ATTACHMENT A

COMMENT ON THE SURFACE TRANSPORTATION BOARD OCTOBER 30, 2020 DRAFT ENVIRONMENTAL IMPACT STATEMENT ON THE UINTA BASIN RAILWAY

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I am a policy analyst, researcher, educator, and consultant with more than three decades of experience assessing the risks associated with transporting hazardous materials. Over the course of my career, I have advised governmental bodies, national chemical and oil worker unions, insurance companies, universities, and environmental groups on the unique health and safety hazards of shipping hazardous materials—including crude oil—by rail. I have testified before both houses of the United States Congress, and have presented as an invited lecturer in twelve countries on chemical transportation accident prevention. As a consultant, I have provided analyses of risks associated with transporting crude oil by rail into and around cities across the United States, including Albany, New York, Baltimore Maryland, Washington, D.C., and Benicia California.

I am familiar with the recent developments and national conferences and debates on crude oil rail transportation, and with the major recent research documents in this area. I am familiar with the Seven Counties Infrastructure Coalition (SCIC) proposal to begin crude oil unit train shipments. I have reviewed the Draft Environmental Impact Statement (DEIS) discussion of the potential safety impacts associated with this proposal.

I. INTRODUCTION

The US Surface Transportation Board's (STB) 2020 Draft Environmental Impact Statement (henceforth "DEIS") for the Uinta Basin Rail does not adequately consider public safety risks.

The professional formula in risk assessment is Risk = Consequence x Probability. The EIS must consider rigorously both major factors for a valid overall assessment result.

The quantitative risk assessment (QRA) prepared for the DEIS is seriously flawed. The DEIS expends much effort on analyzing the probabilities side of the equation without scientific basis that could produce credible risk assessment results.

Most important, the DEIS neglects important risk factors that would impact the consequences (e.g., fires, explosions) of a crude oil release and fails to discuss potential consequences and their severity in meaningful terms.

II. QUANTITATIVE RISK ASSESSMENT IS INHERENTLY PROBLEMATIC

As an initial matter, quantitative risk assessment (QRA) is a highly controversial tool that is easily manipulated to downplay high-consequence risks with assertions of low probability; this is the wrong approach.

In discussions on the public safety risks of hazardous projects, communities nearly always want to talk about potential high derailment release consequences ("How far away is safe enough?"). In the US, assessment of possible Worst Case Accident Scenarios has a long history. Such assessment was outlined in federal guidance as a key part of the work of the 4,100 US Local Emergency Planning Committees

(LEPCs) since the post-Bhopal 1984 disaster enactment of the 1986/1990 Community Right to Know laws. Since then, 3,500 high-risk chemical facilities have provided the mandated facility Risk Management Plans, including Worst Case Scenario releases and Offsite Consequence Analyses, and updated these consequence assessments every five years.

High-risk project proponents and boosters, on the other hand, usually want to talk about low probabilities of hazardous releases. Risk acceptance regarding high-risk facilities or operations in the US has long been a political matter – often turning on disputes on who gets to choose what is acceptable and what levels of information are available to various stakeholders.

High-risk hazardous materials industrial projects, beginning at least as early as the deployment of US nuclear power facilities and associated nuclear waste transportation, and later with toxic cargoes and Liquefied Natural Gas, have long deployed QRA methodologies. An influential 1997 essay from Robert Kuehn outlined these as a tactic to win public and regulator concurrence with industry-proposed "acceptable risks."[1]

These QRA methodologies aim:

a. To divert attention from potential high consequences of a hazardous release

[1] Kuehn, Robert R., *The Environmental Justice Implications of Quantitative Risk Assessment,* 1996 U. ILL. L. Rev. http://publish.illinois.edu/lawreview/archives/volume-1996/

b. To stifle discussion of high release consequence potentials with voluminous and elaborate calculations asserting the low probabilities of serious releases
c. To keep the concerned public at arm's length, since only experts can credibly challenge the methods and findings of a given QRA

Moreover, these assessments are highly unreliable. As one observer of QRA documents has cautioned, "We should remember that risk assessment data can be like a tortured spy: if you torture it long enough, it will tell you anything you want to know."[2]

A recent critique of QRA methodology is the Washington State Energy Facility Siting Evaluation Council's (EFSEC) rigorous and highly critical analysis of the QRA approach adopted by proponents of a proposed crude oil terminal.[3] The agency adopted a more reliable approach utilizing real-world evidence.

EFSEC made a detailed critique in this proceeding of the probabilistic modeling presented in support of the safety of crude by rail transportation to the proposed crude oil terminal by University of Illinois Urbana-Champaign's researchers Dr. Chris Barkan and his team. EFSEC, in its analyses of crude oil train risks, adopted instead the "real-world historical risk" approach of former National Transportation Safety Board expert Robert Chipkevich—which uses data from a robust

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[2] *Id*.
[3] Washington State Energy Facility Site Evaluation Council, Adjudication Findings of Fact, Conclusions of Law, and Order to Proceed to Recommendation to the Governor, In the Matter of: Application No. 2013-01 Tesoro Savage, LLC, Vancouver Energy Distribution Terminal, Case No. 15-001 (Dec. 19, 2017) (hereafter "Washington EFSEC 2017").

database of actual historical crude rail accidents. The terminal project was subsequently rejected as too risky on various grounds by Washington Governor Jay Inslee.

The Uinta Railway Project DEIS has adopted the same QRA methodologies rejected by EFSEC and cited the same experts whose assertions are effectively discredited by the WA EFSEC statement. In the present case, the lack of a historical record specifically of waxy crude oil rail shipper and carrier operations and traffic records, and of accident rates and release behaviors of the specific crude cargoes, renders impossible any definitive assessment by concerned citizens of the likely consequences of a serious oil unit train release involving the crude oils at issue here (i.e., waxy crude and oil shale). But the information gaps also undermine the DEIS's pretense of a reliable QRA, which requires robust and relevant data as opposed to the DEIS's dubiously relevant, cobbled-together data from "all rail operations" and lumping together of data from many kinds of hazardous railcars, routings, and cargoes in various kinds of trains.

III. THE DEIS QRA'S ACCIDENT RATES ARE FLAWED

To calculate the probability of accidents on the proposed rail and downline routes, the DEIS assumes that the specific route hazards on the likely "downline" routes (outside the Uinta Basin vicinity) to major crude oil markets nationwide are accounted for by merely taking into account the national average accident rate data and an accident rate factor for each track class (which indicates the quality of the track). For example, lower class tracks (Class 3), which would be used for the Uinta

Basin Railway, are purportedly twice as likely to involve accidents than the national average for all tracks. Accordingly, the DEIS multiplies the national accident rate by an accident rate factor of “2” to determine the accident rate for the Uinta Basin Railway. However, this approach lumps together recent accident rates data for all localities and types of trains and cargo, despite the fact that this kind of non-relevant data will not support a valid probabilistic risk assessment.

The STB’s OEA DEIS did look more carefully with comparative analyses at some local and geological or infrastructure characteristics of the rail routes that would likely be used by the main few Action Alternatives being considered from the Uinta Basin to nearby junctures with mainline rail tracks. But the DEIS did not extend such analysis to the “downline” routes nationally.

A. The DEIS IGNORES SITE-SPECIFIC RISK FACTORS

The DEIS neglects to analyze “downline” route-specific risk factors for the Uinta Basin Railway and “downline” routes to distant refineries that could contribute to the risk of derailment or accidents. Instead, it attempts to estimate the probability of derailment in a specific local area by in opaque fashion combining the local track class data of tracks within the Study Area, extending as far as the outskirts of Denver, with generic national data on derailment rates derived from previous accidents of all kinds.

From the DEIS:

> [STB's] OEA used data on accident rates by track class to generate a base accident rate for all of the Action Alternatives, which would operate on Track Class 3 in the Basin at an average of 15 miles per hour (mph) based on information provided by the Coalition. The allowable operating speeds are up to 40 mph on Track Class 3, but lower anticipated speeds reflect the geometry, tunnels, bridges, and steep grades on the proposed rail line. OEA started with the nationwide rates over the last 2 years of about 2.7 accidents per million train miles for all railroads and types of track (Table E-1) as the basis for predicting accident rates. OEA also reviewed the combined total for main lines and sidings (i.e., not including yards and industry track) for all railroads, which gave an average of 0.97 accident per million train miles for 2018 and 2019. This was rounded to 1 accident per million train miles (the same as the value for 2019). Using the multiplier of two for Track Class 3, as indicated by Anderson and Barkan (2004) and Liu et al. (2011), OEA predicted a rate of 2.0 accidents per million train miles for the Action Alternatives. For the downline analysis, OEA reviewed the maximum allowable speeds on the different segments and found that the likely track classes involved were primarily Track Classes 3, 4, and 5. OEA used Track Class 3 in the analysis for Kyune to Grand Junction and used Track Class 4 or higher for the other downline segments. For the Action Alternatives, Track Class 3 had a rate of 2.0 accidents per million train miles. Using the findings of Anderson and Barkan (2004), OEA estimated the rate for the other downline segments as 0.5 per million train miles, or one-half that for the average across all track classes.

(DEIS at E-2.)

But track class (which indicates the quality of the track) is not the only factor that should be analyzed in the risk of derailment. The DEIS contains no discussion of the many other potential segment-specific infrastructure risk issues associated with the track structures and roadbed present, such as dangerous curves, washout potentials, trestles or tunnels, or migratory wildlife.

A closer look at specific infrastructure features of the planned downline routes is required to reach any fair estimate of probability of derailments and accidental crude oil releases, especially given possible operational challenges caused by the expected heavy volumes of unit trains.

The DEIS's reliance on data from the accident history along all tracks is especially puzzling, given that the past work of one of the EIS's main sources, Dr. Chris Barkan of the University of Illinois Urbana-Champaign (UIUC), acknowledges the importance of looking at local features when assessing risk.[4]

Dr. Barkan's work also highlights that the top risk factors in rail accident causation on a given stretch of track is broken rails and welds and buckled track—the data for neither of which the DEIS analyzes for the downline transcontinental rail network its shipments will traverse.

NTSB accident investigations will frequently take account of the possibility that local route conditions can be a causal factor in serious derailments. For example, it is clear that specific route characteristics were centrally important in the Lac-Megantic, Quebec crude oil train derailment and fire on July 2, 2013. Although the draft EIS dismisses the cause of the Lac- Megantic accident as "human error," (DEIS at 4.7-19), the disaster was also the result of infrastructure issues involving

[4] Barkan, Christopher, et al., Railroad Derailment Factors Affecting Hazardous Materials Transportation Risk, Transportation Research Record 1825, Paper No. 03-4429 at 67 (2003) (hereinafter "Barkan 2003"), available at https://railtec.illinois.edu/wp/wp-content/uploads/pdf-archive/Barkan-et-al-2003.pdf.

downhill grades and the presence of curves/switches in the downtown area.

Local conditions are a potential factor that experts suggested may have caused or influenced the derailment and oil spill in Lynchburg, Virginia on April 20, 2014. Grady Cothen, a former Federal Railroad Administration official, said "given the recent wet weather in Virginia and the accident's location near a river, it's possible that soft subsoil may have weakened the track."[5]

Local geological conditions, including landslide hazards are another significant factor to consider. Landslides can and have caused train derailments.[6]

The DEIS should conduct site specific analysis to determine whether local factors could increase the risk of accidents and derailment along the Uinta Basin Rail or the routes downline.

B. THE DEIS IGNORES CARGO AND UNIT TRAIN SPECIFIC FACTORS IN CALCULATING ACCIDENT RATES

In Appendix E's section on "Rail Accident Rates" the DEIS estimates probabilities for rail accident rates for all cargoes per year along the main three proposed Uinta Railway routes. The analysis shows very low expected probabilities of future Uinta crude oil unit train accidents. The

[5] CBS/AP, Oil Tankers Fall into James River (May 1, 2014), http://www.pennlive.com/midstate/index.ssf/2014/05/oil_tankers_fall_into_james_ri.html.

[6] Washington EFSEC 2017 at 37, 39, 43, 62-63.

DEIS, however, does not rely on data from the most recent historical crude by rail (CBR) accidents, but on “data for all railroads” (DEIS at E-1) and all types of track, and for a much larger range of freight cargoes in commerce instead of for crude oil cargoes overall.

The DEIS makes a crucial methodological decision to base its analyses on “a larger set of accidents" than on the recent record of several major crude oil accidents (DEIS at E-4). The DEIS defends this choice only summarily, with the unsupported assertion that “the specific cargo type does not determine the chance of a train accident.” (DEIS at E-4.)

The DEIS must examine the specific risks of the planned unit train operational business plan for the Uinta Basin Rail cargoes. As explained by the Pipeline Hazardous Material and Safety Administration, crude oil unit trains (i.e., trains exclusively carrying crude oil, which the project proposes, as opposed to “manifest” (mixed cargo) trains) have a higher risk of derailment:

> There is reason to believe that derailments of [High-Hazard Flammable Trains] will continue to involve more cars than derailments of other types of trains. There are many unique features to the operation of unit trains to differentiate their risk. The trains are longer, heavier in total, more challenging to control, and can produce considerably higher buff and draft forces which affect train stability. In addition, these trains can be more challenging to slow down or stop, and can be more prone to derailments when put in emergency braking, and the loaded tank cars are stiffer and do not

react well to track warp, etc., which when combined with high buff/draft forces can increase the risk of derailments.[7]

Multiple professional outlets have recognized the differences in risk between transporting crude oil by unit train and traditional rail shipment, including the Association of American Railroads' August 2013 Circular OT-55N[8] and the National Traffic Safety Board's April 2014 Safety Forum.[9] Various federal safety studies and federal agency directives have also cited **crude oil** unit trains as a key safety concern.

Dr. Barkan's own "preliminary" report comparing the risks of unit trains and manifest trains concludes that special characteristics of unit trains are important to assessing risk.[10] Unit trains pose more of the risk of what the report terms High Consequence Low Probability derailment releases. Adequately predicting the probability of accidental release of crude oil from a rail line would require an assessment of the particular operations, behavior, and risk of unit trains made up entirely of flammable crude oil cars, especially given their recent history and demonstrated potential for multi-car derailments. However, the DEIS's analysis of probability of derailment (and release) is based on examining the accident history of freight trains generally and not on

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[7] Dept. of Transportation, Pipeline and Hazardous Materials Safety Administration, Draft Regulatory Impact Analysis for Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains; Notice of Proposed Rulemaking, July 2014 ("Draft RIA") at 24.

[8] Association of American Railroads' August 2013 Circular OT-55N (August 5, 2013).

[9] NTSB Rail Safety Forum: Transportation of Crude Oil and Ethanol, Washington, D.C., April 22, 2014, transcript at 30, available at https://data.ntsb.gov/Docket/?NTSBNumber=DCA14SS004.

[10] Li, Weixi and Barkan, Christopher P L, Comparative Risks of Transporting Hazardous Materials by Unit Train and Manifest Train, Transportation Research Board 97th Annual Meeting (2018) ("Li and Barkan 2018"), abstract available at https://trid.trb.org/view/1496768.

crude oil trains, which are proposed to make up the vast majority of traffic along the rail line.

The DEIS fails to explain its methods and assumptions for determining the probability of a range of volume of spills that could occur in a derailment and fails to demonstrate that those methods are sound and rational. Appendix E simply summarizes several datasets that the DEIS appears to rely on, including:

(1) historical data regarding train accidents in Utah in 2019, a very narrow sample which DEIS does not try to argue is representative of a larger range of years or states, including number of derailments, mainline accidents, and collisions;

(2) five large-release rail accidents involving crude oil or other hazardous materials which occurred between 2013 and 2015 in the U.S. and Canada, including the amount of crude oil released;

(3) data from the *Washington State 2014 Marine and Rail Oil Transportation Study* reporting the number of derailed tank cars per major crude oil accidents in 2013 and 2014; and

(4) data from the RPI-AAR Railroad Tank Car Safety Research and Test Project on the probabilities of release for rail cars of different designs and analyzing the chance of different numbers of cars derailing and releasing different quantities of the product carried.

The DEIS then states without explanation and with little transparency regarding its numerous engineering judgments that it used in combining this data and "other" unidentified data to determine the probability of releases as follows:

> OEA used a combination of **these and other data** to determine representative distributions of release sizes for the types of rail cars addressed in the assessment of the Action Alternatives, given that a derailment or collision has occurred on the proposed rail line.
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> - Minor spill from collision/derailment (1,000 gallons): 7 percent
> - Collision/derailment release of 30,000 gallons: 17 percent
> - Collision/derailment release of 90,000 gallons: 2 percent
> - Collision/derailment release of 150,000 gallons: 0.07 percent
> - Extreme collision/derailment release of 450,000 to 900,000 gallons: 0.005 percent
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> Taken together, this distribution suggests that 26 percent or roughly one in four accidents, most of which would be derailments, would have some sort of release, and most of the time the release would be equivalent to one car or less.

(DEIS at E-4.) Release size is in effect the end point of the DEIS probabilistic analysis.

How the DEIS weighted and factored in the above summarized data and "other" unidentified data to determine these probabilities is entirely opaque, illustrating the problems with QRA analysis described above. The EIS must disclose all data sources and the details of combining them. The DEIS also fails to consider or disclose whether some risk factors should be weighted more heavily than others in assessing the probability of hazardous impact.

C. THE DEIS FAILS TO CONSIDER AND WEIGH FACTORS THAT COULD PRODUCE POTENTIALLY HIGH RELEASE PUBLIC SAFETY CONSEQUENCES

According to recent risk discussions from the Federal Railroad Administration and PHMSA (tellingly, both agencies here are relying on a "real world" approach to risk analysis versus a QRA), factors that "have given rise to both higher expected damages and probability of a catastrophic event" from an oil train derailment in recent years include:

(1) "the volumes of crude oil and ethanol carried by rail are relatively large when compared to rail shipments of other flammable liquids. In particular, the volume of crude oil shipped by rail has been increasing rapidly during the past several years; and

(2) "crude oil and ethanol are shipped in [high hazard flammable trains], compounding the risk when an accident does occur."[11]

Rail safety expert Robert Chipkevich's "real world" analysis of what accidents have occurred has also highlighted important factors contributing to increased risk of train derailments today:

(3) larger blocks of tank cars are being grouped in trains in large numbers; and

[11] Draft RIA at 20.

(4) the larger sizes of oil tank cars.[12]

Chipkevich underscores the basic professional critique of defective QRA analyses: "To use . . . [data from] all variety of freight trains to characterize the [high hazard flammable train] experience, creates a fundamentally flawed risk picture."[13] The railroads' and carriers' specific use of unit train configuration for crude by rail shipment (as planned for the project here) contributes significantly to fire and explosion events.

Since 2006, train derailments have experienced a high rate of failure of crude oil and ethanol tank cars in accidents. Below are examples:

- New Brighton, Pennsylvania, 20 of 23 tank cars failed (86.9%);
- Cherry Valley, Illinois, 15 of 19 tank cars failed (78.9%);
- Arcadia, Ohio, 31 of 31 tank cars failed (100%);
- Plevna, Montana, 12 of 17 tank cars failed (70.5%);
- Aliceville, Alabama, 25 of 26 tank cars failed (96.1 %);
- In two separate accidents in Gogama, Ontario, 19 of 29 tank cars failed (65.5%) and 36 of 39 tank cars failed (92.3%);
- Mount Carbon, West Virginia, 20 of 27 tank cars failed (74%); and,
- Casselton, North Dakota, 18 of 20 tank cars failed (90%).[14]

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[12] *See* Prefiled Testimony of Robert Chipkevich Filed by the City of Vancouver, In the Matter of Application No. 2013-01, Tesoro Savage, LLC, Vancouver Energy Distribution Terminal, Case No. 15-001 at 10 (May 9, 2016) (hereafter "Chipkevich Testimony").
[13] *Id*.
[14] *Id*. at 8-9.

Further, a 2016 analysis performed by Chipkevich showed that, based on 24 derailments, 442 tank cars derailed and 314 tank 9 cars released cargo (71 %). (See Table 1 below.) The average number of cars derailed in the 24 accidents is 18.4 and the average number of cars that breached is 13.[15]

Table 1 - Crude Oil and Ethanol Train Derailments

	Location	Date	Railroad	tc derailed	tc release	Fire	Product	Speed	Released gallons
1	Bon Homme County, SD	9/19/2015	BNSF	7	3	Y	Ethanol	10	49,748
2	Heimdal, ND	5/6/2015	BNSF	6	5	Y	Crude oil	24	98,090
3	Gogama, Ontario	3/7/2015	CN	39	36	Y	Crude oil	43	500,000
4	Galena, IL	3/5/2015	BNSF	21	10	Y	Crude oil	23	110,543
5	Mount Carbon, WV	2/16/2015	CSX	27	20	Y	Crude oil	33	378,034
6	Gogama, Ontario	2/14/2015	CN	29	19	Y	Crude oil	38	264,172
7	LaSalle, CO	5/9/2014	UP	6	1	N	Crude oil	9	7,932
8	Lynchburg, VA	4/30/2014	CSX	17	1	Y	Crude oil	23	29,416
9	Vandergrift, PA	2/13/2014	NS	21	4	N	Crude oil	31	4,310
10	New Augusta, MS	1/31/2014	IC/CN	15	7	N	Crude oil	47	50,450
11	Plaster Rock, NB	1/7/2014	CN	6	2	Y	Crude/ethanol	47	60,759
12	Casselton, ND	12/30/2013	BNSF	20	18	Y	Crude oil	42	436,437
13	Aliceville, AL	11/8/2013	AGC	26	25	Y	Crude oil	39	630,000
14	Lac Megantic, Quebec	7/6/2013	MMA	63	59	Y	Crude oil	65	1,580,000
15	White River, Ontario	4/3/2013	CP	7	2	Y	Crude oil	35	26,600
16	Parkers Prairie, MN	3/27/2013	CP	14	3	N	Crude oil	40	30,000
17	Plevna, MT	8/5/2012	BNSF	17	12	Y	Ethanol	23	245,336
18	Columbus, OH	7/11/2012	NS	3	3	Y	Ethanol	25	54,748
19	Tiskilwa, IL	10/7/2011	IIRR	10	9	Y	Ethanol	37	162,000
20	Arcadia, OH	2/6/2011	NS	31	31	Y	Ethanol	46	834,840
21	Cherry Valley, IL	6/19/2011	CN	19	15	Y	Ethanol	36	323,963
22	Luther, OK	8/22/2008	BNSF	8	5	Y	Crude oil	19	80,746
23	Painesville, OH	10/10/2007	CSX	7	4	Y	Ethanol	48	55,200
24	New Brighton, PA	10/20/2006	NS	23	20	Y	Ethanol	37	485,278
	Totals			442	314				6,498,602

The average spill size releases were 270,775 gallons, which is equivalent to about 30 gasoline cargo tank trucks. Further, ten of the 24 accidents had releases of 245,336 gallons or greater, the equivalent of 27 gasoline cargo tank trucks.[16]

[15] *Id*. at 13.
[16] *Id*.

The Washington EFSEC, in considering an application for a crude rail terminal in 2017, similarly observed that since 2006 releases from actual crude oil derailments have averaged 270,000 gallons.[17] In doing so, the EFSEC rejected Dr. Barkan's alternative QRA approach, which downplays the CBR risk and consequences of a derailment, when compared against Chipkevich's more robust use of real-world historical data. EFSEC instead adopted the "real world" historical data analysis:

> Dr. Barkan's projection of the amount of crude oil would be released from derailed cars is unreasonable. He projected that a derailment in Washington would spill 92,000 or larger gallons only once in 110 years or in one out of 17 future spills. However, almost two-thirds of recent crude and ethanol accidents (16 out of 24) spilled more than a quarter of the derailed tank car contents. By this measure, Dr. Barkan projected future tank cars will perform ten times better than they have actually performed in recent incidents. Dr. Barkan also projects DOT-117 tank cars are 83 percent less likely to release crude oil than unjacketed DOT-111s and 35 percent less likely to release than jacketed CPC-1232s, but PHMSA and FRA assume risk reductions of 50 percent and 16 percent, respectively.
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> The Council believes there are more defensible alternative estimates that are supported by the record. For example, one method is to apply the average of 51 percent of derailed tank car contents being released to Dr. Barkan's estimated average derailment of 12.7 tank cars. This yields an average spill of 165,013 gallons. A further reduction of 50 percent to account for safety improvements attributable to use of DOT-117 tank cars, as estimated by PHMSA, results in a projected average spill of 82,500 gallons, which is similar to PHMSA's projected average spill size of 83,602 gallons per mainline derailment. Consideration of tank car releases in North

[17] Washington EFSEC 2017 at 51.

> America since 2006 suggests that actual releases could average 270,000 gallons.[18]

Furthermore, Table 1 above also shows that crude oil disasters sometimes occurred at quite low train speeds, which the DEIS fails to acknowledge. According to Chipkevich: "Many of the catastrophic crude oil and ethanol train accidents between 2006 and 2015 were operating at speeds below maximum speeds established by PHMSA in the [2015] rulemaking; in fact, I7 of 24 serious accidents that I reviewed happened at speeds of 40 mph or less and 8 of those accidents occurred at speeds of 25 mph or less."[19]

A recent 2018 "preliminary" paper co-authored by Dr. Barkan confirmed that unit crude trains present higher risks. The paper concluded on the basis of abstract modeling that general hazmat unit train derailments, which could produce much larger total releases in a serious event, presented a higher risk per trip than "manifest" (mixed cargo) trains, i.e., higher annual risk of "high consequence" events due to more tank cars per train.[20]

IV. The DEIS FAILS TO MEANIINGFULLY CONSIDER THE POTENTIAL CONSEQUENCES OF DERAILMENT

[18] Washington EFSEC 2017 at. 51. *See also id*. at 44-46.

[19] Chipkevich Testimony at 16.

[20] Li and Barkan 2018. *See also* Chapter 3 of Dr. Li's previous thesis at UIUC under Dr. Barkan's supervision: Li, Weixi, Quantitative Analyses of Unit Train Safety and Railroad Tank Care Implementation Policy, Thesis, University of Illinois at Urbana-Champaign (2018), https://www.ideals.illinois.edu/bitstream/handle/2142/101380/LI-THESIS-2018.pdf?sequence=1&isAllowed=y.

The DEIS's quantitative analysis of the "consequences" of derailment narrowly limits the analysis to their selected end points of predicted "spill" sizes and frequency. As a result, the DEIS's quantitative analysis as to the consequences of a rail accident is risk-minimizing and limits the consideration of consequences to only the occurrence of spills, presented in a chart showing quite small probabilities. (DEIS at E-4.)

The DEIS offers no quantitative indications or estimations of the range of <u>fire/explosion impacts</u> that representative crude releases could produce nor of the fatalities/injuries that could be correlated with each size of release generically (e.g., area of evacuation), much less a range of the potential Worst Case Scenario public safety fire/explosion impacts along specific routes with their differing hazards regarding trackside populations, buildings nearby, etc.

Further, the DEIS fails to disclose or analyze the reasonably foreseeable local consequence impacts of a comparable release accident in areas of very different population densities along the far-flung transcontinental routes for crude oil unit trains stretching from the Uinta Basin to the most likely national markets. It does not consider either the absolute or relative public safety risks of the different routings. In 2013, in the small town of Lac-Mḗgantic, Canada, 63 tank cars derailed at night, releasing 1.6 million gallons of crude oil, which then ignited, killing 47 people. Some cities on the downline routes for the rail project would no doubt have populations many times greater than Lac-Mḗgantic, and much denser populations especially during daytime hours.

The FEIS must disclose what impacts on public safety a high impact crude unit train release could have in representative urban areas along the transcontinental “downline” routes to US coastal refineries. In addition, the EIS must consider the crude unit train risks to public safety from releases caused by terrorism, particularly in high population areas.

The DEIS highlights only the largest five of the dozen significant CBR North American derailment releases in the traumatic 2013-2016 era, but cherry-picks the data mainly to support a minimization of CBR derailment risks. (DEIS E-2-E-3.)

The DEIS makes no mention, for example, of the public evacuations seen in these emergencies. Nor does the DEIS consider the emergency response decisions made by the responding fire services which mainly involved not trying to “mitigate” the ongoing fires and explosions, but (as advised by the US DOT Emergency Response Guidebook) mounting only “defensive firefighting”, i.e., expeditiously getting residents and fire service personnel away from the scene. Emergency response experts note that not a single historical example exists in which the fire service succeeded in “suppressing” a serious crude oil derailment fire event.

In discussing the five historical accidents, the DEIS makes risk-minimizing conclusions. The DEIS cites the five CBR cases as having only one with public safety disaster impacts (Lac-Mḗgantic), while neglecting to estimate what could have happened in different CBR accident conditions (e.g., if the April, 30 2014 Lynchburg CBR train or the 2016 Mosier, OR train had derailed into the city instead of on the other side into the river). Shaken local fire chiefs and other officials and the public were quick to express in the media after several of the classic CBR derailment disasters how “lucky” the spared populations had been.

The DEIS also suggests that these accidents were in a distant early era, “involving tank cars that do not meet present-day standards,” but admits that the earlier defective tank cars will remain in service into the future until 2025. (DEIS at E-3.) These tank cars could also remain in service longer if the crude oil industry wins another delay from Congress for updating tank car standards.

The DEIS also implies without evidence that new federal regulations (presumably from the 2015 High Hazard Flammable Train regulations which DEIS does not cite explicitly nor evaluate rigorously) will be effective in reducing future crude oil accidents. (DEIS at E-3.) As discussed further below (section VI), upgraded DOT-117 tank car standards are only marginally better in preventing releases. The PHMSA prediction of a significant risk reduction due to the use of the new DDOT-117 standard cars cannot be relied upon in the absence of an adequate historical record of CBR movements using that car, which in any case has released its contents in actual derailments subsequent to the optimistic PHMSA prediction.

V. THE DEIS DOWNPLAYS THE RISK OF UINTA BASIN CRUDE OILS

The specific rail cargo type (e.g., in a tank car derailment, crude oils vs. syrup) clearly impacts the consequences of an accident. But the DEIS fails to analyze the risks of transporting the specific crudes at issue, including Uinta Basin waxy crude and oil shale/kerogen, as well as the risks of the other major flammable rail cargoes that may travel by rail from the Basin (e.g., refined oil products). Presumably the latter will travel in manifest trains and will not be mixed in with the waxy crude railcars, but close encounters between these products and other hazmat cargoes (including crude oil) in rail siding areas is possible.

The DEIS slips in an important conclusory statement, without evidence, that because Uinta waxy crude is less volatile than crudes involved in previous high-consequence derailments, "explosions are much less likely even in the event of large spills." (DEIS at E-3.)

But the DEIS has neither produced nor cited any rigorous or comprehensive research report or historical data about the fire or explosion risks specifically of waxy crude or oil shale in unit train rail transportation. And the DEIS lacks any evaluation of the public safety of the proposed Uinta shipments based on:

(a) the chemical characteristics of waxy crude or oil shale
(b) expert analysis of how these characteristics lead to various flammable and/or explosive behavior consequences.

Indeed, very little information on the risks of the specific crude oils being widely transported in North America has been publicly available. Railroads' historical secrecy regarding their own data on high-risk operations has hampered assessment of risks by public agencies, the media and the at-risk public. The belated US DOT/DOE-commissioned Sandia National Labs Report to Congress on Crude Oil Characterization Research Study analyzes a wide range of US crude oils in commerce, and it does provide research on (a) and (b) above.[21] The Sandia Literature Survey Executive Summary outlines authoritatively the kinds of significant information gaps researchers found regarding risks even with the long-transported lighter types of tight crude oils and what kinds of future research is vitally needed to fill the gaps.

In their initial Literature Survey Report, the researchers found that there was virtually no comprehensive historical research for US crude oils on their features and fire/fireball behaviors in a release.[22] The researchers noted:

> Relationships between crude oil properties and probability or severity of combustion events in rail car spill scenarios have not been established.
>
> Although it is likely that a combination of crude oil properties—especially those associated with potential for flammable vapor formation—could be used to predict combustibility, no specific, objective data were found that correlated known crude oil properties with the likelihood or severity of rail transport-related combustion events. While industry groups actively working on this problem have been identified, their progress and results have not yet been released to the public.[23]

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[21] *See generally*, Department of Energy, Report to Congress on Crude Oil Characterization Research Study, https://www.energy.gov/fe/report-congress-crude-oil-characterization-research-study.
[22] Sandia National Laboratories, Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport (March 2015), available at https://doi.org/10.2172/1177758 ("Sandia Literature Survey").
[23] *Id*. at 12.

While not directly dealing with waxy crude, the report strongly suggests that even the most basic and widely accepted data on crude oil characteristics generally, including of waxy crude oil, is lacking.

In a matter of considerable high-level debate, the Literature Survey also suggested that the volatility of the crude oil involved may not be as important as previously thought. The Sandia reports on crude oils' characteristics and flammability impacts indicates that the energy created in an accident may contribute more significantly to the flammability impact of an accident:

> No single parameter defines the degree of flammability of a fuel; rather, multiple parameters are relevant.
>
> While a fuel with a lower flashpoint, wider range of flammability limits, lower auto-ignition temperature, lower minimum ignition energy, and higher maximum burning velocity is generally considered more flammable, the energy generated from an accident has the potential to greatly exceed the flammability impact of these and any other crude oil property-based criteria.[24]

The Sandia report notes other key factors that may operate in determining fire event outcomes from crude oil derailments:

> Numerous combustion events can occur from an accident involving hydrocarbons and hydrocarbon mixtures including crude oils, with severity dependent on the amount of fuel involved, surrounding infrastructure, and [the particular accident] environment.[25]

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[24] Sandia Literature Survey at 13-14.
[25] *Id*. at 13.

In light of the existing information gaps, the Sandia researchers performed the most basic research, rigorously analyzing various crude oils' features and assessing their relation to fire and fireball outcomes with relatively small-scale field experiments. Sandia studied three selected types of "representative" US crudes (including "light" crude oil from tight shale formations and conventional crude oil), but (it is important to note) not waxy crude. Waxy crude has been only a minor player in the overall North American energy picture.

The Sandia "Characterization" survey of the available research on crude oils generally indicates that there has been no rigorous established research in the public domain providing a scientific basis for an acceptable safety level of crude oil transportation generally. [26] The Sandia researchers concluded that volatility alone is not a sufficient basis for regulation of crude oil cargoes, a finding seized upon by opponents of the volatility regulations enacted by Washington State.[27]

The current situation with waxy crude and shale oil research is therefore similar to the earlier history with the 2013-2020 North American Bakken crude oil unit train (and ethanol railcar) disaster era. The Sandia public domain federal crude oils characterization research was done only after the 2013-2014 spate of fiery derailments roused media and public concerns. While waxy crude behavior (solidification potential) in pipelines has been studied, even the most basic steps in waxy crude rail safety research have apparently not been planned nor

[26] Sandia National Laboratories, Pool Fire and Fireball Experiments in Support of the US DOE/DOT/TC Crude Oil Characterization Research Study (Aug. 2019), https://doi.org/10.2172/1557808.
[27] *Id*.

conducted, much less any later stage actual field tests which FRA might conduct with waxy crude-loaded railcars which should be tested for collision and fire survivability.

VI. THE NEW TANK CAR STANDARDS WILL BE ONLY MARGINALLY EFFECTIVE

The DEIS downplays the potential for future CBR high-consequence events by suggesting that new safety standards requiring DOT-117 cars or retrofits by 2025 will effectively reduce release risks significantly. (DEIS at E-3.) The DEIS fails to analyze how effective these new standards will be or disclose the uncertainty of their effectiveness.

The DEIS omits to mention that the DOT-117 design (and other features of the Obama Administration's 2015 Final Rule on "High Hazard Flammable Trains" which covers crude oils) will provide only marginal disaster risk-reduction improvements. The PHMSA estimates that the DOT-117 will only provide a 21% risk reduction over the unjacketed CPC-1232 and only a 10% risk reduction over the jacketed CPC-1232.[28] And DOT-117s reportedly have a an estimated puncture velocity of only 12.3 miles per hour and are designed to withstand pool fires for only up to 100 minutes and torch fires for up to 30 minutes.[29] Chlorine tank cars with 3/4-inch shells similar to the DOT-117 model punctured in accidents in South Carolina and Texas.[30] Thus, there will be substantial risks of releases, even if the new requirements can be fully implemented.

[28] Draft RIA at 120.
[29] Washington EFSEC 2017 at 39-40, 346.
[30] *Id*.

Further, experts have questioned whether <u>any</u> train traveling at the speed of 30 mph could withstand the impact from derailment: "When you begin to look at cars that are derailing at speeds of 30, 40 miles an hour, it's very difficult, it's a big ask, to expect that a tank car get hit [and] not be breached," Karl Alexy, staff director of the Federal Railroad Administration's Office of Safety, bluntly stated in a 2014 forum convened by the National Transportation Safety Board.[31] The DEIS should consider the effectiveness of the existing tank car safety requirements at these higher speeds, and that crude oil unit trains from the Uinta Basin will certainly be traveling on the downline transcontinental routes at the railroads' current standard of 50 mph.

In any case, DOT-117 tank car design standards will not fully take until effect for crude oil tankers until May 2025.[32] Even then, the deadline for compliance could be extended by Congress, as that body has seen fit to do before.[33]

Until these new standards take effect, the admittedly defective CPC-1232 cars will be allowed to remain in service. Information gaps exist with respect to the performance of CPC-1232 tank cars in a derailment. In 2014, discussion at the National Transportation Safety Board's April 2014 Safety Forum highlighted the need for multi-year robust historical

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[31] Ailworth, Erin, Local fuel distributor to require safer rail cars at its terminals, Boston Globe (May 8, 2014), available at https://www.bostonglobe.com/business/2014/05/08/local-fuel-distributor-require-safer-rail-cars-its-terminals/QfkKMda2NmE6OC0tUpWWiK/story.html.

[32] Pub. L. 114–94, div. A, title VII, §7304, Dec. 4, 2015, 129 Stat. 1596 (codified at 49 USC 20155(b)).

[33] *Id*.

data in assessing CBR release risks, and that there is simply not enough data from CBR crashes involving the railroad-industry designed CPC-1232 tank cars, which are only marginally safer than the workhorse DOT-111 tank cars, to constitute a strong empirical basis for calculating estimations of future release events. At that forum, Todd Treichel, the director of the RSI-AAR Railroad Tank Car Safety Research and Test Project stated, "The 1232 cars, the CPC-1232 cars in particular, remain fairly scarce in our [historical accident] data, so the specific question how have they performed in accidents so far doesn't really confirm or dispute help us…[in performing probabilistic analyses predicting CBR derailment risks] until there are many more cars that have been derailed in many more types of accidents."[34]

Since then, some limited but suggestive real-world data on the crashworthiness of CPC-1232 cars has emerged. In 2016, rail safety expert Robert Chipkevich's review of 13 accidents involving DOT-111 and CPC-1232 tank cars releasing more than 92,000 gallons of cargo in the 9 year period between 2006 and 2015. Cargo release in these 13 accidents totaled 5,950,603 gallons of cargo, an average of 457,738 gallons per accident. Four of these accidents involved CPC-1232 tank cars: two accidents in Gogama, Ontario and one accident each in Mount Carbon, West Virginia and Galena, Illinois.[35] Five of the most recent spills involving 1232 cars (including one jacketed car with a safety profile similar to DOT-117 cars) failed in significant numbers, averaging 209,000 gallons per spill.[36] Chipkevich's "real world" analysis

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[34] NTSB Rail Safety Forum: Transportation of Crude Oil and Ethanol, Washington, D.C., April 22, 2014, transcript at 82, available at https://data.ntsb.gov/Docket/?NTSBNumber=DCA14SS004.
[35] Chipkevich Testimony at 27.
[36] EFSEC 2017 at 45.

seemingly discredited in EFSEC's eyes Dr. Barkan's QRA predictions that crude oil spills involving these tank cars would occur at much lower frequency and with much lower oil volume releases.[37]

VII. THE DEIS LACKS ADEQUATE DISCUSSION OF EMERGENCY RESPONSE CAPABILITIES

The DEIS proposes a Mitigation Measure that involves the local SCIC staff preparing a voluntary emergency response plan, while proposing no other significant mitigation for potential crude oil release events, but the DEIS does not assess how effective such a plan could be. The most important and sobering evidence from the historical crude by rail derailment disasters is that "offensive firefighting" emergency response was never successful in preventing often repeated hours-long fire/explosion consequences. The DEIS lacks any discussion of this issue.

The DEIS should discuss the capabilities of local emergency responders in difficult-to-evacuate populated cities as well as in rural counties, both types of at-risk communities with limited resources to respond to disasters.

VIII. CONCLUSION: THE FEIS NEEDS ROBUST DATA, PARTICULARLY ON POTENTIAL CONSEQUENCES OF RELEASES, AND A MORE RELIABLE RISK ANALYSIS METHODOLGY

As suggested by the discussions in the Sandia reports, a very long list of information is needed when raising questions to assess risk. And as this report has shown, most of the needed data is completely unavailable

[37] Chipkevich Testimony at 27.

for Uinta waxy crude oils or of dubious reliability. This information includes:

- Inherent properties of the cargo – vapor pressure, flash point, pour point, etc.
- Unit train operations and safety protocols for shippers loading the cargoes and for carrier railroads
- Unit train handling and behavior in various terrains and weather (railcar cargo sloshing, tracks losing integrity in very cold or hot weather, trains leaving the tracks under unit train force stresses, etc.)
- Railcar behaviors in potential multi-car derailments in some representative rail cargo environments
- Derailment crush and puncture forces
- Potential kinds of releases from collision; puncture, thermal tears of railcars, BLEVE explosions in long-lasting fire involvement of tank cars
- Cargo behavior (size, intensity, ability to be extinguished) in representative derailments: release-correlated ignition, fires, "rivers of fire," fireballs, pool fires, explosions if in confined space
- Railcar and cargo behaviors in potential multi-car events
- Possible mitigation strategies
- Guidance for emergency response agencies
- Information available for emergency response in emergencies
- Government reactions towards reducing disaster risks: targeted research, proposed regulations or voluntary guidance for shippers and carriers, enforcement

The STB FEIS should adopt a valid risk assessment methodology which would, among other things:

(a) Take account of potential consequences of serious derailment releases with Uinta waxy crude and shale oil shipments, including a presentation of representative potential Worst Case Scenarios
(b) Abandon the reliance on dubious Quantitative Risk Assessment (QRA) methodologies and on dubiously relevant generalized data vs. data on waxy crude and shale oil cargoes
(c) Instead utilize "real world" assessment of derailment disaster risks, as superior to dubious QRA methodologies, as seen in the recent WA State EFSEC Adjudication decision documents assessing the risks of a proposed hazardous facility in that state
(d) Expand the STB's "study area" of the likely main unit train transportation routes for Uinta waxy crude cargoes beyond "the outskirts of Denver" to consider the risks of all the routings likely to be traversed by Uinta waxy crude unit trains, with any special environmental and geologic hazards, etc. for each route and with attention to risks to densely populated areas
(e) Assess the limitations and inadequacies of current federal and state regulations and the preemption impact of the federal regulatory regime on state or local regulation
(f) Assess the capabilities of local emergency responders along the routes to deal with serious derailments

A technical appendix at the end of this comment cites transportation release-related information sources on waxy crude oil, which sources have not specifically been considered by the DEIS.

TECHNICAL APPENDIX:
OTHER DOCUMENTS RELEVANT TO WAXY CRUDE OIL RISKS BUT NOT CONSIDERED BY DEIS

Official federal documents have long dealt with crude oils as a class of "flammable" hazardous cargoes, but have not singled out "waxy crude" oils or oil shale as a less dangerous cargo for separate consideration, no doubt primarily because of its minor economic importance in the US energy picture.

1. All crude oil cargoes have long been officially **classified by** DOT regulations in 49 CFR Part 179 as "flammable." No mention has been made of waxy crudes or oil shale as an outlier requiring separate, less stringent regulatory mandates. Waxy crude is "flammable" because when a flame is passed over it, it catches fire.

2. Waxy crude currently travels under **a red "flammables" placard** on every truck or railcar – "1267" is the number in the placard, but crude oils are in hazard class 2.

3. **The venerable and heavily relied upon North American 2020 US DOT Emergency Response Guidebook (the Orange Book or ERG) is** placed in every emergency response vehicle and provides key information for actions to take in the first 20 minutes of

dealing with a hazmat transportation release event.[38] ERG never mentions waxy crude as some kind of outlier, and includes all "Petroleum Crude Oil" including waxy crude within **Guide 128** for the class of hazmat cargoes listed as "Flammable Liquids (Water-Immisicible)." Guide 128 cites this whole class of flammable liquids as "highly flammable…easily ignited by heat, sparks or flames." [see online, pp. 193-194] And Guide 128 cites other serious fire and/or explosion hazards.

ERG 2020 **Guide 128** recommends several sobering immediate precautionary measures, in case of a transportation vehicle in a fire:

- "ISOLATE for 800 meters [1/2 mile] in all directions. And consider **initial evacuation for ½ mile** in all directions."
- "Fight fire from maximum distance or use unmanned master stream devices…"
- "ALWAYS stay away from tanks engulfed in fire."

4. **The oil shipper industry's own Safety Data Sheets (SDS)** (I found only two in the public domain) that must accompany each hazmat shipment state that Black Wax Crude is "highly flammable," and they outline several serious recommended safety measures, but the SDSs are incomplete, vague and inconsistent in the information supplied on the cargo's basic

[38] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration and Transport Canada, 2020 Emergency Response Guidebook, https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2020-08/ERG2020-WEB.pdf.

characteristics. The industry SDSs reviewed here never suggest that any type of crude oil should be considered less than dangerous.

These SDS documents are created by various consultant firms for shipper clients and cover mandated subjects needed for transportation employees and communities in case of emergency.

Some SDS examples reviewed for this report suggest that crude oil is "extremely flammable," but all note that (as federal regulations have long indicated) it is "flammable", and all recommend to transportation companies several sets of rigorous safety measures for handling the cargoes and minimizing harm from emergency releases.

For example, Whiting Oil and Gas Corporation's SDS for "Crude Oil (Sweet)", a report dated as last reviewed in October 2013, cautions vaguely that crude oil's ingredients include "variable amounts" of natural gas, benzene, and hexanes.

Even from the same oil field or even the same well, the composition of a sample of crude oil can vary significantly from others. Industry-provided risk-related estimates of measured (usually without specifying the methods used) **flash point** for crude oils sometimes indicate data that can vary in a wide range :

Some examples from existing SDSs:

The Whiting Oil and Gas Corporation's SDS, 2013 for "Crude Oil (Sweet)": -60 degrees F to 200 degrees F -- using the Pensky-Martens Closed Cup Tester method

The Linn SDS for Yellow Wax Crudes 6 3 16 also indicates a broad range for Yellow Wax Crudes: -40 degrees C to 65 degrees C

The Ovintiv SDS issued 9 9 19 states vaguely [p.9 – no method stated] that the flash point for ”Black Wax Crude Oil” is a range: “<28.8 to 37.7 degrees C” (84-100 degrees F)

Whereas the Linn SDS 8 2 13 states that Uinta Basin Black Wax Crude Oil flash point is a simple specific “42 degrees C” [or 108 degrees F]. [no method specified]

This small sample of Industry-supplied Safety Data Sheets [federally mandated for inclusion in official shipping papers accompanying hazmat shipments, etc.] shows that SDS data for crude oils can differ in key ways:

- can leave unreported seemingly important data on the form even when asked to provide data regarding categories such as flammability, ignition temperature, decomposition temperature, explosion limits, etc. [cf. p. 7 of Linn SDS 8 2 13]
- can have various estimates of key flash point estimation for crude oils [[e.g., yellow waxy vs. black waxy]
- can indicate waxy crudes variously as “flammable liquid” [yellow wax crude] or as “flammable solid” [black wax crude] or as in Ovintiv SDS 2019, as a “flammable liquid and vapor” [black wax crude].

All include blunt recommendations for rigorous fire- and explosion-related safety measures for handling cargoes. But some reveal a risk-minimizing tendency. Cf. Linn SDS 8 2 13 re Uinta Black Wax Crude Oil which states disingenuously [p. 7] “Danger of explosion: “Product is not explosive. However, formation of explosive air/vapour mixtures are possible.”

Key data in the existing reports:

- **Linn Energy [2013 SDS]:**

  Vapour pressure at 20°C: <20hPa

  Flash Point: 42°C [108°F]

  Flammability (solid, gaseous): Not applicable

  Ignition temperature: Not determined.

  Self-igniting: Not determined

  Danger of explosion: Product is not explosive. However, formation of explosive air/vapour mixtures are possible.[39]

- **Ovintiv [2019 SDS]:**

[39] Linn Energy, Safety Data Sheet for Uinta Basin Black Wax Crude Oil (Aug. 2, 2013), https://linnenergy.com/wp-content/uploads/2016/06/Uinta-Basin-Black-Wax-Crude-Oil-LINN-Operating.pdf.

Ovintiv 9/9/19 is an industry SDS which specifically addresses "black wax crude oil"[40] and characterizes it as a "flammable liquid and vapor";

- listing many of the crude's component flammable hydrocarbons with variable percentages by weight [p.3]
- listing many rigorous fire- and explosion-related safety measures [pp. 4-6]:

Vapor Pressure: Variable

Flash point: >28.8-37.7°C [so less than about 80-100° F]
Lower explosive limit: Variable
Higher explosive limit: Variable
Decomposition temperature: Not available

[40] Ovintiv, Safety Data Sheet (U.S.) for Black Wax Crude Oil (Sept. 9, 2019), available at https://www.ovintiv.com/wp-content/uploads/2019/10/black-wax-crude.pdf.

REFERENCES CITED

Ailworth, Erin, Local fuel distributor to require safer rail cars at its terminals, Boston Globe (May 8, 2014), available at https://www.bostonglobe.com/business/2014/05/08/local-fuel-distributor-require-safer-rail-cars-its-terminals/QfkKMda2NmE6OC0tUpWWiK/story.html

Association of American Railroads' August 2013 Circular OT-55N (August 5, 2013)

Barkan, Christopher, et al., Railroad Derailment Factors Affecting Hazardous Materials Transportation Risk, Transportation Research Record 1825, Paper No. 03-4429 (2003) (hereinafter "Barkan 2003"), available at https://railtec.illinois.edu/wp/wp-content/uploads/pdf-archive/Barkan-et-al-2003.pdf

CBS/AP, Oil Tankers Fall into James River (May 1, 2014), http://www.pennlive.com/midstate/index.ssf/2014/05/oil_tankers_fall_into_james_ri.html

Kuehn, Robert R., *The Environmental Justice Implications of Quantitative Risk Assessment,* 1996 U. ILL. L. Rev. http://publish.illinois.edu/lawreview/archives/volume-1996/

Li, Weixi and Barkan, Christopher P L, Comparative Risks of Transporting Hazardous Materials by Unit Train and Manifest Train, Transportation Research Board 97th Annual Meeting (2018) ("Li and Barkan 2018"), abstract available at https://trid.trb.org/view/1496768.

Li, Weixi, Quantitative Analyses of Unit Train Safety and Railroad Tank Care Implementation Policy, Thesis, University of Illinois at Urbana-Champaign (2018), https://www.ideals.illinois.edu/bitstream/handle/2142/101380/LI-THESIS-2018.pdf?sequence=1&isAllowed=y

Linn Energy, Safety Data Sheet for Uinta Basin Black Wax Crude Oil (Aug. 2, 2013), https://linnenergy.com/wp-content/uploads/2016/06/Uinta-Basin-Black-Wax-Crude-Oil-LINN-Operating.pdf

NTSB Rail Safety Forum: Transportation of Crude Oil and Ethanol, Washington, D.C., April 22, 2014, transcript, available at https://data.ntsb.gov/Docket/?NTSBNumber=DCA14SS004

Ovintiv, Safety Data Sheet (U.S.) for Black Wax Crude Oil (Sept. 2019), available at https://www.ovintiv.com/wp-content/uploads/2019/10/black-wax-crude.pdf

Prefiled Testimony of Robert Chipkevich Filed by the City of Vancouver, In the Matter of Application No. 2013-01, Tesoro Savage, LLC, Vancouver Energy Distribution Terminal, Case No. 15-001 (May 9, 2016)

Sandia National Laboratories, Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport (March 2015), available at https://doi.org/10.2172/1177758 ("Sandia Literature Survey").

Sandia National Laboratories, Pool Fire and Fireball Experiments in Support of the US DOE/DOT/TC Crude Oil Characterization Research Study (Aug. 2019), https://www.osti.gov/servlets/purl/1557808.

Washington State Energy Facility Site Evaluation Council, Adjudication Findings of Fact, Conclusions of Law, and Order to Proceed to Recommendation to the Governor, In the Matter of: Application No. 2013-01 Tesoro Savage, LLC, Vancouver Energy Distribution Terminal, Case No. 15-001 (Dec. 19, 2017) (hereafter "Washington EFSEC 2017").

U.S. Department of Energy, Report to Congress on Crude Oil Characterization Research Study, https://www.energy.gov/fe/report-congress-crude-oil-characterization-research-study

U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration and Transport Canada, 2020 Emergency Response Guidebook, https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2020-08/ERG2020-WEB.pdf

U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Draft Regulatory Impact Analysis for Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains; Notice of Proposed Rulemaking, July 2014 ("Draft RIA")

ATTACHMENT B

Center for Biological Diversity
Climate Change Science Summary
April 2019

I. An international scientific consensus has established that human-caused climate change is already causing widespread harms, climate change threats are becoming increasingly dangerous, and fossil fuels are the dominant driver of the climate crisis.

II. The IPCC 2018 *Special Report* makes clear that greenhouse gas emissions must be halved in the next decade to avoid the most devastating consequences of climate change.

III. Human-caused climate change is causing widespread harms in the United States and worldwide and these harms will worsen as greenhouse gas pollution continues to rise.

A. Rising temperatures
B. Increasing frequency of extreme weather events
C. Intensifying storms
D. Rising seas
E. Coastal flooding from sea level rise and intensifying storm surge
F. Rapid Arctic warming and polar ice loss
G. Biodiversity loss
H. Public health harms
I. Threats to water resources
J. Declining food security
K. Ocean warming
L. Ocean acidification
M. Coral reef crisis
N. Economic impacts
O. Tipping points and compound climate extremes

IV. Global and U.S. greenhouse gas emissions continue to rise.

V. Climate change impacts are long-lasting.

VI. New fossil fuel production and infrastructure must be halted and much existing production must be phased out to avoid the worst dangers from climate change.

VII. Fossil fuel companies are responsible for the majority of greenhouse gas emissions and global warming.

VIII. U.S. climate policy is inadequate to avoid catastrophic damages from climate change.

Cited References

I. An international scientific consensus has established that human-caused climate change is already causing widespread harms, climate change threats are becoming increasingly dangerous, and fossil fuels are the dominant driver of the climate crisis.

An overwhelming international scientific consensus has established that human-caused climate change is already causing widespread harms and that climate change threats are becoming increasingly dangerous. The Intergovernmental Panel on Climate Change (IPCC), the international scientific body for the assessment of climate change, concluded in its 2014 Fifth Assessment Report that: "[w]arming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen," and further that "[r]ecent climate changes have had widespread impacts on human and natural systems."[1]

The U.S. federal government has repeatedly recognized that human-caused climate change is causing widespread and intensifying harms across the country in the authoritative National Climate Assessments, scientific syntheses prepared by hundreds of scientific experts and reviewed by the National Academy of Sciences and federal agencies. Most recently, the Fourth National Climate Assessment, comprised of the 2017 *Climate Science Special Report* (Volume I)[2] and the 2018 *Impacts, Risks, and Adaptation in the United States* (Volume II),[3] concluded that "there is no convincing alternative explanation" for the observed warming of the climate over the last century other than human activities.[4] It found that "evidence of human-caused climate change is overwhelming and continues to strengthen, that the impacts of climate change are intensifying across the country, and that climate-related threats to Americans' physical, social, and economic well-being are rising."[5]

In 2009 the Environmental Protection Agency found that the then-current and projected concentrations of greenhouse gas pollution endanger the public health and welfare of current and future generations, based on robust scientific evidence of the harms from climate change.[6] A 2018 study reviewed the scientific evidence that has emerged since 2009 and concluded that this

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[1] Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at 2.
[2] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/.
[3] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018).
[4] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 10.
[5] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018) at 36.
[6] U.S. EPA [U.S. Environmental Protection Agency], Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Final Rule, 74 Federal Register 66496 (2009).

evidence "lends increased support" for EPA's endangerment finding.[7] The study by 16 prominent scientists examined the topics covered by the endangerment finding and concluded that "[f]or each of the areas addressed in the [endangerment finding], the amount, diversity, and sophistication of the evidence has increased dramatically, clearly strengthening the case for endangerment."[8] The study also found that the risks of some impacts are even more severe or widespread than anticipated in 2009.

The National Climate Assessments decisively recognize the dominant role of fossil fuels in driving climate change. As stated by the Third National Climate Assessment: "observations unequivocally show that climate is changing and that the warming of the past 50 years is primarily due to human-induced emissions of heat-trapping gases. These emissions come mainly from burning coal, oil, and gas."[9] The Fourth National Climate Assessment reported that "fossil fuel combustion accounts for approximately 85 percent of total U.S. greenhouse gas emissions,"[10] which is "driving an increase in global surface temperatures and other widespread changes in Earth's climate that are unprecedented in the history of modern civilization."[11]

The National Climate Assessments make clear that the harms of climate change are long-lived, and the choices we make now on reducing greenhouse gas pollution will affect the severity of the climate change damages that will be suffered in the coming decades and centuries: "[t]he impacts of global climate change are already being felt in the United States and are projected to intensify in the future—but the severity of future impacts will depend largely on actions taken to reduce greenhouse gas emissions and to adapt to the changes that will occur."[12] As the Fourth National Climate Assessment explains: "[m]any climate change impacts and associated economic damages in the United States can be substantially reduced over the course of the 21st century through global-scale reductions in greenhouse gas emissions, though the magnitude and timing of avoided risks vary by sector and region. The effect of near-term emissions mitigation on reducing risks is expected to become apparent by mid-century and grow substantially thereafter."[13] Similarly, a 2014 White House report found that the cost of delay on reducing emissions is not only extremely steep but also potentially irreversible, and the costs rise

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[7] Duffy, Philip B. et al., Strengthened Scientific Support for the Endangerment Finding for Atmospheric Greenhouse Gases, Science doi: 10.1126/science.aat5982 (2018) at 1.
[8] *Id.* at 1.
[9] Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014) at 2. *See also* Report Finding 1 at 15: "The global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels."
[10] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 60.
[11] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 39.
[12] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 34.
[13] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1347.

exponentially with continued delays.[14] As summarized by the National Research Council:

> Emissions of carbon dioxide from the burning of fossil fuels have ushered in a new epoch where human activities will largely determine the evolution of Earth's climate. Because carbon dioxide in the atmosphere is long lived, it can effectively lock Earth and future generations into a range of impacts, some of which could become very severe. [E]mission reduction choices made today matter in determining impacts experienced not just over the next few decades, but in the coming centuries and millennia.[15]

II. The IPCC 2018 *Special Report* makes clear that greenhouse gas emissions must be halved in the next decade to avoid the most devastating consequences of climate change.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) issued a *Special Report on Global Warming of 1.5°C* that quantified the devastating harms that would occur at 2°C warming, highlighting the necessity of limiting warming to 1.5°C to avoid catastrophic impacts to people and life on Earth.[16] The IPCC 2018 *Special Report* provides overwhelming evidence that climate hazards are more urgent and more severe than previously thought, and that aggressive reductions in emissions within the next decade are essential to avoiding the most devastating climate change harms.

The *Special Report* quantifies the harms that would occur at 2°C warming compared with 1.5°C, and the differences are stark. According to the IPCC's analysis, the damages that would occur at 2°C warming compared with 1.5°C include significantly more deadly heatwaves, drought and flooding; 10 centimeters of additional sea level rise within this century, exposing 10 million more people to flooding; a greater risk of triggering the collapse of the Greenland and Antarctic ice sheets with resulting multi-meter sea level rise; dramatically increased species extinction risk, including a doubling of the number of vertebrate and plant species losing more than half their range, and the virtual elimination of coral reefs; 1.5 to 2.5 million more square kilometers of thawing permafrost area with the associated release of methane, a potent greenhouse gas; a tenfold increase in the probability of ice-free Arctic summers; a higher risk of heat-related and ozone-related deaths and the increased spread of mosquito-borne diseases such as malaria and dengue fever; reduced yields and lower nutritional value of staple crops like maize, rice, and wheat; a doubling of the number of people exposed to climate change-induced increases in water

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[14] The White House, The Cost of Delaying Action to Stem Climate Change (July 29, 2014), https://obamawhitehouse.archives.gov/the-press-office/2014/07/29/white-house-report-cost-delaying-action-stem-climate-change at 2.

[15] National Research Council, Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia (2011) at 3.

[16] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018).

stress; and up to several hundred million more people exposed to climate-related risks and susceptible to poverty by 2050.[17]

The IPCC report concludes that pathways to limit warming to 1.5°C with little or no overshoot require "a rapid phase out of CO_2 emissions and deep emissions reductions in other GHGs and climate forcers."[18] In pathways consistent with limiting warming to 1.5°C, global net anthropogenic CO_2 emissions must decline by about 45 percent from 2010 levels by 2030, reaching net zero around 2050.[19] For a two-thirds chance for limiting warming to 1.5°C, CO_2 emissions must reach net zero in 25 years.[20]

In short, the 2018 IPCC *Special Report* provides overwhelming scientific evidence for the necessity of immediate, deep greenhouse gas reductions across all sectors to avoid devastating climate change-driven damages, and underscores the high costs of inaction or delays, particularly in the next crucial decade, in making these cuts.

III. Human-caused climate change is causing widespread harms in the United States and worldwide, and these harms will worsen as greenhouse gas pollution continues to rise.

As detailed in the National Climate Assessments, key climate change impacts include rising temperatures, the increasing frequency of heat waves and other extreme weather events, the flooding of coastal regions by sea level rise and increasing storm surge, the rapid loss of Arctic sea ice and the collapse of Antarctic ice shelves, declining global food and water security, increasing species extinction risk, ocean acidification, and the global collapse of coral reefs.[21] As summarized by the Fourth National Climate Assessment:

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[17] Intergovernmental Panel on Climate Change, Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018) at SPM-8 to SPM-14.

[18] Intergovernmental Panel on Climate Change, Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018) at 2-28.

[19] Intergovernmental Panel on Climate Change, Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018) at SPM-15.

[20] Intergovernmental Panel on Climate Change, Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018) at SPM-15.

[21] Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/; U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/.

In addition to warming, many other aspects of global climate are changing, primarily in response to human activities. Thousands of studies conducted by researchers around the world have documented changes in surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor.[22]

Rising temperatures

Global average surface temperatures have risen by 1.8°F (1.0°C) since 1901, most of which occurred during the past three decades.[23] As of 2018, 16 of the last 17 years were the warmest ever recorded by human observations.[24] Global average temperature reached a record high in 2016, which scientists determined was "only possible" because of anthropogenic climate change,[25] with 2017 ranked as the second hottest year on record.[26]

The United States warmed by 1.8°F (1.0°C) between 1901 and 2016, with the most rapid warming occurring after 1979.[27] The U.S. is expected to warm by an additional 2.5°F (1.4°C), on average, by mid-century relative to 1976-2005, and record-setting hot years will become commonplace.[28] By late century, much greater warming is projected, ranging from 2.8 to 7.3°F (1.6 to 4.1°C) under a lower emissions scenario and 5.8 to 11.9°F (3.2 to 6.6°C) under a higher emissions scenario,[29] with the largest increases in the upper Midwest and Alaska.[30] The urban

[22] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 10.
[23] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 13.
[24] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018) at 76.
[25] Knutson, Thomas R. et al., CMIP5 model-based assessment of anthropogenic influence on record global warmth during 2016, 99 Bulletin of the American Meteorological Society S11 (2017).
[26] National Aeronautics and Space Administration, Long-term warming trend continued in 2017: NASA, NOAA, Release 18-003, January 18, 2018, https://www.nasa.gov/press-release/long-term-warming-trend-continued-in-2017-nasa-noaa
[27] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 17.
[28] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 11.
[29] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 17.
[29] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 17 and 136: The high emissions scenario RCP 8.5 corresponds to a rise of CO_2 levels from the current-day 400 ppm up to 936 ppm by the end of this century. The lower emissions scenarios RCP4.5 and RCP 2.6 correspond to atmospheric CO_2 levels remaining below 550 and 450 ppm by 2100, respectively. These scenarios are numbered according to change in radiative forcing by 2100: +2.6, +4.5, +8.5 watts per square meter (W/m^2).
[30] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at Figure ES.4.

heat island effect—which is expected to strengthen as urban areas expand and become denser—will amplify climate-related warming even beyond those dangerous increases.[31]

Increasing frequency of extreme weather events

Extreme weather events are striking with increasing frequency, most notably heat waves and heavy precipitation events.[32] In the contiguous United States, extreme temperatures are expected to increase even more than average temperatures, with more intense heat waves and 20 to 30 more days per year above 90°F by mid-century for most regions under a higher emissions scenario.[33] Heavy precipitation has become more frequent and intense in most regions of the U.S. since 1901,[34] as more water vapor is available to fuel extreme rain and snowstorms as the world warms.[35] Heavy precipitation events are projected to continue to increase in frequency and intensity across the United States, with the number of extreme events rising by two to three times the historical average by the end of the century under a higher emissions scenario.[36] Climate warming also has exacerbated recent historic droughts by reducing soil moisture and contributing to earlier spring melt and reduced water storage in snowpack.[37] As conditions become hotter and drier, climate change is contributing to an increase in area burned by wildfire and a lengthening of the wildfire season in recent decades.[38]

A growing body of attribution studies (i.e., studies assessing how human-caused climate change may have affected the strength and likelihood of individual extreme events) has determined that human-caused climate change has not only intensified many recent extreme weather events, but that some extreme weather events could not have happened without human-induced climate

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[31] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 17.

[32] Coumou, Dim & Stefan Rahmstorf, A decade of weather extremes, 2 Nature Climate Change 491 (2012); Intergovernmental Panel on Climate Change, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Special Report of the Intergovernmental Panel on Climate Change (2012); Herring, Stephanie C. et al., Explaining extreme events of 2016 from a climate perspective, 99 Bulletin of the American Meteorological Society S1 (2017); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 18-20.

[33] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 185, 199.

[34] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 20.

[35] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 214.

[36] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 207, 218.

[37] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 45, 236.

[38] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/

change.[39] For example, in 2016, the intense marine heat wave off Alaska—which drove oyster farm failures, harmful algal blooms, mass seabird die offs, and failed subsistence harvests—was found to be up to fifty times more likely due to anthropogenic warming.[40] The sequence of consecutive record-breaking temperatures in 2014–2016 had a negligible (<0.03%) likelihood of occurring in the absence of anthropogenic warming.[41]

Climate change-related extremes are also weakening the ability of the terrestrial biosphere (vegetation and soil) to uptake carbon, a significant development because the terrestrial biosphere absorbs about 25 percent of anthropogenic carbon dioxide emissions.[42] Droughts, heat waves and other extreme climate-related events reduce soil moisture, lowering carbon uptake now and projected into the future.

Intensifying storms

Climate change has contributed to an increase in North Atlantic hurricane activity since the 1970s.[43] Hurricane-generated storm surge events—the enormous walls of water pushed onto the coast—have also become more frequent and severe.[44] One study found that large storm surge events of Hurricane Katrina magnitude have already doubled in response to warming during the 20th century, and projected that Atlantic hurricane surge events will increase in frequency by twofold to sevenfold for each 1°C in temperature rise.[45] As the climate warms, Atlantic and eastern North Pacific hurricane rainfall and intensity are projected to increase, making hurricanes more destructive.[46] Studies of Hurricane Harvey concluded that climate warming made the

[39] Herring, Stephanie C. et al., Explaining extreme events of 2016 from a climate perspective, 99 Bulletin of the American Meteorological Society S1 (2017). The Bulletin of the American Meteorological Society has published an annual attribution study compendium since 2011.
[40] Oliver, Eric C. et al., Anthropogenic and natural influences on record 2016 marine heat waves, 99 Bulletin of the American Meteorological Society S44 (2017); Walsh, John E. et al., The high latitude marine heat wave of 2016 and its impacts on Alaska, 99 Bulletin of the American Meteorological Society S39 (2017).
[41] Mann, Michael E. et al., Record temperature streak bears anthropogenic fingerprint, 44 Geophysical Research Letters 7936 (2017).
[42] Green, Julia K. et al., Large influence of soil moisture on long-term terrestrial carbon uptake, 564 Nature 476 (2019).
[43] Elsner, James B. et al., The increasing intensity of the strongest tropical cyclones, 455 Nature 92 (2008); Saunders, Mark A. & Adam S. Lea, Large contribution of sea surface warming to recent increase in Atlantic hurricane activity, 451 Nature 557 (2008); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 257; U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.
[44] Komar, Paul D. & Jonathan C. Allan, Increasing hurricane-generated wave heights along the U.S. east coast and their climate controls, 24 Journal of Coastal Research 479 (2008); Grinsted, Aslak et al., Homogeneous record of Atlantic hurricane surge threat since 1923, 109 PNAS 19601 (2012).
[45] Grinsted, Aslak et al., Projected hurricane surge threat from rising temperatures, 110 PNAS 5369 (2013).
[46] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.

storm's record rainfall more likely and intense.[47] Climate change is also projected to increase the frequency and severity of landfalling "atmospheric rivers" on the West Coast.[48]

Rising seas

Global average sea level rose by seven to eight inches since 1900 as the oceans have warmed and land-based ice has melted.[49] Sea level rise is accelerating in pace with almost half of recorded sea level rise occurring since 1993.[50] The Fourth National Climate Assessment estimated that global sea level is very likely to rise by 1.0 to 4.3 feet by the end of the century relative to the year 2000, with sea level rise of 8.2 feet possible.[51] Sea level rise will be much more extreme without strong action to reduce greenhouse gas pollution. By the end of the century, global mean sea level is projected to increase by 0.8 to 2.6 feet under a lower emissions RCP 2.6 scenario, compared with 1.6 to 6 feet under a high emissions RCP 8.5 scenario.[52] The impacts of sea level rise will be long-lived: under all emissions scenarios, sea levels will continue to rise for many centuries.[53]

Coastal flooding from sea level rise and intensifying storm surge

Coastal regions are threatened by increased flooding due to sea level rise and intensifying storm surge.[54] A nation-wide study estimated that approximately 3.7 million Americans live within

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[47] Emanuel, Kerry, Assessing the present and future probability of Hurricane Harvey's rainfall 2017, 114 PNAS 12681 (2017); Risser, Mark D. and Michael F. Wehner, Attributable human-induced changes in the likelihood and magnitude of the observed extreme precipitation during Hurricane Harvey, 44 Geophysical Research Letters 12,457 (2017); van Oldenborgh, Geert J. et al., Attribution of extreme rainfall from Hurricane Harvey, 12 Environmental Research Letters 124009 (2017).

[48] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.

[49] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.

[50] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 339; U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.

[51] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 487, 758; U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74.

[52] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 344.

[53] Melillo, Jerry M. et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 45. Also U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 345-346.

[54] Climate Central, Surging Seas Risk Zone Map, http://sealevel.climatecentral.org/ (accessed March 22, 2019); Hauer, Mathew E. et al., Millions projected to be at risk from sea-level rise in the continental United States, 6 Nature Climate Change 691 (2016); See online mapping tools at National Oceanic and Atmospheric Administration, Office for Coastal Management, DigitalCoast, Sea Level Rise Viewer, https://coast.noaa.gov/digitalcoast/tools/slr.html.

three feet of high tide, putting them at extreme risk of flooding from sea level rise in the next few decades, with the most vulnerable residents in Florida, Louisiana, California, New York and New Jersey.[55] Another study forecast that 4.2 million Americans would be at risk of flooding from three feet of sea level rise, while 13.1 million people would be at risk from six feet of sea level rise, driving mass human migration and societal disruption.[56] An analysis of 136 of the world's largest coastal cities projected that global flood losses of US$6 billion per year in 2005 will grow to US$1 trillion or more per year by 2050 due to sea level rise and subsidence, if no adaptation actions are taken, with Miami, New York and New Orleans suffering the highest current and projected economic losses in the U.S.[57]

Coastal flooding is becoming more damaging as Atlantic hurricanes and hurricane-generated storm surges grow more severe due to climate change.[58] Sea levels on the U.S. East Coast from Cape Hatteras to Boston are rising three to four times faster than the global average,[59] which when combined with intensifying hurricanes and storm surge, is greatly increasing the flooding risk along the East Coast.[60] Under a lower emissions RCP 4.5 scenario, storm surge is projected to increase by 25 to 47 percent along the U.S. Gulf and Florida coasts due to the combined effects of sea level rise and growing hurricane intensity.[61] The increasing frequency of extreme precipitation events is also compounding coastal flooding risk when storm surge and heavy rainfall occur together.[62]

Since the 1960s, sea level rise has increased the frequency of high tide flooding by a factor of 5 to 10 for several U.S. coastal communities, and flooding rates are accelerating in many Atlantic and Gulf Coast cities.[63] For much of the U.S. Atlantic coastline, a local sea level rise of 1.0 to 2.3 feet (0.3 to 0.7 m) would be sufficient to turn nuisance high tide events into major destructive

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[55] Strauss, Benjamin H. et al., Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States, 7 Environmental Research Letters 014033 (2012).
[56] Hauer, Matthew E. et al., Millions projected to be at risk from sea-level rise in the continental United States, 6 Nature Climate Change 691 (2016); Hauer, Mathew E., Migration induced by sea-level rise could reshape the US population landscape, 7 Nature Climate Change 321 (2017).
[57] Hallegatte, Stephane et al., Future flood losses in major coastal cities, 3 Nature Climate Change 802 (2013).
[58] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 99.
[59] Sallenger, Asbury H. et al., Hotspot of accelerated sea-level rise on the Atlantic coast of North America, 2 Nature Climate Change 884 (2012).
[60] Little, Christopher M. et al., Joint projections of US East Coast sea level and storm surge, 5 Nature Climate Change 1114 (2015).
[61] Balaguru, Karthik et al., Future hurricane storm surge risk for the U.S. gulf and Florida coasts based on projections of thermodynamic potential intensity, 138 Climatic Change 99 (2016).
[62] Wahl, T. et al., Increasing risk of compound flooding from storm surge and rainfall for major US cities, 5 Nature Climate Change 1093 (2015).
[63] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 98-99.

floods.[64] In Florida and Virginia, nuisance flooding due to sea level rise has already resulted in severe property damage and social disruption.[65] The frequency, depth, and extent of tidal flooding are expected to continue to increase in the future.[66]

Rapid Arctic warming and polar ice loss

Alaska and the Arctic have experienced some of the most severe and rapid warming associated with climate change, with temperatures rising at twice the rate of the rest of the globe on average.[67] Arctic summer sea ice extent has decreased by 40 percent during the past several decades, and sea ice thickness is also plummeting.[68] The Arctic lost 95 percent of its oldest and thickest sea ice during the past three decades, and the remaining thinner, younger ice is more vulnerable to melting.[69] Sea ice loss has accelerated since 2000, with Alaska's coast suffering some of the fastest losses.[70] The length of the sea ice season is shortening as ice melts earlier in spring and forms later in autumn.[71] Along Alaska's northern and western coasts, the sea ice season has already shortened by more than 90 days.[72] As sea ice continues to plummet, the Arctic is projected to be nearly ice-free in summer by 2040.[73] As summarized by the Fourth National Climate Assessment:

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[64] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 99.
[65] Atkinson, Larry P. et al., Sea level rise and flooding risk in Virginia, CCPO Publications, Paper 102 (2013), http://digitalcommons.odu.edu/ccpo_pubs/102; Wdowinski, Shimon et al., Increasing flooding hazard in coastal communities due to rising sea level: Case study of Miami Beach, Florida, 126 Ocean & Coastal Management 1 (2016).
[66] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 75.
[67] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 92.
[68] Meier, Walter N. et al., Arctic sea ice in transformation: A review of recent observed changes and impacts on biology and human activity, 51 Reviews of Geophysics 185 (2014); U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II,U.S. Global Change Research Program (2018), https://nca2018.globalchange.gov/, at 1192-1193.
[69] Osborne, Emily, et al. (eds.), Arctic Report Card 2018, NOAA (2018), https://www.arctic.noaa.gov/Report-Card at 2.
[70] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 305.
[71] Parkinson, Claire L., Spatially mapped reductions in the length of the Arctic sea ice season, 41 Geophysical Research Letters 4316 (2014).
[72] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 307.
[73] Overland, James E. & Muyin Wang, When will the summer Arctic be nearly sea ice free? 40 Geophysical Research Letters 2097 (2013); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 303.

Since the early 1980s, annual average arctic sea ice has decreased in extent between 3.5% and 4.1% per decade, become thinner by between 4.3 and 7.5 feet, and began melting at least 15 more days each year. September sea ice extent has decreased between 10.7% and 15.9% per decade (*very high confidence*). Arctic-wide ice loss is expected to continue through the 21st century, *very likely* resulting in nearly sea ice-free late summers by the 2040s (*very high confidence*)."[74]

The Greenland and Antarctic ice sheets are losing ice at an accelerating rate through increasing glacier calving and surface melting, and are approaching or already may have passed a tipping point of irreversible melting. A 2019 study found that Greenland's southwest ice sheet is losing ice at nearly four times the rate it did in 2003, and concluded that "Greenland's air–sea–ice system crossed one or more thresholds or tipping points near the beginning of this millennium, triggering more rapid deglaciation."[75] Another study found that, over the past two decades, Greenland's ice sheets have been melting at a rate 50 percent higher than pre-industrial levels and 33 percent above 20th-century levels, meaning that more meltwater is running off Greenland's ice sheet now than at any time in the last 350 years and likely going back 6,000 to 7,000 years.[76] A separate study estimated that the rate of Arctic ice loss from melting glaciers and the Greenland ice sheet tripled during the past decade compared with the previous two decades, now adding over a millimeter to the global sea level each year.[77] The rate of ice loss from the massive Antarctic ice sheet has increased by more than six-fold since the late 1970s, leading to 250 billion tons of ice pouring into the ocean each year, and research suggests that the East Antarctic ice sheet, once thought to be stable, is losing substantial amounts of ice.[78] Glaciers are also rapidly melting, raising sea levels and threatening water supplies in many regions.[79] Permafrost is thawing worldwide as temperatures rise, and the carbon dioxide and methane released from thawing permafrost has the potential to amplify human-induced warming, possibly significantly.[80]

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[74] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 29, 303.
[75] Bevis, Michael et al., Accelerating changes in ice mass within Greenland and the ice sheet's sensitivity to atmospheric forcing, 116 PNAS 6 (2019).
[76] Trusel, Luke D. et al., Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming, 564 Nature 104 (2018).
[77] Box, Jason E. et al., Global sea-level contribution from Arctic land ice: 1971-2017, 13 Environmental Research Letters 125012 (2018).
[78] Rignot, Eric et al., Four decades of Antarctic ice sheet mass balance from 1979-2017, 116 PNAS 4 (2019); Slater, Thomas and Andrew Shepherd, Antarctic ice losses tracking high, 8 Nature Climate Change 1025 (2018); IMBIE, Mass balance of the Antarctic ice sheet from 1992 to 2017, 558 Nature 219 (2018).
[79] Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at 4; U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 303.
[80] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 74; Biskaborn, Boris K. et al., Permafrost is warming at a global scale, 10 Nature Communications 264 (2019).

Biodiversity loss

Anthropogenic climate change is causing widespread harm to life across the planet. Climate change is increasing stress on species and ecosystems—causing changes in distribution, phenology, physiology, vital rates, genetics, ecosystem structure and processes—in addition to increasing species extinction risk.[81] Climate change is already affecting 82 percent of key ecological processes that underpin ecosystem function and support basic human needs.[82] Climate change-related local extinctions are already widespread and have occurred in hundreds of species, including almost half of the 976 species surveyed.[83] Nearly half of terrestrial non-flying threatened mammals and nearly one-quarter of threatened birds may have already been negatively impacted by climate change in at least part of their range.[84] Furthermore, across the globe, populations of terrestrial birds and mammals that are experiencing greater rates of climate warming are more likely to be declining at a faster rate.[85] Genes are changing, species' physiology and physical features such as body size are changing, species are moving to try to keep pace with suitable climate space, species are shifting their timing of breeding and migration, and entire ecosystems are under stress.[86]

Because climate change is occurring at an unprecedented pace with multiple synergistic impacts, human-caused climate change is increasing the extinction risk for many species. Numerous studies have projected catastrophic species losses during this century if climate change continues unabated: 15 to 37 percent of the world's plants and animals committed to extinction by 2050 under a mid-level emissions scenario[87]; the potential extinction of 10 to 14 percent of species by

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[81] Warren, Rachel et al., Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise, 106 Climatic Change 141 (2011).
[82] Scheffers, Brett R. et al., The broad footprint of climate change from genes to biomes to people, 354 Science 719 (2016).
[83] Wiens, John J., Climate-related local extinctions are already widespread among plant and animal species, 14 PLoS Biology e2001104 (2016).
[84] Pacifici, Michela et al., Species' traits influenced their response to recent climate change, 7 Nature Climate Change 205 (2017). The study concluded that "populations of large numbers of threatened species are likely to be already affected by climate change, and … conservation managers, planners and policy makers must take this into account in efforts to safeguard the future of biodiversity."
[85] Spooner, Fiona E.B. et al., Rapid warming is associated with population decline among terrestrial birds and mammals globally, 24 Global Change Biology 4521 (2018).
[86] Parmesan, Camille & Gary Yohe, A globally coherent fingerprint of climate change impacts across natural systems, 421 Nature 37 (2003); Root, Terry L. et al., Fingerprints of global warming on wild animals and plants, 421 Nature 57 (2003); Parmesan, Camille, Ecological and evolutionary responses to recent climate change, 37 Annual Review of Ecology Evolution and Systematics 637 (2006); Chen, I-Ching et al., Rapid range shifts of species associated with high levels of climate warming, 333 Science 1024 (2011); Maclean, Ilya M. D. & Robert J. Wilson, Recent ecological responses to climate change support predictions of high extinction risk, 108 Proceedings of the National Academy of Sciences of the United States of America 12337 (2011); Warren, Rachel et al., Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise, 106 Climatic Change 141 (2011); Cahill, Abigail E. et al., How does climate change cause extinction?, 280 Proceedings of the Royal Society B 20121890 (2012).
[87] Thomas, Chris. D. et al., Extinction risk from climate change, 427 Nature 145 (2004).

2100[88]; global extinction of five percent of species with 2°C of warming and 16 percent of species with business-as-usual warming[89]; and the loss of more than half of the present climatic range for 58 percent of plants and 35 percent of animals by the 2080s under the current emissions pathway, in a sample of 48,786 species.[90] It is predicted that within a century, over 300 North American bird species will lose at least half of their current ranges due to climate change.[91]

Scientists have warned that the Earth is fast approaching a global "state-shift" that could result in unanticipated and rapid changes to biological systems.[92] As summarized by the Third National Climate Assessment, "landscapes and seascapes are changing rapidly, and species, including many iconic species, may disappear from regions where they have been prevalent or become extinct, altering some regions so much that their mix of plant and animal life will become almost unrecognizable."[93]

Public health harms

Climate change poses serious threats to public health and well-being.[94] The Fourth National Climate Assessment concluded that "[t]he health and well-being of Americans are already affected by climate change, with the adverse health consequences projected to worsen with additional climate change."[95] The health impacts from climate change include increased exposure to heat waves, floods, droughts, and other extreme weather events; increases in vector-, food- and waterborne infectious diseases; decreases in the quality and safety of air, food, and water including rising food insecurity and increases in air pollution; displacement; and stresses to mental health and well-being.[96] Although everyone is vulnerable to health harms from climate

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[88] Maclean, Ilya M. D. & Robert J. Wilson, Recent ecological responses to climate change support predictions of high extinction risk, 108 PNAS 12337 (2011).
[89] Urban, Mark C., Accelerating extinction risk from climate change, 348 Science 571 (2015).
[90] Warren, Rachel et al., Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss, 3 Nature Climate Change 678 (2013).
[91] National Audubon Society, Audubon's Birds and Climate Change Report (2014) at p. 5, http://climate.audubon.org/sites/default/files/NAS_EXTBIRD_V1.3_9.2.15%20lb.pdf.
[92] Barnosky, Anthony D. et al., Approaching a state shift in Earth's biosphere, 486 Nature 52 (2012).
[93] Melillo, Jerry M. et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 196.
[94] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 540; U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016); Melillo, Jerry M et al., Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 220.
[95] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 540.
[96] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 540; U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016);

change, populations experiencing greater health risks include children, older adults, low-income communities, some communities of color, immigrant groups, and persons with disabilities and pre-existing medical conditions.[97] The 2015 Lancet Commission on Health and Climate Change warned that climate change is causing a global medical emergency, concluding that "the implications of climate change for a global population of 9 billion people threatens to undermine the last half century of gains in development and global health."[98]

Climate change-driven health impacts are already occurring in the United States, particularly from illnesses and deaths caused by extreme weather events which are increasing in frequency and intensity.[99] Heat is the leading cause of weather-related deaths in the U.S., and extreme heat is projected to increase future mortality on the scale of thousands to tens of thousands of additional premature deaths per year across the U.S. by the end of this century.[100] Hot days have been conclusively linked to an increase in heat-related deaths and illnesses—particularly among older adults, pregnant women, and children—including cardiovascular and respiratory complications, renal failure, electrolyte imbalance, kidney stones, negative impacts on fetal health, and preterm birth.[101] One study estimated that nearly one-third of the world's population is currently exposed to a deadly combination of heat and humidity for at least 20 days a year, and that percentage is projected to rise to nearly three-quarters by the end of the century without deep cuts in greenhouse gas pollution, with particular impacts to the southeastern U.S.[102]

Extreme precipitation events have become more common in the United States, contributing to increases in severe flooding in some regions.[103] Floods are the second deadliest of all weather-

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Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 221; Sheffield, Perry and Philip J. Landrigan, Global climate change and children's health: Threats and strategies for prevention, 119 Environmental Health Perspectives 291 (2011).

[97] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 548; U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016).

[98] Watts, Nick et al., Health and climate change: policy responses to protect public health, 386 The Lancet 1861 (2015) at 1861.

[99] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 541.

[100] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016).

[101] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 544-545.

[102] Mora, Camilo et al., Global risk of deadly heat, 7 Nature Climate Change 501 (2017).

[103] Melillo, Jerry M et al., Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 221.

related hazards in the United States and can lead to drowning, contaminated drinking water, and mold-related illnesses.[104]

Air pollutants—particularly ozone, particulate matter, and allergens—are expected to increase with climate change.[105] Climate-driven increases in ozone will cause more premature deaths, hospital visits, lost school days, and acute respiratory symptoms.[106] In 2020, projected climate-related increases in ground-level ozone concentrations could lead to an average of 2.8 million more occurrences of acute respiratory symptoms, 944,000 more missed school days, and over 5,000 more hospitalizations for respiratory-related problems.[107] The continental U.S. could pay an average of $5.4 billion (2008$) in health impact costs associated with climate-related increases in ozone in 2020, with California experiencing the greatest impacts estimated at $729 million.[108]

Risks from infectious diseases are increasing as climate change alters the geographic and seasonal distribution of tick- and mosquito-borne diseases like Lyme disease and West Nile virus.[109] The risk of human exposure to Lyme disease—the most common vector-borne illness in the U.S.[110]— is expected to increase as ticks carrying Lyme disease and other pathogens become active earlier in the season and expand northward in response to warming temperatures.[111] The two species of ticks capable of spreading Lyme disease have already expanded to new regions of the U.S. partly because of rising temperatures: in 2015, they were found in more than 49 percent of counties in the continental U.S., a nearly 45 percent increase since 1998.[112] Rising temperatures and changes in rainfall have also contributed to the maintenance of West Nile virus in parts of the United States,[113] and cases of West Nile disease are projected to more than double

[104] Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 at 224.
[105] U.S. Environmental Protection Agency, Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Final Rule, 74 Federal Register 66496 (2009); U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, (2016).
[106] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016).
[107] Union of Concerned Scientists, Rising Temperatures and Your Health: Rising Temperatures, Worsening Ozone Pollution (2011).
[108] Union of Concerned Scientists, Rising Temperatures and Your Health: Rising Temperatures, Worsening Ozone Pollution (2011).
[109] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016).
[110] Schwartz, Amy M., et al., Surveillance for Lyme Disease — United States, 2008-2015, 66 MMWR , Centers for Disease Control and Prevention (2017).
[111] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016).
[112] Eisen, Rebecca J., County-Scale Distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the Continental United States, 53 Journal of Medical Entomology 349 (2016).
[113] Harrigan, Ryan J. et al., A continental risk assessment of West Nile virus under climate change, 20 Global Change Biology 2417(2014); Paz, Shlomit, Climate change impacts on West Nile virus transmission in a global context, 370 Philosophical Transactions of the Royal Society B 20130561 (2015).

by 2050 due in part to increasing temperatures, resulting in approximately $1 billion per year in hospitalization costs and premature deaths under a higher emissions scenario.[114]

Numerous studies have emphasized that many lives could be saved with rapid reductions in greenhouse gas pollution.[115] The Fourth National Climate Assessment concludes that "reducing greenhouse gas emissions would benefit the health of Americans in the near and long term."[116] The Assessment projects that "by the end of this century, thousands of American lives could be saved and hundreds of billions of dollars in health-related economic benefits gained each year under a pathway of lower greenhouse gas emissions."[117] Another recent study reported that faster reductions in carbon pollution will prevent millions of premature deaths globally. Compared with a 2°C pathway, a 1.5°C pathway is projected to result in 153 million fewer premature deaths worldwide due to reduced PM 2.5 and ozone exposure, including 130,000 fewer premature deaths in Los Angeles and 120,000 in the New York metropolitan area.[118]

Threats to water resources

Climate change is altering the water cycle in ways that threaten water supplies in the United States. As summarized by the Fourth National Climate Assessment, variable precipitation and rising temperature due to climate change are "intensifying droughts, increasing heavy downpours, and reducing snowpack. Reduced snow-to-rain ratios are leading to significant differences between the timing of water supply and demand. Groundwater depletion is exacerbating drought risk. Surface water quality is declining as water temperature increases and more frequent high-intensity rainfall events mobilize pollutants such as sediments and nutrients."[119]

Snowpack is important for providing water in many parts of the United States. In the western U.S., earlier spring snowmelt, reduced snowpack, lower snow water equivalent (i.e. the amount of water contained in snowpack), and reduced river flows have been attributed to human-caused

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[114] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 552.

[115] Gasparrini, Antonio et al., Projections of temperature-related excess mortality under climate change scenarios, 1 Lancet Planet Health e360 (2017); Hsiang, Solomon et al., Estimating economic damage from climate change in the United States, 356 Science 1362 (2017); Silva, Raquel A. et al., Future global mortality from changes in air pollution attributable to climate change, 7 Nature Climate Change 647 (2017); Burke, Marshall et al., Higher temperatures increase suicide rates in the United States and Mexico, 8 Nature Climate Change 723 (2018); Shindell, Drew et al., Quantified, localized health benefits of accelerate carbon dioxide emissions reductions, 8 Nature Climate Change 723 (2018).

[116] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 541.

[117] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 541.

[118] Shindell, Drew et al., Quantified, localized health benefits of accelerated carbo n dioxide emissions reductions, 8 Nature Climate Change 291 (2018).

[119] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 146.

warming.[120] As temperatures rise, western U.S. winter and spring snowpack are projected to continue to decline,[121] and more precipitation will fall as rain instead of snow in the cold season in many parts of the U.S.[122] Under higher emissions scenarios, reductions in snowfall and earlier snowmelt are expected to lead to more frequent "hydrological" drought conditions in the western U.S., characterized by deficits in runoff.[123]

As a key example, the Colorado River Basin is one of the most important water systems in the United States, encompassing seven western states and providing water for 40 million people. Across much of the Colorado River Basin, spring snowpack, runoff, and streamflow have declined, disrupting the region's water supply.[124] Rising temperatures are contributing to significantly declining Colorado River flows, and flow losses due to warming alone may exceed 20 percent by mid-century.[125] Drought activity in the Colorado River Basin is projected to increase as temperatures continue to rise and snowpack declines.[126]

Climate change is also playing an important role in reducing soil moisture as temperatures rise, intensifying "agricultural" droughts.[127] Under higher emissions scenarios, continuing decreases in surface soil moisture and widespread drying over most of the United States are projected.[128] Future warming is expected to lead to greater frequencies and magnitudes of agricultural droughts throughout the continental United States as evapotranspiration outpaces precipitation.[129]

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[120] Barnett, Tim, et al., Human-induced changes in the hydrology of the Western United States, 319 Science 1080 (2008); Pierce, David et al., Attribution of declining Western U.S. snowpack to human effects, American Meteorological Society 6425 (2008); Hidalgo, H.G. et al., Detection and attribution of streamflow timing changes to climate change in the western United States, 22 Journal of Climate 3838 (2009); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Volume I (2017), https://science2017.globalchange.gov/at 231, 236.

[121] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017) https://science2017.globalchange.gov/ at 207, 231.

[122] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 207.

[123] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 231, 232, 239, 240.

[124] Garfin, Gregg et al. (eds.), Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, Southwest Climate Alliance (2013); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 236.

[125] Udall, Bradley & Jonathan Overpeck, The twenty-first century Colorado River hot drought and implications for the future, 53 Water Resources Research 2404 (2017).

[126] Cayan, Daniel R. et al., Future dryness in the southwest US and the hydrology of the early 21st century drought, 107 PNAS 107 (2010).

[127] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 237.

[128] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 237.

[129] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 237.

Declining food security

In the United States, climate change threatens food security for millions of Americans. About 14 percent of U.S. households currently do not have food security—defined as access by all people at all times to enough food for an active, healthy life—and more than 48 million people live in food insecure homes.[130] Climate change threatens food security through a number of pathways, including through reduced crop and livestock production, contamination of food supplies, changes in land use and land availability, and decreasing access to food.[131]

Climate-related harms to crop and livestock production include increases in weeds, diseases, and insect pests; rising heat stress increasing livestock mortality; insufficient winter chill hours needed for many important tree crops; degradation of soils; changes in water availability; and the increasing frequency of extreme weather events.[132] The Third National Climate Assessment warned that "[c]limate disruptions to agricultural production have increased in the past 40 years and are projected to increase over the next 25 years" and that "[b]y mid-century and beyond, these impacts will be increasingly negative on most crops and livestock."[133]

A 2017 study using multiple independent methods projected negative temperature impacts on the yields of four major crops that make up two-thirds of human caloric intake and are critical for food security.[134] The U.S. is expected to suffer the greatest losses globally for maize (averaging −10.3% per degree Celsius warming) and soybeans (−6.8% per degree Celsius), with large losses for wheat (−5.5% per degree Celsius).[135] Research also indicates that crops will become less nutritious as carbon dioxide levels increase, worsening the global prevalence of malnutrition. In one study, major crops, including wheat, barley, rice and potato, when grown at carbon dioxide levels projected for the year 2100, had 6 to 15 percent less protein than the same crops grown at current carbon dioxide levels, as well as fewer key nutrients such as zinc, calcium and

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[130] Public Health Institute/Center for Climate Change and Health, Food Security, Climate Change and Health (2016).
[131] Melillo, Jerry M. et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014) at 150; Brown, M.E. et al., Climate Change, Global Food Security, and the U.S. Food System (2015).
[132] Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014), https://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0 (2014) at 150; Brown, M.E. et al., Climate Change, Global Food Security, and the U.S. Food System (2015); U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 391–437.
[133] Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014) at 150.
[134] Zhao, Chuang et al., Temperature increase reduces global yields of major crops in four independent estimates, 114 PNAS 9326 (2017).
[135] Zhao, Chuang et al., Temperature increase reduces global yields of major crops in four independent estimates, 114 PNAS 9326 (2017).

magnesium.[136] The United States is one of the countries projected to suffer the largest increases in pest-related crop losses as warming increases the population growth and metabolic rates of insects.[137] Further, since agriculture is the biggest driver of water shortages in the world, accounting for 70 percent of global water withdrawals, future changes in water availability will profoundly impact agricultural production on the whole.[138]

Livestock cultivation occurs over approximately 30 percent of the Earth's ice-free land surface, and provides a livelihood for over a billion people globally. As with crop yields, one of the greatest threats to livestock yields is heat stress.[139] Heat stress diminishes food intake and physical activity for livestock. This leads to less growth, survival, and reproductive rates, and also lower production of meat, milk, and eggs. Heat stress can also weaken immune function in livestock, contributing to the need for more veterinary medications. Increasing temperatures also require greater water intake, which presents further complications if increasing temperatures are combined with increasing drought as predicted for some locations. Such conditions also allow for certain pathogens and parasites to expand their ranges, resulting in increased livestock exposure.[140]

Fisheries and aquaculture provide 4.3 billion people with 15 to 20 percent of their intake of animal protein.[141] Ocean warming and ocean acidification threaten marine food resources by disrupting marine communities, promoting harmful algal blooms and the spread of diseases, and increasing contaminants in fish and shellfish.[142] For example, the types of fish caught in fisheries are starting to change due to increasing ocean temperatures. In the rapidly warming Northeast Atlantic Ocean, for instance, fish species are migrating northward over time as waters become warmer, meaning that fish catches in higher latitudes now contain more warm water species, whereas fish catches in lower latitudes contain fewer subtropical species.[143] This shift in fish distribution has negative implications for fisheries that rely on specific fish species for subsistence.

Algal bloom species have been expanding their ranges, and many are dangerous to humans because of the toxins they produce that make their way into shellfish. These toxins when

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[136] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016) at 198.
[137] Deutsch, Curtis A. et al., Increase in crop losses to insect pests in a warming climate, 361 Science 916 (2018).
[138] United Nations Convention to Combat Desertification, The Global Land Outlook (2017), https://www.unccd.int/actions/global-land-outlook-glo.
[139] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 406-408.
[140] Brown, M.E. et al. Climate Change, Global Food Security, and the U.S. Food System (2015) at 57.
[141] Brown, M.E. et al. Climate Change, Global Food Security, and the U.S. Food System (2015) at 58.
[142] Tirado, M. C. et al., Climate change and food safety: A review, 43 Food Research International 1745 (2010).
[143] Porter, J.R. et al., Food security and food production systems, Climate Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate (2014) at p. 493.

consumed by humans are associated with illnesses such as amnesic shellfish poisoning, diarrheic shellfish poisoning, neurotoxic shellfish poisoning, and paralytic shellfish poisoning. These illnesses may cause respiratory and digestive problems, memory loss, seizures, skin lesions, and even death.[144] As an example of their increasing prevalence, cases of paralytic shellfish poisoning (PSP) were just a few decades ago primarily seen along the west coast of the United States. At present, cases of PSP have expanded along both U.S. coasts, and also throughout Southeast Asia, Europe, and South America.[145] Consuming raw shellfish can also spread pathogens such as *Vibrio* bacteria which are linked to conditions as mild as diarrhea or as severe and fatal blood infections. Ocean warming has a known impact on both the abundance of *Vibrio* and harmful algal blooms.[146]

Ocean warming

U.S. and global oceans are being hard-hit by climate change. The world's oceans have absorbed more than 90 percent of the excess heat caused by greenhouse gas warming, resulting in average sea surface warming of 1.3°F (0.7°C) per century since 1900.[147] A 2019 study estimated that oceans are warming 40 percent faster than scientists projected, and that the rate of ocean warming is accelerating.[148] Rapid warming of the oceans has widespread impacts and has contributed to increases in rainfall intensity, rising sea levels, the destruction of coral reefs, declining ocean oxygen levels, and ice loss from glaciers, ice sheets and polar sea ice.[149] Global average sea surface temperature is projected to rise by 4.9°F (2.7°C) by the end of the century under a higher emissions scenario, with even greater warming in the coastal waters of the Northeastern U.S. and Alaska.[150]

Large-scale oxygen losses that create harmful low or no-oxygen zones have been developing in the coastal and open oceans due in large part to ocean warming.[151] In the past 50 years, open-ocean low-oxygen zones have expanded by an area the size the European Union, no-oxygen areas have more than quadrupled in size, and the number of low-oxygen sites near the coast has increased tenfold.[152]

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144 Tirado, M. C. et al., Climate change and food safety: A review, 43 Food Research International 1745 (2010).
145 Gilbert, P. et al., The global complex phenomena of harmful algal blooms, 18 Oceanography 136 (2005).
146 Tirado, M. C. et al., Climate change and food safety: A review, 43 Food Research International 1745 (2010).
147 U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 364, 367.
148 Cheng, Lijing et al., How fast are the oceans warming?, 363 Science 128 (2019).
149 Cheng, Liging et al., How fast are the oceans warming?, 363 Science 128 (2019).
150 U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 368.
151 U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 364, 377.
152 Breitburg, Denise et al., Declining oxygen in the global ocean and coastal waters, 359 Science 46 (2018).

Ocean acidification

The global oceans have absorbed more than a quarter of the CO_2 emitted to the atmosphere by human activities, which has significantly increased the acidity of the surface ocean. Ocean acidification has reduced the availability of key chemicals—aragonite and calcite—that many marine species use to build their shells and skeletons.[153] The ocean's absorption of anthropogenic CO_2 has already resulted in more than a 30 percent increase in the acidity of ocean surface waters, at a rate likely faster than anything experienced in the past 300 million years.[154] Ocean acidity could increase by 150 percent by the end of the century if CO_2 emissions continue unabated.[155] In the United States, the West Coast, Alaska, and the Gulf of Maine are experiencing the earliest, most severe changes due to ocean acidification.[156] Regions of the East and Gulf Coasts are also vulnerable because of local stressors such as coastal eutrophication from fertilizer runoff and river discharge that increase acidification.[157]

Ocean acidification negatively affects a wide range of marine species by hindering the ability of calcifying marine creatures like corals, oysters, and crabs to build protective shells and skeletons and by disrupting metabolism and critical biological functions.[158] The adverse effects of ocean acidification are already being observed in wild populations, including severe shell damage to pteropods (marine snails at the base of the food web) along the U.S. west coast,[159] reduced coral calcification rates in reefs worldwide,[160] and mass die-offs of larval Pacific oysters in the Pacific Northwest.[161] An expert science panel concluded in 2016 that "growth, survival and behavioral

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[153] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 371-372.
[154] Hönisch, Barbel et al., The geological record of ocean acidification, 335 Science 1058 (2012); U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 372, 374.
[155] Orr, James C. et al., Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, 437 Nature 681 (2005); Feely, Richard et al., Ocean acidification: Present conditions and future changes in a high CO_2 world, 22 Oceanography 36 (2009).
[156] Feely, Richard A. et al., Evidence for upwelling of corrosive 'acidified' water onto the continental shelf, 320 Science 1490 (2008); Ekstrom, Julia A. et al., Vulnerability and adaptation of U.S. shellfisheries to ocean acidification, 5 Nature Climate Change 207 (2015); Mathis, Jeremy T. et al., Ocean acidification in the surface waters of the Pacific-Arctic boundary regions, 28 Oceanography 122 (2015); Mathis, Jeremy T. et al., Ocean acidification risk assessment for Alaska's fishery sector, 136 Progress in Oceanography 71 (2015); Chan, F. et al., The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions, California Ocean Science Trust (April 2016).
[157] Ekstrom, Julia A. et al., Vulnerability and adaptation of U.S. shellfisheries to ocean acidification, 5 Nature Climate Change 207 (2015).
[158] Fabry, Victoria J. et al., Impacts of ocean acidification on marine fauna and ecosystem processes, 65 ICES Journal of Marine Science 414 (2008); Kroeker, Kristy J. et al., Impacts of ocean acidification on marine organisms: quantifying sensitivities and interactions with warming, 19 Global Change Biology 1884 (2013).
[159] Bednaršek, N. et al., *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem, 281 Proceedings of the Royal Society B 20140123 (2014).
[160] Albright, Rebecca et al., Reversal of ocean acidification enhances net coral reef calcification, 531 Nature 362 (2016).
[161] Barton, Alan et al., The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects, 57 Limnology and Oceanography 698 (2012).

effects linked to OA [ocean acidification] extend throughout food webs, threatening coastal ecosystems, and marine-dependent industries and human communities."[162]

Coral reef crisis

The world's coral reefs, which support one-third of marine species and the livelihoods of a half billion people, are in crisis. Rising ocean temperatures and ocean acidification caused by greenhouse gas pollution threaten the continued survival of corals and coral reef ecosystems due to the increasing frequency of mass bleaching events and the dissolution of corals due to ocean acidification.[163] An estimated 50 percent of the world's coral reefs have already been lost,[164] and an estimated one-third of all reef-building coral species are at risk of extinction.[165] The 2014 to 2017 global coral bleaching event was the longest and most widespread on record, affecting more reefs than any previous mass bleaching event and causing mass bleaching of reefs that had never bleached before, with U.S. reefs particularly hard-hit.[166] Since the first mass bleaching events began in the 1980s, severe bleaching events have increased five-fold and now occur every six years on average, which is too frequent to allow full recovery of coral reefs.[167] Coral scientists have warned that unless global temperature is kept under 1.5°C and atmospheric CO_2 concentration is restored to less than 350 ppm, coral reefs and reef-dependent marine life will be committed to a terminal and irreversible decline.[168]

Economic impacts

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[162] Chan, Francis et al., The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions, California Ocean Science Trust, Oakland, California, USA (April 2016) at 4.
[163] Hoegh-Guldberg, Ove et al., Coral reefs under rapid climate change and ocean acidification, 318 Science 1737 (2007); Eakin, C. Mark et al., Caribbean corals in crisis: record thermal stress, bleaching, and mortality in 2005, 5 PLoS ONE e13969 (2010).
[164] Jackson, Jeremy, Status and Trends of Caribbean Coral Reefs: 1970-2012, Executive Summary, Global Coral Reef Monitoring Network - IUCN (2014) at 14, Figure 3: Average coral cover in the Caribbean declined by more than 50 percent since the 1970s; Bruno, John F. & Elizabeth R. Selig, Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons, 8 PLoS One e711 (2007) at 4: Average coral cover in the Indo-Pacific declined by nearly 50 percent between the 1980s and 2003.
[165] Carpenter, Kent E. et al., One-third of reef-building corals face elevated extinction risk from climate change and local impacts, 321 Science 560 (2008).
[166] Lewis, Sophie C. & J. Mallela, A multifactor analysis of the record 2018 Great Barrier Reef bleaching, 99 Bulletin of the American Meteorological Society S144 (2017); National Oceanic and Atmospheric Administration, Global coral bleaching event likely ending , but scientists forecast high ocean temperatures may persist in some areas (June 19, 2017), http://www.noaa.gov/media-release/global-coral-bleaching-event-likely-ending.
[167] Hughes, Terry P. et al., Spatial and temporal patterns of mass bleaching of corals in the Anthropocene, 359 Science 80 (2018).
[168] Veron, John E.N. et al., The coral reef crisis: the critical importance of <350 ppm CO_2, 58 Marine Pollution Bulletin 1428 (2009); Frieler, Katja, et al., Limiting global warming to 2ºC is unlikely to save most coral reefs, 3 Nature Climate Change 165 (2012); van Hooidonk, Ruben et al., Opposite latitudinal gradients in projected ocean acidification and bleaching impacts on coral reefs, 20 Global Change Biology 103 (2014): Even on the lowest emissions pathway considered (RCP 2.6) in which CO_2 concentrations peak at ~430ppm around 2050 followed by a decline to around 400 ppm CO_2 by the end of the century, 88 percent of reef locations experience severe bleaching events annually by the end of the century.

The Fourth National Climate Assessment makes clear that human-caused climate change is already leading to substantial economic losses in the U.S. and that these losses will be much more severe under higher emissions scenarios, impeding economic growth:

> Without substantial and sustained global mitigation and regional adaptation efforts, climate change is expected to cause growing losses to American infrastructure and property and impede the rate of economic growth over this century.[169]
>
> In the absence of more significant global mitigation efforts, climate change is projected to impose substantial damages on the U.S. economy, human health, and the environment. Under scenarios with high emissions and limited or no adaptation, annual losses in some sectors are estimated to grow to hundreds of billions of dollars by the end of the century. It is very likely that some physical and ecological impacts will be irreversible for thousands of years, while others will be permanent.[170]

According to the Fourth National Climate Assessment, the number of extreme weather events per year costing more than one billion dollars per event has increased significantly since 1980, with total costs exceeding $1.1 trillion.[171] The National Oceanic and Atmospheric Administration estimated that, between 2015 and April 2018, 44 billion-dollar weather and climate disasters struck the United States, producing nearly $400 billion in damages. [172] The 2017 Atlantic Hurricane season alone is estimated to have caused more than $250 billion in damages and hundreds of deaths throughout the U.S. Caribbean, Southeast, and Southern Great Plains.[173]

By the end of the century, the Fourth National Climate Assessment estimates that warming on our current trajectory would cost the U.S. economy hundreds of billions of dollars each year and up to 10 percent of U.S. gross domestic product due to damages including lost crop yields, lost labor, increased disease incidence, property loss from sea level rise, and extreme weather damage.[174] Ultimately, the magnitude of financial burdens imposed by climate change depends

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[169] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 25.
[170] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1357.
[171] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 81.
[172] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 66.
[173] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 66.
[174] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1358, 1360.

on how effectively we curb emissions. Across sectors and regions, significant reductions in emissions will substantially lower the costs resulting from climate change damages.[175] For example, annual damages associated with additional extreme temperature-related deaths are projected at $140 billion (in 2015$) under the higher RCP 8.5 emissions scenario compared with $60 billion under the lower RCP 4.5 scenario by 2090.[176] Annual damages to labor would be approximately $155 billion under RCP 8.5, but reduced by 48 percent under RCP 4.5.[177] While coastal property damage would carry an annual cost of $118 billion under RCP 8.5 in 2090, 22 percent of this cost would be avoided under RCP 4.5.[178]

Tipping points and compound climate extremes

The Fourth National Climate Assessment concluded with very high confidence that large-scale shifts in the climate system, known as tipping points, and the compound effects of simultaneous extreme climate events have the potential to create unanticipated and potentially abrupt and irreversible "surprises" that become more likely as warming increases.[179] The IPCC Fifth Assessment Report similarly concluded that "with increasing warming, some physical and ecological systems are at risk of abrupt and/or irreversible changes" and that the risk "increases as the magnitude of the warming increases."[180] The crossing of tipping points could result in climate states wholly outside human experience and result in severe physical and socioeconomic impacts.[181]

There is evidence that warm-water coral reefs and Arctic ecosystems are already experiencing irreversible regime shifts, and the climate system is close to crossing other tipping points.[182] For example, research indicates that a critical tipping point important to the stability of the West Antarctic Ice Sheet has been crossed, and that rapid and irreversible collapse of the ice sheet is

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175 U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1349.
176 U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 552.
177 U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1349.
178 U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 1349.
179 U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 32, 411-423; Lenton, Timothy M. et al, Tipping elements in the Earth's climate system, 105 PNAS 1786 (2008).
180 Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at 72-73.
181 U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 411.
182 Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at 73-74.

likely in the next 200 to 900 years.[183] According to the Fourth National Climate Assessment, "observational evidence suggests that ice dynamics already in progress have committed the planet to as much as 3.9 feet (1.2 m) worth of sea level rise from the West Antarctic Ice Sheet alone" and that "under the higher RCP8.5 scenario, Antarctic ice could contribute 3.3 feet (1 m) or more to global mean sea level over the remainder of this century, with some authors arguing that rates of change could be even faster."[184] Another potential tipping point is the release of carbon as CO_2 and methane from thawing Arctic permafrost, which has the potential to "drive continued warming even if human-caused emissions stopped altogether."[185] Increased rainfall and meltwater from Arctic glaciers have the potential to slow a major ocean current called the Atlantic meridional overturning circulation ("AMOC"). If the AMOC slows or collapses, the northeastern U.S. will see a dramatic increase in regional sea levels of as much as 1.6 feet (0.5 meters).[186] A recent analysis suggests the Earth System is at risk of crossing a planetary threshold that could lock in a rapid pathway toward much hotter conditions ("Hothouse Earth") propelled by self-reinforcing feedbacks, and that this risk could exist at 2°C temperature rise and increase significantly with additional warming.[187]

The disastrous effects of compound extreme events are already occurring, such as during Hurricane Sandy when sea level rise, abnormally high ocean temperatures, and high tides combined to intensify the storm and associated storm surge, and an atmospheric pressure field over Greenland steered the hurricane inland to an "exceptionally high-exposure location."[188]

IV. Global and U.S. greenhouse gas emissions continue to rise.

Global and U.S. greenhouse gas emissions continue to rise due to U.S. and international failures to adequately address climate change. Carbon dioxide (CO_2) is the dominant greenhouse gas

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[183] Joughin, Ian et al., Marine ice sheet collapse potentially under way for the Thwaites Glacier Basin, West Antarctica, 344 Science 735 (2014); Mouginot, Jérémie et al., Sustained increase in ice discharge from the Amundsen Sea Embayment, West Antarctica, from 1973 to 2013, 41 Geophysical Research Letters 1576 (2014); Rignot, Eric et al., Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011, 41 Geophysical Research Letters 3502 (2014); DeConto, Robert M. & David Pollard, Contribution of Antarctica to past and future sea-level rise, 531 Nature 591 (2016); Hansen, James et al., Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observation that 2°C global warming could be dangerous, 16 Atmospheric Chemistry and Physics 3761 (2016).
[184] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 420.
[185] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 303, 314-315, 419; Koven, Charles D. et al., Permafrost carbon-climate feedbacks accelerate global warming, 108 PNAS 14769 (2011); Commane, Róisín et al., Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic tundra, 114 PNAS 5361 (2017).
[186] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 418.
[187] Steffen, Will et al., Trajectories of the Earth System in the Anthropocene, 115 PNAS 33 (2018).
[188] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Vol. I (2017), https://science2017.globalchange.gov/ at 416.

driving anthropogenic climate change.[189] After three years of little or no emissions growth, global fossil CO_2 emissions increased 1.6 percent in 2017, reaching 36.2 Gt (billion tonnes) of CO_2 pollution—a level 63 percent higher than in 1990.[190] In 2018, global fossil CO_2 emissions grew even more steeply, estimated at 2.7 percent higher than 2017, reaching a record of 37.1 Gt CO_2 in just one year.[191]

U.S. carbon dioxide emissions rose sharply in 2018 after three years of decline and an overall downward trend since 2007. Analysis by the Global Carbon Project estimated that U.S. fossil CO_2 emissions increased by 2.5 percent in 2018, reaching 5.4 Gt of CO_2 pollution.[192] According to the analysis, the U.S. emissions increase largely came from a rise in natural gas consumption. Although emissions from U.S. coal use declined by 3.1 percent, emissions from natural gas use increased by 9.2 percent and emissions from oil use increased by 1.6 percent in 2018.[193]

Analysis by the International Energy Agency (IEA) estimated that U.S. energy-related emissions rose by 3.1 percent in 2018, fueled by a large increase in U.S. oil and gas consumption—the biggest increase globally.[194] U.S. natural gas consumption rose by 10 percent—the fastest increase since the beginning of IEA records in 1971—and oil demand increased by 540,000 barrels per day in 2018.[195] Additional analyses found that U.S. emissions in 2018 rose across all sectors—power, transport, industry and buildings.[196] In the power sector, although a record number of coal-fired power plants were retired, natural gas replaced most of the lost coal generation and fed most of the increase in electricity demand.[197] The transportation sector was the largest source of U.S. emissions, as demand rose for diesel and jet fuel.[198] As this analysis warned, "the U.S. was already off track in meeting its Paris Agreement targets" and the steep emissions increase in 2018 has made the gap even wider.[199]

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[189] National Research Council, Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia (2011), http://www.nap.edu/catalog/12877.html.
[190] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018); Jackson, Robert B. et al., Global energy growth is outpacing decarbonization, 13 Environmental Research Letters 120401 (2018).
[191] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018); Jackson, R.B. et al., Global energy growth is outpacing decarbonization, 13 Environmental Research Letters 120401 (2018).
[192] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018).
[193] Global Carbon Project, Global Carbon Budget 2018 (published on 5 December 2018) https://www.globalcarbonproject.org/carbonbudget/18/files/GCP_CarbonBudget_2018.pdf, at 35 (Fossil CO_2 Emissions in USA).
[194] International Energy Agency, Global Energy and CO2 Status Report (2019), https://www.iea.org/geco/
[195] International Energy Agency, Global Energy and CO2 Status Report (2019), https://www.iea.org/geco/
[196] Rhodium Group, Preliminary US Emissions Estimates for 2018, Energy and Climate Staff (January 8, 2019), https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/
[197] Rhodium Group, Preliminary US Emissions Estimates for 2018, Energy and Climate Staff (January 8, 2019), https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/
[198] Rhodium Group, Preliminary US Emissions Estimates for 2018, Energy and Climate Staff (January 8, 2019), https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/
[199] Rhodium Group, Preliminary US Emissions Estimates for 2018, Energy and Climate Staff (January 8, 2019), https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/

As emissions continue to rise, the average global atmospheric CO_2 concentration in 2018 reached 405 parts per million (ppm), a level not seen for millions of years.[200] The last time CO_2 in Earth's atmosphere was at 400 ppm, global mean surface temperatures were 2 to 3°C warmer and the Greenland and West Antarctic ice sheets melted, leading to sea levels that were 10 to 20 meters higher than today.[201] The current atmospheric CO_2 concentration is nearly one and half times larger than the pre-industrial level of 280 ppm, and much greater than levels during the past 800,000 years when the atmospheric CO_2 concentration fluctuated between ~174 and 280 ppm.[202] The atmospheric concentrations of methane (CH_4) and nitrous oxide (N_2O), two other potent greenhouse gases, are 257 percent and 122 percent of their pre-industrial levels.[203] Global carbon emissions over the past 15 to 20 years have tracked the highest emission scenario used in IPCC climate projections, the RCP8.5 scenario[204] which is projected to lead to devastating impacts.[205]

V. Climate change impacts are long-lasting.

The greenhouse gases currently in the atmosphere commit the planet to long-lasting climate change impacts that are irreversible on a multi-century to millennial time scale.[206] CO_2 has a long residence time in the atmosphere, meaning that a large fraction of the CO_2 emitted to date will remain in the atmosphere for tens to hundreds of thousands of years.[207] Climatic changes that are caused by CO_2 emissions, such as surface warming, ocean warming, sea level rise, and ocean acidification are long-lasting and irreversible on human timescales.[208] Even if all greenhouse emissions were to completely cease today, significant ongoing regional changes in temperature

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[200] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018); World Meteorological Organization, WMO Greenhouse Gas Bulletin, No. 13, October 30, 2017 at 5.
[201] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018); World Meteorological Organization, WMO Greenhouse Gas Bulletin, No. 13, October 30, 2017 at 5.
[202] Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at 4, 44; World Meteorological Organization, WMO Greenhouse Gas Bulletin, No. 13, October 30, 2017 at 1, 4.
[203] World Meteorological Organization, WMO Greenhouse Gas Bulletin, No. 13, October 30, 2017 at 2.
[204] U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Volume I x(2017), https://science2017.globalchange.gov/ at 31, 133, 134, and 152 (e.g. "The observed increase in global carbon emissions over the past 15–20 years has been consistent with higher scenarios (e.g., RCP8.5) (*very high confidence*)" at 31.)
[205] Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) at Figure 2.1.
[206] Intergovernmental Panel on Climate Change, 2013: Summary for Policymakers *in* Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2013) at 26.
[207] Clark, Peter U. et al., Consequences of twenty-first century policy for multi-millennial climate and sea-level change, 6 Nature Climate Change 360 (2016).
[208] Archer, David & Victor Brovkin, The millennial atmospheric lifetime of anthropogenic CO_2, 90 Climatic Change 283 (2008); Solomon, Susan et al., Irreversible climate change due to carbon dioxide emissions, 106 PNAS 1704 (2009).

and precipitation would still occur,[209] global average temperatures would not drop significantly for at least 1,000 years,[210] and sea-level rise would continue for millennia.[211] The National Research Council cautioned that "emission reduction choices made today matter in determining impacts that will be experienced not just over the next few decades, but also into the coming centuries and millennia."[212]

VI. New fossil fuel production and infrastructure must be halted and much existing production must be phased out to avoid the worst dangers from climate change.

Scientific research has established that there is no room in the global carbon budget for new fossil fuel extraction if we are to avoid the worst dangers from climate change. Instead, new fossil fuel production and infrastructure must be halted and much existing production must be phased out to meet the Paris Agreement climate targets and avoid catastrophic climate damages.

The United States has committed to the climate change target of holding the long-term global average temperature "to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" under the Paris Agreement.[213] The Paris Agreement established the 1.5°C climate target given the evidence that 2°C of warming would lead to catastrophic climate harms.[214] Scientific research has estimated the global carbon budget—the remaining amount of carbon dioxide that can be emitted—for maintaining a likely chance of meeting the Paris climate targets, providing clear benchmarks for United States and global climate action.[215]

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[209] Gillett, Nathan P. et al, Ongoing climate change following a complete cessation of carbon dioxide emissions, 4 Nature Geoscience 83 (2011).

[210] Archer, David & Victor Brovkin, The millennial atmospheric lifetime of anthropogenic CO_2, 90 Climatic Change 283 (2008); Solomon, Susan et al., Irreversible climate change due to carbon dioxide emissions, 106 PNAS 1704 (2009).

[211] Solomon, Susan et al., Irreversible climate change due to carbon dioxide emissions, 106 PNAS 1704 (2009).

[212] National Research Council, Warming World: Impacts by Degree (2011) at 3.

[213] United Nations Framework Convention on Climate Change, Conference of the Parties, Nov. 30-Dec. 11, 2015, Adoption of the Paris Agreement Art. 2, U.N. Doc. FCCC/CP/2015/L.9 (December 12, 2015), http://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf ("Paris Agreement"). The United States signed the Paris Agreement on April 22, 2016 as a legally binding instrument through executive agreement, and the treaty entered into force on November 4, 2016.

[214] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (October 6, 2018), http://www.ipcc.ch/report/sr15/.

[215] The 2018 IPCC special report on *Global Warming of 1.5°C* estimated the carbon budget for a 66 percent probability of limiting warming to 1.5°C at 420 $GtCO_2$ and 570 $GtCO_2$ from January 2018 onwards, depending on the temperature dataset used. At the current emissions rate of 42 $GtCO_2$ per year, this carbon budget would be expended in just 10 to 14 years. *See* Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (October 6, 2018), at SPM-16.

Importantly, a 2016 global analysis found that the carbon emissions that would be released from burning the oil, gas, and coal in the world's currently operating fields and mines would fully exhaust and exceed the carbon budget consistent with staying below 1.5°C.[216] The reserves in currently operating oil and gas fields alone, even excluding coal mines, would likely lead to warming beyond 1.5°C.[217] An important conclusion of the analysis is that no new fossil fuel extraction or infrastructure should be built, and governments should grant no new permits for extraction and infrastructure. Furthermore, many of the world's existing oil and gas fields and coal mines will need to be closed before their reserves are fully extracted in order to limit warming to 1.5°C.[218] In short, the analysis established that there is no room in the carbon budget for new fossil fuel extraction or infrastructure anywhere, including in the United States, and much existing fossil fuel production must be phased out to avoid the catastrophic damages from climate change.[219]

A 2019 analysis underscored that the United States must halt new fossil fuel extraction and rapidly phase out existing production to avoid jeopardizing our ability to meet the Paris climate targets and avoid the worst dangers of climate change.[220] The analysis showed that the U.S. oil and gas industry is on track to account for 60 percent of the world's projected growth in oil and gas production between now and 2030—the time period over which the IPCC concluded that global carbon dioxide emissions should be roughly halved to meet the 1.5°C Paris Agreement target.[221] Between 2018 and 2050, the United States is poised to unleash the world's largest burst of CO_2 emissions from new oil and gas development—primarily from shale and largely dependent on fracking—estimated at 120 billion metric tons of CO_2 which is equivalent to the lifetime CO_2 emissions of nearly 1,000 coal-fired power plants. Based on a 1.5°C IPCC pathway, U.S. production alone would exhaust nearly 50 percent of the world's total allowance for oil and

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[216] Oil Change International, The Sky's Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel Production (September 2016), http://priceofoil.org/2016/09/22/the-skys-limit-report/ at Table 3. According to this analysis, the CO_2 emissions from developed reserves in existing and under-construction global oil and gas fields and existing coal mines are estimated at 942 Gt CO_2, which vastly exceeds the 1.5°C-compatible carbon budget estimated in the 2018 IPCC report on *Global Warming of 1.5°C* at 420 $GtCO_2$ to 570 $GtCO_2$.

[217] The CO_2 emissions from developed reserves in currently operating oil and gas fields alone are estimated at 517 Gt CO_2, which would likely exhaust the 1.5°C-compatible carbon budget estimated in the 2018 IPCC report on *Global Warming of 1.5°C* at 420 $GtCO_2$ to 570 $GtCO_2$.

[218] Oil Change International, The Sky's Limit California: Why the Paris Climate Goals Demand That California Lead in a Managed Decline of Oil Extraction (2018), http://priceofoil.org/ca-skys-limit at 7, 13.

[219] This conclusion was reinforced by the IPCC Fifth Assessment Report which estimated that global fossil fuel reserves exceed the remaining carbon budget (from 2011 onward) for staying below 2°C (a target incompatible with the Paris Agreement) by 4 to 7 times, while fossil fuel resources exceed the carbon budget for 2°C by 31 to 50 times. *See* Bruckner, Thomas et al., 2014: Energy Systems *in* Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (2014), at Table 7.2.

[220] Oil Change International, Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits (January 2019), http://priceofoil.org/drilling-towards-disaster.

[221] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018), http://www.ipcc.ch/report/sr15/ at SPM-15.

gas by 2030 and exhaust more than 90 percent by 2050. Additionally, if U.S. coal production is to be phased out over a timeframe consistent with equitably meeting the Paris goals, at least 70 percent of U.S. coal reserves in already-producing mines must stay in the ground. In short, if not curtailed, U.S. fossil fuel expansion will impede the world's ability to meet the Paris climate targets and preserve a livable planet.

These analyses highlights that the United States has an urgent responsibility to lead in the transition from fossil fuel production to 100 percent clean energy, as a wealthy nation with ample financial resources and technical capabilities, and due to its dominant role in driving climate change and its harms. The U.S. is currently the world's largest oil and gas producer and third-largest coal producer.[222] The U.S. is also the world's largest historic emitter of greenhouse gas pollution, responsible for 25 percent of cumulative global CO_2 emissions since 1870, and is currently the world's second highest emitter on an annual and per capita basis.[223] The U.S. must focus its resources and technology to rapidly phase out extraction while investing in a just transition for affected workers and communities currently living on the front lines of the fossil fuel industry and its pollution.[224]

Research on the United States' carbon budget and the carbon emissions locked in U.S. fossil fuels similarly establishes that the U.S. must halt new fossil fuel production and rapidly phase out existing production to avoid the worst dangers of climate change. An analysis of U.S. fossil fuel resources demonstrates that the potential carbon emissions from already leased fossil fuel resources on U.S. federal lands would essentially exhaust the remaining U.S. carbon budget consistent with the 1.5°C target. This 2015 analysis estimated that recoverable fossil fuels from U.S. federal lands would release up to 349 to 492 $GtCO_2eq$ of carbon emissions, if fully extracted and burned.[225] Of that amount, already leased fossil fuels would release 30 to 43 $GtCO_2eq$ of emissions, while as yet unleased fossil fuels would emit 319 to 450 $GtCO_2eq$ of emissions. Thus, carbon emissions from already leased fossil fuel resources on federal lands alone (30 to 43 $GtCO_2eq$) would essentially exhaust the U.S. carbon budget for a 1.5°C target (25 to 57 $GtCO_2eq$)[226], if these leased fossil fuels are fully extracted and burned. The potential carbon emissions from unleased federal fossil fuel resources (319 to 450 $GtCO_2eq$) would

[222] Oil Change International, Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits (January 2019), http://priceofoil.org/drilling-towards-disaster at 5.
[223] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth System Science Data 2141 (2018) at Figure 5, 2167; Global Carbon Project, Global Carbon Budget 2018 (published on 5 December 2018) https://www.globalcarbonproject.org/carbonbudget/18/files/GCP_CarbonBudget_2018.pdf at 19 (Historical cumulative fossil CO_2 emissions by country).
[224] Piggot, Georgia et al., Realizing a just and equitable transition away from fossil fuels, Discussion brief, Stockholm Environment Institute (January 2019), https://www.sei.org/publications/just-and-equitable-transition-fossil-fuels/.
[225] Ecoshift Consulting, et al., The Potential Greenhouse Gas Emissions of U.S. Federal Fossil Fuels, Prepared for Center for Biological Diversity & Friends of the Earth (2015).
[226] Robiou du Pont, Yann et al., Equitable mitigation to achieve the Paris Agreement goals, 7 Nature Climate Change 38 (2017), at Supplemental Table 1.

exceed the U.S. carbon budget for limiting warming to 1.5°C many times over.[227] This does not include the additional carbon emissions that will be emitted from fossil fuels extracted on non-federal lands, estimated up to 500 $GtCO_2eq$ if fully extracted and burned.[228]

In 2018, the U.S. Geological Survey and Department of the Interior estimated that carbon emissions released from extraction and end-use combustion of fossil fuels produced on federal lands alone—not including non-federal lands—accounted for approximately one quarter of total U.S. carbon emissions during 2005 to 2014.[229] This research further establishes that the United States must halt new fossil fuel projects and close existing fields and mines before their reserves are fully extracted to achieve the Paris climate targets and avoid the worst damages from climate change.

Research that models the emissions pathways needed to meet the Paris climate targets also shows that a rapid end to fossil fuel extraction is critical. The 2018 IPCC special report on *Global Warming of 1.5°C* concluded that pathways to limit warming to 1.5°C with little or no overshoot require "a rapid phase out of CO_2 emissions and deep emissions reductions in other GHGs and climate forcers."[230] In pathways consistent with 1.5°C, global net anthropogenic CO_2 emissions must decline by about 45 percent from 2010 levels by 2030 and reach net zero around 2045 or 2050.[231] Additionally, 1.5°C-consistent pathways require a full decarbonization of the power sector by mid-century.[232] The report makes clear the necessity of immediate, deep greenhouse gas reductions to avoid devastating climate change-driven damages, and underscores the high costs of inaction or delays, particularly in the next crucial decade, in making these cuts.

Ending the approval of new fossil fuel production and infrastructure is also critical for preventing "carbon lock-in," where approvals and investments made now can lock in decades-worth of fossil fuel extraction that we cannot afford. New approvals for wells, mines, and fossil fuel

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[227] Ecoshift Consulting, et al., The Potential Greenhouse Gas Emissions of U.S. Federal Fossil Fuels, Prepared for Center for Biological Diversity & Friends of the Earth (2015), at 4.

[228] Ecoshift Consulting, et al., The Potential Greenhouse Gas Emissions of U.S. Federal Fossil Fuels, Prepared for Center for Biological Diversity & Friends of the Earth (2015) at 3 ("the potential GHG emissions of federal fossil fuels (leased and unleased) are 349 to 492 Gt CO2e, representing 46 percent to 50 percent of potential emissions from all remaining U.S. fossil fuels").

[229] Merrill, Matthew D. et al., Federal lands greenhouse gas emissions and sequestration in the United States—Estimates for 2005–14: U.S. Geological Survey Scientific Investigations Report 2018–5131 (2018) at 8.

[230] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018), http://www.ipcc.ch/report/sr15/ at 2-28.

[231] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018), http://www.ipcc.ch/report/sr15/ at SPM-15.

[232] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018), http://www.ipcc.ch/report/sr15/ at 2-29.

infrastructure—such as pipelines and marine and rail import and export terminals—require upfront investments that provide financial incentives for companies to continue production for decades into the future.[233] As summarized by Green and Denniss (2018):

> When production processes require a large, upfront investment in fixed costs, such as the construction of a port, pipeline or coalmine, future production will take place even when the market price of the resultant product is lower than the long-run opportunity cost of production. This is because rational producers will ignore 'sunk costs' and continue to produce as long as the market price is sufficient to cover the marginal cost (but not the average cost) of production. This is known as 'lock-in.'"[234]

Given the long-lived nature of fossil fuel projects, ending the approval of new fossil fuel projects is necessary to avoid the lock-in of decades of fossil fuel production and associated emissions.

A 2019 study highlighted the importance of immediately halting all new fossil fuel infrastructure projects to preserve a livable planet. The study found that phasing out all fossil fuel infrastructure at the end of its design lifetime, starting immediately, preserves a 64 percent chance of keeping peak global mean temperature rise below 1.5°C.[235] This means replacing fossil fuel power plants, cars, aircraft, ships, and industrial infrastructure with zero carbon alternatives at the end of their lifespans, starting now. The study found that delaying mitigation until 2030 reduces the likelihood that 1.5 °C would be attainable to below 50 percent, even if the rate of fossil fuel retirement were accelerated. In other words, every year of delay in phasing out fossil fuel infrastructure makes "lock-in" more difficult to escape and the possibility of keeping global temperature rise below 1.5°C less likely. The study concluded that although difficult, "1.5 °C remains possible and is attainable with ambitious and immediate emission reduction across all sectors."

VII. Fossil fuel companies are responsible for the majority of greenhouse gas emissions and global warming.

Research has found that a group of the world's largest fossil fuel producers are responsible for the majority of greenhouse gas emissions and global warming since the Industrial Revolution and during the past three decades. A study that analyzed emissions primarily from companies

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233 Davis, Steven J. and Robert H. Socolow, Commitment accounting of CO_2 emissions, 9 Environmental Research Letters 084018 (2014); Erickson, Peter et al., Assessing carbon lock-in, 10 Environmental Research Letters 084023 (2015); Erickson, Peter et al., Carbon lock-in from fossil fuel supply infrastructure, Stockholm Environment Institute, Discussion Brief (2015); Seto, Karen C. et al., Carbon Lock-In: Types, Causes, and Policy Implications, 41 Annual Review of Environmental Resources 425 (2016); Green, Fergus and Richard Denniss, Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies, 150 Climatic Change 73(2018).

234 Green, Fergus and Richard Denniss, Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies, 150 Climatic Change 73(2018) at 78.

235 Smith, Christopher J. et al., Current fossil fuel infrastructure does not yet commit us to 1.5°C warming, Nature Communications, doi.org/10.1038/s41467-018-07999-w (2019).

that produce fossil fuels found that 63 percent of global industrial CO_2 and methane emissions between 1751 and 2010 came from just 90 international entities—56 crude oil and natural gas producers, 37 coal extractors, and 7 cement producers. These 90 entities—consisting of 50 investor-owned companies, 31 majority state-owned companies, and 9 centrally-planned state industries—are responsible for 914 billion tonnes of CO_2-equivalent ($GtCO_2e$) emissions. Cumulatively, investor-owned entities are responsible for 315 $GtCO_2e$, state-owned companies for 288 $GtCO_2e$, and nation-states for 312 $GtCO_2e$.[236]

Based on historical data and climate modeling, emissions from these 90 fossil fuel "majors" have contributed an estimated 57 percent to the observed rise in atmospheric CO_2, approximately 50 percent to the rise in global mean surface temperature, and approximately 32 percent to global mean sea level rise between 1751 and 2010.[237] A separate study attributed 71 percent of global industrial greenhouse gas emissions since 1988 to just 100 fossil fuel producers, with 51 percent of emissions since 1988 attributable to just 25 corporate and state producers, including ExxonMobil, Shell, BP, Chevron, and Peabody.[238]

Several U.S. fossil fuel companies rank in the top 20 worst cumulative emitters, including Chevron at #1, ExxonMobil at #2, ConocoPhillips at #9, Peabody Energy at #12, and Consol Energy, Inc. at #18.[239] Cumulative emissions from the 20 largest investor-owned and state-owned energy companies alone account for 30 percent of the global industrial emissions between 1751 and 2010. Emissions from the top 20 contributed approximately 27 percent of the increase in atmospheric CO_2, approximately 24 percent of the increase in warming, and approximately 13 to 16 percent of the increase in global sea level rise.[240]

Fourteen companies were consistently found to be in the top 20 in terms of the global impacts of their emissions: seven investor-owned companies (Chevron, ExxonMobil, BP, Royal Dutch Shell, ConocoPhillips, Peabody Energy, and Total), and seven majority state-owned companies (Saudi Aramco, Gazprom, National Iranian oil Company, Pemex, Petroleos de Venezuela, Coal India, and Kuwait Petroleum). Chevron is the largest company contributor to rises in both global temperatures and sea level rise between 1880 and 2010 and the second-largest contributor to the rise in atmospheric carbon dioxide. Meanwhile, ExxonMobil is the third-largest contributor to

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[236] Heede, Richard, Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854-2010, 122 Climatic Change 229 (2014).
[237] Ekwurzel, Brenda et al., The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers, 144 Climatic Change 579 (2017).
[238] CDP and Climate Accountability Institute, The Carbon Majors Database, CDP Carbon Majors Report 2017 (July 2017), https://www.cdp.net/en/articles/media/new-report-shows-just-100-companies-are-source-of-over-70-of-emissions.
[239] Heede, Richard, Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854-2010, 122 Climatic Change 229 (2014).
[240] Ekwurzel, Brenda et al., The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers, 144 Climatic Change 579 (2017).

both the historical rise in atmospheric CO_2 and warming, and the second-largest contributor to global sea level rise.[241]

The year 1988 marks when James Hansen testified in the U.S. Congress that the human signal of climate change had been detected. 1988 was also the year in which the Intergovernmental Panel on Climate Change was formed to provide a scientific basis for policy action on climate change.[242] Yet, half of all industrial emissions of CO_2 since the Industrial Revolution have been emitted *since* 1988. In the face of scientific evidence of the dangers of fossil fuel emissions and resulting climate change, fossil fuel producers failed to reduce their emissions or disclose climate risks, [243] and instead often worked in direct contradiction to emissions reduction goals and spread climate misinformation.[244]

For instance, between 1988 and 2005, ExxonMobil invested over $16 million into front groups that spread misleading claims about climate science.[245] Rather than changing their business models, fossil fuel companies remain focused on not only exploiting existing oil, gas, and coal reserves, but also on developing new ones. Rather than supporting fair and effective climate policies, fossil fuel majors including Chevron, Shell, and ConocoPhillips remain members of the American Legislative Exchange Council's (ALEC) Energy, Environment and Agriculture Task Force which is focused on repealing renewable energy standards and regional climate policy initiatives in U.S. states.[246] Rather than disclosing climate risks, ExxonMobil consistently focused on the uncertainties surrounding climate change in its New York Times advertorials, while only acknowledging the true risks in less public internal and peer-reviewed communications.[247] In October 2018, the New York Attorney General sued Exxon for lying to its investors about climate change.[248] Fossil fuel companies have not even begun to pay their fair share of the costs for climate damages and adaptation.[249]

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241 Ekwurzel, Brenda et al., The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers, 144 Climatic Change 579 (2017).

242 Hansen, James et al., Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model, 93 Journal of Geophysical Research 9341 (1988); Frumhoff, Peter et al., The climate responsibilities of industrial carbon producers, 132 Climatic Change 157 (2015).

243 Frumhoff, Peter et al., The climate responsibilities of industrial carbon producers, 132 Climatic Change 157 (2015).

244 Union of Concerned Scientists, The Climate Accountability Scorecard: Ranking Major Fossil Fuel Companies on Climate Deception, Disclosure, and Action (2016).

245 Ward, Robert, Letter dated Sept 4, 2006 from the Royal Society to ExxonMobil (accessed January 17, 2018); Frumhoff, Peter et al., The climate responsibilities of industrial carbon producers, 132 Climatic Change 157 (2015).

246 Frumhoff, Peter et al., The climate responsibilities of industrial carbon producers, 132 Climatic Change 157 (2015).

247 Supran, Geoffrey and Oreskes, Naomi, Assessing ExxonMobil's climate change communications (1977-2014), 12 Environ. Res. Lett. 084019 (2017).

248 Mufson, Steven, *New York sues ExxonMobil, saying it 'misled' investors about climate change risks,* The Washington Post, October 24, 2018, https://www.washingtonpost.com/energy-environment/2018/10/24/new-york-sues-exxonmobil-accusing-it-deceiving-investors-about-climate-change-risks/?utm_term=.b3da65e26bf4

249 Union of Concerned Scientists, The Climate Accountability Scorecard: Ranking Major Fossil Fuel Companies on Climate Deception, Disclosure, and Action (2016).

However, there are evolving efforts to hold fossil fuel companies directly accountable for their role in climate change. In July 2018, Rhode Island became the first state to file suit against the fossil fuel industry, naming 14 oil companies including BP, Chevron, ConcocoPhillips, ExxonMobil, and Royal Dutch Shell to hold them accountable for their role in propagating the climate crisis. As stated in the lawsuit:

> As a direct and proximate consequence of Defendants' wrongful conduct described in this Complaint, average sea level will rise substantially along Rhode Island's coast; average temperatures and extreme heat days will increase; flooding, extreme precipitation events, such as tropical storms and hurricanes, and drought will become more frequent and more severe; and the ocean will warm and become more acidic.[250]

The lawsuit states the Rhode Island is already seeing such effects.

Similar lawsuits had previously been filed by cities and counties. In July 2017, Marin County, San Mateo County, and the city of Imperial Beach in California sued dozens of fossil fuel companies including Chevron, ExxonMobil, BP, and Dutch Shell for future damages from sea level rise.[251] In September 2017, the cities of San Francisco and Oakland likewise filed suit to pressure fossil fuel companies to fulfill their obligations to address climate change.[252] Then, in January 2018, the New York City government filed suit against BP, Chevron, ConocoPhillips, ExxonMobil and Royal Dutch Shell because of their role in propagating the climate crisis.[253] The latter two suits were dismissed, but are currently on appeal and have only fueled momentum, with the list of cities and counties filing lawsuits continuing to grow. Between May and June of 2018, Kings County, Washington and Boulder, Boulder County, and San Miguel County, Colorado also filed lawsuits seeking to hold fossil fuel companies accountable for costs related to climate change.[254]

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[250] Kusnetz, Nicholas, *Faced with the costs of climate change, R.I. sues fossil-fuel companies*, The Boston Globe, July 3, 2018, https://www.bostonglobe.com/metro/2018/07/02/faced-with-costs-climate-change-sues-fossil-fuel-companies/mGflVecLlTflLHCmBHYzAM/story.html

[251] Mooney, Chris and Dennis, Brady, *This could be the next big strategy for suing over climate change*, The Washington Post, July 20, 2017, https://www.washingtonpost.com/news/energy-environment/wp/2017/07/20/this-could-be-the-next-big-strategy-for-suing-over-climate-change/?tid=a_mcntx&utm_term=.2f4a5b5a6ec3

[252] Mooney, Chris and Grandoni, Dino, *New York City sues Shell, ExxonMobil and other oil companies over climate change,* The Washington Post, January 10, 2018, https://www.washingtonpost.com/news/energy-environment/wp/2018/01/10/new-york-city-sues-shell-exxonmobil-and-other-oil-majors-over-climate-change/?utm_term=.f57ed9b8d05e

[253] Mooney, Chris and Grandoni, Dino, *New York City sues Shell, ExxonMobil and other oil companies over climate change*, The Washington Post, January 10, 2018, https://www.washingtonpost.com/news/energy-environment/wp/2018/01/10/new-york-city-sues-shell-exxonmobil-and-other-oil-majors-over-climate-change/?utm_term=.f57ed9b8d05e

[254] Hasemyer, David, *Fossil Fuels on Trial: Where the Major Climate Change Lawsuits Stand Today*, InsideClimate News, January 6, 2019, https://insideclimatenews.org/news/04042018/climate-change-fossil-fuel-company-lawsuits-timeline-exxon-children-california-cities-attorney-general

The list even extends beyond municipalities. In November 2018, the Pacific Coast Federation of Fishermen's Associations filed a lawsuit against 30 fossil fuel companies seeking damages brought about by climate change on behalf of crab fishers, their businesses and families, and local communities in California and Oregon.[255]

VIII. U.S. climate policy is inadequate to avoid catastrophic damages from climate change.

The United States has contributed more to climate change than any other country. The U.S. is the world's biggest cumulative emitter of greenhouse gas pollution, responsible for 25 percent of cumulative global CO_2 emissions since 1850, and is currently the world's second highest emitter on an annual and per capita basis.[256] However, U.S. climate policy is wholly inadequate to meet the international Paris Agreement target to hold global average temperature rise well below 2°C to avoid the worst dangers of climate change.

As summarized by the Fourth National Climate Assessment, efforts to mitigate greenhouse gas emissions do not approach the scale needed to avoid "substantial damages to the U.S. economy, environment, and human health and well-being over the coming decades":

> Climate-related risks will continue to grow without additional action. Decisions made today determine risk exposure for current and future generations and will either broaden or limit options to reduce the negative consequences of climate change. While Americans are responding in ways that can bolster resilience and improve livelihoods, neither global efforts to mitigate the causes of climate change nor regional efforts to adapt to the impacts currently approach the scales needed to avoid substantial damages to the U.S. economy, environment, and human health and well-being over the coming decades.[257]

In 2016, the U.S. committed to holding the long-term global average temperature to well below 2°C and "to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" under the international Paris Agreement.[258] Existing U.S. domestic laws including the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act, and others provide authority to executive branch agencies to require greenhouse gas emissions reductions from virtually all major sources in the U.S., sufficient to meet the Paris Agreement temperature

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[255] Hasemyer, David, *Crab Fishers Sue Fossil Fuel Industry Over Climate Change Damage*, InsideClimate News, November 14, 2018, https://insideclimatenews.org/news/14112018/crab-fishermen-climate-change-lawsuit-fossil-fuel-companies-ocean-algae-neurotoxin-fishery-closure

[256] LeQuéré, Corinne et al., Global carbon budget 2018, 10 Earth Syst. Sci. Data 2141 (2018).

[257] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States, Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/ at 34.

[258] United Nations Framework Convention on Climate Change, Conference of the Parties Nov. 30-Dec. 11, 2015, Adoption of the Paris Agreement Art. 2, U.N. Doc. FCCC/CP/2015/L.9 (Dec. 12, 2015) ("Paris Agreement").

commitment.

However, the Trump administration has focused on pushing through harmful rollbacks of federal climate policy, and federal agencies are either failing to implement or only partially implementing domestic law and policy mandating greenhouse gas reductions. Trump administration rollbacks of federal climate policy include rescinding the Climate Action Plan, attempts to repeal the Clean Power Plan, a plan to dramatically expand offshore oil drilling in all oceans along U.S. coast, an attempt to rescind the Obama-era withdrawal of offshore drilling in U.S. federal waters in most of the Arctic and parts of the Atlantic, lifting of the moratorium on new federal coal leases, attempts to weaken emissions standards for cars and light duty trucks, delaying the implementation of methane emissions standards for new and modified oil and gas facilities, and the intended withdrawal from the Paris Agreement.

As a result, current U.S. climate policy has been ranked as "critically insufficient" by an international team of climate policy experts and climate scientists who concluded: "These steps represent a severe backwards move and an abrogation of the United States' responsibility as the world's second largest emitter at a time when more, not less, commitment is needed from all governments to avert the worst impacts of climate change."[259]

In 2016 during the Obama administration, the United States pledged a Nationally Determined Contribution (NDC) under the Paris Agreement to reduce net greenhouse gas emissions by 26 to 28 percent below 2005 levels by 2025 including land use, land use change and forestry (LULUCF), equivalent to 9 to 16 percent below 1990 levels excluding LULUCF.[260] Although the U.S. NDC legally remains in place at least until 2019, the Trump Administration has already stopped implementation.[261] However, this NDC was ranked as inconsistent with keeping warming below 2°C "let alone with the Paris Agreement's stronger 1.5°C limit" by an international team of climate experts.[262] Moreover, under the Trump administration, U.S. climate policy is insufficient to attain even this inadequate NDC pledge.[263]

Furthermore, to meet the carbon budget for keeping temperature rise well below 2°C, most U.S. and global fossil fuels must remain undeveloped and fossil fuel production must be phased out globally within the next several decades.[264] However, U.S. policies aggressively promote ever

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[259] Climate Action Tracker, USA (last updated November 29, 2018), http://climateactiontracker.org/countries/usa.
[260] *See* the U.S. Nationally Determined Contribution submitted to the UNFCCC, *available at* http://www4.unfccc.int/Submissions/INDC/Published percent20Documents/United percent20States percent20of percent20America/1/U.S. percent20Cover percent20Note percent20INDC percent20and percent20Accompanying percent20Information.pdf
[261] Climate Action Tracker, USA (last updated November 29, 2018), http://climateactiontracker.org/countries/usa.
[262] Climate Action Tracker, USA (last updated November 29, 2018), http://climateactiontracker.org/countries/usa.
[263] Climate Action Tracker, USA (last updated November 29, 2018), http://climateactiontracker.org/countries/usa.
[264] Rogelj, Joeri et al., Energy system transformations for limiting end-of-century warming to below 1.5°C, 5 Nature Climate Change 519 (2015): Rogelj et al. (2015) estimated that a reasonable likelihood of limiting warming to 1.5°

greater fossil fuel production in many ways. For example, in 2005, Congress exempted fracking from the Safe Drinking Water Act in legislation known as the "Halliburton Loophole." Thereafter, fracking spread rapidly and facilitated a dramatic increase in U.S. natural gas[265] and crude oil production.[266] After Congress lifted the 40-year old crude oil export ban in December 2015, U.S. crude oil shipments have exceeded two million barrels per day.[267] The U.S. is currently the world's largest oil and gas producer and third-largest coal producer.[268] U.S. subsidies are also spurring fossil fuel production. A recent study assessing the impact of major federal and state subsidies on oil production found that these subsidies push nearly half of new oil investments into profitability, potentially increasing U.S. oil production by 17 billion barrels over the next few decades.[269] In short, U.S. policy is incentivizing rather than reducing fossil fuel production.

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or 2°C requires global CO_2 emissions to be phased out by mid-century and likely as early as 2040-2045; Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (October 6, 2018), http://www.ipcc.ch/report/sr15/; Oil Change International, Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits (January 2019), http://priceofoil.org/drilling-towards-disaster.

[265] U.S. Energy Information Administration, Hydraulically fractured wells provide two-thirds of U.S. natural gas production (May 5, 2016), https://www.eia.gov/todayinenergy/detail.php?id=26112.

[266] U.S. Energy Information Administration, Hydraulic fracturing accounts for about half of current U.S. crude oil production (March 15, 2016), https://www.eia.gov/todayinenergy/detail.php?id=25372.

[267] U.S. Energy Information Administration, For one week in November, the U.S. was a net exporter of crude oil and petroleum products (December 12, 2018), https://www.eia.gov/todayinenergy/detail.php?id=37772

[268] Oil Change International, Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits (January 2019), http://priceofoil.org/drilling-towards-disaster.

[269] Erickson, Peter et al., Effect of subsidies to fossil fuel companies on united states crude oil production, 2 Nature Energy 891 (2017).

Cited References

Albright, Rebecca et al., Reversal of ocean acidification enhances net coral reef calcification, 531 Nature 362 (2016)

Archer, David & Victor Brovkin, The millennial atmospheric lifetime of anthropogenic CO2, 90 Climatic Change 283 (2008)

Atkinson, L.P. et al., Sea Level Rise and Flooding Risk in Virginia, CCPO Publications, Paper 102 (2013), http://digitalcommons.odu.edu/ccpo_pubs/102

Balaguru, Karthik et al., Future hurricane storm surge risk for the U.S. gulf and Florida coasts based on projections of thermodynamic potential intensity, 138 Climatic Change 99 (2016)

Barnett, Tim, et al., Human-Induced changes in the hydrology of the Western United States, 319 Science 1080 (2008)

Barnosky, Anthony D. et al., Approaching a state shift in Earth's biosphere, 486 Nature 52 (2012)

Barton, Alan et al., The Pacific oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects, 57 Limnology and Oceanography 698 (2012)

Bednaršek, N. et al., Limacina helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem, 281 Proceedings of the Royal Society B 20140123 (2014)

Bevis, Michael et al., Accelerating changes in ice mass within Greenland and the ice sheet's sensitivity to atmospheric forcing, 116 PNAS 6 (2019)

Biskaborn, Boris K. et al., Permafrost is warming at a global scale, 10 Nature Communications 264 (2019)

Box, Jason E. et al., Global sea-level contribution from Arctic land ice: 1971-2017, 13 Environmental Research Letters 125012 (2018)

Breitburg, Denise et al., Declining oxygen in the global ocean and coastal waters, 359 Science 46 (2018)

Brown, M.E. et al., Climate Change, Global Food Security, and the U.S. Food System (2015)

Bruckner, Thomas et al., 2014: Energy Systems *in* Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (2014)

Bruno, John F. & Elizabeth R. Selig, Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons, 8 PLoS One e711 (2007)

Burke, Marshall et al., Higher temperatures increase suicide rates in the United States and Mexico, 8 Nature Climate Change 723 (2018)

Cahill, A.E. et al., How does climate change cause extinction?, 280 Proceedings of the Royal Society B 20121890 (2012)

Carpenter, Kent E. et al., One-third of reef-building corals face elevated extinction risk from climate change and local impacts, 321 Science 560 (2008)

Cayan, Daniel R. et al., Future dryness in the southwest US and the hydrology of the early 21st century drought, 107 PNAS 107 (2010)

CDP and Climate Accountability Institute, The Carbon Majors Database, CDP Carbon Majors Report 2017 (July 2017)

Chan, F. et al., The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions, California Ocean Science Trust (April 2016)

Chen, I-Ching et al., Rapid range shifts of species associated with high levels of climate warming, 333 Science 1024 (2011)

Cheng, Liging et al., How fast are the oceans warming?, 363 Science 128 (2019)

Clark, Peter U. et al., Consequences of twenty-first century policy for multi-millennial climate and sea-level change, 6 Nature Climate Change 360 (2016)

Climate Action Tracker, USA, http://climateactiontracker.org/countries/usa (last updated November 29, 2018)

Climate Central, Surging Seas Risk Zone Map, http://sealevel.climatecentral.org/ (accessed March 22, 2019)

Commane, Róisín et al., Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic tundra, 114 PNAS 5361 (2017)

Coumou, Dim & Stefan Rahmstorf, A decade of weather extremes, 2 Nature Climate Change 491 (2012)

Davis, Steven J. and Robert H. Socolow, Commitment accounting of CO2 emissions, Environmental Research Letters 9: 084018 (2014)

DeConto, Robert M. & David Pollard, Contribution of Antarctica to past and future sea-level rise, 531 Nature 591 (2016)

Deutsch, Curtis A. et al., Increase in crop losses to insect pests in a warming climate, 361

Science 916 (2018)

Duffy, Philip B. et al., Strengthened scientific support for the Endangerment Finding for atmospheric greenhouse gases, 363 Science 6427 (2019)

Eakin, C. Mark et al., Caribbean corals in crisis: record thermal stress, bleaching, and mortality in 2005, 5 PLoS ONE e13969 (2010)

Ecoshift Consulting, et al., The Potential Greenhouse Gas Emissions of U.S. Federal Fossil Fuels, Prepared for Center for Biological Diversity & Friends of the Earth (2015)

Eisen, Rebecca J., County-Scale Distribution of Ixodes scapularis and Ixodes pacificus (Acari: Ixodidae) in the Continental United States, 53 Journal of Medical Entomology 349 (2016)

Ekstrom, Julia A. et al., Vulnerability and adaptation of U.S. shellfisheries to ocean acidification, 5 Nature Climate Change 207 (2015)

Ekwurzel, B. et al., The rise in global atmospheric CO2, surface temperature, and sea level from emissions traced to major carbon producers, 144 Climatic Change 579 (2017)

Elsner, James B. et al., The increasing intensity of the strongest tropical cyclones, 455 Nature 92 (2008)

Emanuel, Kerry, Assessing the present and future probability of Hurricane Harvey's rainfall 2017, 114 PNAS 12681 (2017)

Erickson, Peter et al., Assessing carbon lock-in, 10 Environmental Research Letters 084023 (2015)

Erickson, Peter et al., Carbon lock-in from fossil fuel supply infrastructure, Stockholm Environment Institute (2015)

Erickson, Peter et al., Effect of subsidies to fossil fuel companies on united states crude oil production, 2 Nature Energy 891 (2017)

Fabry, Victoria J. et al., Impacts of ocean acidification on marine fauna and ecosystem processes, 65 ICES Journal of Marine Science 414 (2008)

Feely, Richard A. et al., Evidence for upwelling of corrosive 'acidified' water onto the continental shelf, 320 Science 1490 (2008)

Feely, Richard et al., Ocean acidification: Present conditions and future changes in a high CO2 world, 22 Oceanography 36 (2009)

Frieler, K., et al., Limiting global warming to 2ºC is unlikely to save most coral reefs, 3 Nature Climate Change 165 (2012)

Frumhoff et al., The climate responsibilities of industrial carbon producers, 132 Climatic

Change 157 (2015)

Garfin, Gregg et al. (eds.), Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, Southwest Climate Alliance (2013)

Gasparrini, Antonio et al., Projections of temperature-related excess mortality under climate change scenarios, 1 Lancet Planet Health e360 (2017)

Gilbert, P. et al., The global complex phenomena of harmful algal blooms, 18 Oceanography 136 (2005)

Gillett, Nathan P. et al, Ongoing climate change following a complete cessation of carbon dioxide emissions, 4 Nature Geoscience 83 (2011)

Global Carbon Project, Global Carbon Budget 2018 (2018)

Green, Fergus and Richard Denniss, Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies, 150 Climatic Change 73(2018)

Grinsted, Aslak et al., Homogeneous record of Atlantic hurricane surge threat since 1923, 109 PNAS 19601 (2012)

Grinsted, Aslak et al., Projected hurricane surge threat from rising temperatures, 110 PNAS 5369 (2013)

Hallegatte, Stephane et al., Future flood losses in major coastal cities, 3 Nature Climate Change 802 (2013)

Hansen et al., Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model, 93 J. Geophys. Res. 9341 (1988)

Hansen, James et al., Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observation that 2°C global warming could be dangerous, 16 Atmospheric Chemistry and Physics 3761 (2016)

Harrigan, Ryan J. et al., A continental risk assessment of West Nile virus under climate change, 20 Global Change Biology 2417(2014)

Hasemyer, David, Crab Fishers Sue Fossil Fuel Industry Over Climate Change Damage, InsideClimate News, November 14, 2018, https://insideclimatenews.org/news/14112018/crab-fishermen-climate-change-lawsuit-fossil-fuel-companies-ocean-algae-neurotoxin-fishery-closure

Hasemyer, David, Fossil Fuels on Trial: Where the Major Climate Change Lawsuits Stand Today, InsideClimate News, January 6, 2019, https://insideclimatenews.org/news/04042018/climate-change-fossil-fuel-company-lawsuits-timeline-exxon-children-california-cities-attorney-general

Hauer, Mathew E., Migration induced by sea-level rise could reshape the US population landscape, 7 Nature Climate Change 321 (2017)

Hauer, Matthew E. et al., Millions projected to be at risk from sea-level rise in the continental United States, 6 Nature Climate Change 691 (2016)

Heede, R., Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854-2010, 122 Climatic Change 229 (2014)

Herring, S.C. et al., Explaining extreme events of 2016 from a climate perspective, 99 Bulletin of the American Meteorological Society S1 (2017)

Hidalgo, H.G. et al., Detection and Attibution of Streamflow Timing Changes to Climate Change in the Western United States, 22 Journal of Climate 3838 (2009)

Hoegh-Guldberg, O. et al., Coral reefs under rapid climate change and ocean acidification, 318 Science 1737 (2007)

Hönisch, Barbel et al., The geological record of ocean acidification, 335 Science 1058 (2012)

Hsiang, S. et al., Estimating economic damage from climate change in the United States, 356 Science 1362 (2017)

Hughes, Terry P. et al., Spatial and temporal patterns of mass bleaching of corals in the Anthropocene, 359 Science 80 (2018)

IMBIE, Mass balance of the Antarctic ice sheet from 1992 to 2017, 558 Nature 219 (2018)

Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2013)

Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014)

Intergovernmental Panel on Climate Change, Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018)

Intergovernmental Panel on Climate Change, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Special Report of the Intergovernmental Panel on Climate Change (2012)

International Energy Agency, Global Energy and CO2 Status Report (2019), https://www.iea.org/geco/

Jackson, Jeremy, Status and Trends of Caribbean Coral Reefs: 1970-2012 Executive Summary, Global Coral Reef Monitoring Network - IUCN (2014)

Jackson, Robert B. et al., Global energy growth is outpacing decarbonization, 13 Environmental Research Letters 120401 (2018)

Joughin, Ian et al., Marine ice sheet collapse potentially under way for the Thwaites Glacier Basin, West Antarctica, 344 Science 735 (2014)

Knutson, Thomas R. et al., CMIP5 model-based assessment of anthropogenic influence on record global warmth during 2016, 99 Bulletin of the American Meteorological Society S11 (2017)

Komar, Paul D. & Jonathan C. Allan, Increasing hurricane-generated wave heights along the U.S. east coast and their climate controls, 24 Journal of Coastal Research 479 (2008)

Koven, Charles D. et al., Permafrost carbon-climate feedbacks accelerate global warming, 108 PNAS 14769 (2011)

Kroeker, Kristy J. et al., Impacts of ocean acidification on marine organisms: quantifying sensitivities and interactions with warming, 19 Global Change Biology 1884 (2013)

Kusnetz, Nicholas, Faced with the costs of climate change, R.I. sues fossil-fuel companies, The Boston Globe, July 3, 2018, https://www.bostonglobe.com/metro/2018/07/02/faced-with-costs-climate-change-sues-fossil-fuel-companies/mGflVecLlTflLHCmBHYzAM/story.html

Le Quéré, Corrine, et al., Global Carbon Budget 2017, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-123 (2017), http://www.globalcarbonproject.org/carbonbudget/17/data.htm

Lenton, Timothy M. et al, Tipping elements in the Earth's climate system, 105 PNAS 1786 (2008)

Lewis, Sophie C. & J. Mallela, A multifactor analysis of the record 2018 Great Barrier Reef bleaching, 99 Bulletin of the American Meteorological Society S144 (2017)

Little, Christopher M. et al., Joint projections of US East Coast sea level and storm surge, 5 Nature Climate Change 1114 (2015)

Maclean, Ilya M. D. & Robert J. Wilson, Recent ecological responses to climate change support predictions of high extinction risk, 108 PNAS 12337 (2011)

Mann, Michael E. et al., Record temperature streak bears anthropogenic fingerprint, 44

Geophysical Research Letters 7936 (2017)

Mathis, Jeremy T. et al., Ocean acidification in the surface waters of the Pacific-Arctic boundary regions, 28 Oceanography 122 (2015)

Meier, Walter N. et al., Arctic sea ice in transformation: A review of recent observed changes and impacts on biology and human activity, 51 Reviews of Geophysics 185 (2014)

Melillo, Jerry M et al. (eds.), Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program (2014)

Merrill, Matthew D. et al., Federal lands greenhouse gas emissions and sequestration in the United States—Estimates for 2005–14: U.S. Geological Survey Scientific Investigations Report 2018–5131 (2018)

Mooney, Chris and Grandoni, Dino, New York City sues Shell, ExxonMobil and other oil companies over climate change, The Washington Post, January 10, 2018, https://www.washingtonpost.com/news/energy-environment/wp/2018/01/10/new-york-city-sues-shell-exxonmobil-and-other-oil-majors-over-climate-change/?utm_term=.f57ed9b8d05e

Mooney, Chris and Dennis, Brady, This could be the next big strategy for suing over climate change, The Washington Post, July 20, 2017, https://www.washingtonpost.com/news/energy-environment/wp/2017/07/20/this-could-be-the-next-big-strategy-for-suing-over-climate-change/?tid=a_mcntx&utm_term=.2f4a5b5a6ec3

Mora, Camilo et al., Global risk of deadly heat, 7 Nature Climate Change 501 (2017)

Mouginot, Jérémie et al., Sustained increase in ice discharge from the Amundsen Sea Embayment, West Antarctica, from 1973 to 2013, 41 Geophysical Research Letters 1576 (2014)

Mufson, Steven, New York sues ExxonMobil, saying it 'misled' investors about climate change risks, The Washington Post, October 24, 2018, https://www.washingtonpost.com/energy-environment/2018/10/24/new-york-sues-exxonmobil-accusing-it-deceiving-investors-about-climate-change-risks/?utm_term=.b3da65e26bf4

National Audubon Society, Audubon's Birds and Climate Change Report (2014)

National Aeronautics and Space Administration, Long-term warming trend continued in 2017: NASA, NOAA, Release 18-003, January 18, 2018, https://www.nasa.gov/press-release/long-term-warming-trend-continued-in-2017-nasa-noaa

National Oceanic and Atmospheric Administration, Global coral bleaching event likely ending , but scientists forecast high ocean temperatures may persist in some areas (June

19, 2017), http://www.noaa.gov/media-release/global-coral-bleaching-event-likely-ending

National Oceanic and Atmospheric Administration, Office for Coastal Management, DigitalCoast, Sea Level Rise Viewer, https://coast.noaa.gov/digitalcoast/tools/slr.html

National Research Council, Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia, Washington, DC: National Academies Press (2011)

National Research Council, Warming World: Impacts by Degree (2011)

Oil Change International, Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits (2019)

Oil Change International, The Sky's Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel Production (2016)

Oil Change International, The Sky's Limit California: Why the Paris Climate Goals Demand That California Lead in a Managed Decline of Oil Extraction (2018)

Oliver, Eric C. et al., Anthropogenic and natural influences on record 2016 marine heat waves, 99 Bulletin of the American Meteorological Society S44 (2017)

Orr, James C. et al., Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, 437 Nature 681 (2005)

Osborne, Emily, et al. (eds.), Arctic Report Card 2018, NOAA (2018), https://www.arctic.noaa.gov/Report-Card

Overland, James E. & Muyin Wang, When will the summer Arctic be nearly sea ice free? 40 Geophysical Research Letters 2097 (2013)

Pacifici, Michela et al., Species' traits influenced their response to recent climate change, 7 Nature Climate Change 205 (2017)

Parkinson, Claire L., Spatially mapped reductions in the length of the Arctic sea ice season, 41 Geophysical Research Letters 4316 (2014)

Parmesan, Camille & Gary Yohe, A globally coherent fingerprint of climate change impacts across natural systems, 421 Nature 37 (2003)

Parmesan, Camille, Ecological and evolutionary responses to recent climate change, 37 Annual Review of Ecology Evolution and Systematics 637 (2006)

Paz, Shlomit, Climate change impacts on West Nile virus transmission in a global context, 370 Philosophical Transactions of the Royal Society B 20130561 (2015)

Pierce, David et al., Attribution of Declining Western U.S. Snowpack to Human Effects, American Meteorological Society 6425, DOI: 10.1175/2008JCLI2405.1 (Dec 1, 2008)

Piggot, Georgia et al., Realizing a just and equitable transition away from fossil fuels, Discussion brief, Stockholm Environment Institute (2019)

Porter, J.R. et al., Food security and food production systems, Climate Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B. et al. (eds.)] (2014)

Public Health Institute/Center for Climate Change and Health, Food Security, Climate Change and Health (2016)

Rhodium Group, Preliminary US Emissions Estimates for 2018, Energy and Climate Staff (2019)

Rignot, Eric et al., Four decades of Antarctic ice sheet mass balance from 1979-2017, 116 PNAS 4 (2019)

Rignot, Eric et al., Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011, 41 Geophysical Research Letters 3502 (2014)

Risser, Mark D. and Michael F. Wehner, Attributable human-induced changes in the likelihood and magnitude of the observed extreme precipitation during Hurricane Harvey, 44 Geophysical Research Letters 12,457 (2017)

Robiou du Pont, Yann et al., Equitable mitigation to achieve the Paris Agreement goals, 7 Nature Climate Change 38 (2017)

Rogelj, Joeri et al., Energy system transformations for limiting end-of-century warming to below 1.5°C, 5 Nature Climate Change 519 (2015)

Root, Terry L. et al., Fingerprints of global warming on wild animals and plants, 421 Nature 57 (2003)

Sallenger, Asbury H. et al., Hotspot of accelerated sea-level rise on the Atlantic coast of North America, 2 Nature Climate Change 884 (2012)

Saunders, Mark A. & Adam S. Lea, Large contribution of sea surface warming to recent increase in Atlantic hurricane activity, 451 Nature 557 (2008)

Scheffers, Brett R. et al., The broad footprint of climate change from genes to biomes to people, 354 Science 719 (2016)

Schwartz, Amy M., et al., Surveillance for Lyme Disease¬ — United States, 2008-2015, 66 MMWR 1, Centers for Diseas Control and Prevention (2017)

Seto, Karen C. et al., Carbon Lock-In: Types, Causes, and Policy Implications, 41 Annual Review of Environmental Resources 425 (2016)

Sheffield, Perry and Philip J. Landrigan, Global climate change and children's health: Threats and strategies for prevention, 119 Environmental Health Perspectives 291 (2011)

Shindell, Drew et al., Quantified, localized health benefits of accelerate carbon dioxide emissions reductions, 8 Nature Climate Change 723 (2018)

Silva, Raquel A. et al., Future global mortality from changes in air pollution attributable to climate change, 7 Nature Climate Change 647 (2017)

Slater, Thomas and Andrew Shepherd, Antarctic ice losses tracking high, 8 Nature Climate Change 1025 (2018)

Smith, Christopher J. et al., Current fossil fuel infrastructure does not yet commit us to 1.5°C warming, Nature Communications, doi.org/10.1038/s41467-018-07999-w (2019)

Solomon, Susan et al., Irreversible climate change due to carbon dioxide emissions, 106 PNAS 1704 (2009)

Spooner, Fiona E.B. et al., Rapid warming is associated with population decline among terrestrial birds and mammals globally, 24 Global Change Biology 4521 (2018)

Steffen, Will et al., Trajectories of the Earth System in the Anthropocene, 115 PNAS 33 (2018)

Strauss, Benjamin H. et al., Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States, 7 Environmental Research Letters 014033 (2012)

Supran, G. and Oreskes, N., Assessing ExxonMobil's climate change communications (1977-2014), 12 Environ. Res. Lett. 084019 (2017)

The White House, The Cost of Delaying Action to Stem Climate Change (July 29, 2014), https://obamawhitehouse.archives.gov/the-press-office/2014/07/29/white-house-report-cost-delaying-action-stem-climate-change

Thomas, Chris. D. et al., Extinction risk from climate change, 427 Nature 145 (2004)

Tirado, M. C. et al., Climate change and food safety: A review, 43 Food Research International 1745 (2010)

Trusel, Luke D. et al., Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming, 564 Nature 104 (2018)

U.S. Energy Information Administration, For one week in November, the U.S. was a net exporter of crude oil and petroleum products, Today in Energy (December 12, 2018), https://www.eia.gov/todayinenergy/detail.php?id=37772

U.S. Energy Information Administration, Hydraulically fractured wells provide two-thirds of U.S. natural gas production (May 5, 2016), https://www.eia.gov/todayinenergy/detail.php?id=26112

U.S. Environmental Protection Agency, Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, Final Rule, 74 Federal Register 66496 (2009)

U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment, Volume I (2017), https://science2017.globalchange.gov/

U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II (2018), https://nca2018.globalchange.gov/

U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (2016)

Udall, Bradley & Jonathan Overpeck, The twenty-first century Colorado River hot drought and implications for the future, 53 Water Resources Research 2404 (2017)

Union of Concerned Scientists, Rising Temperatures and Your Health: Rising Temperatures, Worsening Ozone Pollution (2011)

Union of Concerned Scientists, The Climate Accountability Scorecard: Ranking Major Fossil Fuel Companies on Climate Deception, Disclosure, and Action (2016)

United Nations Convention to Combat Desertification, The Global Land Outlook (2017)

United Nations Framework Convention on Climate Change, Conference of the Parties, Nov. 30-Dec. 11, 2015, Adoption of the Paris Agreement Art. 2, U.N. Doc. FCCC/CP/2015/L.9 (December 12, 2015)

United Nations Framework Convention on Climate Change, U.S. cover note, INDC and Accompanying Information, submission by the United States of America to UNFCCC (2016)

Urban, Mark C., Accelerating extinction risk from climate change, 348 Science 571 (2015)

van Hooidonk, R. et al., Opposite latitudinal gradients in projected ocean acidification and bleaching impacts on coral reefs, 20 Global Change Biology 103 (2014)

van Oldenborgh, Geert J. et al., Attribution of extreme rainfall from Hurricane Harvey, 12 Environmental Research Letters 124009 (2017)

Veron, J.E.N. et al., The coral reef crisis: the critical importance of <350 ppm CO2, 58 Marine Pollution Bulletin 1428 (2009)

Wahl, T. et al., Increasing risk of compound flooding from storm surge and rainfall for major US cities, 5 Nature Climate Change 1093 (2015)

Walsh, John E. et al., The high latitude marine heat wave of 2016 and its impacts on Alaska, 99 Bulletin of the American Meteorological Society S39 (2017)

Ward, R., Letter dated Sept 4, 2006 from the Royal Society to ExxonMobil, https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2006/8257.pdf (accessed January 17, 2018)

Warren, Rachel et al., Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise, 106 Climatic Change 141 (2011)

Warren, Rachel et al., Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss, 3 Nature Climate Change 678 (2013)

Watts, Nick et al., Health and climate change: policy responses to protect public health, 386 The Lancet 1861 (2015)

Wdowinski, S. et al., Increasing flooding hazard in coastal communities due to rising sea level: Case study of Miami Beach, Florida, 126 Ocean & Coastal Management 1 (2016)

Wiens, John J., Climate-related local extinctions are already widespread among plant and animal species, 14 PLoS Biology e2001104 (2016)

World Meteorological Organization, WMO Greenhouse Gas Bulletin, No. 13 (October 30, 2017)

Zhao, C. et al., Temperature increase reduces global yields of major crops in four independent estimates, 114 PNAS 9326 (2017)

ATTACHMENT C

Review of the DEIS Revegetation Mitigation and Monitoring

By Ileene Anderson

February 5, 2021

I work for the Center for Biological Diversity as the Public Lands Desert Director and as a senior scientist, where I provide scientific expertise necessary for the conservation of unique flora and fauna in a variety of public and private land use arenas. My professional background and qualifications are summarized at the end of this comment.

After reviewing the DEIS Chapter 4 Mitigation regarding revegetation mitigation and monitoring, I have found its analysis to be incomplete and not standard revegetation procedure. The mitigation and monitoring plan for vegetation impacts states:

> **VM-22:** The Coalition will revegetate disturbed areas, where practical and in consultation with the Ute Indian Tribe as applicable, when construction is completed. The goal of reclamation will be the rapid and permanent re-establishment of native groundcover on disturbed areas to prevent soil erosion, where feasible. If weather or seasonal conditions prevent vegetation from being quickly re-established, the Coalition will use measures such as mulching, erosion-control blankets, or dust-control palliatives to prevent erosion until vegetative cover is established. The Coalition will monitor reclaimed areas for 3 years. For areas where efforts to establish vegetative cover have been unsuccessful after 1 year, the Coalition will reseed annually for up to 3 years as needed.

The EIS should provide the Coalition's comprehensive revegetation plans, including concrete measures and specific performance criteria, for public review and comment. Mitigation to revegetate disturbed areas should be based on best practices and local ecological processes, or efforts to revegetate the "temporarily impacted" areas are not likely to succeed.

Revegetation plans should require planning and collection of seeds in advance of soil disturbance. The planting palette should include seeds appropriate to the environment and climate conditions. Only local native plant propagules should be used and the plantings/seedings should be administered in an ecologically successional way – introducing early successional species first, followed sequentially over a multiple year process with mid-successional species and finally late-successional species. A frequent weeding schedule particularly during the growing season (removal before seeds are produced is best) should be implemented, particularly in the first three years to reduce non-native and invasive species from proliferating, which would doom revegetation efforts.

Revegetation plans should include short-term and robust "establishment" criteria, so that problems can be identified and remedied early (e.g., protection from herbivory, adequate soil moisture, stopping weed invasions before they start). Long-term success criteria should also be included (e.g., monitoring shows that the revegetation site is statistically similar to a reference (undisturbed) site by looking at cover, density, diversity). The project developer should be held to all revegetation plan requirements and success criteria. Otherwise, revegetation is unlikely to be successfully implemented. The DEIS does not specify whether and how the STB or other agencies would monitor compliance. To the extent any state or federal agency or tribal authority has management authority over disturbed areas, the agency or tribal authority should be required to monitor compliance with all revegetation requirements for those lands. For example, the Army Corps should enforce mitigation for riparian vegetation impacts.

Finally, required revegetation periods and monitoring in the Coalition's mitigation plan falls short of what's needed to be successful. Most agencies require five years of monitoring with the last two years not having any "interventions" (no additional irrigation, weed removal, augmentation of revegetation). If additional remediation/revegetation is required, then the clock should restart in those areas with five more years of monitoring. For example, if most of the revegetation area is meeting success criteria (which should be clearly identified in the revegetation plan), but one area is not meeting the success criteria, then additional revegetation augmentation should be done in the "unsuccessful" area and the monitoring continues for five years after the augmentation, which is standard practice.

The better practice, however, would be to require long-term monitoring up to ten years (with a reduced monitoring schedule in years 6-10 – once every 2 years) to assure that the success criteria are met. There is not much data on long-term outcomes of revegetation, so ultimately the long-term success for most projects is unknown. Thus, long-term monitoring is advisable.

From revisiting and observing revegetation projects that I worked on from twenty plus years ago, I do believe if you get the revegetation process started right, in the first 2-3 years (following a natural "successional" model of introducing early, mid and late successional species sequentially) functional habitat can be "created." It is never as diverse even after twenty years as undisturbed habitat of course, but it is on its way.

Professional Background

Ileene Anderson works for the Center for Biological Diversity as the Public Lands Desert Director and as a senior scientist, where she provides scientific expertise necessary for the conservation of unique flora and fauna in a variety of public and private land use arenas. Ms. Anderson received a Master of Science in Biology from the California State University at Northridge. Ms. Anderson studied and surveyed for native species in the western U.S. for over 30 years. Ms. Anderson researches and keeps abreast of the latest science on many rare and listed plants and animals and their habitat needs as well as more common plants and animals and natural communities.

Before her tenure at the Center for Biological Diversity, Ms. Anderson was the Southern California Regional Botanist for the California Native Plant Society (CNPS) from 1997 to 2005 and continues to volunteer with CNPS on conservation and litigation issues. Ms. Anderson has been a member of CNPS since 1992. From 1995-2005, she also worked as an independent biological consultant throughout the southwestern United States.

Relevant Experience:

Ms. Anderson has worked on numerous reclamation, revegetation and restoration projects in California and Arizona including coastal, mountain and desert landscapes. Activities included pre-disturbance/baseline quantitative vegetation assessments, producing site specific reclamation, revegetation and restoration plans, implementing reclamation, revegetation and restoration plans, post-installation monitoring of the reclamation, revegetation and restoration sites, remediation memos and plans when the sites were failing to meet success criteria. Many of the projects were implemented as threatened or endangered species habitat mitigation and/or wetland mitigation overseen by trustee agencies including the U.S. Fish and Wildlife Service, Army Corps of Engineers or state and local jurisdictional agencies.

Ms. Anderson served on the Bureau of Land Management's California Desert District Advisory Council as a Department of Interior Appointee Representing Renewable Resources from 1996-2002 including 2001 as chairperson. She also co-led the Society for Ecological Restoration's Coastal Sage Scrub Guild from 1995 to 2001where she organized field trips, lectures and symposia on cutting edge revegetation projects.

Professional Courses:

Methods of Habitat Restoration - University of California, Riverside, Winter 1993

Desert Restoration - SERCAL, October 1993

Habitat Restoration Evaluation - University of California, Riverside, Winter 1994

Basic Wetlands Delineation - Wetland Training Institute, Inc. November 1995

Mycorrhizae in Habitat Restoration - University of California, Riverside, Winter 1995

Soils Workshop – Natural Resources Conservation Service, November 1998

Plant Community Characterization and Series Identification– Native Plant Society, June 1999