Testimony of Professor William Happer

on Kansas State Senate Bill No. 224, "An Act concerning environmental, social and governance standards"

by the Committee on Federal and State Affairs

Let me begin by stating categorically that the "Act concerning environmental, social and governance standards" will bring major benefits to the citizens Kansas. I hope the legislators will pass it on a bipartisan basis.

To help others judge my qualifications to testify, I provide a little biographical information here. In the summer of 2014 I retired from teaching at Princeton University, where I have been on the faculty since 1980. I left the University from 1990 to 1993 to serve as the Director of Energy Research at the United States Department of Energy in Washington, DC, and I also served for one year from 2018 to 2019 as Deputy Assistant to the President and Senior Director for Emerging Technologies in the National Security Council of the White House. My DOE office supervised a research budget of some $3.5 billion, including environmental and climate science, along with physics, chemistry, biology, climate change and many other scientific areas. I have won a number of awards and I am an elected member of various scientific societies, including the National Academy of Sciences, the American Philosophical Society, the American Academy of Arts and Sciences. I am a fellow of the American Physical Society. I have done research in nuclear physics, atomic, molecular and optical physics, atmospheric physics and other areas. I am probably best known for my invention of the "sodium guide star" concept, used in most modern ground-based telescopes to compensate for deleterious effects of atmospheric turbulence on astronomical observations. I know more than most scientists about the details of Earth's climate.

My testimony concerns those parts environmental, social and governance (ESG) standards that aim to stop the use of fossil fuels. Supposedly, fossil fuels are causing a "climate emergency." This is not true. ESG efforts to eliminate fossil fuels will do great harm to the people of Kansas and, indeed, to the people of the world.

Many well-intentioned people have been misled to think that the carbon dioxide gas emitted when fossil fuels are burned, is a "pollutant. Nothing could be further from the truth. CO_2 is really the gas of life. Without CO_2 plants and all other life on Earth would die. Some 300 years ago, the Irish poet, Alexander Pope diagnosed the problem correctly.

>A little learning is a dangerous thing;
>
>Drink deep, or taste not the Pierian spring:
>
>There shallow draughts intoxicate the brain,
>
>And drinking largely sobers us again.

Too many decent people have taken shallow drafts of the propaganda against CO_2 and have become intoxicated. Sobering up is not easy. As Charles Mackay wrote in his wonderful book, *Extraordinary Popular Delusions and the Madness of Crowds*,

>Men, it has been well said, think in herds; it will be seen that they go mad in herds, while they only recover their senses slowly, one by one.

Nearly everyone today is an environmentalist. We want to live on a clean and healthy planet. Most of us recognize that fossil fuels must be extracted responsibly, minimizing environmental damage from mining and drilling operations, and with due consideration of costs and benefits. Similarly, fossil fuels must be used responsibly, deploying cost-effective technologies that minimize emissions of real pollutants such as fly ash, carbon monoxide, oxides of sulfur and nitrogen, heavy metals, and volatile organic compounds. CO_2 and H_2O, by far the dominant emissions from fossil fuel combustion, are not pollutants, no matter how the definition of the word *pollutant* is distorted.

Human exhaled breath is mostly nitrogen, oxygen, water vapor and carbon dioxide. If fully cleansed of real pollutants, the exhaust from fossil-fuel combustion only differs from our breath by having much less oxygen, most of which has been converted into water vapor and carbon dioxide.

Pure CO_2 gas is completely transparent, as we know from the fact that human breath, with its 4% CO_2 content, is normally invisible. On a frosty day the chilled outside air can condense the water vapor of your breath into visible fog. Around

the year 1861, the Anglo-Irish physicist John Tyndall discovered that water-vapor molecules, H_2O, CO_2 and many other molecular gases that are transparent to visible light, can absorb and emit invisible heat radiation, like that given off by a warm tea kettle or by the Earth. Today, we call these *greenhouse gases.* Commenting on greenhouse warming of the earth by water vapor on p. 359 of his classic book, *Heat, Mode of Motion [3], Tyndall makes the eloquent (and correct) statement:*

> Aqueous vapor is a blanket, more necessary to the vegetable life of England than clothing is to man. Remove for a single summer-night the aqueous vapor from the air which overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost.

Tyndall correctly recognized that the most important greenhouse gas of the earth's atmosphere is water vapor, but he was aware that CO_2 also contributed. The magnitude of the warming from CO_2 is a key issue. "The dose makes the poison!" If increasing CO_2 were toxic to humans or if it were to cause large warmings, harm could indeed be done, and it would make sense to consider limitations to fossil fuel use. However, basic scientific theory and all observational evidence indicates that doubling CO_2 concentrations, which would take more than a century of continued fossil fuel use, would cause about 1 C or less of warming and would have no physiological effects on humans or other animals. The crews of US Navy submarines breathe air with several thousand ppm of CO_2 for months with no ill effects. Here 1 ppm is one CO_2 molecule per million molecules of air. Objective economic studies show that warmings of up to 2 K will be good for the planet.

Although doubling atmospheric CO_2 will cause only a small and benign increase in temperature, it will be enormously beneficial for agriculture and forestry. Few people realize that the Earth is in a CO_2 famine by the standards of geological history. Plant growth is being stunted by too little CO_2. More CO_2 helps plants in two main ways. Most importantly, more CO_2 makes plants more resistant to drought. Agriculture in Kansas, with its occasional dry years will benefit substantially from the increased drought resistance of wheat and other crops. A second subtle but important benefit of CO_2 is suppression of photorespiration,

where low CO2 levels cause the photosynthetic tool of plants, the enzyme rubisco, to mistakenly and harmfully use oxygen molecules, O_2, when CO_2 is in short supply. Photorespiration is estimated to reduce the productivity of most crops today, notably the C3 plant wheat, by about 25%.   Doubling or quadrupling CO_2 will substantially reduce these losses. The positive role of CO_2 on agriculture was highlighted in a recent study by C. Taylor and W. Shlenker (*Environmental Drivers of Agricultural Productivity Growth: CO₂ Fertilization of US Field Crops*, https://www.nber.org/papers/w29320):

> We find consistently high fertilization effects: a 1 ppm increase in CO_2 equates to a 0.5 %, 0.6 %, and 0.8 % yield increase for corn, soybeans, and wheat, respectively. Viewed retrospectively, 10 %, 30 %, and 40 % of each crop's yield improvements since 1940 are attributable to rising CO_2

I will conclude this brief testimony with a little hard-core physics. I hope that legislators with a technical background will pay close attention. The figure on the last page shows the spectrum of Earth's thermal radiation to outer space, http://arxiv.org/abs/2103.16465 . The horizontal axis is the spatial frequency of the thermal radiation or the inverse of the wavelength. The vertical axis is the intensity of the radiation flux, shown as curves of various colors for various hypothetical atmospheres. Heat from the Earth is dumped into cold space by thermal radiation of various wavelengths. Like visible sunlight where red light has a longer wavelengths than blue light, Earth emits thermal radiation that has longer and shorter wavelengths. Different greenhouse gases absorb and emit radiation of different thermal wavelengths. A few wavelengths can be absorbed and emitted by several different gases simultaneously.

The area under the smooth blue curve is what the radiation flux (or heat flux) to space would be if you could remove all of Earth's greenhouse gases, H_2O, CO_2, ozone O_3, methane CH_4 and nitrous oxide N_2O. The area under the blue curve, Z=394 W/m^2, turns out to be given by the simple Stefan-Boltzmann formula, Z = σT^4, where σ is a physical constant and T is the absolute temperature of the Earth, or about T= 289 K on a representative spring day in Kansas.

The jagged black curve shows the actual heat flux to space from the top of Earth's atmosphere at a representative temperate latitude like Kansas. The notch in the spectrum, centered a frequency of 667 cm^{-1} , illustrates the suppression of radiation to space due to the greenhouse gas, CO_2. For lower and higher frequencies, water vapor, H_2O, decreases the radiation to space. The smaller area

under the black jagged line, Z=277 W/m^2, is what the Earth actually radiates. The real radiation flux is substantially less than flux, Z=394 W/m^2, the Earth's surface would radiate if there were no greenhouse gases.

The energy radiated to space is provided by sunlight. If one could instantaneously remove all greenhouse gases but the same solar heating were to continue, the Earth would be radiating 394-277=117 W/m^2 more heat to space than it receives from sunlight. The extra radiated flux would have to be provided by the internal energy of a cooling surface, and the present temperature of the surface 16 C, would have to drop to -9 C, well below freezing, to bring solar heating and thermal radiation to space back into balance. Greenhouse gases convert what would otherwise be a lifeless, icy planet to our warm and verdant Earth. We should be very grateful for greenhouse gases.

If you could "instantaneously" remove all the CO_2 from the atmosphere, the black jagged curve would be replaced by the green jagged curve, which coincides with the black curve except for frequencies where CO_2 absorbs and emits strongly. Here the word "instantaneously" means that the altitude dependences of the temperature and of all other greenhouse gases remain the same when all the CO_2 is removed. Removing all of the CO_2 would increase the flux to space, the area under the green/black jagged curve, to Z=307 W/m^2, a 30 W/m^2 increase in flux compared to the 277 W/m^2 before removal of the CO_2. Removing all CO_2 from the atmosphere would cause devastating cooling, but even more, it would be a death sentence to life on Earth, which is built of carbon-based organic compounds that plants have manufactured from atmospheric CO_2.

Now suppose the CO_2 concentration were to double, from today's values of about 400 ppm to 800 ppm. This would take more than a century if the use of fossil fuels continues or increases somewhat from current rates. Then the spectrum of radiation to space would be given by the red curve, which is nearly coincident with the black curve, today's heat flux, except for the strongly absorbed frequencies near 667 cm^{-1} and a few other parts of the spectrum. The area under the red/black jagged curve is, to Z= 274 W/m^2, a 3.0 W/m^2 decrease in flux compared to the 277 W/m^2 before doubling the CO_2 concentration. The IPCC has made the same calculation, and they report a slightly smaller figure, 2.8 W/m2 for the decrease of flux to space caused by an instantaneous doubling of CO2.

Since the radiation flux to space is very nearly proportional to T^4, the fourth power of the absolute temperature T, a 1.1% decrease in flux to space, due to

doubling CO2, can be compensated by a 1.1 % / 4 = 0.28 % increase in absolute temperature. This gives an "equilibrium climate sensitivity," the surface warming needed to bring solar heating back into balance with the heat radiated to space of

$\Delta T = 0.0028 \times 289$ K $= 0.81$ C.

Temperature intervals are the same for the Kelvin scale (K) and the centigrade scale (C).

A temperature rise of about 0.81 C would bring only benefits to the people of Kansas. Climate alarmists like to quote much larger warmings from doubling CO_2 concentrations. The larger warmings quoted by true believers and opportunists, $\Delta T = 3$ C, $\Delta T = 6$ C, and even larger estimates, come from assuming absurdly large "positive feedbacks." Most feedbacks in nature are negative, not positive (Le Chatelier's principle). Observed temperature increases over the past century are consistent with no feedback.

Few people realize how small the effect of doubling CO2 concentrations is

Doubling atmospheric CO_2 concentration, from 400 ppm to 800 ppm, only reduces radiation to space by 3 W/ m² , out of 277 W/m², about 1.1% (or slightly less, 2.8 W/m² per IPCC).
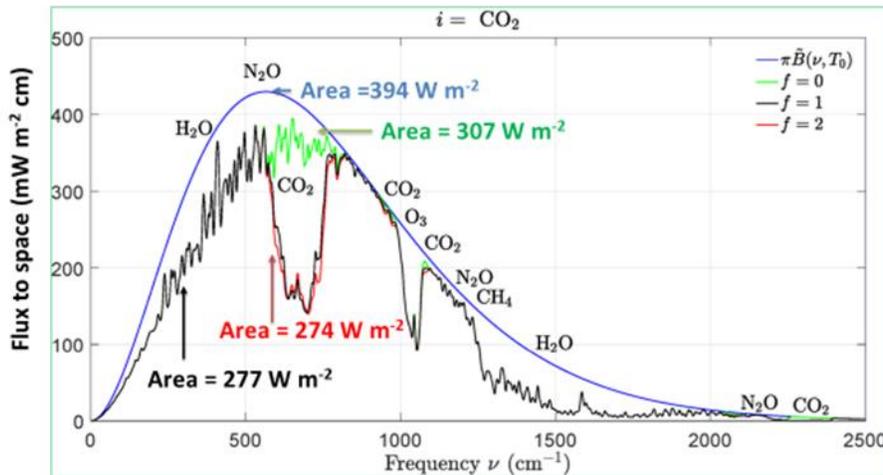
In this example, the surface temperature is 16 C with current greenhouse gas concentrations. Without them the temperature would drop to 264 K = -9 C, well below freezing.

There is no observational support for any of the other claims of climate alarmists. Although sea levels are of little significance to Kansas, they have been rising at the same rates for over a century, with no significant acceleration. There has been no observed increase in extreme weather, tornados, hurricanes, etc.

Let me end my testimony by stating unequivocally that there is no climate crisis. ESG efforts to suppress the use of fossil fuels will be all pain and will cause enormous   environmental and economic damage. Please vote to pass Kansas State Senate Bill No. 224.