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ANGIE SPARKS, Clerk of District Court
By [signature] Deputy Clerk

MONTANA FIRST JUDICIAL DISTRICT COURT, LEWIS & CLARK COUNTY

RIKKI HELD, et al., Plaintiffs, v. STATE OF MONTANA, et al., Defendants.	Cause CDV 2020–307 Hon. Kathy Seeley (email) **DEFENDANTS' SUPPLEMENTAL EXPERT WITNESS DISCLOSURE**

Pursuant to Mont. R. Civ. P. 26 (e)(2), Defendants State of Montana, et al. provide this supplemental expert witness disclosure. Following the disclosure of Dr. Curry on October 31, 2022, Dr. Curry discovered errors in her report. Her Amended Report correcting these errors is attached as **Exhibit A**. Dr. Curry's disclosure is unchanged in all other respects. Additionally, Defendants withdraw the following hybrid witnesses.

Julie Merkel
Craig Henrikson
Ed Warner
Dan Lloyd
Bob Smith
Dan Walsh
Rebecca Harbage
Craig Jones
Martin VanOort

Other than the amendments made by this Supplemental Expert Witness Disclosure, Defendant's Expert Witness Disclosure of October 31, 2022 remain unchanged in all respects.

DATED this 22nd day of November, 2022.

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CERTIFICATE OF SERVICE

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Date: November 22, 2022

Dia C. Lang

Report of Judith Curry, PhD

I submit this report to the Montana First Judicial District Court of Lewis and Clark County, with regards to Rikki Held et al. versus the State of Montana et al. as an expert witness for the State of Montana on the topics of climate change and the energy transition. The facts and data that I considered in forming my opinions are available from public sources and cited in this report.

Executive Summary

This report responds to the Plaintiffs' claims that:

- the release of greenhouse gases from fossil fuel emissions into the atmosphere is already triggering a host of adverse consequences in Montana;
- the threats posed by fossil fuels and the climate crisis are existential;
- Montana's energy system should transition to a portfolio of 100% renewable energy by 2050.

My report provides evidence that supports the following conclusions:

- The climate-related concerns observed by the Plaintiffs are well within the range of historical natural weather and climate variability, with worse occurrences of weather and climate extremes observed during the early 20th century.
- Plaintiffs' concerns about climate change in the 21st century are greatly exaggerated, and not consistent with the most recent assessment reports and research publications.
- In 2021, Montana ranked 10th among U.S states in terms of the share of electricity generated from renewables, about 52%. There are significant problems with a portfolio of 100% renewable energy for Montana by 2050.
- Emissions from fossil fuels generated in Montana provide a miniscule contribution to global greenhouse gas emissions and do not influence directly Montana's weather and climate.

Qualifications

I am Professor Emerita and former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I am currently President and co-founder of Climate Forecast Applications Network (CFAN).

I received a Ph.D. in Geophysical Sciences from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, I held faculty positions at the University of Colorado, Penn State University and Purdue University. My published research spans a variety of topics including climate dynamics of the Arctic, climate dynamics of extreme weather events, cloud microphysics and climate feedbacks, climate sensitivity and scenarios of future climate variability, and reasoning about climate uncertainty. I have been elected to the rank of Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union. I have previously served on the NASA Advisory Council Earth Science Subcommittee, the Department of Energy's Biological and Environmental Research

EXHIBIT A

Advisory Committee (BERAC), the National Academies Climate Research Committee and the Space Studies Board, and the National Oceanic and Atmospheric Administration (NOAA) Climate Working Group. My company CFAN translates cutting-edge weather and climate research into forecast products that support the mitigation of weather and climate risk, on timescales from days to decades.

Additional information can be found at:
http://curry.eas.gatech.edu/
http://www.cfanclimate.net/
http://judithcurry.com/about/

My particular qualifications relevant to this Report include:

- Extensive published research on the topics of climate dynamics and change
- My expertise on these topics is supported by my invitations to provide Congressional testimony twelve times since 2006.
- My company CFAN supports the energy sector with extended-range probabilistic forecasts of temperature extremes, severe convective weather, hurricanes, fire weather and renewable energy. CFAN's climate scenario projections and impact assessments support power plant siting and investment decisions, insurance decisions, electric power demand, and severe weather vulnerability.
- I have provided consulting services to numerous electric utility providers on topics related to weather variability and climate change, and the pros and cons of various energy sources in context of climate change and political frameworks.
- I have authored a book entitled "Climate Uncertainty and Risk" that is in press at Anthem Press.

My complete curriculum vitae is included in Appendix A.

1. Weather and climate variability in Montana

Montana has a highly variable climate and is subject to weather extremes. The Plaintiffs attribute recent adverse weather and climate conditions to human-caused climate change associated with fossil fuel emissions. These impressions of the Plaintiffs do not hold up to scrutiny against Montana's historical weather and climate records.

1.1 Concerns of plaintiffs about the current climate

Concerns of the individual Youth Plaintiffs on pages 5-26 of the Complaint are generally related to concerns about climate change impacts on their physical and psychological health and safety, challenges to family and cultural foundations, economic deprivations, and degrading and depleting natural resources. Their specific weather- and climate-related concerns are summarized as follows:

- Variability in river levels and stream flow, ranging from drought to flood
- Summertime warm temperatures in rivers and streams that impact fish
- Reduced water availability for livestock during summer

- Severe hail storm
- Trees and large animals under stress from disease carrying insects that are surviving warmer winters
- Wildfires
- Reduced winter snow pack
- Abnormally wet, cold and muddy weather
- Extreme summer heat
- Disappearance of glaciers in Glacier National Park

Impacts of "Climate Disruption" in Montana provided on pages 57-75 of the Complaint are summarized as:

- Increase in temperatures from 2-3°F between 1950 and 2015
- More heat waves
- Snow is melting earlier in spring
- Days above 90 °F have increased by 20 days between 1970 and 2015
- Warmer springs and delay of frost in fall
- Reduced irrigation capacity
- Decreasing snowpack
- Melting glaciers

1.2 Historical context

By considering only data since 1950 and 1970, the Plaintiffs have erroneously assumed that recent adverse weather and climate conditions in Montana are unusual, and have inferred that they are caused by fossil fuel emissions. The slow increase in average temperature for Montana has not translated into an increase in weather/climate extremes. Ancestors of the Youth Plaintiffs living in the 19th and early 20th century encountered weather and climate extremes that are as bad as, or worse than, those that have been encountered by the Youth Plaintiffs.

Here are Montana's historical record temperature and precipitation extremes:

- Hottest temperature: 117°F, Medicine Lake, 7/5/1937 and Glendive 7/20/1893[1]
- Record hottest years: 1934 and 2015[2]
- Record driest year: 1931, avg precipitation 12.62 inches[3]
- Record wettest year: 1927, avg precipitation 26.15 inches[4]
- Precipitation record for 24 hours: Circle (Springbrook), 6/20/1921, 11.50 inches[5]
- Worst floods: 1908, 1948, 1964, 1978, and 2011[6]

The NOAA State Climate Summary for Montana (2022) provides an up-to-date summary of Montana's climate.[7]

While the two decades in the 21st century have overall been the warmest for Montana since 1900, there has been no trend in weather and climate extremes. Average winter temperatures show an overall increase, although comparably warm years were observed from the 1920-50s. The warmest summer temperatures were in the 1930s. In terms of annual average temperature, 2015 is tied with 1934 for the hottest year on record.[8]

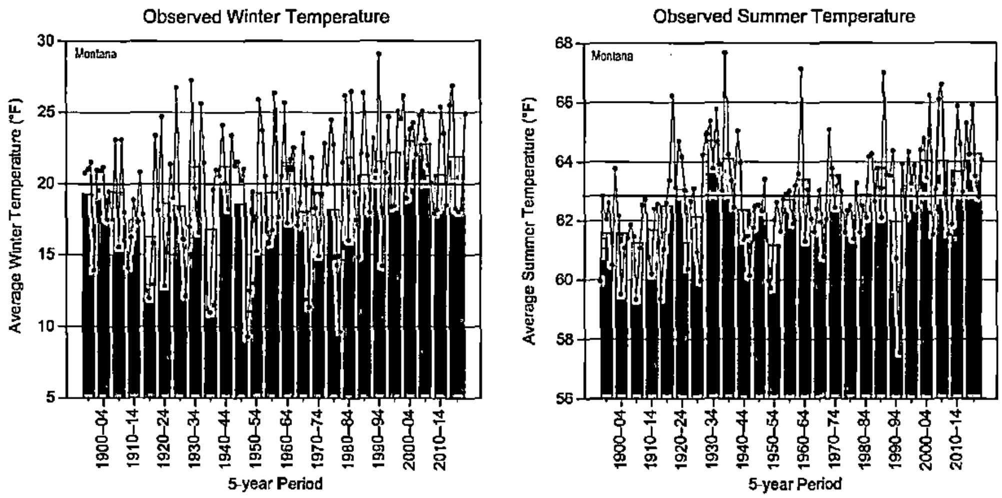

Figure 1.1 – Reprint of Figure 4a-b from Frankson et al. 2022 – (left) winter (December-February) and (right) summer (June-August) average temperature from 1895 through 2020. Dots represent annual values, bars show 5-year averages and horizontal lines show long term averages.[9]

The number of very hot days (≥95 °F) and warm nights (≥70 °F) was highest in the 1930s.

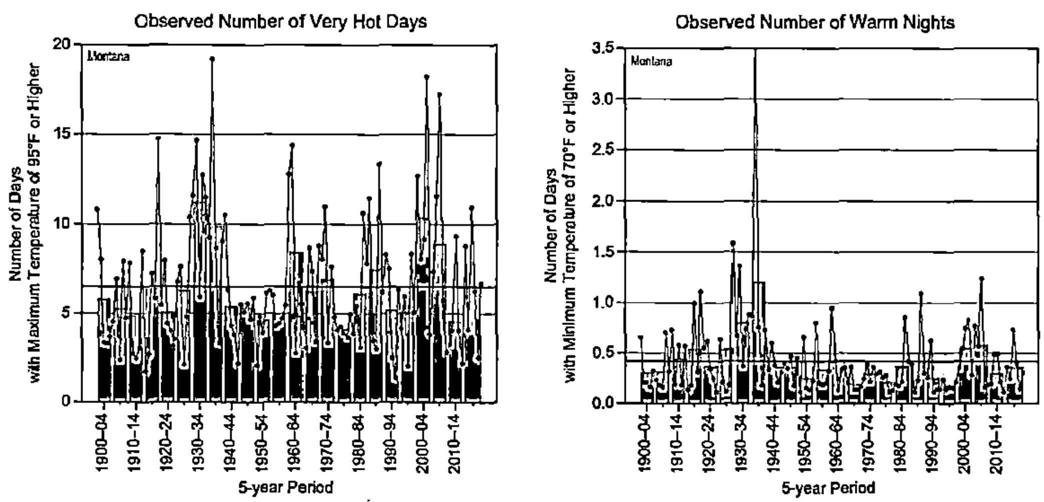

Figure 1.2 – Reprint of Figure 2a-b from Frankson et al. 2022 – (left) very hot days (≥95 °F) and (right) very warm nights (≥70 °F) 1900 through 2020. Dots represent annual values, bars show 5-year averages and horizontal lines show long term averages.[10]

The number of very cold days (maximum temperature ≤ 0 °F) shows an overall decline, although the low numbers since 2005 are comparable to the low numbers in the 1940s.

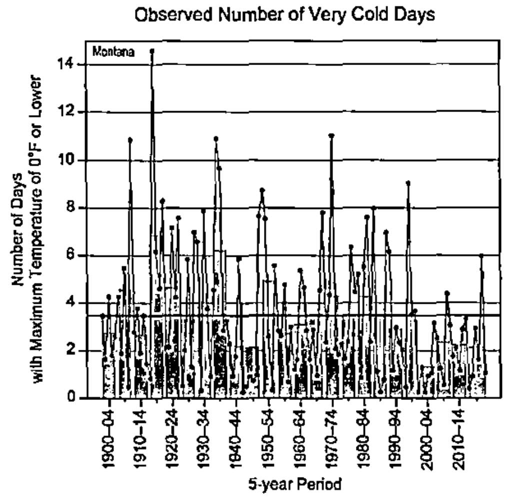

Figure 1.3 – Reprint of Figure 3 from Frankson et al. 2022 – very colds days (maximum temperature ≤ 0 °F) 1900 through 2020. Dots represent annual values, bars show 5-year averages and horizontal lines show long term average.[11]

There is no overall trend in annual precipitation, although there is substantial year-to-year variability. The lowest values were observed in the 1930's. In terms of extreme precipitation events, there is no trend.[12]

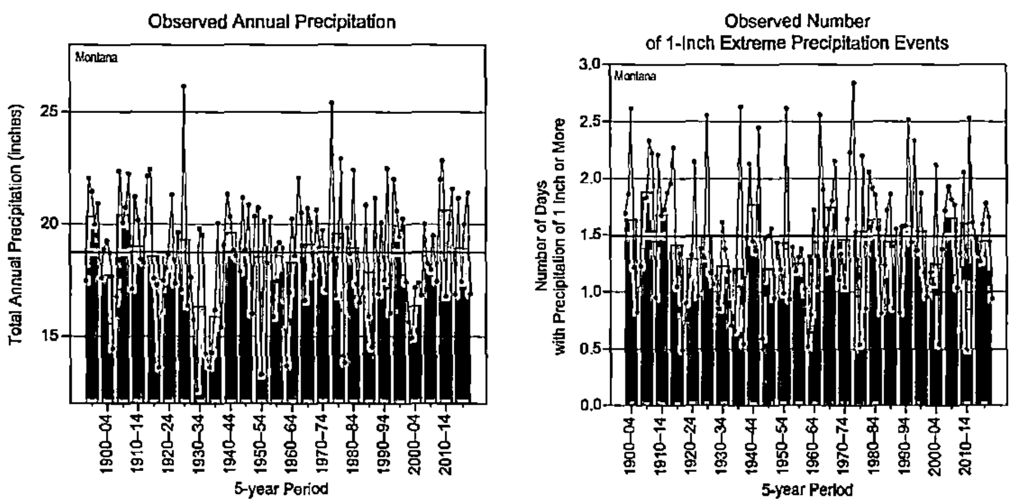

Figure 1.4 – Reprint of Figure 2c-d from Frankson et al. 2022 – (left) observed annual precipitation and (right) extreme precipitation events (≥1 inch) 1900 through 2020. Dots represent annual values, bars show 5-year averages and horizontal lines show long term averages.[13]

Since 1970, there have been as many as 200 snow measuring sites across Montana, most of which are in the western mountain area. Currently there are about 90 active daily sites in the state measuring snow water equivalent, with about 50% of these sites extending back 50 years. There has overall been a declining trend in April snowpack in Montana during the period 1955-2016, as cited in the Complaint. However, since 2016, most of the last 7 years have shown normal to above normal spring snowpack across Montana. This behavior reflects the variable nature of climate on both seasonal and decadal scales as well as the potential limitations of inferring causal mechanisms when analyzing short periods of data.

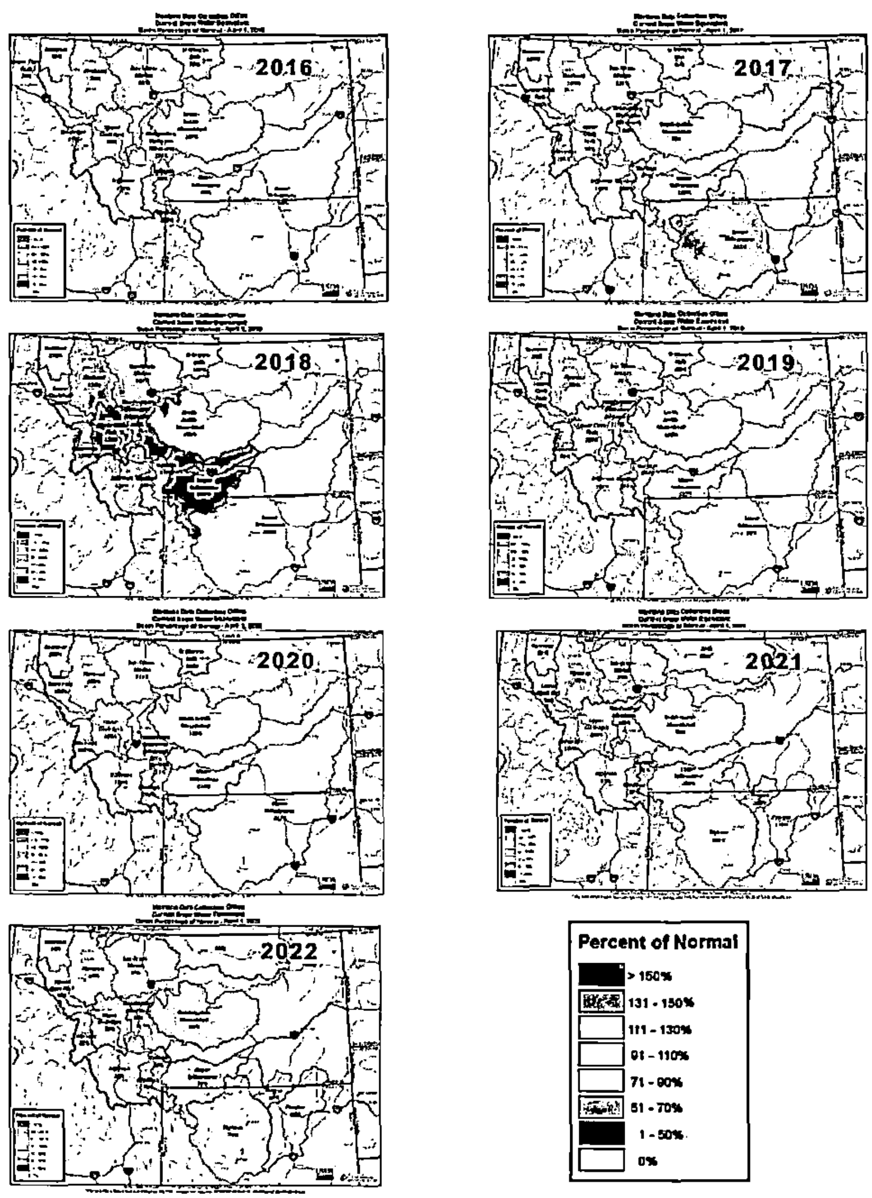

Figure 1.5 – April 1st snow water equivalent estimates produced by National Resources Conservation Service with data from the Montana Snow Survey Program from 2016 through 2022.[14]

To extend understanding of past snowpack behavior, paleoclimate records have been developed to supplement the modern data pool. These records include lake sediment and tree ring data. An important study focused on the American West was published in 2011, providing a data record over 500 years.[15] This length of record revealed climate variability on century scales including features like The Little Ice Age. The study also demonstrated more short-term climatic features that show different anomalies between the northern and southern Rockies. Of particular relevance, the study identified a snow drought during the 1930s in the Greater Yellowstone Region that is similar to low values seen toward the end of the 20th century.

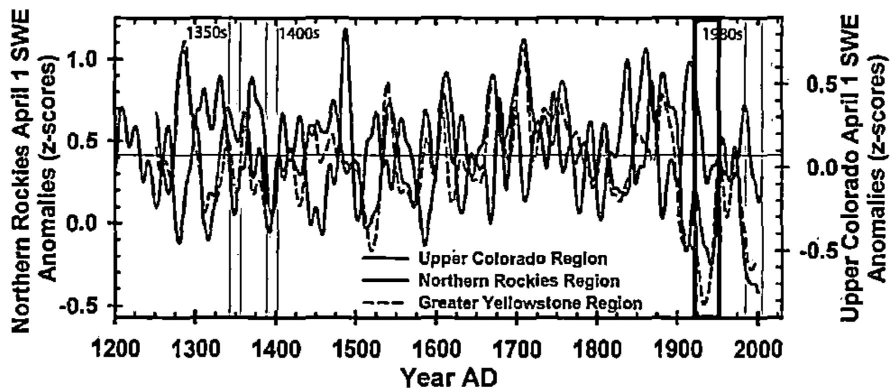

Fig. 3. Decadal-scale antiphasing of the N-S snowpack dipole and periods of synchronous snowpack decline. The 20-year splines of the regional average snowpack anomalies highlight antiphasing and variability at decadal scales. The shaded bars highlight periods of synchronous snowpack decline.

Figure 1.6 – Reprint of Figure 3 from Pederson et al. 2011 with the addition of red box to denote period of phase lock that includes the 1930s.

The first surveys of glaciers in Glacier National Park began in the 1880s, with most of the focus on the two largest glaciers – Grinnell and Sperry. A 2017 publication issued by the U.S. Geological Survey entitled Status of Glaciers in Glacier National Park includes a table of the areal extent of named glaciers in the Glacier National Park since the Little Ice Age (LIA) with markers at LIA, 1966, 1998, 2005 and 2015.[16] Analysis of these data show:

- A ~50% loss from LIA to 1966 (~115 years), averaging a loss of ~4.5% per decade.
- Additional ~12% loss from 1966-98 (32 years), averaging a loss of ~3.7% per decade.
- Additional ~4.75% loss from 1998-2015 (17 years), averaging a loss of ~ 2.8% per decade.

Much of the glacier loss occurred prior to 1966, when fossil-fueled warming was minimal. The percentage rate of glacier loss during this early period exceeded the percentage rate of loss observed in the 21st century.

Looking much further back, Glacier National Park was virtually ice free 11,000 years ago.[17] Glaciers have been present within the boundaries of present-day Glacier National Park since about 6,500 years ago.[18] These glaciers have varied in size, tracking climatic variations, but did not grow to their recent maximum size until the end of the Little Ice Age, around 1850. An 80-year period (~1770-1840) of cool, wet summers and above-average winter snowfall led to a rapid growth of glaciers just prior to the end of the Little Ice Age.[19] So, the recent loss of glacier mass must be understood in light of the fact the glaciers reached their largest mass for the past 11,000 years during the 19th century.

Devastating forest fires are not a new phenomenon in and around Montana. Forest fires have always been a part of nature, and they can certainly create conditions that are inhospitable in the short term for all life including humans. Science has confirmed the overall benefit and necessity of the occurrence of forest fires. While recent high-profile fires and seasons serve as a reminder of the potential destructive impact, the region's highest profile forest fire remains the 1910 Big Blowup fire which destroyed over three million acres including the elimination of entire towns like Taft, MT.[20] The 1910 fire reshaped the U.S. Forest Service,[21] leading to a focus on fire suppression with a primary goal to defeat all forest fires.[22] This led to the 10 am rule in 1935 that meant all fires spotted on any day had to be controlled by the following day at 10 am.[23]

While defeating fire is certainly a noble goal, questions began to arise as to whether this behavior "followed the science."[24] Over time the U.S. Forest Service has begun to rethink its behavior, recognizing that new approaches such as prescribed burns, fuel elimination and controlled wildfires are more appropriate.[25] Recent research is validating this approach and recognizing that more frequent smaller fires in forests likely result in the most healthy forests, water ecosystems and biodiversity.[26]

With regards to the Plaintiff's concerns about hail storms, the recent Intergovernmental Panel on Climate change 6th Assessment Report (IPCC AR6) concludes: "There is low confidence in past trends in characteristics of severe convective storms, such as hail and severe winds, beyond an increase in precipitation rates."[27]

1.3 Summary

The Plaintiffs' concerns about extreme weather and climate conditions reflect natural weather and climate variability, rather than fossil-fuel driven climate change. The extreme conditions encountered by the youth Plaintiffs are not exceptional in context of historical conditions back to 1900. Trends since 1950 or 1970 that are cited in the Complaint fail to consider conditions that were as bad as or worse than the current conditions during the first half of the 20th century.

2. Concerns about the future climate

The Plaintiffs have concerns about the future climate that are highly exaggerated relative to projections in recent assessment reports.

2.1 Concerns of Plaintiffs

The Complaint cites specific concerns of the Youth Plaintiffs about the future:

- "Sariel is worried that her and her community's activities, practices, and beliefs of cultural significance will be entirely lost if climate change continues. Sariel is distraught when thinking about her future and if she will have one."[28 29]

- "Georgi sometimes has feelings of despair and hopelessness; she has invested years into a snow-based sport, but understands that snow and the sport may not exist in her future."[30]
- "Witnessing climate change impacts occur around her is devastating emotionally to Grace and she is anxious about her future and fearful that her generation may not survive the climate crisis. Grace has doubts about whether she would want to have her own children given her anxieties about the future."[31]
- "[Eva] is distressed that the climate crisis will worsen if action is not immediately taken."[32]
- "Olivia values her family and would like to have and raise children of her own, but she questions whether this is even an option in a world devastated by the climate crisis. She fears that if she has children they, or their children, would suffer or starve. Imagining the future that she will inherit, or that her children would live in, and the current suffering that the climate crisis is already causing her and others is a heavy burden for her to carry,' and Olivia feels heartbroken and desperate."[33]

The Complaint further cites the following concerns:

- "There is an overwhelming scientific consensus that human-caused climate disruption is occurring and is dangerous to humans and other life and ecosystems on which humans depend."[34]
- "The threats posed by fossil fuels and the climate crisis are existential."[35]
- "Atmospheric CO_2 is the primary forcer of climate change" [on timescales of hundreds of thousands of years, Figure 5].[36]
- "Unless GHGs are reduced to meet science-based targets, climatic tipping points, such as massive species extinction and rapid ice sheet disintegration, will be reached and the Earth will cross a point of no return after which catastrophic climate change impacts will be unavoidable and irreversible. The continued GHG emissions from fossil fuels will further disrupt Earth's climate system and that, in turn, will impose profound and mounting risks of ecological, economic, and social collapse."[37]
- "By mid-century, when the Youth Plaintiffs will be adults, models project that the annual average daily maximum temperature in Montana will increase by approximately 4.5-6.0 ° F, a temperature increase that would imperil human civilization. By the end of the century, models predict that the annual average daily maximum temperature in Montana will increase by approximately 5-10 °F."[38]

2.2 Recent assessments of 21st century climate scenarios

This Section refers to the following recent assessment reports:

- Intergovernmental Panel on Climate Change 5th and 6th Assessment Report (IPCC AR5 2013; IPCC AR6 2021)
- UN Framework Convention on Climate Change (UNFCCC) Reports
- International Energy Agency (IEA) Global Energy Review
- 4th U.S. National Climate Assessment (2017)

2.2.1 How much warming?

The temperature projections for the 21st century from the IPCC AR6 are provided below.

Table 2.1 Projected changes in global surface temperature for three 20-year time periods for five emissions scenarios. Temperature differences are relative to the baseline period 1850–1900. Changes relative to the recent reference period 1995–2014 may be calculated approximately by subtracting 1.5 °F, the best estimate of the observed warming from 1850–1900 to 1995–2014 (IPCC AR6 Summary for Policy Makers (SPM) Table SPM.1; note that temperatures have been converted from °C to °F for the convenience of the reader).[39] Changes relative to 2020 can be obtained by subtracting 2 °F

	Near term, 2021–40		**Mid-term, 2041–60**		**Long term, 2081–2100**	
Scenario	*Best estimate (°F)*	*Very likely range (°F)*	*Best estimate (°F)*	*Very likely range (°F)*	*Best estimate (°F)*	*Very likely range (°F)*
SSP1–1.9	2.7	2.2 to 3.1	2.9	2.2 to 3.6	2.5	1.8 to 3.2
SSP1–2.6	2.7	2.2 to 3.2	3.1	2.3 to 4.0	3.2	2.3 to 4.3
SSP2–4.5	2.7	2.2 to 3.2	3.6	2.9 to 4.5	4.9	3.8 to 6.3
SSP3–7.0	2.7	2.2 to 3.2	3.8	3.1 to 4.7	6.5	5.0 to 8.3
SSP5–8.5	2.9	2.3 to 3.4	4.3	3.4 to 5.4	7.9	5.9 to 10.3

The numbers cited by the Plaintiffs of 4.5-6.0 °F warming by mid-century and 5-10 °F by the end of the 21st century relate to emissions scenario SSP5-8.5 (roughly equivalent to RCP8.5 in the previous IPCC AR5 that is cited by the Plaintiffs), relative to the reference period 1850-1900.

RCP8.5 and SSP5-8.5 are extreme emissions scenarios that are now generally regarded as implausible. The IPCC AR6 states:

> "In the scenario literature, the plausibility of the high emissions levels underlying scenarios such as RCP8.5 or SSP5–8.5 has been debated in light of recent developments in the energy sector."[40]

The 8.5 emissions scenarios can only emerge under a very narrow range of circumstances, comprising a severe course change from recent energy use. Both the RCP8.5 and the SSP5–8.5 scenarios have drawn criticism owing to the assumptions around future coal use, requiring up to 6.5 times more coal use in 2100 than today—an amount larger than some estimates of economically-recoverable coal reserves.[41]

Table 2.2 compares the SSP emissions scenarios used in the IPCC AR6 in terms of gigatons of CO_2 emitted per year, for the year 2050. For reference, emissions in 2021 are about 36 gigatons of carbon dioxide ($GtCO_2$) per year.[42] The UNFCCC objective is net zero emissions by 2050.[43]

The International Energy Agency (IEA) has provided more realistic scenarios of future emissions that are now widely being used in decision and policy making (Table 2.1).[44] Policies to reduce emissions that have actually been implemented are described in a scenario referred to as STEPS, which projects continued emissions through 2050 at the rate of about 36 $GtCO_2$ per year. The trajectory that would be achieved if all countries met their current commitments under the Paris Agreement is referred to as APC, which projects emissions declining to about 22 $GtCO_2$ per year by 2050.[45] The implication of the IEA STEPS scenario is that maintaining the policies that have already been implemented would result in global carbon dioxide emissions out to 2050 that are similar to what they are in 2021.

Table 2.2: $GtCO_2$/yr emissions by 2050 under different SSP scenarios.[46] [47]

Scenario	$GtCO_2$/yr
SSP5–8.5	82
SSP4–6.0	48
SSP2–4.5	42
SSP4–3.4	20
SSP1–2.6	18
IEA STEPS	36
IEA APC	22

The IEA analysis indicates that the world is entering an extended plateauing of emissions. For climate change to 2050, SSP2–4.5 and SSP4–3.4 are the most likely of the IPCC scenarios to serve as a baseline and should be the focus of impact assessments and policy planning.[48]

The most striking aspect of the comparison between the IPCC and IEA scenarios is the strong divergence of the extreme emissions scenario SSP5–8.5 (and RCP8.5) from the IEA scenarios, with the 8.5 emissions values more than twice as high as the IEA STEP scenario at 2050. It is difficult to overstate the importance of the shift in expectations for future emissions that is represented by the difference in the new IEA scenarios versus RCP8.5. The IPCC, the U.S. National Climate Assessment and a majority of published papers have centered their analyses on RCP8.5 as a reference scenario against which climate impacts and policies are evaluated.[49]

International climate policy negotiations under the UN Framework Convention for Climate Change (UNFCCC) no longer considers RCP8.5 in its negotiations, as per the COP26 in 2021.[50]

While there is growing acceptance that the RCP8.5 and SSP5-8.5 scenarios are implausible, temperature projections associated with the RCP8.5 projections are featured prominently in the Expert Report written by Steven Running and Cathy Whitlock. Every future climate outlook graphic presented in sections B5-B9 as well as the entire set of projections included in Attachment 6 include, sometimes exclusively, RCP8.5-based projections.

Further, climate model simulations used in the IPCC AR6 to project the amount of warming in the 21st century (Table 2.1) are not providing the full range of scenarios of plausible climate outcomes. Two recent journal publications have found that climate models are too sensitive to increasing CO_2,[51] [52] and that more likely values of warming are on the lower part of the *very likely* range in Table 2.1 (or even lower). The climate model simulations used in the IPCC AR6 include very limited scenarios of volcanic eruptions and solar variability. Further, the climate models have inadequate representations of solar indirect effects and multi-decadal to century-scale variations in the large-scale ocean circulations. All of the components of natural variability point to cooling during the period 2020 to 2050. Individually these terms are not expected to be large. However when summed, their magnitude approaches, or could even exceed, the magnitude of the emissions-driven warming for the next three decades.[53]

The bottom line is that we do not know how the climate of the remainder of the 21st century will evolve. We are bound to be surprised, particularly by unpredictable natural climate variability.

2.2.2 Is warming dangerous?

The Plaintiffs make the following assertions:

- "There is an overwhelming scientific consensus that human-caused climate disruption is occurring and is **dangerous** to humans and other life and ecosystems on which humans depend."[54]
- "The threats posed by fossil fuels and the climate crisis are **existential**."[55]

As described in Section 1.2, detecting any change in extreme weather or climate events associated with fossil-fuel driven global warming is very difficult against the background of natural weather and climate variability. The concern about dangers is largely hypothetical and in the future, based on climate model simulations. Once the RCP8.5/SSP5-8.5 scenarios are eliminated, any future "dangers" from climate change, however subjectively defined, become much diminished.

The issue of "dangerous" relates to societal values and psychological perceptions of risk, about which science has little to say. To avoid making value judgments, the IPCC does not define a level at which climate change becomes dangerous. The IPCC Assessment Reports refer to "reasons for concern." There is no truly objective determination of the level at which climate change becomes dangerous, or how we should compare the climate risk with other risks.

The 1992 UN Framework Convention on Climate Change (UNFCCC) Treaty states as its objective: "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent **dangerous** anthropogenic interference with the climate system."[56] Despite the treaty aimed at preventing dangerous anthropogenic interference with the climate system, the UNFCCC has avoided and then struggled to provide a definition of dangerous.

It wasn't until 2010 that clarification of "dangerous" was provided by UN international negotiators: "In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below two degrees Celsius."[57] The 2 °C (3.6 °F) target is relative to pre-industrial temperatures, which presupposes that the warming observed to date since the mid-19th century (at the end of the Little Ice Age) is contributing to climate danger. The scientific validity of the two-degree target has been questioned. The two-degree limit has evolved in a somewhat *ad hoc* and contradictory fashion: policy makers have treated it as a scientific finding, and scientists treat it as a political issue.[58] The 2 °C target was not so much a policy goal but rather a political motivation, reflecting "a mindset that is common to the entire exercise: to create maximum pressure for action."[59]

Apart from the arbitrariness of the 2 °C (3.6 °F) threshold of danger since preindustrial times (with 1.1 °C, or 2 °F, already having occurred), best estimates of future emissions, climate sensitivity to CO_2 and natural climate variability (Section 2.1) indicate that we will likely be close to, or within, the 2 °C target by 2100, based on our current understanding.[60]

So, how dangerous has warming been in recent decades? A recent study quantified the changes in socio-economic vulnerability, expressed as fatalities over exposed population and economic losses, to climate-related hazards between 1980 and 2016.[61] A clear decreasing trend in both human and economic vulnerability was found, with global average mortality and economic loss rates dropping by 6.5 and nearly 5 times over the past 40 years. Vulnerability to weather and climate extremes decrease with wealth and human development. Brian O'Neill, one of the lead architects of the Shared Socioeconomic Pathways (SSPs) developed for the IPCC AR6, stated:

> "There isn't, you know, like a Mad Max scenario among the SSPs [emissions scenarios], we're generally in the climate-change field not talking about futures that are worse than today."[62]

Apart from the objective facts about a risk, our interpretation of those facts is ultimately subjective. Risk science makes a clear distinction between professional judgments about risk versus the public perception of risk. A person's subjective judgement or appraisal of risk can involve social, cultural and psychological factors. No matter how strongly we feel about our perceptions of risk, we often get risk wrong. Understanding the psychology of risk perception is important for rationally managing the risks that arise when our subjective risk perception system gets things dangerously wrong.[63] The cultural theory of risk proposes that individual views on risk are filtered through cultural world views about how society should operate.[64]

Even if the initial harm is small, the social risk may be greatly amplified by the collective response or irrational behaviors of individuals. The response to climate risk, driven by apocalyptic and extinction rhetoric, has arguably crossed the threshold to actually increasing the social risk associated with climate change.

2.3 Harm to children from apocalyptic climate change rhetoric

Numerous academic studies have highlighted the psychological health effects of climate change on children and young adults, including elevated levels of anxiety, depression, post-traumatic stress disorder, increased incidences of suicide, substance abuse, social disruptions including increased violence, and a distressing sense of loss. I have personally received emails from children and young adults suffering from such effects.[65] [66]

As described in the previous sections of this Report, there is little basis in the IPCC assessments for a level of alarm that would induce such psychological effects. The apocalyptic and misleading rhetoric surrounding climate change is arguably the driving impetus of the adverse psychological health effects.

In context of a complex scientific and political debate, there are strong incentives to raising the alarm about climate change. Media gets more clicks and views with alarming stories. Activist campaigners get attention and funding. Researchers who position themselves in the mainstream of apocalyptic rhetoric receive media attention, professional recognition from increasingly activist professional societies, and greater funding opportunities. Politicians that emphasize alarming climate scenarios seek the authority to distribute significant resources to fix the problem according to their own political values.

Are the adverse psychological impacts on children and young adults merely collateral damage of the complex debate on climate change, or are children being used as political tools? It is well known that children are fostering climate change concern among their parents,[67] [68] providing a motivation for apocalyptic messaging targeted at children and young adults.

Public school districts are adopting curricula on climate change that portrays climate change only in context of human causes and as a peril beyond dispute, emphasizing worst case scenarios. Further, there is an explicit objective that students should respond through activism.[69] The materials used in these curricula include those from UNESCO Office for Climate Education[70] and the North American Association for Environmental Education,[71] as well as materials provided by advocacy groups such as the Sierra Club.[72]

- Kristen Hargis of the North American Association for Environmental Education states: "There are a lot of resources out there that are ... helping students draft policies as well, and getting them involved from the beginning. And this is what we want to see, this whole-institution approach where we're creating this culture of climate action."[73]
- The Director-General of UNESCO, Audrey Azoulay, states: "Climate change, which results from our own behaviour, is the greatest threat to our common existence. Education is an essential tool to empower young people to take action for a more sustainable future."[74] The website for the UNESCO Office for Climate Education states: "These resources aim at promoting action"[75]

The "K12 Climate Action Plan" was published by the Aspen Institute. The Commission that prepared this report includes: Randi Weingarten, President of the American Federation of Teachers; Becky Pringle, President of the National Educational Association; John King, U.S. Secretary of Education (Obama Administration); Christine Todd Whitman, EPA Administrator (Bush Administration) and former NJ Governor; Linda Darling-Hammond, President of the California State Board of Education; Pedro Martinez, Superintendent of the San Antonio Independent School District. Their stated mission and beliefs:[76]

- "MISSION: Our mission is to unlock the power of the public K-12 education sector to be a force for climate action, solutions, and environmental justice to help prepare children and youth to advance a more sustainable, resilient, and equitable society."
- "BELIEFS: We believe today's children and youth will be essential in the fight against climate change, and we must empower children and youth with the knowledge and skills to build a more sustainable, resilient, and equitable world."

Additional statements of note:[77]

- "Advocacy and the media will help build the narrative for supporting our schools in moving toward climate action, solutions, and environmental justice."

- "In fact, education has been identified as an underutilized social tipping point needed for decarbonization — the process of phasing out reliance on carbon across all parts of the economy."

The presentation of climate change to children is far more alarming and less nuanced than what adults are exposed to. Stories of the coming climate apocalypse have become commonplace in schools, textbooks, churches, movies and even children's books. A prominent example is the book "Our House Is on Fire: Greta Thunberg's Call to Save the Planet,"[78] a picture book aimed at ages 3-8. The book's overarching message is summed by this statement in the book: "There might not be a world to live in when she grows up. What use is school without a future?"[79]

Media targeted at teens and young adults portrays relentless doom. The 2018 U.N. warning that governments need to take action on climate change within 12 years led Rep. Alexandria Ocasio-Cortez to incorrectly conclude that millennials fear "the world is gonna end in 12 years if we don't address climate change."[80] The website of the U.K.-based group Extinction Rebellion warns that "societal collapse and mass death are seen as inevitable by scientists and other credible voices."[81]

The world's teens and young adults seem to have gotten the message: A 2021 study polled 10,000 people between the ages of 16 and 25 from numerous different countries, and found that over half thought that humanity was "doomed" because of climate change. Further, there is an explicitly political message being fed to teens and young adults as evidenced by this finding from the study: "Climate anxiety and distress were correlated with perceived inadequate government response and associated feelings of betrayal."[82]

However, there is growing alarm about alarmism among climate activists. There is a fierce debate about whether more pessimistic messaging energizes people to fight climate change or causes them to conclude the world is doomed and tune out, leading us down a path of inaction.[83]

Some voices are suggesting that we would all be better off if we dialed down the hyperbole about climate change. Kate Marvel, climate scientist at Columbia University and science communicator: "This message of 'We're all going to die, how dare you say there might be something we can do' ... that's just not supported by the science." "There are so many futures between doomed and fine." "I'm not saying we can all rest, and I'm not saying we live in the best of all possible worlds. But one can have a sense of optimism by working towards a solution."[84]

Some serious journalists admit that they have been misled. Journalist David Wallace-Wells published a book in 2019 entitled *The Uninhabitable Earth.* His article in the New York Magazine with the same title has the subtitle: "Famine, economic collapse, a sun that cooks us: What climate change could wreak—sooner than you think."[85] This book describes some extreme scenarios that are worth contemplating, but they do not add up to an uninhabitable Earth, or even a place that would be an awful place to live. Subsequent to publication of his book, David Wallace-Wells made this statement: "Anyone, including me, who has built their understanding on what level of warming is likely this century on that RCP8.5 scenario should probably revise that understanding in a less alarmist direction."[86] (see Section 2.2 of this Report).

The responsibility of adults is to teach children and young adults how to solve problems effectively, not to preach the end of the world. Adults also need to help children become more resilient. The book *The Coddling of the American Mind* describes how parents' attempts to promote their kids' emotional well-being often instead makes them more emotionally fragile.[87] Apart from ill-advised parenting, children and young adults are being used as tools in a national and international political campaign. Blaming this unfortunate situation of psychological stress on a changing climate is incorrect, and the use of this situation to achieve political goals is arguably acting to reinforce the childrens' psychological injuries.

2.4 Summary

The climate "catastrophe" isn't what it used to be. Circa 2013 with publication of the IPCC AR5 Report, RCP8.5 was regarded as the business-as-usual emissions scenario, with expected warming of 4 to 5 °C (7.2 to 9 °F) by 2100. Now there is growing acceptance that RCP8.5 is implausible, and RCP4.5 is arguably the current business-as-usual emissions scenario. Only a few years ago, an emissions trajectory that followed RCP4.5 with 2 to 3 °C (3.6 to 5.4 °F) warming was regarded as climate policy success. As limiting warming to 2 °C (3.6 °F) seems to be in reach (now deemed to be the "threshold of catastrophe"),[88] the goal posts were moved in 2018 to reduce the warming target to 1.5 °C (2.7 °F).[89] Climate catastrophe rhetoric now seems linked to extreme weather events, most of which are difficult to identify any role for human-caused climate change in increasing either their intensity or frequency.

3. Montana's electric power systems

Montana is the U.S. state with the third lowest population density, ranking behind Wyoming and Alaska. Geographically, Montana is one of northern most states in the nation as well as one of the coldest. Montana's economy is largely based on its natural resources: agriculture and ranching; oil, gas, coal, mineral extraction; lumber; and tourism. Montana ranks 11th in overall energy consumption per capita, but ranks 1st in residential energy use per capita owing to cold wintertime temperatures.[90] Montana has nearly one-third of U.S. recoverable coal reserves,[91] and coal currently provides approximately 43% of its electricity.[92] Montana also has abundant renewable energy resources: for 2021, Montana ranked 10th in the U.S. in terms of electricity generated from renewables at roughly 52%.[93]

This section addresses the feasibility of a rapid transition to 100% renewable energy, as articulated in the Complaint and the Expert Report of Mark Jacobson.

3.1 Montana's renewable energy resources

Montana has abundant renewable energy resources, but their modes of variability are far from optimal for providing 24/365 electricity owing to the climatological and weather variability of the renewable resources.

3.1.1 Hydropower

The infancy of hydropower in America began in the early 1880s. Within the first two years of statehood, Montana's first hydropower facility would go live in Great Falls.[94] Hydropower has remained a critical resource within the state and as of June 2022 was the source of over 54% of Montana's electricity generation.[95] Montana is the seventh-largest producer of hydroelectric power in the nation.[96] However, hydropower comes with challenges that cap its benefits.

There is a strong seasonal cycle in the availability of water available for Montana's hydroelectric production. The peak season for generation is from early spring through mid-summer, during which time snowmelt drives the highest water levels in most of Montana's streams and rivers. On longer time scales, there are fluctuations from climate regimes such as El Niño/La Niña. These factors can influence availability levels throughout the year and from year-to-year.

As can be seen in Figure 3.1, these factors can result in annual and seasonal variances that deviate significantly from the mean. For instance, a pronounced drought and warm spring in 2017 resulted in suppressed peak season behavior. The year 1937 saw values well below the mean throughout the entire year. Lost production can also occur during heavy streamflow seasons such as those experienced in 1975 and 2011 that cannot be fully leveraged. Some short-term extreme behavior can be partially regulated via regulating flow from existing reservoirs, but flood and drought management do not always coincide with optimal hydropower production.

While hydroelectric power has been a critical element of Montana's energy portfolio, it is unlikely to increase meaningfully. Costs associated with large hydropower facilities along with potential environmental and ecological impacts would likely limit future expansion.

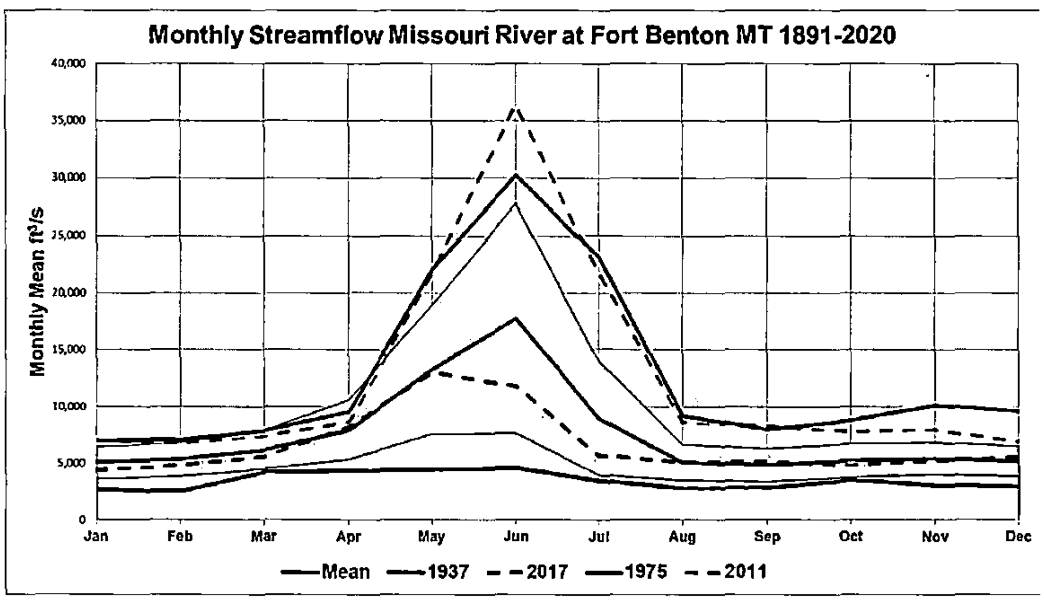

Figure 3.1 – Missouri River monthly mean streamflow at Fort Benton, MT. Mean and +/-1 standard deviation (blue shaded) for years 1891 to 2020 along with representative strong (green) and weak (red) streamflow scenarios. Graphic based on data from USGS.[97]

3.1.2 Solar Power

Solar power generation has traditionally focused in the southwestern portion of the U.S., where low latitudes deliver year-round long days combined with sunny skies that create an optimal situation for solar power. As can be seen in mapping developed by the National Renewable Energy Laboratory (Figure 3.2), much of Montana receives the lowest classification of solar irradiance.[98] Most effective solar power generation is achieved when the sun's light arrives perpendicular to the receiving solar panel. Higher latitudes require more panel tilt to achieve better production, leading to increased spacing between panels and angles that are not always conducive to rooftop installations.

Weather elements also reduce solar potential in Montana, including cloud cover that decreases the amount of sun reaching the panels and snowpack which may cover the panels. This has meant that traditional single angle installations are effective only during summer. Historical costs associated with solar panel installations have limited the potential of such seasonally-targeted installations in Montana.

The capacity for solar energy in Montana will never reach that seen in the more southern states. Advancements in adjustable tilt installations, bifacial panels and energy storage technologies could provide increased opportunity for solar power installations in the future.

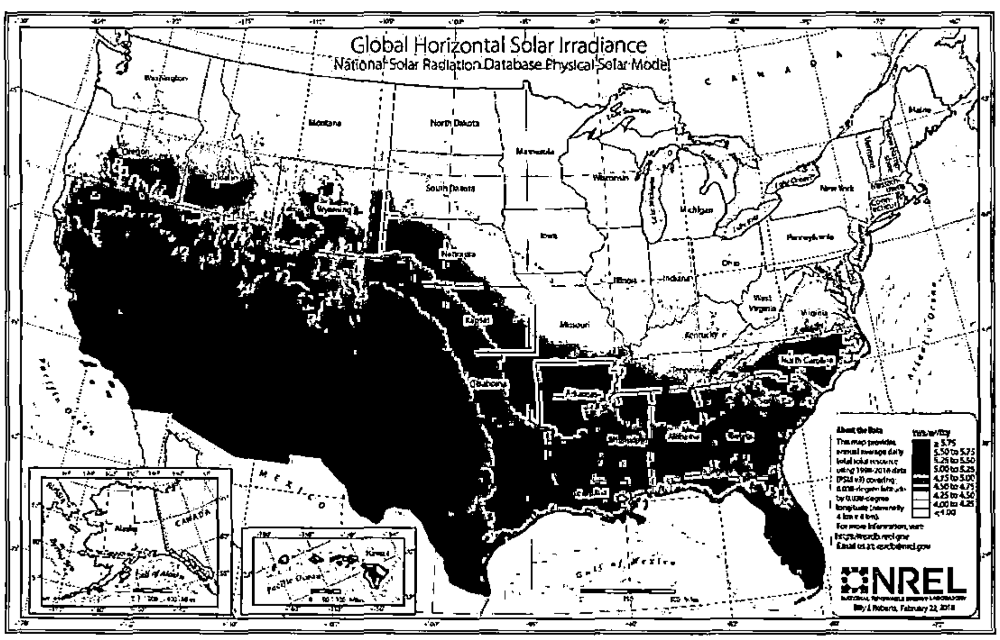

Figure 3.2 – US Global Horizontal Solar Irradiance map developed by the National Renewable Energy Laboratory (NREL).

3.1.3 Wind Power

Like hydropower, harnessing the wind for energy production has been viable for over a century. Wind power requires distributed large-scale installations and electricity transmission infrastructure located relative to high wind regions. Montana's wind energy production has increased sevenfold between 2006 and 2020,[99] and Montana's electric grid mix currently includes 11.5% wind power.[100]

In general, wind speeds in Montana peak in strength during winter with a lull in summer. Wind is complementary to hydropower during much of the year, excluding late summer when both are at the lower end of their annual production cycle. However, wind energy is susceptible to periods of relative stilling that can last decades.[101] [102] An extreme seasonal wind drought occurred in early 2015 that set records across much of the western U.S.[103] [104]

Aside from the mountainous areas in the western portion of Montana, much of the state contains areas that rank high for wind power potential. Existing installations have struck a balance of positioning in areas of high average wind speed and proximity to transmission lines. A recent development is wind turbines that sit higher than the 80-meter standard of the last two decades. As can be seen in analysis by NREL (Figure 3.3), Montana has strong average wind speeds at the 100-meter level and while not all locations sit near Montana's existing transmission network (Figure 3.3 inset), there is certainly opportunity to cost effectively add additional wind energy production.

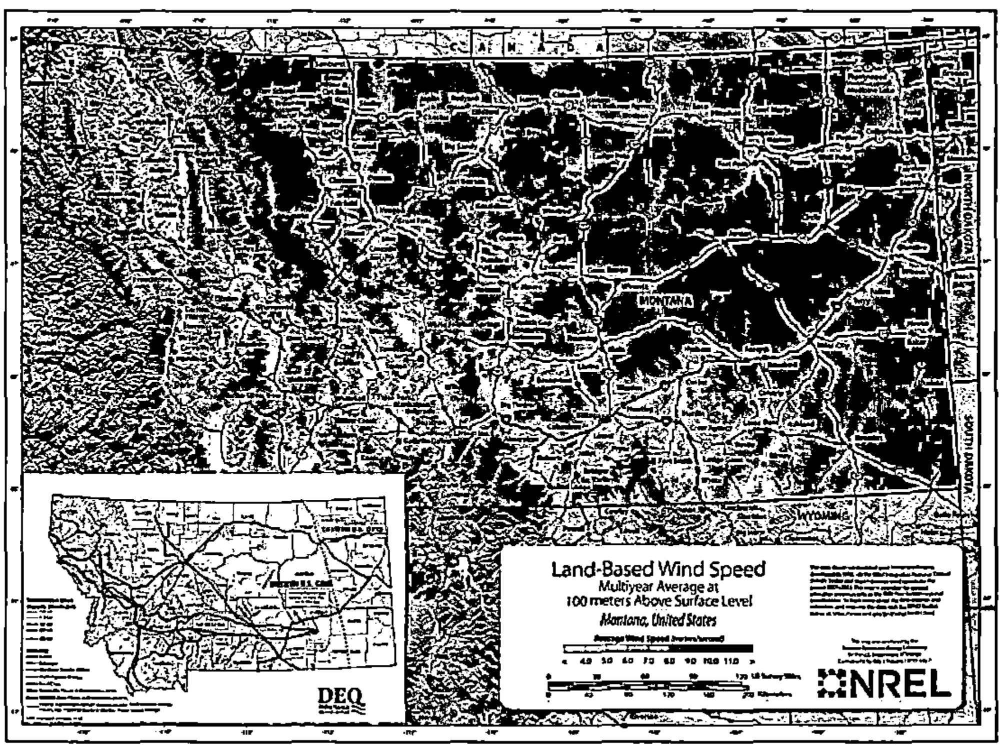

Figure 3.3 – NREL developed 100-meter average wind speeds for the state of Montana.[105] Insert is the network of Montana's electric grid transmission lines as provided by the Montana Department of Environmental Quality.[106]

3.1.4 Geothermal Power

An area of relatively untapped energy production across the U.S. is geothermal power. Today less than 1% of U.S. electricity production comes from geothermal sources. Recognizing the opportunity, the Advanced Geothermal Research and Development Act was passed in 2007.[107] This has contributed to a sharp increase in related patents awarded in the US.[108]

Montana has a long history of leveraging its geothermal resources for tourism as well as other non-power production uses.[109] As can be seen in Figure 3.4, much of the state demonstrates geothermal potential with the most validated area being in the southwestern portion near the Yellowstone Caldera.

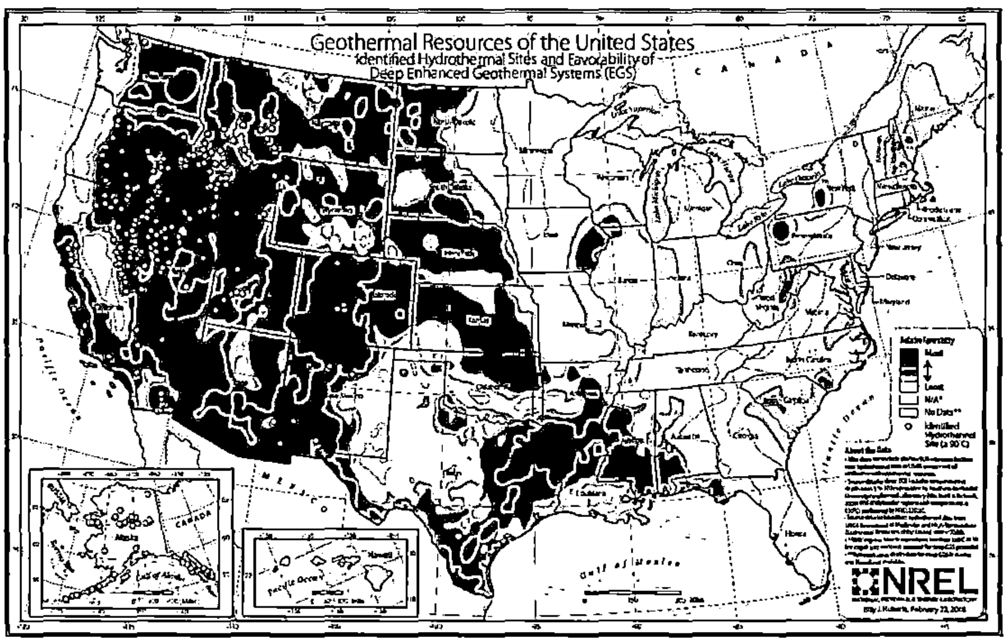

Figure 3.4 – NREL developed geothermal resources in the United States.[110]

With the advent of Enhanced Geothermal Systems,[111] there is an increasing opportunity to leverage this resource with a minimal footprint and environmental impact.[112] This also provides an opportunity for Montana to distribute renewable energy production to a region of the state not particularly well suited for wind and solar.

3.2 Feasibility of 100% renewable energy for Montana

Montana has abundant renewable energy resources from hydropower and wind. Even so, an electric power system based solely on hydropower, wind and solar is not viable without storage on a scale that is anywhere close to feasible or affordable by 2035 and 2050. Advanced geothermal energy, while showing much promise, requires substantial research and development for large-scale deployments.

The key issue is the variability and intermittency of the renewable energy sources, ranging from intermittency on time scales of minutes, diurnal variations, variations from weather systems, seasonal cycles, interannual variability and even decadal-scale variability.

Mark Jacobson's Expert Report proposes to address this intermittency/variability using electricity storage in batteries, pumped hydroelectric storage (PHS) and hydroelectric dams. Current battery technology can provide electricity storage on time scales of minutes to hours, and long-term utility-scale energy storage using batteries may be infeasible. Green hydrogen is a possibility for energy storage, but this requires substantial research and development before it can be considered for large-scale applications for energy storage.

The Gordon Butte PHS project is being designed to take advantage of the unique geological features to create a new PHS facility within Montana. While this is very promising technology and a recent NREL study shows technical PHS potential within Montana,[113] the Gordon Butte PHS has even been described as a "spotted, multicolor unicorn" by the CEO of Absaroka Energy who is developing Gordon Butte.[114] These projects can take over a decade to come to fruition and much of the process is outside the purview of Montana. For example, Gordon Butte began permitting with the federal government in 2013,[115] is being funded by a Danish group of investors,[116] and is not anticipated to be online until 2029.[117]

Mark Jacobson's plan also relies on the WECC transmission grid to keep the grid stable in Montana. Montana currently exports about 40% of its electricity, primarily to Oregon and Washington.[118] When weather and climate conditions are sufficiently adverse that Montana would need to import electricity, it is likely that much of the western U.S. would also be impacted by the same weather conditions and would also be looking to import electricity.

Consider the following scenario, which can be expected to occur multiple times each winter with varying magnitudes and durations. "Arctic outbreaks" periodically bring exceptionally cold temperatures to large regions of the continental U.S., even in this era of global warming. An exceptionally cold outbreak occurred during February and March 2019, with similar outbreaks in 2014 and 2017. In February 2019, average temperature departures from normal in Montana were as much as 27 to 28 °F below normal, with Great Falls at the heart of the cold. Temperatures did not rise above 0 °F on 11 days and dropped to 0 °F or below on 24 nights. While the cold in February was remarkable for its persistence, the subsequent Arctic blast in early March 2019 delivered the coldest temperatures. Almost two dozen official stations in Montana broke monthly records, with an all-time record state low temperature for March of -46 °F.[119]

While Arctic outbreaks generally impact the northern Great Plains states the worst, the spatial extent of these outbreaks can be very large. The cold outbreak during February 2021 that impacted Montana also covered half of the U.S. and extended down to Texas, where massive power outages ensued that resulted in considerable loss of life.[120]

In addition to exceptional power demand for residential heating during such Arctic outbreaks, any power generation from renewables is at a minimum during such periods. Montana's solar and hydropower capacity are at their lowest during winter. While winter winds are generally strong, the Arctic cold air outbreaks are accompanied by large regions of high pressure that are called cold-core anticyclones (note: Arctic cold air outbreaks and the formation of cold-core anticyclones was the topic of my PhD thesis).[121] [122] The nature of these circulations is that wind speeds are very low within the high pressure system, resulting in very low amounts of wind power production. The large horizontal scale of these high pressure systems indicates that the WECC transmission grid is not going to be of much help if much of the region is also suffering from cold temperatures and low winds.

Providing sufficient power for Montana during such an Arctic outbreak with 100% renewable energy requires hugely infeasible amounts of energy storage. Apart from the possibility of advanced geothermal energy, there seems to be no options other than nuclear or fossil fuels to produce the needed amounts of energy under these conditions. Renewable-only energy for Montana is an exceptionally challenging and costly endeavor, and the proposal put forward by Marc Jacobson is little more than a fairy tale, particularly on the proposed time scales and with available technology.

3.3 Challenges of the mid-21st century energy transition

For the past two centuries, fossil fuels have fueled the progress of humanity, improved standards of living and increased the life span for billions of people.[123] In the 21st century, a rapid transition towards eliminating CO_2 emissions has become an international imperative for climate change mitigation under the auspices of the UNFCCC Paris Agreement.

Currently there is rapid technological innovation across all domains of the global energy sector. Innovation is transforming every part of the modern energy system, including long-distance transmission and power grid control, energy storage, residential heating, electric vehicles, and remarkable progress in advanced designs for nuclear power. In context of carbon management (carbon capture and storage, direct air capture), rapid technological innovation is also underway.

3.3.1 Status of the energy transition

The U.S. electricity system began transitioning two decades ago. The old system was characterized by a relatively small number of large generators that were connected to a transmission grid. There were baseload and peak generators to accommodate variations in weather-driven demand. Coal reserves guaranteed an inexpensive supply of fuel if demand was high or there were supply or cost issues with natural gas.

Over the past two decades, the electricity system has connected enormous numbers of smaller generators from wind and solar to the grid. Weather-driven variations now occur in both supply and demand, which are managed by demand response, storage, overcapacity, and interconnections with neighboring systems. Wind and solar power have developed synergistically with natural gas power plants (and to a lesser extent coal), since it is easy to turn gas power plants off and on to balance the intermittent energy supplies from wind and solar.

The realization is growing that countries and states face substantial economic and geopolitical risks if they reduce production of fossil fuel-based energy under the assumption that renewables can quickly replace them. Premature retirements of baseload generating units, such as coal and nuclear plants, combined with the intermittency of wind and solar as power sources, have seriously impaired grid resiliency and reliability in some regions and countries. These risks have been emphasized by Russia's war on Ukraine, with the ensuing gas and oil shortages and price spikes, leading to political pressures to abandon green energy pledges and return to coal and burn biomass. The energy transition has been further disrupted by supply-chain problems, declining government subsidies and an affordability crisis for materials needed for wind, solar and batteries.

There are substantial institutional and structural barriers in the U.S. that are slowing down or preventing wind and solar generating capacity from being quickly integrated into transmission grids. The U.S. transmission grid has been growing very slowly in recent decades, at a pace that is a fraction of that required for net-zero emissions plans. Transmission and renewable energy projects are being blocked across the country by landowners, consumer and environmental groups. Even when all relevant parties agree to proceed with new transition lines, the cost allocation process can take years.[124] A further challenge is that utilities and grid operators need to analyze the impacts of new generating projects when added to the grid.[125]

In the U.S., electric vehicles (EVs) are rapidly growing in popularity, but it is becoming increasingly difficult to actually purchase an EV. Tesla CEO Elon Musk said his electric-car factories are "losing billions of dollars" as global supply-chain disruptions and challenges in battery manufacturing constrain the company's ability to scale up production.[126] According to the CEO of Rivian, a manufacturer of electric adventure vehicles: "All the world's cell production combined represents well under 10% of what we will need in 10 years...meaning 90% to 95% of the battery supply chain does not exist."[127]

The net outcome of the energy transition to date is that in 2022, very few of the world's countries are on track to meet their emissions reductions commitment. Further, the shortages and price spikes in the global natural gas and oil supply caused by Russia's war on Ukraine and supply chain issues for materials have demonstrated the current fragility of the transition and the importance of maintaining the capacity to burn natural gas and coal.

3.3.2 Competing values in the energy transition

The overall vision for future energy systems as per the IPCC AR6 WGIII Report is predicated around net-zero emissions, with energy systems having the following characteristics: (1) electricity systems that produce no net CO_2 or remove CO_2 from the atmosphere; (2) widespread electrification of end uses; (3) substantially lower use of fossil fuels; (4) use of hydrogen, bioenergy, and ammonia in sectors less amenable to electrification; (5) more efficient use of energy; (6) greater energy system integration across regions and components; and (7) use of CO_2 removal technologies.[128] It is noted here that the IPCC vision is far less constraining and restrictive than the vision put forward by Mark Jacobson in his Expert Report.

A more holistic vision for future energy systems considers a broader range of values plus potential dangers and risks associated with the transition. Table 3.1 provides a list of relevant values and the associated risks or dangers to be considered while envisioning electric power systems humans will want and need to thrive during the 21st century.

Table 3.1 Values and risks/dangers associated with electric power systems.[129]

Values	Risks / Dangers
Abundant	Structural inadequacies to meet energy needs
Reliable	Catastrophic power cuts in the face of weather extremes
Secure	Subject to supply shocks (availability, cost); cyberattacks
Clean	Pollution from emissions, mining; ecosystem and human health concerns
Food & Water	High cost and/or lower food supply; competition for scarce water resources
Local Control	Loss of autonomy; loss of economic opportunity
Minimal Land Use	Interference with other land use priorities and ecosystems
Minimal Material Use	Scarcity of rare minerals; scope and scale of mining; supply chain issues
No CO_2 emissions	Long-term concerns about adverse impacts of climate change

On this list, the key values for the state of Montana seem to be abundance, reliability, security and clean in terms of conventional pollution.[130] In context of this Complaint, it seems we need to add the value of "urgency" of reducing CO_2 emissions to allay the dangers of psychological injuries to the Youth Plaintiffs. We should also add "coal on tribal lands" to allay concerns of the Crow Nation, who is actively seeking to develop the coal resources on their land.[131] The Crow Nation's coal and resource assets are worth an estimated $27 billion, making it among the largest coal owners worldwide. "Resource tribes depend on the development of their resources to create better tomorrows for our children," states Conrad Stewart, director of energy and water for the Crow Nation of Montana.[132] One wonders whether the children of the Crow Nation are suffering psychological injuries from the prospect of continued poverty from being unable to benefit from the natural resources on their land.

Prioritizing and balancing these values and concerns is what the political process is for. Rather than focusing on the single value of CO_2 emissions reductions, wise policy seeks to balance the competing objectives. Focusing only on one goal without due attention to other major goals can result in worsening conditions for all goals.

In considering the energy transition, we need to acknowledge that the world, including Montana, will need much more energy in the future than it is currently consuming. Apart from supporting human development and emergence from poverty, more electricity can help reduce our vulnerability to the weather and climate: air conditioners and cleaners, water desalination plants, irrigation, vertical farming operations, water pumps, and environmental monitoring systems. Further, abundant electricity is key to innovations in advanced materials, advanced manufacturing, artificial intelligence, blockchain, robotics, photonics, electronics, quantum computing and others that are currently unforeseen or unimagined.

The energy choices are fossil fuels (with carbon capture and removal as needed), renewable energy and nuclear energy. Of these three choices, nuclear has the greatest potential to provide the very large amounts of energy that we will need through the 21st century with minimal impact on the environment. Different countries and locales will use different combinations of these energy sources based upon their climate, local resources, power needs, and sociopolitical preferences.

3.3.3 Managing Transition Risk: Electric Power Systems

The tightly integrated system of systems that provides the backbone for advanced economies—power, transport, telecommunications, health services, logistics, payments, emergency services, public information—all depend on electricity. The rapid transition of electric power systems away from fossil fuels to meet net-zero emissions targets is introducing substantial new risks to electric power systems. A transition of the electric power system that produces reduced amounts of electricity, less reliable electricity and/or more expensive electricity to achieve net-zero goals would be a tourniquet that restricts the lifeblood of modern society, hampering development and thwarting sustainability efforts.

The Russian war on Ukraine provides a stark conflict between net-zero emissions goals versus immediate needs for abundant, reliable and secure energy. The dangers from inadequate, unreliable and insecure electricity supply are well known and becoming increasingly apparent as European and other countries struggle with inadequate natural gas supplies that they had been receiving from Russia. By contrast, the dangers from CO_2 emissions are much more uncertain, with a long time horizon and a far weaker knowledge base. The debate is then between imposition of certain, intolerable risks from the rapid transition away from fossil fuels, versus the highly uncertain long-term, future impacts from climate change.

This conflict can be resolved by relaxing the time horizon for the 21st century energy transition (including reducing CO_2 emissions) and maintaining energy abundance, reliability and security through the energy transition. Yes, CO_2 emissions are a problem and should be reduced, but not as an urgent problem that trumps the need for abundant, reliable and secure sources of energy for the global population or the population of Montana.

The low feasibility and high costs of reaching net-zero emissions targets by 2050 while maintaining energy security and reliability are at the heart of the debate over allowing near-term net-zero targets to dominate future energy systems. Attempts to speed up the transition away from fossil fuels by restricting the production of fossil fuels and new generating plants has backfired, with increasing power shortages during extreme weather and by making many countries reliant on Russia's fossil fuels.

The long time horizons of the transition and uncertainties about both the technologies that will be available and future climate impacts are best handled by adaptive risk management. Adaptive risk management includes learning from trial and error and incorporating changes in the technologies and knowledge base over time.[133]

The 21st century energy transition can be facilitated with minimal regrets by:

- Accepting that the world will continue to need and desire much more energy.
- Accepting that we will need more fossil fuels in the near term to maintain energy security and reliability and to facilitate the transition in terms of developing and implementing new, cleaner technologies.
- Continuing to develop and test a range of options for energy production, transmission and other technologies that address goals of lessening the environmental impact of energy production, CO_2 emissions and other societal values (Table 3.1).

- Using the next two to three decades as a learning period with new technologies, experimentation and intelligent trial and error, without the restrictions of near-term targets for CO_2 emissions.

In the near term, laying the foundation for abundant, secure, inexpensive and clean electricity is substantially more important than trying to stamp out fossil fuel use. A practical and humane transition focuses on developing and deploying new sources of clean energy. A practical and humane transition does not focus on eliminating electricity from fossil fuels, since we will need much more energy to support the materials required for renewable energy and battery storage and building nuclear power plants, as well as to support electric vehicles and heat pumps.

Coal production in the U.S. declined by one third between 2000 and 2019.[134] However, since 2021 coal production has risen sharply to meet surging global coal demand.[135] Coal's current demand is largely driven by the shortages and high prices of natural gas.[136] The EIA says the increase in coal generation is unlikely to continue in the long term due to continued power plant retirements and competition from other generation alternatives like natural gas.[137] The long-term future of U.S. coal production (including Montana's) and global demand will depend on geopolitics, macroeconomics and technology developments.

The push for weather-based renewable energy (wind, solar, hydro) such as Mark Jacobson's proposal seems somewhat ironic. One of the main motivations for transitioning away from fossil fuels is to avoid the extreme weather that is alleged to be associated with increasing CO_2 levels. So why subject our energy supply to the vagaries of water droughts and wind droughts, icing and forest fires?

4. Role of Montana in mitigating climate change

A central tenet of the Complaint is apparent in this paragraph:

> "Importantly, there can be prompt redress for Youth Plaintiffs' psychological injuries with declaratory and/or injunctive relief. If the Court granted declaratory relief, it would help redress Youth Plaintiffs psychological injuries by making it clear that their fears were understood by the judiciary and by restoring their confidence that there is recourse for government conduct that violates their constitutional rights–it would give them hope and restore their confidence in their government. Injunctive relief would also provide redress for Youth Plaintiffs psychological injuries because they would then know that their government was taking meaningful action to respond to the dangers posed by the climate crisis."[138]

Apart from the issues described in earlier sections of this report, this paragraph reflects three mistaken assumptions:

- Global reductions in fossil fuel emissions will meaningfully influence Montana's climate on the time scale of the 21st century.
- Reduction of emissions from Montana would result in a meaningful fraction of global emissions.
- The two Montana laws challenged by the Plaintiffs meaningfully contribute to Montana's climate change.

With regards to Montana's CO_2 emissions, based on 2019 estimates Montana produces 0.63% of U.S. emissions and 0.09% of global emissions.[139] [140] CO_2 is a well-mixed gas in the atmosphere, and local CO_2 emissions do not influence the local climate. The premise behind the UN treaties and agreements on climate change is that reducing global emissions is required to stabilize the global climate, with the implicit assumption that reducing CO_2 emissions will rapidly decrease atmospheric CO_2 and improve regional climates. Reducing 0.09% of global emissions will not make a meaningful difference in atmospheric CO_2 or improve Montana's climate.

The Plaintiffs seem to assume that the two laws they challenge are responsible for a significant percentage of Montana's GHG emissions. Even if this were the case, it would not make any noticeable difference in the global amount of atmospheric CO_2 or in Montana's climate. Simply put, Montana is powerless on its own to influence the global or its local climate.

It is a substantial scientific challenge to understand how atmospheric CO_2 will evolve in response to emissions reductions, and how the fast and slow elements of the climate system will respond. The vagaries of the carbon cycle, in combination with natural climate variability, makes it difficult to identify a measurable change in the evolution of global warming in response to emissions reduction. Inertia in the ocean and ice sheets along with natural internal variability of the climate system will delay the emergence of a discernible response of the climate in the 21st century even to strong CO_2 emissions reductions.[141]

Even with large reductions in carbon emissions, a corresponding significant shift in surface temperature evolution is not anticipated until decades later.[142] It is unclear how the climate will evolve after net-zero emissions is achieved. To address this issue, the Zero Emissions Commitment Model Intercomparison Project (ZECMIP) used multiple Earth System Models to investigate how the climate system including the carbon cycle will respond 50 years after an immediate cessation of CO_2 emissions.[143] The models exhibit a wide variety of behaviors, with some models continuing to warm for decades to millennia while others cool. Carbon uptake by both the ocean and the terrestrial biosphere is shown to be important in counteracting the warming effect created by reduction in ocean heat uptake anticipated decades after emissions cease. This response is difficult to constrain primarily given the high uncertainty in the effectiveness of ocean carbon uptake.[144]

The bottom line is that there is substantial inertia in the global carbon cycle and the climate system. Even if emissions are successfully reduced/eliminated, it takes time for the CO_2 concentration in the atmosphere to respond to the emissions reduction and it takes time for the climate to respond to the change in atmospheric CO_2 concentration. There is substantial uncertainty regarding how much time this will take – we may not see much of a beneficial change to the climate before the 22nd century even if emissions are successfully eliminated, particularly against the background of large natural climate variability.

Climate change is an ongoing predicament.[145] Even if CO_2 and other GHG emissions are eliminated, natural climate variability and inevitable surprises will provide ongoing challenges that require continuing adaptation by communities and states. The 21st century energy transition will be driven by politics, economics and technological developments, with each state and community responding in a different way that best balances their values and perceived risks and opportunities.

5. Conclusion

Climate change and its interactions with humans and their societies are exceedingly complex issues. The misidentification of climate change as a "crisis" and the ensuing precautionary mandate to rapidly eliminate the use of fossil fuels is creating new risks associated with an energy supply that is not adequate for Montana's cold winter temperatures.

Our hubristic aspirations for control fail to acknowledge the wickedness and systemic aspects of the climate change problem and its proposed solutions. We can seek to lower our emissions, but we should not pretend that we are controlling the climate.[146]

This Complaint reflects an unfortunate cycle of:

- Psychological injuries of the Youth Plaintiffs associated with unjustified apocalyptic rhetoric about climate change targeted at children and young adults.
- The rhetoric in the media and political motivations that blames these adverse weather events and environmental changes on fossil fuel companies and government inaction.
- Further validation of the Youth Plaintiffs' concerns and psychological distress through this Complaint, which is largely driven by the adults in these childrens' lives (particularly for the 2-year old Plaintiffs).
- Demands that are being made of the Defendants that would have no material impact on the weather and climate of Montana, but that would allegedly lessen the anxiety and psychological injuries being suffered by the Youth Plaintiffs that have been triggered by unjustified apocalyptic rhetoric about climate change.

The Plaintiffs challenge two laws: the codified "State Energy Policy" and a 2011 amendment to the Montana Environmental Policy Act (MEPA) that cabins environmental review to intra-Montana impacts. It is my understanding of the Complaint that the only relief available to Plaintiffs moving forward is an order from the court declaring these two statutes unconstitutional and enjoining them.

Based on the evidence presented in this report, the Plaintiffs' challenge of these two laws is based on the following mistaken assumptions and assertions:

- *Plaintiffs:* the release of greenhouse gases from fossil fuel emissions into the atmosphere is already triggering a host of adverse consequences in Montana. *Section 1 of this Report* demonstrates that the climate-related concerns observed by the Plaintiffs are well within the range of historical natural weather and climate variability, with worse occurrences of weather and climate extremes observed during the early 20th century.

- *Plaintiffs:* the future threats posed by fossil fuels and the climate crisis are existential. *Section 2 of this Report* demonstrates that the Plaintiffs' concerns about climate change in the 21st century are greatly exaggerated, and not consistent with the most recent assessment reports and research publications.

- *Plaintiffs:* Montana's fossil-fuel based emissions are causing harm to Montana and the world. *Section 4 of this Report* demonstrates that emissions from fossil fuels generated in Montana provide a miniscule contribution to global greenhouse gas emissions and do not influence directly Montana's weather and climate.

- *Plaintiffs:* to avoid the alleged existential threat of climate change, Montana's energy system should transition to a portfolio of 100% renewable energy by 2050. *Section 3 of this Report* demonstrates that Montana's energy mix already has a larger than average share of renewables relative to other states in the U.S., and that a rapid transition to 100% renewable energy on the timescale of 2030 or 2050 risks substantial adverse impacts on the reliability and security of Montana's energy supply.

Elimination of the two laws challenged by the Plaintiffs would have essentially no impact on the climate of Montana, even if their elimination in fact acted to reduce Montana's emissions.

Signed this 27th day of October, 2022 in Reno, Nevada

Judith Curry

APPENDIX A

JUDITH A. CURRY

GENERAL INFORMATION

Education

1982	Ph.D.	The University of Chicago, Geophysical Sciences
1974	B.S. cum laude	Northern Illinois University, Geography

Professional Experience

2016-present	Professor Emerita, School of Earth and Atmospheric Sciences Georgia Institute of Technology
2006-present	President, Climate Forecast Applications Network, LLC
2002-2016	Professor, School of Earth and Atmospheric Sciences Georgia Institute of Technology
2002-2014	Chair, School of Earth and Atmospheric Sciences Georgia Institute of Technology
1992-2002	Professor, University of Colorado-Boulder Department of Aerospace Engineering Sciences Program in Atmospheric and Oceanic Sciences Environmental Studies Program
1989-1992	Associate Professor, Department of Meteorology, Penn State
1986-1989	Assistant Professor, Dept of Earth and Atmospheric Sciences, Purdue University
1982-1986	Assistant Scientist, Dept of Meteorology, University of Wisconsin-Madison

Awards/Honors

2017	Top 50 Women in STEM – Best Schools
2011	Graetzinger Moving School Forward Award, Georgia Tech
2007	Fellow, American Association for the Advancement of Science
2006	Best Faculty Paper Award, Georgia Tech Sigma Xi
2004	Fellow, American Geophysical Union
2002	NASA Group Achievement Award for CAMEX-4
2002	Green Faculty Award, University of Colorado
1997	Elected Councilor, American Meteorological Society
1995	Fellow, American Meteorological Society
1992	Henry G. Houghton Award, the American Meteorological Society
1988	Presidential Young Investigator Award, the National Science Foundation

Professional Activities (since 2000)

World Meteorological Organization / International Council of Scientific Unions / International Ocean Commission / World Climate Research Programme

- Global Energy and Water Experiment (GEWEX) Radiation Panel (1994-2004)
- GEWEX Cloud System Studies (GCSS) Science Steering Group (1998-2004)
- Chair, GCSS Working Group on Polar Clouds (1998-2004)
- Chair, GEWEX Radiation Panel SEAFLUX Project (1999-2004)
- Steering Committee, IGAC/SOLAS Air-Ice Chemical Interactions (2003-2006)
- Science Steering Group, Arctic Climate System (ACSYS) Programme (1994-2000)

National Research Council – National Academies

- Space Studies Board (2004-2007)
- Climate Research Committee (2003-2006)
- Panel: A Strategy to Mitigate the Impact of Sensor Descopes and De-manifests on the NPOESS and GOES-R Spacecraft (2007-2008)
- Committee to review CCSP SAP 1.1 Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences (2007)

U.S. Federal Agencies

- DOE Biological & Environmental Research Advisory Committee (BERAC) (2012-2015)
- Earth Science Subcommittee, NASA Advisory Council (2009-2013)
- Search Committee, NSF Director for Geoscience (2007)
- External Advisory Board, NCAR Atmospheric Technology Division (2004-2006)
- Science Board, DOE ARM Climate Reference Facility, (2008-2011)
- External Review Committee, COSIM Program, Los Alamos National Laboratory (2007)
- NOAA Climate Working Group (2004-2009)

Professional Societies

- Executive Committee, American Physical Society Topical Group on Physics of Climate (2013-2016)
- Member, Fellows Committee, American Geophysical Union (2013-2014)
- Executive Committee of the Council, American Meteorological Society (1998-2000)
- Councilor, American Meteorological Society (1997-2000)

RESEARCH

Books

Curry, J.A, 2023: *Climate Uncertainty and Risk*, Anthem Press, 250 pp, in press.

Khvorostyanov, V.I. and J.A. Curry, 2014: *Kinetics and Thermodynamics of Clouds and Precipitation. Cambridge University Press*, Cambridge University, 762 pp

Curry, J.A. and P.J. Webster, 1999: *Thermodynamics of Atmospheres and Oceans.* Academic Press, London, 467 pp (second edition under contract).

Holton, J.P., J.A. Curry, and J. Doyle, eds., 2003: *Encyclopedia of Atmospheric Sciences.* Academic Press, London, 6244 pp.

Refereed Journal Publications

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