211	1%

Q. What are the alternatives to propane in the Governor's Upper Peninsula Energy Task Force Committee report?

A. The UP Energy Task Force report suggests the following alternatives to propane supplies via Line 5: the increased use of rail infrastructure and the creation of new track capacity; improvement of transloading in the Upper Peninsula; new wholesale and retail storage capacity, maximizing propane injected into storage reserves; developing a "Strategic Propane Reserve;" requiring contracts with the state government to have an attestation that

[12] U.S. EIA. 2015 Residential Energy Consumption Survey (RECS). Available: https://www.eia.gov/consumption/residential/data/2015/#waterheating. Data are for EIA's East North Central region, which consists of Illinois, Indiana, Michigan, Ohio, and Wisconsin.
[13] U.S. Census. 2019 ACS 5-Year Estimates Detailed Tables [Table: B25040]
[14] U.S. EIA. 2015 Residential Energy Consumption Survey (RECS). Available: https://www.eia.gov/consumption/residential/data/2015/#waterheating. Data are for EIA's East North Central region, which consists of Illinois, Indiana, Michigan, Ohio, and Wisconsin.

companies will meet their supply obligations if Line 5 is shut down; pre-buying of propane to lock-in supply; and removal of barriers to propane deliverability (land acquisition, brownfield redevelopment assistance and permitting).[15] The UP Energy Task Force's analysis of propane supply alternatives also considered trucking.[16] Much of the 2020 report by Michigan DEP and PSC's Public Sector Consultants focused on "estimated commodity costs at major hubs within the U.S. and Canada, costs of available transportation options, and associated storage costs" based on a number of delivery points.[17] The lowest-cost option identified originates in Edmonton, Alberta and relies on a mixture of rail transportation to deliver to a site in the vicinity and then rely on trucks for the remaining short distance (trucking the whole way is cost prohibitive).[18] The key limitation of this option is that rail is relied upon for most of the distance.[19] No options were identified for pipeline transit and only one option using shipping from Western Canada to the United States.[20]

Q: What scenarios for supply disruption have been examined by the Michigan PSC?

A. The Public Sector Consultants report considered three scenarios from which it assessed supply alternatives to Line 5: a supply disruption of the Lakehead System via Line 1; a potential disruption in Line 5; and a weather-related disruption of propane supply and consumption similar to the 2013-2014 winter season.[21] The first scenario assumes Line 5 would not continue operating, removing 51 percent of Michigan's propane supplies because of the loss of crude and natural gas supplies to propane production facilities.[22] The

[15] Exhibit ELP-22 (EAS-6) MPSC. 2021. *MI Propane Security Plan: Ensuring Resilience without Line 5.*
[16] Exhibit ELP-23 (EAS-7) Public Sector Consultants. 2020. *Analysis of Propane Supply Alternatives for Michigan.* Prepared for Michigan DEP and PSC.
[17] *Ibid*, pg. 82.
[18] *Ibid*.
[19] *Ibid*.
[20] *Ibid*.
[21] Exhibit ELP-23 (EAS-7) at 7.
[22] *Ibid*.

second removes 46 percent of Michigan's propane supplies.[23] Finally, a polar vortex similar to 2013-2014 would result in sharply increased demand, associated price spikes, and supply shortages as Michigan's current supply options would be insufficient to meet demand.[24]

IV. THERE ARE VIABLE ALTERNATIVES TO HEATING WITH PROPANE

Q. What alternatives to propane exist?

A. Modern electric heat pumps are a practical and economic alternative to propane space heating; electric hot water heaters (including heat pump hot water heaters), stoves and dryers can replace propane water heaters, stoves and dryers. Propane has the advantage of not requiring a transmission and distribution system in the ways that utility gas (local distribution pipelines) or fuel oil (tanker trucks) do. That means that homes and businesses can heat and serve other energy end uses with propane that they can self-deliver in bottles or small tanks. Very nearly all Michigan properties, however, are already served by grid-based electricity.[25] While old-fashioned electric resistance heating vies with propane for the least economic space heating fuel source, modern electric heat pumps are among the most economic heating sources to run and have the advantage of the same unit also providing cooling at a lower cost that window air conditioners.

Q. What are the cost impacts of propane usage versus electric heat pump usage?

A. Electric heat pump usage is less expensive than propane for heating homes. According to research by the Massachusetts Department of Energy, propane is far more expensive than other forms of heating—its costs are exceeded only by old fashioned electric resistance

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[23] *Ibid.*
[24] *Ibid.*
[25] U.S. EIA. 2015 Residential Energy Consumption Survey (RECS). Available: https://www.eia.gov/consumption/residential/data/2015/#waterheating. Data are for EIA's East North Central region, which consists of Illinois, Indiana, Michigan, Ohio, and Wisconsin.

heating. For example, heating with air source heat pumps, which are all electric heating and cooling systems designed for cold climates like Michigan, provides 44 percent reduction in heating costs compared to heat pumps.[26] Research (of which I am an author) from the AEC found that the relative costs of heating methods depend on fuel and electric prices and that in Massachusetts air source heat pumps will have lower heating costs than utility gas furnaces somewhere between 2026 and 2030 (depending on the cost to repair the state's aging pipeline infrastructure).[27] Recent research from the Rocky Mountain Institute showed modern air source heat pumps to have excellent efficiency in cold climate. Air source heat pumps coefficient of performance (COP, a measure of efficiency where 0.0 to 0.9 is a loss of energy, 1.0 is no loss, and higher than one is a gain of energy above that embedded in the fuel used) was 2.34 in Minneapolis, MN, compared to propane's COP of around 0.8.[28] A study performed for the City of San Francisco found that heat pumps are currently cost-effective as an end-of-life replacement for other heating sources.[29]

Q. What are the emission impacts of propane usage versus electric heat pump usage?

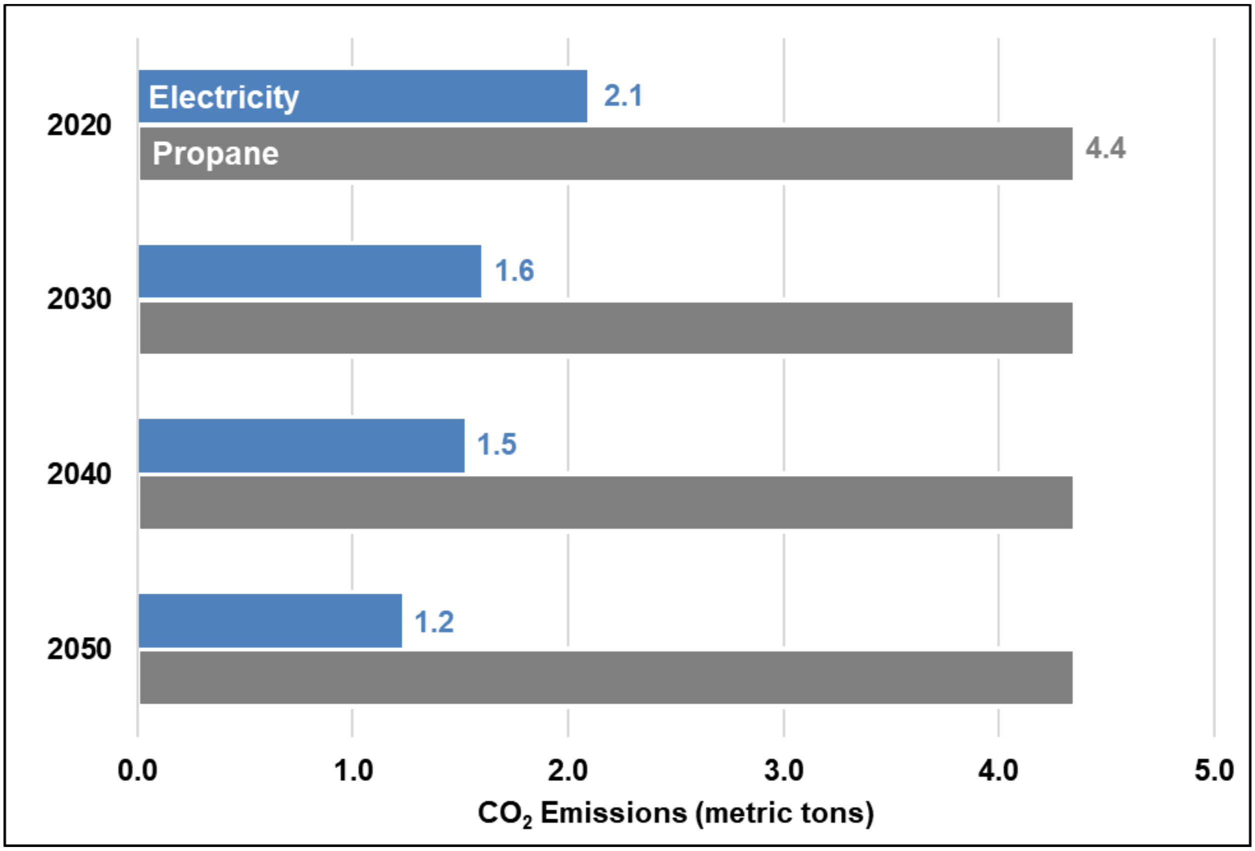
A. Air source heat pumps are almost four times more efficient than propane heaters and today Michigan's electric grid provides energy (MMBtus) at an emissions rate that is almost double that of burning propane directly for heat. I have determined that these two facts taken together result in propane heaters in Michigan emitting twice the greenhouse gases than air source heat pumps do for the same amount of heat.

Q. How will the emissions impacts of heat pumps and propane change over time?

[26] https://www.mass.gov/info-details/household-heating-costs
[27] https://aeclinic.org/publicationpages/2021/01/13/inflection-point-when-heating-with-gas-costs-more
[28] https://rmi.org/its-time-to-incentivize-residential-heat-pumps/ and U.S. EIA. June 2017. "Residential End Uses: Historical Efficiency Data and Incremental Installed Costs for Efficiency." Available at: https://www.eia.gov/analysis/studies/residential/pdf/res_ee_fuel_switch.pdf. p. 68
[29] https://sfenvironment.org/sites/default/files/fliers/files/sfe_cc_sustainable_future_siemens_climate_report.pdf, p25

A. While greenhouse gas emissions from propane heaters will stay constant, the emissions from air source heat pumps will fall as Michigan's electric grid becomes green (see **Error! Reference source not found.**).

Figure 1. Heat pump versus propane emissions from heating an average home in Michigan



Q. Are heat pumps available today in Michigan?

A. Heat pumps are available today in Michigan[30] and the state's utilities offer a small rebate for their installation.[31]

Q: Is converting to heat pumps cost-effective when equipment and installation costs are included?

[30] https://www.michigan.gov/documents/mpsc/MPG_New_Tech_Heat_Pumps_Full_Slides_717380_7.pdf
[31] https://www.michigan.gov/documents/mdcd/Residential_Incentives_Flyer_2011_367083_7.pdf

A: Yes, heat pumps are less expensive to purchase, install and run over the course of their lifetimes as compared to fossil fuel heating. However, any change in heating system requires significant upfront costs. This disincentive can be addressed by state or utility sponsored zero-interest loans for green energy investments and/or by rebates to offset these costs (for example: https://www.masssave.com/saving/residential-rebates/heat-loan-program and https://michigansaves.org/). Research by the American Council for an Energy-Efficient Economy has found that median payback period for a heat pump is about 5 years if the equipment is also used to provide central air conditioning and 15 years if it is not.(https://www.aceee.org/blog/2016/05/should-we-promote-heat-pumps-save). Other potential obstacles in heat pump installation include the costs of modernizing older electric systems to be able to support a heat pump (usually 200+ amps).

III. OTHER POTENTIAL IMPACTS ON MICHIGAN CAN BE RESOLVED

Q: Are you aware of any concerns with the no-action alternative other than the availability of propane for heating homes?

A: Yes. I am aware of Enbridge's argument that failing to transport hydrocarbons across the Straits will have negative impacts on Michigan oil producers, Michigan refineries, and consumers of jet fuel and other fuels in Michigan.[32]

Q: Have you formed any opinions about whether those concerns make the no-action alternative infeasible?

A: Yes. I have not done an independent analysis on each of these issues, but I have reviewed a variety of analyses and information on these issues, and I do not believe that these concerns render the no-action alternative either unreasonable or imprudent. Some

[32] See Enbridge. *The impact of a Line 5 shutdown.* Available at: https://www.enbridge.com/~/media/Enb/Documents/Factsheets/FS_Without_Line5_econ_impact.pdf

businesses with investments concentrated in fossil fuels may see reduced profits with a transition to electrification, while other businesses (electric utilities and generators, manufacturers and installers of heat pumps, efficiency measures and other electric equipment) will prosper. The State of Michigan does not have a role to play in choosing winners and losers among particular business actors in the economy. The fact that a particular alternative to a risky pipeline in a critical water body may benefit some businesses more than others makes no difference to a determination of whether it is reasonable and prudent.

Q: Can you explain the likely impact on jet fuel in Michigan?

A: Enbridge claims a Line 5 shutdown would impact half of jet fuel supplies to Detroit Metropolitan Wayne County Airport.[33] Enbridge also argues that Michigan would have to find alternative crude oil to supply refined products like jet fuel, but does not provide specific analysis or sources for third-party verification.[34] Enbridge's claim echoes that of Ohio Governor Mike DeWine who argued Line 5 supplies 40 percent of the jet fuel in DTW.[35] However, a recent "fact check" assessment suggests that Line 5 only provides 10 percent of DTW's jet fuel, from the following refineries: PBF, Husky, and Marathon.[36] (Note however that 2020 fuel consumption numbers at DTW for this assessment were based on numbers from the 2010 DTW Master Plan.[37]) While I have not independently verified the methods or results of this fact check, it does suggest that Enbridge has provided insufficient evidence to back up its claims.

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[33] Enbridge. *The impact of a Line 5 shutdown.* Available at: https://www.enbridge.com/~/media/Enb/Documents/Factsheets/FS_Without_Line5_econ_impact.pdf
[34] *Ibid.*
[35] FLOW. 2021. "Fact Check: When Line 5 Shuts Down, Detroit Jets Will Still Fly and Union Refinery Jobs Will Still Exist." Available at: https://forloveofwater.org/fact-check-when-line-5-shuts-down-detroit-jets-will-still-fly-and-union-refinery-jobs-will-still-exist-3/
[36] *Ibid.*
[37] *Ibid.*

Q. Can you explain the likely impact on Michigan refineries?

A. In the event of a Line 5 shutdown, the industry association Consumer Energy Alliance's (CEA) 2021 report suggests that two refineries in Ohio (PBF Energy and BP Husky) would cease operation while the Marathon Refinery near Detroit and refineries in Indiana and Pennsylvania will remain open but operate at reduced levels; overall, CEA estimates that refineries in Michigan, Ohio, Pennsylvania, Ontario, and Quebec would lose 45 percent of their crude oil input with a Line 5 disruption.[38] Another 2021 assessment by IHS Markit notes that there are nine refineries affected by the Line 5 and Line 78 system that have the collective potential to refine 1 million b/d, including 150,000 b/d of jet fuel.[39] Line 5 ships 540,000 b/d of light crude and natural gas, while the remaining (excluding Line 5) mainline capacity starting at the Wisconsin border is 2 million b/d, suggestion an impact on area refineries closer to 20 percent. Again, Enbridge has not provided analysis, sources, or data for third-party verification of any negative impacts on Michigan refineries

Q. Overall, in your opinion, what impacts would a closure of Line 5 have on the Michigan economy?

A. Overall, I would expect a closure of Line 5 to have a positive or neutral effect on the Michigan economy. Certainly, there would be losses to some businesses that have concentrated all of their investment in fossil fuel-related activities. But losses and gains in business sectors are the normal workings of a capitalist economy; and losses to businesses with concentrated investments in greenhouse-gas emitting fuels and technologies are inevitable as Michigan, the United States, and the world decarbonize.

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[38] Consumer Energy Alliance. 2021. *The Regional Economic and Fiscal Impacts of an Enbridge Line 5 Shutdown.* Available at: https://consumerenergyalliance.org/cms/wp-content/uploads/2021/05/CEA_LINE5_REPORT_2021_DIGITAL_FINAL.pdf. Pg. 3; 7; 9.

[39] Bradley, A. 2021. "Line 5 shutdown could create a logistical scramble, reducing competitiveness of crude oil producers and refiners." HIS Markit. Available at: https://ihsmarkit.com/research-analysis/line-5-shutdown-could-create-a-logistical-scramble-reduci.html.

Businesses with diverse investments that include some fossil fuels and other non-energy businesses should experience a neutral impact from a Line 5 closure, while businesses with investments in electric supply, electric equipment manufacture and installation, and other "green" goods and services should benefits from a Line 5 closure.

Workers in these industries would experience related impacts, with jobs added in electric supply and equipment manufacture and installation, and some job losses in businesses with concentrated investments in fossil fuel-related activities. State policy to support retraining fossil-fuel-related workers for skills in zero-carbon industries could play an important role in smoothing the decarbonization transition for workers, while insuring that a loss of worker income (while limited to a small set of workers) does not negatively impact on the economy as a whole.

Energy consumers (households and businesses) may need state assistance in the form of rebates and no-interest loans to transition to heat pumps and other electric equipment. But after this transition is complete will benefit from lower energy bills.

Overall, while the closure of Line 5 (and the greater project of Michigan decarbonization) will cause some shift in consumer expenditures I see no reason to believe that it will be a detriment to consumers or the economy as a whole.

Q. Are your conclusions consistent with other analyses that you have reviewed?

A. Yes. As I discussed above, Governor Whitmer's Upper Peninsula Energy Task Force Committee's report provide detailed plans for addressing a temporary energy shortfall from a Line 5 closure. Dynamic Risk's 2017 *Alternatives Analysis for the Straits Pipelines* (on behalf of the State of Michigan) includes a no action alternative (Alternative 6) that "Eliminate[s] the transportation of all petroleum products and natural gas liquids…through the Straits of Mackinac segment of Enbridge's Link 5 and then decommission[s] that segment."[40] This alternative eliminates all risks to the Straits and results in increases to some fossil fuel prices and decreases to other prices. The report does not examine impacts on other related industries or non-fossil-fuel energy alternatives.

Similarly, London Economics' analysis of alternatives to Line 5 found that losses to Michigan refineries would by limited to 15 percent of supply (much lower than Enbridge's estimate) and that the related increase in gasoline prices would be lower than 1 cent per gallon. London Economics' also suggests that Enbridge has the capacity to increase supplies using its existing Line 78, reducing economic impacts still further.[41]

IV. MICHIGAN AGENCIES ARE OBLIGATED TO REDUCE EMISSIONS, INCLUDING IN THE BUILDING SECTOR

Q. Is public policy relevant to the future demand for fossil fuels and related products in Michigan?

A. Yes. Michigan's energy plans and policies, climate plans and policies, and environmental standards and regulations all impact on the future demand for fossil fuels, today and in the future. As an economist, I am aware of the importance of considering costs and benefits throughout (and often beyond) a project's lifetime. For energy projects, that includes consideration of demand for the type of energy in question over the lifespan of the project and the lifetime of the projects impacts on local communities, local environments and the climate. In other words, an appropriate alternatives analysis must consider whether demand for fossil fuel will be the same or different in 10 years, 25 years, and 100 years.

[40] Exhibit ELP-24 (EAS-8) Dynamic Risk's 2017 *Alternatives Analysis for the Straits Pipelines* at p.ES-2.
[41] http://blog.nwf.org/wp-content/blogs.dir/11/files/2018/09/LEI-Enbridge-Line-5-Michigan-Refining_9_12_2018.pdf

Climate forecasts, regulations, and policies, like those being undertaken in the State of Michigan today, suggest that it is not sensible to assume that fossil fuel demand will be the same or higher in future years.

Q. What efforts is the State of Michigan undertaking to reduce Michigan's carbon footprint?

A. Michigan's EO 2020-182 requires the Department of Environment, Great Lakes, and Energy to "develop, issue, and oversee the implementation of the MI Healthy Climate Plan…, which will serve as the action plan for this state to reduce greenhouse gas emissions and transition towards economywide carbon neutrality."[42] The MI Healthy Climate Plan must be submitted to the Governor by December 31, 2021.[43] ED 2020-10 requires the Department of Environment, Great Lakes, and Energy to oversee the Plan's implementation. In addition, the Department of Treasure is charged with developing and implementing an Energy Transition Impact Project to identify and minimize impacts of clean energy transition on vulnerable communities.[44]

Q. How will the states' actions towards carbon neutrality impact the use of fossil fuels in Michigan?

A. To achieve carbon neutrality, Michigan must transition away from fossil fuel energy towards zero-emitting energy resources like wind and solar. The forthcoming MI Healthy Climate Plan will likely set out an expected pace for this transition. Within the next two to three decades, operating fossil fuel-fired equipment will not be permitted in the State of Michigan.

[42] Exhibit ELP-25 (EAS-9) Executive Order No. 2020-182.
[43] Exhibit ELP-19 (EAS-3), Executive Directive 2020-10.
[44] *Ibid*.

Q. Are you aware of any efforts by the U.S. federal government to reduce the national carbon footprint?

A. The Biden Administration has promised to rejoin the Paris Agreement and achieve nationwide carbon neutrality by 2050. Biden's National Climate Task Force is in the process of setting a new 2030 emission target and develop a detailed plan for lower emissions while improving environmental justice outcomes.[45]

V. INVESTMENT THAT EXTENDS THE LIFE OF PROPANE HEATING AND TRANSMISSION EQUIPMENT IS NOT PRUDENT

Q. What is a stranded asset?

A. A stranded asset is an investment in equipment or infrastructure that is no longer of use before it has been paid off. For example, fossil fuel heaters built today may have a 30-year economic life and their financing decision will be made on that basis: 30 years of revenues (or value) to cover the initial cost, plus upkeep. If greenhouse gas emissions limits or other zero emission energy requirements (such as a renewable portfolio standard) require substantial emission reductions before the end of those 30 years, use of the fossil fuel equipment will no longer be permitted and the value of the asset will become "stranded": the equipment is there but it cannot be used, and it cannot generate value for its owner.

Q. Why are fossil-fuel heaters, water heaters, dryers and stoves likely to become stranded assets in Michigan?

A. Michigan's ED 2020-10 requires agencies to achieve a statewide 28 percent reduction in emissions (from 2005 levels) by 2025 and carbon neutrality no later than 2050.[46] EIA

[45] https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

[46] Exhibit ELP-19 (EAS-3), Executive Directive 2020-10.

assumes a lifetime for a propane furnace of between 16 and 27 years.[47] That means that a propane furnace installed today has the potential—with appropriate maintenance—to continue to provide heat through the year 2048. But by 2050 at the latest, Michigan will no longer permit carbon emissions. Furthermore, it is likely that many carbon reduction goals will not permit any significant number of emissions "offsets," requiring true and significant reductions in greenhouse gas emissions. With every passing year, new purchases of fossil fuel heaters and new investments in pipelines and related infrastructure become less likely to remain operational throughout their economic lifetimes.

VI. CONCLUSIONS

Q. Can you please summarize your conclusions?

A. In its application to build a tunnel beneath the Straits of Mackinac to house a new segment of its Line 5 oil and natural gas liquids pipeline, Enbridge has failed to consider and present a reasonable and prudent no-action alternative to shut down Line 5 (thus achieving the stated purpose of eliminating environmental risk) and not building a new pipeline or tunnel to replace it.

The closure of Line 5 would accelerate Michigan's transition to a zero-carbon economy, benefit "green" and electric-related businesses, and reduce consumer energy costs—important positive effects on Michigan's economy. Governor Whitmer's task force provides detailed plans for addressing temporary energy supply concerns from a closure, and any more permanent shift away from spending on fossil fuel-related business towards green and electric businesses is inevitable given the state's greenhouse gas emission requirements.

[47] https://www.eia.gov/outlooks/aeo/assumptions/pdf/residential.pdf

A no action alternative eliminates environmental (including climate) risks, moves Michigan forward in its climate goals, and does not prevent consumers from getting the energy supply that they need.

Q. Does this conclude your testimony?

A. Yes.