# On the False Statement by Dr. Ken Caldeira, under Penalty of Perjury, that Table 1 of Jacobson et al. (PNAS, 112, 15,060-15,065, 2015, hereinafter the Jacobson Paper) Contains Maximum Rather Than Average Values

By Mark Z. Jacobson
July 4, 2020

On May 26, 2020, Dr. Ken Caldeira, one of the three primary authors of the Clack et al. (PNAS, 114, 6722-6727, 2017, hereinafter the Clack Paper) made the following false statement under penalty of perjury (Exhibit 1),

"Dr. Jacobson's paper does not say what he appears to now be arguing, and we (the Clack Paper authors) correctly used the maximums from Table 1."

The false statement by Dr. Caldeira is that Table 1 of the Jacobson Paper contains maximum values. This false statement follows from a written public admission by Dr. Caldeira on February 16, 2019, where he admitted the opposite, that Table 1 contains average values, not maximum values (Exhibit 2). In that tweet, Dr. Caldeira admitted twice that Table 1 contains average values. He first replied, "Yes," to the question

"Just to see whether @KenCaldeira can act in good faith, please tell us, @KenCaldeira, does Table 1 of our paper contain avg or max values? You claimed max. Will you correct this factually false claim & resulting conclusion in PNAS? If no, your false fact is intentional."

He then subsequently explained in the rest of his response why he made his error in the first place ("I should have realized that when someone writes that 67.66% of the load is flexible, they might mean to communicate that 100% of the load is flexible but only 67.66% of the time.") As such, he admitted twice in the tweet that Table 1 contains average values.

Dr. Caldeira's May 20, 2020 false declaration that Table 1 of the Jacobson Paper contains maximum values is contradicted not only by his own previous two admissions (Exhibit 2), but also by the Jacobson Paper itself (Exhibit 3), the original published source of the data for Table 1 referenced in the footnote to Table 1 of the Jacobson Paper (Exhibit 3), model output published in the Jacobson Paper (Exhibit 4), and my own declaration under penalty of perjury as the author of the data in Table 1 that the values are average values:

http://blogs2.law.columbia.edu/climate-change-litigation/wp-content/uploads/sites/16/case-documents/2020/20200608_docket-2017-CA-006685-B_affidavit.pdf

Dr. Caldeira's false statement under penalty of perjury was submitted by Dr. Clack and his attorney in their effort to claim that a scientific debate exists around Table 1. Whether Table 1 contains average or maximum values is a clear question of fact, not a question of debate. Not only is there a "yes" or "no" answer to this question, but all evidence shows Table 1 contains average values (Exhibits 3, 4). No evidence shows the table contains maximum values.

Let's analyze how the Clack Authors came to mistakenly believe Table 1 of the Jacobson Paper contains maximum values. The only reference by the Clack Authors to their understanding of the data in Table 1 appears in Section S1.2 of the Clack Paper. In that section, they mistakenly claim that the maximum (rather than average) flexible load in the Jacobson Paper was 1064.16 GW.

The Clack Authors admit in that section that the 1064.16 GW was obtained by multiplying the summed load in Column 1 of Table 1 of the Jacobson Paper (1,572.8 GW) by the fraction of the load that is flexible, which is given in Column 4 of Table 1 of the Jacobson Paper as 67.66%. This gives 1064.16 GW.

However, for the 1064.16 GW to be a maximum value, this means that the total in Column 1 must be a maximum value as well. However, this is just not true, and the Clack Authors provide no information in their paper or in any Court document as to why or how they assumed this was the case. In other words, the Clack Authors simply made up out of thin air the claim that the values in Column 1 of Table 1 of the Jacobson paper contained maximum values. They did not present an explanation for this and never have. Nor could they, because the values in Column 1 of Table 1 have always been average values (Exhibits 3 and 4 and my sworn testimony).

For a scientific disagreement to exist, the Clack Authors would need to have evidence that Column 1 of Table 1 of the Jacobson Paper contains maximum values, and that evidence must contradict all the evidence that exists that shows the values are average values. However, nowhere in their paper or any Court document do the Clack Authors or NAS even attempt to provide evidence of why the Clack Authors claim values in Column 1 of Table 1 are maximum values. To the contrary, they falsely state a scientific disagreement exists when in fact the Clack Authors simply made a horrible mistake.

Dr. Caldeira has now compounded this mistake by making a false statement under penalty of perjury that Table 1 of the Jacobson Paper contains maximum values.

**EXHIBIT 1**

**SUPERIOR COURT OF THE DISTRICT OF COLUMBIA**
**CIVIL DIVISION**

| | | |
|---|---|---|
| Mark Z. Jacobson, Ph.D., | ) | |
| | ) | |
| Plaintiff, | ) | |
| | ) | |
| v. | ) | 2017 CA 006685 B |
| | ) | Judge Elizabeth Wingo |
| Christopher T.M. Clack, Ph.D. | ) | Next Court Date: None Scheduled |
| | ) | |
| and | ) | |
| | ) | |
| National Academy of Sciences, | ) | |
| | ) | |
| Defendants. | ) | |
| ___________________________________ | ) | |

**DECLARATION OF DR. KENNETH CALDEIRA**

**Declaration of Dr. Kenneth Caldeira**

1. My name is Dr. Kenneth George Caldeira. I am over the age of 18 and competent to make the following Declaration.

2. I currently am a Senior Advisor (Climate Science) at Gates Ventures LLC. From 2005 until 2020, I held the position of Senior Staff Scientist at the Carnegie Institution's Department of Global Ecology on the Stanford University campus in California.

3. In 2017, I was one of 21 authors who produced a paper that was published in the Proceedings for the National Academy of Sciences entitled *Evaluation of a proposal for reliable low-cost grid power with 100% wind, water and solar,* PNAS, doi:1073/pnas.1610381114, 2017 (the "Clack Paper").

4. I am aware of the litigation filed by Dr. Jacobson and certain claims relating to the Clack Paper and Dr. Clack.

5. I was not named as a defendant in the litigation and have not participated in the litigation prior to submitting this Declaration.

6. I understand in *Plaintiff Mark Z. Jacobson's Motion for Reconsideration of Order Granting Defendants' Motions for Costs and Attorney Fees Under the D.C. Anti-SLAPP Act*, Dr. Jacobson contends I made certain admissions in a tweet I wrote in February of 2019.

7. The tweet in question was a response to a tweet by Dr. Jacobson in which he stated:

> *Just to see whether @KenCaldeira can act in good faith, please tell us, @KenCaldeira, does Table 1 of our paper contain avg or max values? You claimed max. Will you correct this factually false claim & resulting conclusion in PNAS? If no, your false fact is intentional.*

8. I responded in what I intended to be a good-natured but sardonic manner that:

> *Yes, I should have realized that when someone writes that 67.66% of the load is flexible, they might mean to convey that 100% of the load is flexible but only 67.66% of the time.*

*i.e.* Dr. Jacobson's paper does not say what he appears to now be arguing, and we (the Clack Paper authors) correctly used the maximums from Table 1. His suggestions to the contrary seemed so implausible to me, that I responded in what I intended to be a humorous fashion. I assumed Dr. Jacobson understood the nature of my comment and my humorous intent because his immediate response to my tweet began *"**Seriously**, Ken you made that up out of thin air."* (emphasis added).

9. I understand Dr. Jacobson now contends that in that tweet, "as a factual matter, one of the three primary authors of the Clack Paper admitted the falsity of one of the three defamatory statements it made about the Jacobson Paper." That is not correct.

10. To be clear, my tweet was not intended as an admission (nor do I think it can plausibly be read that way) that anything in the Clack Paper was false or that anything we published in the Clack Paper relating to Table 1 was incorrect.

11. I continue to stand by the work done in the Clack Paper and, to the best of my knowledge, its analyses (and specifically its analysis regarding Table 1) are correct. I have seen Dr. Jacobson's rebuttals to our paper and have considered his explanations, but I do not agree with him.

I declare under penalty of perjury that the foregoing is true and correct. Executed on May 26, 2020.

[signature]

__________________________
Kenneth G. Caldeira

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**EXHIBIT 2**

**Mark Z. Jacobson** @mzjacobson · 2h

Just to see whether @KenCaldeira can act in good faith, please tell us, @KenCaldeira, does Table 1 of our paper contain avg or max values? You claimed max. Will you correct this factually false claim & resulting conclusion in PNAS? If no, your false fact is intentional.

1 1

**Ken Caldeira**
@KenCaldeira

Following

Replying to @mzjacobson @Revkin and 2 others

Yes, I should have realized that when someone writes that 67.66% of the load is flexible, they might mean to communicate that 100% of the load is flexible but only 67.66% of the time.

5:31 PM - 16 Feb 2019

**1** Like

1 1

Tweet your reply

**Mark Z. Jacobson** @mzjacobson · 1h

Replying to @KenCaldeira @Revkin and 2 others

Seriously, Ken, you made that up out of thin air. Fig 2C clearly shows that flexible and inflexible loads were separated the entire 6y simulation. You owe it to the science community to correct your paper of its egregious misrepresentation of facts I enumerated @MaryAliceCam

# EXHIBIT 3

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PNAS

# Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes

Mark Z. Jacobson[a,1], Mark A. Delucchi[b], Mary A. Cameron[a], and Bethany A. Frew[a]

**Loads and Storage.** CONUS loads for 2050–2055 for use in LOADMATCH are derived as follows. Annual CONUS loads are first estimated for 2050 assuming each end-use energy sector (residential, transportation, commercial, industrial) is converted to electricity and some electrolytic hydrogen after accounting for modest improvements in end-use energy efficiency (22). Annual loads in each sector are next separated into cooling and heating loads that can be met with thermal energy storage (TES), loads that can be met with hydrogen production and storage, flexible loads that can be met with DR, and inflexible loads (Table 1).

Table 1. Projected 2050 CONUS load by sector and use in sector and projected percent and quantity of load for each use that is flexible and/or can be coupled with storage

| (1) End-use sector | (2) 2050 total load (GW)* | (3) Percent of sector load (%)† | (4) Percent of load that is flexible (F) or coupled with TES (S) or used for $H_2$ (H) (%)‡ | (5) 2050 load that is flexible or coupled with TES (GW)§ | (6) 2050 load used for $H_2$ production and compression (GW)¶ |
|---|---|---|---|---|---|
| Residential | | | | | |
| Air conditioning | 17.44 | 6.2 | 85 (S) | 14.82 | 0 |
| Air heating | 116.7 | 41.5 | 85 (S, H) | 99.23 | 0 |
| Water heating | 49.79 | 17.7 | 85 (S) | 42.32 | 0 |
| Other | 97.33 | 34.6 | 15 (S, H) | 14.60 | 0 |
| **Total residential** | **281.3** | **100** | **60.78** | **171.0** | **0** |
| Commercial | | | | | |
| Air conditioning | 23.19 | 7.91 | 95 (S) | 22.02 | 0 |
| Refrigeration | 17.12 | 5.84 | 50 (S) | 8.56 | 0 |
| Air heating | 106.3 | 36.26 | 95 (S, H) | 100.95 | 0 |
| Water heating | 22.51 | 7.68 | 95 (S) | 21.39 | 0 |
| Other | 124.0 | 42.31 | 5 (S, H) | 6.20 | 0 |
| **Total commercial** | **293.1** | **100** | **54.29** | **159.1** | **0** |
| **Transportation** | **292.6** | **100** | **85.0 (F, S, H)** | **108.9** | **139.8** |
| Industry | | | | | |
| Air conditioning | 6.61 | 0.936 | 95 (S) | 6.28 | 0 |
| Refrigeration | 16.92 | 2.40 | 50 (S) | 8.46 | 0 |
| Air heating | 37.44 | 5.304 | 95 (S) | 35.57 | 0 |
| On-site transport | 5.07 | 0.72 | 85 (F) | 4.31 | 0 |
| Hi-T/chem/elec procs | 615.4 | 87.19 | 70 (F, H) | 390.44 | 40.35 |
| Other | 24.35 | 3.45 | 0 | 0 | 0 |
| **Total industry** | **705.8** | **100** | **68.77** | **445.05** | **40.35** |
| **All sectors** | **1,572.8** <-- | | **67.66** | **884.03** | **180.2** |

*Total 2050 loads for each sector are from ref. 22 and include inflexible and flexible loads and loads coupled with storage. Column 2 minus columns 5 and 6 is

22. Jacobson MZ, et al. (2015) 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States. *Energy Environ Sci* 8(7): 2093–2117.

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SUSTAINABILITY SCIENCE

**Jacobson et al. (*PNAS*, 2015) clearly state that values in Table 1 are "annual loads," not maximum loads, and clearly states that the "Total 2050 loads for each sector are from ref. 22," which itself clearly defines the data as "derived from a spreadsheet analysis of annually averaged end use load data," NOT from "maximum end use load data."**

Energy &
Environmental
Science

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PAPER

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Cite this: *Energy Environ. Sci.*, 2015, 8, 2093

# 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States†

Mark Z. Jacobson,*[a] Mark A. Delucchi,[b] Guillaume Bazouin,[a] Zack A. F. Bauer,[a] Christa C. Heavey,[a] Emma Fisher,[a] Sean B. Morris,[a] Diniana J. Y. Piekutowski,[a] Taylor A. Vencill[a] and Tim W. Yeskoo[a]

## 3. Changes in U.S. power load upon conversion to WWS

Table 1 summarizes the state-by-state end-use load calculated by sector in 2050 if conventional fuel use continues along BAU or "conventional energy" trajectory. It also shows the estimated new load upon a conversion to a 100% WWS infrastructure (with zero fossil fuels, biofuels, or nuclear fuels). The table is derived from a spreadsheet analysis of annually averaged end-use load data.[9] <----

Table 3 Percent of annually-averaged 2050 U.S. state all-purpose end-use load in a WWS world from Table 1 proposed here to be met by the given electric power generator. Power generation by each resource in each state is limited by resource availability, as discussed in Section 5. All rows add up to 100%

Table 1 1st row of each state: estimated 2050 total end-use load (GW) and percent of total load by sector if conventional fossil-fuel, nuclear, and biofuel use continue from today to 2050 under a business-as-usual (BAU) trajectory. 2nd row of each state: estimated 2050 total end-use load (GW) and percent of total load by sector if 100% of BAU end-use all-purpose delivered load in 2050 is instead provided by WWS. The estimate in the "% change" column for each state is the percent reduction in total 2050 BAU load due to switching to WWS, including (second-to-last column) the effects of assumed policy-based improvements in end-use efficiency, inherent reductions in energy use due to electrification, and the elimination of energy use for the upstream production of fuels (e.g., petroleum refining). The number in the last column is the reduction due only to assumed, policy-driven end-use energy efficiency measures[a]

| State | Scenario | 2050 total end-use load (GW) | Residential % of total | Commercial % of total | Industrial % of total | Transport % of total | % change in end-use power with WWS: Overall | Effic. only |
|---|---|---|---|---|---|---|---|---|
| Alabama | BAU | 53.9 | 11.3 | 9.3 | 51.2 | 28.2 | | |
| | WWS | 35.3 | 13.5 | 11.2 | 60.4 | 14.9 | −34.4 | −4.5 |
| Alaska | BAU | 24.0 | 4.9 | 7.8 | 56.4 | 30.9 | | |
| | WWS | 14.5 <-- | 5.6 | 10.9 | 66.2 | 17.2 | −39.8 | −3.0 |
| Arizona | BAU | 38.0 | 20.7 | 18.9 | 15.5 | 44.9 | | |
| | WWS | 21.9 | 28.7 | 25.4 | 19.0 | 27.0 | −42.2 | −10.5 |
| Hawaii | BAU | 7.4 | 7.1 | 13.6 | 22.1 | 57.2 | | |
| | WWS | 3.8 <-- | 10.3 | 22.1 | 32.6 | 35.0 | −49.5 | −6.6 |
| United States | BAU | 2621.4 | 14.3 | 14.1 | 38.5 | 33.1 | | |
| | WWS | 1591.0 <-- | 17.8 | 18.6 | 45.0 | 18.6 | −39.3 | −6.9 |

**The table above is not only defined to contain "annually-averaged" 2050 end use loads, but the U.S. (1591.0 GW) minus Alaska (14.5 GW) & Hawaii (3.8 GW) WWS value =1572.7 GW, which is the CONUS (continental U.S.) load and is exactly the same (within roundoff error) as the bottom left number in Table 1 of Jacobson et al. (*PNAS*, 2015), proving again beyond any doubt that Table 1 of Jacobson et al. (*PNAS*, 2015) also contains annually-averaged loads.**

**EXHIBIT 4**

**Subject:** Re: Time series data for PNAS 2015 paper
**From:** "Mark Z. Jacobson" <jacobson@stanford.edu>
**Date:** 7/11/17, 10:53 AM
**To:** Christopher Clack <chrisclack84@gmail.com>
**CC:** Mark Anthony Delucchi <madelucchi@berkeley.edu>, verma@salk.edu, "Salsbury, Daniel" <DSalsbur@nas.edu>, PNAS News <PNASNews@nas.edu>

Dr. Clack,

This should save us all some time. The relevant 30-second time series to determine whether your two claims of model error are incorrect are (a) the hydropower time series and (b) the flexible load time series (really two time series corresponding to Columns 5 and 6 of Table 1 of our 2015 paper)

*************************
With respect to the 30-second hydropower time-series (which I have generated after taking some time), here is the summed hydropower energy over 6 years (52547.9874993792 hours, or 6.306 million 30-second time steps:

2413.37597110289 TWh

This is exactly consistent with the 2413 TWh in Table 2 of our 2015 PNAS paper and with the 2413.38 TWh I previously provided you from the 1-hour time series and with the 2413.37 TWh from the 1 month time series, both of which are located at

http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/HydroTimeSeriesPNAS2015.xlsx

The peak hydropower discharge rate from the 30-s time series was 1.36999094810873 TW

This is close to the 1.348 TW maximum in the hourly average time series.

Thus, the fact that we kept hydropower energy constant while increasing the peak discharge rate is exactly consistent with what I told you on February 29, 2016 and exactly consistent with the hourly and monthly time series, which I posted previously, and with the figures in our 2015 paper and in Table 2 of our paper. In fact, the hourly and monthly time series merely derive mathematically from the 30-second time series.

As such, your claim of a model error with respect to our hydropower treatment is unequivocally wrong.

*************************

Second, with regard to your claim that the numbers in Table 1 of our paper are maximum numbers, and that as a result our figures show a modeling error, that claim is also unequivocally wrong, as proven here and as also indicated in our 2015 paper itself.

Specifically, the sum, over the 30-second time series for 6 years, of all energy that is flexible or coupled with TES storage is

46449.0718411728 TWh

Dividing by the number of hours of simulation (52547.9874993792 hours) gives the average load that is flexible or coupled with storage as

0.883936265717532 TW (or ~884 GW)

which is within roundoff error of the 884.03 GW at the bottom of Column 5 of Table 1 of our 2015 PNAS paper.

As such, the 884.03 GW in Column 5 of Table 1 is an AVERAGE value, not a maximum value.

Similarly, the sum, over the 30-second time series for 6 years, of all energy used for H2 production and compression is

9468.62071183395 TWh

Dividing this by the number of hours of simulation gives

0.180189978007165 TW (~180.1899 GW)

which is also within roundoff error of the 180.2 GW in the bottom of Column 6 of Table 1), indicating again that the values in Table 1 are average values, not maximum values. In fact, all loads in Table 1 are AVERAGE loads, not maximum loads.

So, to sum clearly, the values in Table 1 are average loads, and there is nothing in the text that hints in any way that these are maximum loads.

If you want to see these three time series at 30 second resolution, I can make these available to you.

Sincerely,
Mark Jacobson

On 7/10/17 9:28 AM, Christopher Clack wrote:

> Dear Professor Jacobson,
>
> We would like to request the time series for the results that you presented in the PNAS paper http://www.pnas.org/content/112/49/15060. We would like the 30 second data for the main case demonstrated throughout that paper.
>
> We do not request the model LOADMATCH, just the outputs - notably the hydroelectric, wind, solar, flexible load, hydrogen production, storage charge/discharge (by type), the different loads that are modeled (heat vs electricity etc.), solar thermal, geothermal, wave, tidal. Indeed ALL generation, loads, and storage on the 30 second resolution claimed in in the PNAS paper.
>
> We are happy to download it off an FTP or from online. Or you can send it directly. It

> states in the paper that all data is available from you, so that is why I am requesting it.
>
> Thank you for your cooperation in this request for data from your published paper.
>
> Best,
>
> Chris
>
> --
> Dr Christopher T M Clack
>
> 720-668-6873
>
> LinkedIn Profile | Academia Profile | Researchgate Profile | Google Scholar
>
> "As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality." - Albert Einstein

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