STATE OF IOWA
DEPARTMENT OF COMMERCE
BEFORE THE IOWA UTILITIES BOARD

IN RE:	)	
	)	Docket No. HLP-2021-0001
SUMMIT CARBON SOLUTIONS LLC	)	

DIRECT TESTIMONY OF PROF. MARK Z. JACOBSON

ON BEHALF OF

SIERRA CLUB IOWA CHAPTER

July 24, 2023

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I. WITNESS INTRODUCTION

Q. PLEASE STATE YOUR NAME AND CURRENT PROFESSION

A. Mark Z. Jacobson, Professor of Civil and Environmental Engineering at Stanford University.

Q. WHAT IS YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND?

A. I have a B.S. with distinction in Civil Engineering from Stanford University (1988), a B.A. in Economics with distinction from Stanford University (1988), and an M.S. in Environmental Engineering from Stanford University (1988), an M.S. in Atmospheric Sciences from the University of California at Los Angeles (1991), and a Ph.D. in Atmospheric Sciences from the University of California at Los Angeles (1994). I started as an Assistant Professor at Stanford in 1994. I became a tenured Associate Professor in 2001 and a full Professor in 2007. I still work at Stanford University. Thus, I have been employed there for about 29 years.

Q. WHAT ARE YOUR PRIMARY AREAS OF RESEARCH AND WRITING?

A. Since 1989, I have been researching academically and professionally, the impacts of human emissions of gases (including carbon dioxide and other greenhouse gases) and particles (including black carbon) on air pollution, human health, weather, and climate. Starting in 1999, I began examining in detail clean, renewable energy solutions to these problems.

With respect to ethanol, in 2007, I published a study examining the effects of E85 versus gasoline combustion exhaust on air pollution health in the United States (Jacobson, 2007). A Ph.D. student of mine and I co-published several additional studies on this topic (Ginnebaugh et al., 2010; Ginnebaugh and Jacobson, 2012a,b). In 2009, I published a review paper examining the impacts of E85 vehicles on climate, air pollution, land use, and water supply relative to battery-electric vehicles (BEVs) and hydrogen-fuel-cell-electric vehicles powered by renewable electricity (Jacobson, 2009).

With respect to carbon capture, in Jacobson (2009), I also discussed a comparison among different energy technologies, including coal with carbon capture and storage. In 2019, I published a paper entitled, "The health and climate impacts of carbon capture and direct air capture" (Jacobson, 2019). In 2021, I co-authored a paper (Howarth and Jacobson, 2021) comparing hydrogen production from natural gas with and without carbon capture. I have also written two books that discuss carbon capture and ethanol extensively (Jacobson, 2020; 2023).

II. PURPOSE AND COVERAGE OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY?

A. My testimony will cover the technical and economic issues regarding carbon capture and storage in general and as it applies to the Summit Carbon Solutions LLC (hereinafter, "Summit") project to capture, pipe, and store carbon dioxide obtained during the fermentation of ethanol. In particular, I will estimate the proposed carbon dioxide emissions reductions from the Summit project due to capturing carbon dioxide from fermentation during ethanol production, where the ethanol is used in flex-fuel vehicles (FFVs). I will then compare the emission and driving cost difference of using the same investment for the

Summit project to instead produce electricity from wind or solar for battery-electric vehicles (BEVs) or to replace a coal plant. I will also estimate the difference in air pollution, land use, and jobs from the two scenarios.

III. DESCRIPTION OF CARBON CAPTURE AND STORAGE (CCS)

Q. PLEASE EXPLAIN WHAT CARBON CAPTURE AND STORAGE IS.

A. Carbon capture and storage (CCS) involves the separation of carbon dioxide from other exhaust gases following fossil fuel or biofuel combustion; following chemical reaction, such as during cement or steel manufacturing; or during fermentation to produce ethanol. The purified carbon dioxide is usually compressed, often from 1 bar (atmospheric pressure) to 150 bars so that it can be transferred in a pipe. At a certain point during compression, carbon dioxide converts from a gas to a liquid. In the present proposal, however, the carbon dioxide will be compressed to above 74.5 bars and the temperature raised to above 31.1 degrees Celsius so that it will reside in a supercritical state, which is a very dense form of carbon dioxide that is neither liquid nor gas. The supercritical CO_2 is then sent by pipe to an underground geological formation (such as a saline aquifer), a depleted oil and gas field, or an un-minable coal seam. The remaining combustion gases are emitted to the air or filtered further.

Q. WHAT IS YOUR UNDERSTANDING OF THE CARBON CAPTURE AND STORAGE PROJECT AS PROPOSED BY SUMMIT CARBON SOLUTIONS.

A. Summit's proposal is first to capture carbon dioxide from the fermentation process at 34 ethanol-production facilities in five states: Iowa, Nebraska, South Dakota, Minnesota, and

North Dakota. Because carbon dioxide off-gassed during fermentation is relatively pure, traditional carbon capture equipment needed to separate carbon dioxide from other impurities in natural gas or coal electricity generating plants is not needed. However, electricity is still needed to dehydrate, compress, and heat the carbon dioxide so that it can enter a supercritical state. The electricity needed is estimated to be similar to that needed simply to dehydrate the CO_2 and compress it to 150 bars, which is about 110 kWh/tonne-CO_2-compressed (Dees et al., 2023).

This additional electricity requirement is estimated to result in carbon dioxide emissions that will offset about 15.2% of the captured and piped CO_2 (Table 1). The reason is that the electricity needed for compressing carbon dioxide is a new demand for electricity that is not otherwise needed for any purpose. If the electricity is taken from the grid, then more coal will likely be used in each state to replace that grid electricity, since increasing coal electricity output is the easiest way to supply a constant incremental electricity demand in each state. About 25.4%, 48.8%, 10%, 26.4%, and 57% of all electricity generated in Iowa, Nebraska, South Dakota, Minnesota, and North Dakota, respectively, is from coal (EIA, 2023). Even if existing wind were used to provide that incremental electricity, that wind could no longer displace coal electricity Thus, in all cases, the incremental electricity demand increases coal electricity use.

Coal-fired electricity generation results in about 1,381 g-CO_2e/kWh-electricity-generated over a 20-year time frame (most relevant for climate tipping points – Howarth and Jacobson, 2021) and ~1,168 g-CO_2e/kWh over a 100-year time frame (Jacobson, 2019).

These emission numbers include not only combustion emissions but also coal mining emissions of both carbon dioxide and of methane (after it is converted with appropriate global warming potentials to carbon dioxide equivalent (CO_2e) emissions). Multiplying 1,381 g-CO2e/kWh by 110 kWh/tonne-of-CO_2-compressed gives 152 g-CO_2e-emitted per kg-CO_2-compressed. Thus, 15.2% of carbon dioxide that is captured is returned to the air through electricity-related emissions.

Summit's pipeline will connect 34 ethanol refineries (Summit, 2023) with 2,000 miles of pipes ranging from 4 to 24 inches in diameter. The carbon dioxide, after it is compressed to a supercritical state, will be piped to an underground storage site near Bismarck, North Dakota. It is not clear if the carbon dioxide will be permanently sequestered there or used later for some other purpose, including enhanced oil recovery.

IV. ISSUES REGARDING CCS AND CLIMATE CHANGE

Q. BASED ON THESE FACTS AND YOUR RESEARCH ON CARBON CAPTURE AND STORAGE, DO YOU HAVE AN OPINION AS TO WHETHER THE SUMMIT PROJECT WILL ADDRESS CLIMATE CHANGE?

A. Yes, my opinion is that the Summit project, which involves spending $5.6 billion on pipes and carbon capture from ethanol refineries to power flex-fuel vehicles, is a significant opportunity cost. It substantially increases consumer costs and carbon dioxide and air pollution emissions in the five states at issue (Iowa, Nebraska, South Dakota, Minnesota, and North Dakota) relative to a viable alternative. Specifically, if the same money is instead spent on onshore wind and/or solar photovoltaics (PVs) to power battery-electric vehicles (BEVs), drivers in the five states will likely save $75.9-$126 billion over 30 years on fuel costs alone (Table 1) due to the price difference between E85 and electricity and due to the far greater mileage per unit energy of a BEV than an equivalent FFV. In this report, I will use a 2023 Ford F-150 4WD Lightning extended range BEV and a 2023 Ford F-150 4WD, 8-cyclinder FFV as the example vehicles for comparison. The 8-cylinder FFV is chosen because it gives the closest acceleration as the BEV. These two vehicles were selected not only because they are built by the same manufacturer and are roughly equivalent in capabilities, but also because they are common vehicle types used in these states.

What is more, using the same funds to instead produce wind electricity for BEVs will likely reduce 2.5-4.2 the carbon dioxide emissions as will capturing carbon from ethanol refineries that provide E85 for FFVs [20.2-33.5 million metric tonnes of CO_2 per annum (MMTPA) avoided with BEVs versus 8.1 MMTPA avoided with FFVs] (Table 2). In fact, even building wind electricity to replace coal plants will likely save more carbon dioxide than will the Summit plan (12.6-20.8 MMTPA avoided with wind replacing coal versus 8.1 MMTPA avoided with Summit's plan) (Table 1).

Finally, Summit's plan will significantly increase air pollution and land use requirements while creating fewer jobs than using the same money to purchase wind turbines and solar panels to power BEVs or to replace coal.

Q. ON WHAT DO YOU BASE THAT OPINION?

A. According to James Powell, Summit's Chief Operating Officer (May 25, 2023 testimony), the Summit pipeline is proposed to transport 9.5 MMTPA from 34 ethanol facilities in five states. He projects that the capital cost of the project will be $5.6 billion.

This is $1.1 billion more than the estimated cost in 2022 of $4.5 billion, published on Summit's webpage as of June 13, 2023 (Summit, 2023).

First, accounting for the 15.2% CO_2 returned to the air due the energy penalty (the energy needed to compress and dehydrate the CO_2), the net CO_2 captured based on Mr. Powell's numbers is 8.06 MMTPA rather than 9.5 MMTPA.

Second, Lazard (2023) provides the 2022 capital cost of buying and installing a new wind turbine in the U.S. as $1.025-$1.7 million/MW. This accounts for the costs of the turbine, financing, a wind resource analysis, a site analysis, a permitting and interconnection study, utility system upgrades, construction, transformers, protection and metering equipment, insurance, and legal and consultation fees. Another 10% of the capital cost ($103,000-$170,000/MW) may be needed for greater transmission capacity added to the existing grid for the new turbines.

Dividing the $5.6 billion initial outlay for the Summit project by the wind turbine plus additional transmission capital costs gives 3.0-4.97 GW nameplate capacity of wind turbines that could be purchased instead (Table 1). Assuming a 38.5% wind capacity factor, which is the mean capacity factor of all U.S. wind projects built from 2014-2021 (DOE, 2022) and transmission, distribution, and BEV charging losses of 10% of raw wind electricity output, the energy produced by these wind turbines that could be used in electric vehicles is 9.1-15.1 TWh/y (Table 1). Given the 2023 EPA rating of 480 Wh/mi for the F-150 BEV (EPA, 2023) this translates to 18.9-31.4 billion miles per year drivable by such BEVs (Table 1).

The U.S. Department of Energy (DOE, 2023) defines E85 as "containing 51% to 83% ethanol, depending on geography and season." E85 consists of E100 blended with gasoline. E100 contains at least 2% gasoline as a denaturant so that people do not drink it. Thus, if 15% gasoline is blended with 85% E100, the resulting mix (E85) contains 83.3% ethanol and 16.7% gasoline. This mix is assumed here. Assuming such a mix, an E85 vehicle emits 6.22 kg-CO_2/gallon-E85 at the tailpipe (Table 1).

Table 1. Input data and calculated parameters relative to the results shown in Table 2.

a)	Project cost (S23)	\$5.6 billion
b)	Estimated project life	30 years
c)	Projected CO_2 savings per year (S23)	9.5 million metric tonnes/y (MMTPA)
d)	Energy to compress CO_2 (Dees et al., 2023)	110 kWh/tonne-CO_2
e)	Carbon captured per unit energy (P23)	30 g-CO_2/MJ
f)	Electricity needed to compress CO_2 = d x e / 10^6	0.0033 kWh/MJ
g)	Coal upstream plus stack emissions (20 y time frame)	1,381 g-CO2/kWh
h)	Energy penalty to compress CO_2 = f x g	4.56 g-CO_2/MJ
i)	Energy penalty to compress CO_2 during project = c x h / e	1.44 MMTPA
j)	Net CO_2 savings per year from project = c - i	8.06 MMTPA
k)	2023 Ford F-150 4WD 8-cylinder FFV E85 (EPA, 2023)	14 mi/gal-E85
l)	2023 Ford F-150 4WD Ext. Range BEV (EPA, 2023)	480 Wh/mi
m)	Moles CO_2 per mole of ETOH combusted	2
n)	Ethanol molecular weight	46.07 g/mol
o)	Carbon dioxide molecular weight	44.01 g/mol
p)	Ethanol density	789.3 g-ETOH/L
q)	Liters per gallon	3.785 L/gal
r)	Percent gasoline added to pure ETOH as denaturant	2%
s)	CO_2 from burning ETOH = m x (o/n) x p x q / 1000	5.71 kg-CO_2/gal-ETOH
t)	CO_2 from burning gasoline	8.79 kg-CO_2/gal-gasoline
u)	CO_2 from burning E85 = (s x (1-r) + t x r) x 0.85 + t x 0.15	6.22 kg-CO_2/gal-E85
v)	Wind turbine capital cost (Lazard, 2023)	\$1.025-\$1.7 million/MW-wind
w)	Capital cost due to additional transmission	\$103,000-\$170,000/MW-wind
x)	Wind turbine capacity factor (DOE, 2022)	38.5%
y)	Wind electricity transmission/distribution/charging losses	10%
z)	Nameplate capacity of wind turbines = a / (v + w)	3.0-4.97 GW
aa)	Wind electricity output = zx(1-y) x 8760 hours/yr / 10^6	9.1-15.1 TWh/y
bb)	Miles F-150 BEV can travel with this output = 10^{12} x aa / l	18.9-31.4 billion miles/y
cc)	Tailpipe CO_2 savings due to wind-BEVs = bb x u / k	8.42-14.0 MMTPA
dd)	CO_2 savings due to wind replacing coal = aa x g / 1000	12.6-20.8 MMTPA
ee)	E85 fuel cost in Iowa (June, 2023)	\$2.65 / gallon
ff)	Residential electricity cost Iowa (June 2023)	\$0.116/kWh
gg)	Gallons/y E85 to drive same distance as BEV = bb / k	1.35-2.24 billion gallons E85
hh)	Fuel cost driving F-150 w/E85 over project life=gg x ee x b	\$108-178 billion
ii)	Fuel cost driving F-150 BEV over project life = aa x ff x b	\$31.6-52.5 billion
jj)	Fuel cost savings due to BEV v FFV over project life= hh-ii	\$75.9-126 billion

ETOH = ethanol; S23 = Summit's James Powell testimony May 25, 2023; P23 = Summit's James Pirolli testimony May 26, 2023.

Multiplying the miles per year drivable by BEVs replacing FFVs by the combustion emissions of E85 vehicles just provided and dividing by the 2023 EPA rating of 14 mpg for a 2023 Ford F-150 4WD, 8-cylinder FFV (EPA, 2023) gives tailpipe emissions from FFVs avoided by BEVs as 8.4-14.0 MMTPA. In other words, BEVs have zero tailpipe emissions, whereas FFVs have substantial tailpipe emissions that BEVs eliminate.

The ethanol at issue here is produced from corn, which grows through photosynthesis by pulling CO_2 and water vapor out of the air. However, even with BEVs, CO_2 is still pulled out of the air to grow corn or another crop or vegetation, so transitioning to BEVs eliminates entirely tailpipe emission from FFVs without reducing the carbon uptake by vegetation. The tailpipe emission reduction alone due to BEVs is already greater than the CO_2 avoided by the Summit project. However, the overall CO_2 avoided due to BEVs are far greater than those avoided by the tailpipe alone.

The lifecycle emissions, excluding land-use change (LUC), of producing and distributing corn ethanol are estimated from multiple studies to be 47.5-77 g-CO_2e/MJ (Lark et al., 2023; Scully et al., 2021a) (Table 2). Summit (James Pirolli May 26, 2023 data response) references Scully et al.'s lifecycle emissions estimate of 51.4 g-CO_2e/MJ for corn ethanol. Scully et al.'s LUC estimate included in that number is 3.9 g-CO_2e/MJ, giving the non-LUC portion of the emissions as 47.5 g-CO_2e/MJ. Spawn-Lee et al. (2021) critiqued Scully et al.'s central estimate of LUC emissions as being "roughly half the smallest comparable value they review," thus unrealistic. Scully et al. (2021b) responded, but the problem remains.

Lark et al. (2023) performed a more detailed analysis of land-use change emissions associated with the U.S. renewable fuels standard from 2008-2016 and concluded:

> "We find that the RFS increased corn prices by 30% and the prices of other crops by 20%, which, in turn, expanded US corn cultivation by 2.8 Mha (8.7%) and total cropland by 2.1 Mha (2.4%) in the years following policy enactment (2008 to 2016). These changes increased annual nationwide fertilizer use by 3 to 8%, increased water quality degradants by 3 to 5%, and caused enough domestic land use change emissions such that the carbon intensity of corn ethanol produced under the RFS is no less than gasoline and likely at least 24% higher."

Their estimate of land-use change emissions associated with ethanol production was a mean of 38.7 g-CO_2e/MJ (Table 2). Adding this LCU emissions to the rest of the non-LCU lifecycle emission range gives total LCA emissions due to ethanol as 86.2-115.7 g-CO_2e/MJ (Table 2), which compares with LCA emissions due to gasoline of 93.1 g-CO_2e/MJ (Lark al., 2023) (Table 2). Thus, corn-ethanol carbon-dioxide-equivalent emissions may be higher or lower than those of gasoline. The ethanol LCA emission range just cited corresponds to 7.0-9.4 kg-CO_2e/gallon-ethanol, or 7.9-9.8 kg-CO_2e/gallon-E85 (Table 2).

Replacing FFVs with BEVs avoids the emissions associated with the upstream production of E85. Combining the CO_2 savings per gallon due to switching to BEV with the mileage of the Ford F-150 FFV and the number of miles driven by the BEVs replacing the FFVs gives a reduction of 11.8-19.6 MMTPA of CO_2 due to BEVs replacing FFVs and their upstream production of E85 (Table 2). Adding this to the avoided tailpipe emission gives a total of 20.2-33.5 MMTPA of CO_2 avoided by BEVs replacing FFVs and their tailpipe and upstream emissions (Table 2). This compares with the 8.1 MMTPA avoided by the Summit proposal (Table 1).

In sum, using the same investment for the Summit proposal to eliminate E85 for FFVs in favor of wind electricity for BEVs results in 2.5-4.2 times the avoided CO_2 as the Summit proposal (Table 2).

Table 2. Row 1: Lifecycle assessment (LCA) emissions, including land-use change (LUC) emissions, for corn-ethanol (ETOH) production and distribution without carbon capture, from four studies. Row 2: The LCA values from the four studies minus their LUC emissions. Row 3: The LUC emissions from the four studies. Row 4: The LUC emissions from L23. Row 5: The non-LUC LCA emissions from the four studies plus the LUC emissions from L23. Row 6: The LCA emissions of gasoline. Row 7: The LCA emissions from Row 5 converted to emissions per gallon of pure ethanol (without a denaturant added). Row 8: The LCA emissions of gasoline per gallon of gasoline. Row 9: The total LCA emissions (with LUC) per gallon of E85 after accounting for the addition of 2% gasoline as a denaturant to pure ethanol and considering E85 consists of 85% ethanol with denaturant and 15% gasoline. Row 10: Million metric tonnes per annum (MMTPA) of CO_2e emissions avoided by using wind-BEVs instead of E85 from corn ethanol with carbon capture, calculated as Row 9 multiplied by the miles/y driven from Table 1 and divided by the FFV miles per gallon from Table 1. Row 11: Tailpipe CO_2 emissions avoided with wind plan A , from Table 1. Row 12: Sum of upstream and tailpipe CO_2 emissions avoided with wind plan A. Row 13: Equals Row 12 divided by 8.06 MMTPA, the emissions avoided due to the ethanol plan (Table 1).

	EPA RIA*		CARB LCFS*		GREET*		S21			
1.LCA (g-CO_2e/MJ)	73.2		71.0		53.6		51.4			
2.LCA without LUC (g-CO_2e/MJ)	77.0		66.0		51.6		47.5			
3.LUC (g-CO_2e/MJ)	3.77		5.0		2.0		3.9			
4.LUC from L23 (g-CO_2e/MJ)	38.7		38.7		38.7		38.7			
5.LCA+LUC from L23 (g-CO_2e/MJ)	115.7		104.7		90.3		86.2			
6.LCA gasoline (L23) (g-CO_2e/MJ)	93.1		93.1		93.1		93.1			
7.LCA ETOH (kg-CO2/gal-ETOH)	9.4		8.5		7.3		7.0			
8.LCA gas (kg-CO2/gal-gasoline)	12.1		12.1		12.1		12.1			
9.LCA E85 (kg-CO2/gal-E85)	9.84		9.10		8.12		7.85			
									Average	
	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo
10Upstream MMTPA saved w/BEVs	22.1	13.31	20.4	12.3	18.2	11.0	17.6	10.6	**19.58**	**11.80**
11.Tailpipe MMTPA saved w/ BEVs	14.0	8.42	14.0	8.42	14.0	8.42	14.0	8.42	**14.0**	**8.42**
12.Total MMTPA saved w/ BEVs	36.0	21.7	34.4	20.7	32.2	19.4	31.6	19.0	**33.54**	**20.22**
13.Ratio MMTPA saved BEVs:E85	4.47	2.70	4.27	2.57	3.99	2.41	3.92	2.36	**4.16**	**2.51**

*Table 2 of Lark et al. (2023). S21 = Scully et al. (2021a). L23 = Lark et al. (2023)

What is more, BEVs eliminate 100% of air pollutants from the tailpipes of FFVs. FFVs cause greater air pollution damage than do even gasoline vehicles on average throughout the U.S. (Jacobson, 2007, 2009; Ginnebaugh et al., 2010; Ginnebaugh and Jacobson, 2012). Further, the energy used in an ethanol refinery causes air pollution that BEVs avoid entirely. Finally, transporting ethanol by truck, train, or barge results in air pollution that electricity production for BEVs does not cause (Jacobson, 2009). The overall upstream air pollution emissions of ethanol are greater than are those of gasoline (Jacobson, 2009).

Further, ethanol for E85 vehicles use far more land than does wind or solar producing electricity for BEVs. First, photosynthesis is only 1% efficient. Solar PV panels, for example, are 20-23% efficient. As such, a solar PV farm needs only 1/20th-1/23rd the land to produce the same energy as does a biofuel crop. Further, BEVs convert 80-90% of the electricity within a battery to motion. The rest is waste heat. FFVs running on E85 convert roughly ~17-24% of energy in the E85 to motion. As such, driving a BEV requires 1/4th the energy as driving a FFV running on E85. For instance, the 2023 Ford F-150 BEV obtains 579 mi/GJ, whereas the 2023 Ford F-150 FFV obtains 156.8 mi/GJ, a factor of 3.7 difference. Combining the difference in PV versus photosynthesis efficiency with the difference in BEV versus FFV efficiency indicates that driving a BEV powered by solar PV requires ~1/80th the land area on the ground as driving a FFV powered by E85 produced from corn ethanol (Jacobson, 2009). A wind turbine requires less than 1/5000th the footprint on the ground (pole plus cement base) as does a solar PV farm to provide the same electricity. As such, BEVs may take up less than 1/400,000th the footprint as do corn-E85 vehicles (*Id.*). Wind turbines do require space between them to prevent interference of the wakes of one turbine with another turbine. However, even the spacing area for wind turbines powering BEVs may be ~1/10th to 1/20th the land needed to grow corn for E85 powering FFVs (*Id.*). Because most all of wind's spacing area is open space between turbines, crops can even grow within it.

In terms of jobs, I calculate that using the Summit funds for wind electricity powering BEVs may create 21,600-35,800 one-year construction jobs and 1,100-1,800 continuous operation jobs across the five states at issue to build out the wind infrastructure proposed. Even if only 17% of these jobs are in Iowa, this appears to exceed the 2,000 construction jobs and 320 permanent operation jobs in Iowa estimated by Mr. Powell.

The calculations supporting my opinion are set forth in detail in Jacobson Direct Exhibit 1.

Q. ARE THERE MORE EFFECTIVE AND EFFICIENT WAYS TO ADDRESS CLIMATE CHANGE?

A. Yes. As described above, it is far more beneficial in terms of costs, CO_2e emissions, air pollution, land use, and jobs to use the same investment proposed for the Summit pipeline to build wind turbines and/or solar PV panels to provide electricity for BEVs. The fuel cost saving to consumers alone ($75.9-$126 billion over 30 years) is 14-23 times the cost of the Summit project. Combustion fuels are extremely inefficient. A BEV travels about four times the distance as an equivalent FFV for the same energy (Table 1), as demonstrated with the 2023 Ford F-150 BEV versus FFV. This difference combined with the relative prices of electricity versus E85 give the enormous fuel cost savings due to BEVs. Summit's investment in an ethanol pipeline will lock in the five states at issue to promoting a very inefficient fuel. Even if the upfront cost of BEV today were $20,000 more than an equivalent FFV (which it is not) and if that cost difference dissipates in 15 years, the net fuel cost minus upfront car cost savings to consumers over 30 years is still $63-$105 billion.

Similarly, Summit's proposed CO_2e avoided emissions are 24-40% those that could be obtained by investing in wind-BEVs instead. This is because wind-BEVs eliminate 100% of both tailpipe and upstream ethanol production emissions from E85. The proposed project would eliminate only a portion of upstream emissions and no tailpipe emissions.

Air pollution from producing and burning ethanol in a FFV is similar to or greater than that of burning gasoline. BEVs powered by wind or solar eliminate 100% of tailpipe emissions, so improve health compared with both (Jacobson, 2007; 2009). Land use is similarly reduced and more jobs are created by going to BEVs powered by wind or solar.

Q. WILL SUMMIT BENEFIT FROM CALIFORNIA'S LOW-CARBON FUEL STANDARD?

A. Summit argues that a benefit of capturing carbon from ethanol refineries is that the ethanol can then be sold to California, which has a low-carbon fuel standard. First, even if Summit could capture and store 30 g-CO_2e/MJ as proposed, that still leaves 56.2-85.2 g-CO_2e/MJ remaining (subtracting 30 from Table 2, line 5), an emission rate that may or may not meet the standard. CARB (2020) set the following standards that gasoline and any fuel replacing it must meet: 2023: 88.25 g-CO_2e/MJ; 2024: 87.01; 2025: 85.77; 2026: 84.52; 2027: 83.28; 2028: 82.04; 2029: 80.80; 2030: 79.55. Thus, depending on what lifecycle emission numbers are used, E85 with carbon capture may still not meet the standard.

Regardless, the California Air Resources Board has set new regulations (Advanced Clean Cars II Regulations) that require all new passenger cars, trucks, and SUVs sold in California to be zero emission. To meet the standard, such vehicles must be either battery-electric, hydrogen fuel cell-electric, or plug-in hybrid electric. These regulations follow from Executive Order N-79-20 (2020) that required all new passenger vehicles in California to be zero emissions by 2035. Since the regulations require zero emissions, they will likely preclude the use of any combustion fuel, including E85, that produces tailpipe emissions. Vehicles running on E85 produce tailpipe emissions that result in air pollution higher than gasoline in NOx-rich California (Jacobson, 2007; Ginnebaugh et al., 2010; Ginnebaugh and Jacobson, 2012a,b).

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STATE OF IOWA
DEPARTMENT OF COMMERCE
BEFORE THE IOWA UTILITIES BOARD

IN RE:	)	
	)	Docket No. HLP-2021-0001
SUMMIT CARBON SOLUTIONS LLC	)	

AFFIDAVIT OF MARK Z. JACOBSON

I, Mark Z. Jacobson, being first duly sworn on oath stat that I am the same Mark Z. Jacobson identified in the Direct Testimony and Exhibit; that I have caused the Direct Testimony and Exhibit to be prepared and am familiar with the contents thereof; and that the Direct Testimony and Exhibit are true and correct to the best of my knowledge and belief as of the date of this Affidavit.

I certify under penalty of perjury and pursuant to the laws of the State of Iowa that the foregoing statement is true and correct to the best of my knowledge and belief.

Dated June 26, 2023.

/s/ Mark Z. Jacobson

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MARK Z. JACOBSON