Factual Correction to the Scientific Record The 21 Authors of *PNAS* 114, 6722-6727 (2017) and *PNAS* Itself Should Make

The main conclusion of *Clack et al.* (*PNAS*, 114, 6722-6727, 2017) is based entirely on two reckless factual errors by the *Clack et al.* authors concerning *Jacobson et al.* (*PNAS*, 112, 15,060-15,065, 2015). Specifically, the *Clack et al*. main conclusion is

"*From the information given by ref. 11, it is clear that hydroelectric power and flexible load have been modeled in erroneous ways and that these errors alone invalidate the study and its results.*" (page 6727, paragraph 3)

This conclusion is based entirely on the following two reckless factual errors by the Clack authors:

(1) *Clack et al.* erroneously claim that Table 1 of *Jacobson et al*. (2015), which shows flexible and inflexible loads, contains maximum possible loads when it factually contains annual average loads. *Clack et al.* then use their own error to incorrectly state that some figures in *Jacobson et al*. are inconsistent with Table 1; therefore, *Jacobson et al*. made a modeling error. However, *Jacobson et al.* made no such modeling error. The only error was by *Clack et al.*, who recklessly and erroneously reported the definition of the data in Table 1 even after they were informed both before and after their publication of the clear definition of the data.

(2) *Clack et al.* erroneously claimed a modeling error existed in the treatment of hydropower (namely that the model did not conserve energy or water) and erroneously claimed they were unaware how it was treated by stating, "we hope there is another explanation" when they were fully aware, both before and after publication, how it was treated. (The first author acknowledged this in an email a year before publication). Further, the time series output

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

which the authors never requested until two weeks after publication, shows clearly that the model conserves energy thus water. As such, the

Clack et al. authors recklessly misrepresented the hydropower assumption in the *Jacobson et al.* paper.

Based on these reckless errors and misrepresentations and on an additional error in their paper, the authors of the *Clack et al.* paper and *PNAS* itself should correct the *Clack et al.* paper as follows:

"We correct our paper as follows:

"1) On page 6727, we retract the statement, '*From the information given by ref. 11, it is clear that hydroelectric power and flexible load have been modeled in erroneous ways and that these errors alone invalidate the study and its results.*'

"2) On page 6724, we withdraw the statement, '*In fact the flexible load used by LOADMATCH is more than double the maximum possible value from table 1 of ref. 11*' and the statement, '*Indeed, in all of the figures in ref. 11 that show flexible load, the restrictions enumerated in table 1 of ref. 11 are not satisfied*,' because we mistakenly assumed that the values in Table 1 of Jacobson et al. (2015) were maximum values when they were actually annually-averaged values. As such, we no longer claim that Jacobson et al. (2015) made a modeling error with respect to the flexible loads provided in their Table 1.

"3) We understand that the reason for the high discharge rates of hydropower shown in Figure 4B and some other figures in Jacobson et al. (2015) versus the much lower hydropower "installed capacity" provided in their Table 1 is due to the fact that the authors assumed turbines were added to existing dams to increase the peak discharge rate of hydro without changing the annually-averaged power output or water flow rate through the dams. While we disagree with the realism of this assumption, we have no reason to believe the discrepancy was due to a mathematical error or bug in the model of Jacobson et al. (2015) as opposed to a poor explanation of their assumptions and data.

"4) We correct the caption to Figure 3 to state that, whereas the historical data we provided are for the U.S. only, the data from Jacobson et al. (2015) include 44.7 TWh of imported Canadian hydro. Conclusions in the main text and supplementary information that we draw from this figure should be adjusted accordingly."

IN THE SUPERIOR COURT
FOR THE DISTRICT OF COLUMBIA

MARK Z. JACOBSON, Ph.D.,	
Plaintiff,	
v.	**C. A. No. 2017 CA 006685 B** **Judge Elizabeth Wingo** **Next Court Event:** **2/2/2017 – Initial Scheduling Conf.**
CHRISTOPHER T. M. CLACK, Ph.D.,	
and	
NATIONAL ACADEMY OF SCIENCES	
Defendants.	

PLAINTIFF MARK Z. JACOBSON'S OPPOSITION TO DEFENDANT CHRISTOPHER CLACK'S SPECIAL MOTION TO DISMISS PURSUANT TO THE ANTI-SLAPP ACT OR IN THE ALTERNATIVE TO DISMISS FOR FAILURE TO STATE A CLAIM PURSUANT TO RULE 12(b)(6)

Paul S. Thaler (Bar No. 416614)
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EXHIBIT 3

THE STATEMENTS REGARDING TABLE 1 ARE FALSE

The first most egregious misrepresentation in the Clack Article concerns Table 1 of the Jacobson Article, which the Clack Article characterizes as containing a "modeling error." *See* attached infographic summary of this issue prepared by Dr. Jacobson. Dr. Clack asserts that his statements about the Table 1 data are a matter of "interpretation" of the data. Clack Memo. at 17. The premise of this statement is incorrect because the data in Table 1, on which Dr. Clack bases his assertion of a modeling error, is not subject to interpretation. Dr. Clack asserts that the values used by Dr. Jacobson were maximums, not averages. Yet Dr. Clack does not point to anywhere in the Jacobson Article that states they are maximum values. Once Dr. Jacobson explained and showed numerical evidence to Dr. Clack demonstrating hat the numbers are in fact averages (it is, after all, Dr. Jacobson's article and his research), it is no answer for Dr. Clack to insist that because he made something up out of thin air about Dr. Jacobson's article (that they are maximum values) he has created a scientific debate. Had Dr. Clack stated in his article that he disagreed with Dr. Jacobson's *decision* to use average values, that would be the type of scientific opinion and disagreement not subject to a defamation claim. What Dr. Clack did is different. He stated, as a fact, that Dr. Jacobson used maximum values. That statement is factually untrue; it is not a question of science, where multiple opinions are possible.

The Jacobson Article does not state anywhere that the values in Table 1 are maximum values, and the original source of the data for the Jacobson Article itself unequivocally prove that the values are average values. Specifically, the footnote to Table 1 clearly states, "Total 2050 loads for each sector are from ref. 22," which is a separate paper co-authored by Dr. Jacobson and published in Energy and Environmental Science, 8, 2093-2117, 2015 (the "Jacobson EES Paper"). Dr. Clack was fully aware of the Jacobson EES Paper because the Clack Article cites to it. Page 2095 of Jacobson EES Paper clearly states: "Table 1...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." (emphasis added). Similarly, page 2099 of Jacobson EES Paper clearly states in the caption to 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." (emphasis added). *See* Attached infographic summary prepared by Dr. Jacobson. The numbers in Table 1 of the Jacobson EES paper, which are stated twice to be annually-averaged numbers proving without a doubt that the numbers in Table 1 of thc Jacobson Article are also annually-averaged, not maximum numbers.

Thus, it is indisputable that Table 1 in Jacobson Article at issue in this litigation was based on annual averages, not maximum load, as falsely represented by Dr. Clack, a falsehood perpetuated by NAS when it agreed to publish (and refused to retract or require correction of) the Clack Article. The Clack Article asserts, falsely, that this purported error "invalidate[s] the (Jacobson Authors') study and its results." Clack Article at p. 6726.

Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar

Christopher T. M. Clack[a,b,1,2], Staffan A. Qvist[c], Jay Apt[d,e], Morgan Bazilian[f], Adam R. Brandt[g], Ken Caldeira[h], Steven J. Davis[i], Victor Diakov[j], Mark A. Handschy[b,k], Paul D. H. Hines[l], Paulina Jaramillo[d], Daniel M. Kammen[m,n,o], Jane C. S. Long[p,3], M. Granger Morgan[d], Adam Reed[q], Varun Sivaram[r], James Sweeney[s,t], George R. Tynan[u], David G. Victor[v,w], John P. Weyant[s,t], and Jay F. Whitacre[d]

In particular, we point out that this work used invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions..

Significance

We find that their analy-sis involves errors, inappropriate methods, and implausible assumptions.

Modeling Errors

As we detail in *SI Appendix*, section S1, ref. 11 includes several modeling mistakes that call into question the conclusions of the study.

Similarly, as detailed in *SI Appendix*, section S1.2, the total amount of load labeled as flexible in the figures of ref. 11 is much greater than the amount of flexible load represented in their supporting tabular data. In fact, the flexible load used by LOADMATCH is more than double the maximum possible value from table 1 of ref. 11. The maximum possible from table 1 of ref. 11 is given as 1,064.16 GW, whereas figure 3 of ref. 11 shows that flexible load (in green) used up to 1,944 GW (on day 912.6). Indeed, in all of the figures in ref. 11 that show flexible load, the restrictions enumerated in table 1 of ref. 11 are not satisfied.

<--- **The Clack Authors falsely claim that Table 1 of the Jacobson Article (*PNAS*, 2015) contains maximum loads when that table factually and unambiguously contains annual average loads, as shown on the next two pages.**

Conclusions

From the information given by ref. 11, it is clear that both hydroelectric power and flexible load have been modeled in erroneous ways and that these errors alone invalidate the study and its results.

<--- **The Clack Authors then use their own factual error along with a second factual error of their own as the primary basis for the main conclusion of their study - that the Jacobson Article is invalid.**

11. Jacobson MZ, Delucchi MA, Cameron MA, Frew BA (2015) Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes. *Proc Natl Acad Sci USA* 112:15060–15065.

Despite being informed three times ahead of publication, NAS refused to conduct their own investigation or require the Clack Authors to correct their obvious factual error, and the Clack Authors refused to correct this either. Instead, the NAS legal response was (P. 13 of their Nov. 27, 2017 *Memorandum in Support...*) "The Academy therefore provided its readers with both plaintiff's and the Clack authors' positions on how the data (in Table 1) should be interpreted, which is how scientific disagreements are supposed to be addressed and resolved." No, it is not a "scientific disagreement," but a question of fact, and it is an undisputable fact that Table 1 contains average values and NAS and the Clack Authors intentionally and negligently refused to correct this error.

 www.pnas.org/cgi/doi/10.1073/pnas.1610381114

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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.

<----

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."

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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]

							% change in end-use power with WWS	
State	Scenario	2050 total end-use load (GW)	Residential % of total	Commercial % of total	Industrial % of total	Transport % of total	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

<u>THE STATEMENT REGARDING PEAK DISCHARGE RATES OF HYDROPOWER IS FALSE.</u>

The second egregious untrue factual statement in the Clack Article used to invalidate Dr. Jacobson's conclusions is that Dr. Jacobson's model erroneously allowed peak instantaneous discharge rates of hydropower, shown in Figures 4b, S4b, and S5b, to exceed the 87.48 "installed capacity" of hydropower in 2050 listed in Table S2 of the Jacobson Article. Clack Article at p. 6724, Clack Article at Supporting Information at 2. Because of the difference between the peak discharge rate and the "installed capacity," Dr. Clack concocted a claim that the Jacobson Authors must have made a "modeling mistake" and "a major error in their analysis," However, Dr. Clack clearly knew from his communications with Dr. Jacobson more than a year earlier that there was ***no*** model error with the large hydropower discharge rate because he knew that the Jacobson Authors had added additional turbines to existing dams to increase the peak discharge rate of hydropower without increasing the annually averaged hydropower discharge rate or energy output. *See* attached infographic summary of this issue prepared by Dr. Jacobson.

More specifically, the Clack Authors made the following false claim of model error in the Jacobson Article related to hydropower: "This figure (figure 4B from [the Jacobson Article]) shows hydropower supply rates peaking at nearly 1,300 GW despite the fact that the proposal calls for less than 150 GW hydropower capacity. ***This discrepancy indicates a major error in their analysis***." Clack Article at p. 6724 (caption to figure 1) (emphasis added). Dr. Clack's statement and assertion of error are demonstrably false. The Jacobson Article itself proves unequivocally that the large instantaneous discharge rates of hydropower in Figures 4b, S4b, and S5b and for the remainder of the 6-year time series of the Jacobson Article, when summed then averaged over the 6-year time series, equal an annual average discharge rate much less than 150 GW referred to by the Clack Authors and much less than the 87.48 GW listed in Table S2 of the Jacobson Article (at SI p. 14). As such, the "nearly 1,300 GW" of peak discharge referred to by the Clack Authors is consistent with a very low (much less than 150 GW) annually averaged discharge rate, meaning there is no model error. *See* Dr. Jacobson's attached infographic analysis. Thus, there was no model error.

Dr. Clack was made fully aware of Dr. Jacobson's assumption on February 29, 2016, yet still claimed otherwise in the Clack Article. Specifically, in his February 29, 2016 email to Dr. Clack's following their telephone conversation the same day, two months after the publication of the Jacobson Article, Dr. Jacobson explained: "The result is based on the assumption that we would increase the discharge rate [of] conventional hydro while holding the 2050 annual energy output constant (as stated in Forrtnote 4 of Table S.2 of the paper)." Compl. Exh. 4. In the same email, Dr. Jacobson stated that, to do this, "we increased the number of generators/turbines for each hydro plant (without increasing the dam capacity) . . .." Dr. Clack acknowledged in writing his understanding of the assumption and the possibility it could work in theory on March 2, 2016, stating, "***I am not disagreeing*** with the possibility it can be done with CSP and hydro, etc. I just think that the costs are skewed quite badly by getting all this free dispatchable power . . .." (emphasis added).

Notwithstanding Dr. Clack's actual knowledge of Dr. Jacobson's factual assumption regarding discharge rate, he wrote in the Clack Article, "[t]his error is so substantial, we hope there is another explanation for the large amounts of hydropower output depicted in these figures," as if he were unaware of the assumption. Compl. ¶50 (quoting Compl. Exh. 11 at p.8). Dr. Clack refused to remove this claim, even after being reminded of the correct assumption prior to publication of the Clack Article. In fact, Dr. Clack made it worse by adding a second deceitful statement: "One possible explanation for the errors in the hydroelectric modeling . . .." Clack Article at SI at p.2. This was deceitful because Dr. Clack knew there was no error and he knew that this was not merely a "possible explanation" he had come up with but, rather, was the actual assumption on which Dr. Jacobson's statement was based. Because the explanation provided to Dr. Clack by Dr. Jacobson eliminated the inconsistency and because Dr. Clack admitted that he understood the explanation in his March 2, 2016 email (as noted above), he was fully aware there was no resulting model error. Dr. Clack should have disclosed that he in fact knew the assumption that Dr. Jacobson had made, and that he agreed it was possible, but that in his opinion the assumption was cost prohibitive. Instead, however, Dr. Clack chose to discredit Dr. Jacobson by falsely asserting a non-existent modeling error.

Thus, Dr. Clack was fully aware, prior to publication, that adding turbines without changing the annual average hydropower energy output was the exact explanation and that the assumption did not result in a "modeling error." Instead of investigating further (by requesting model output prior to publication) or truthfully stating the exact explanation provided by Dr. Jacobson, Dr. Clack concocted hypothetical explanations spread throughout the Clack Article to justify his false claim of "model error" and his conclusion that "these errors alone invalidate the study and its results." Clack Article at p. 6727. In sum, Dr. Clack knew that Dr. Jacobson had a consistent and accurate explanation of why the instantaneous discharge rates in Figures 4b, S4b, and S5b of the Jacobson Article were larger than the maximum potential annually averaged discharge rate in Table S2 of the paper, and he knew there were no data to support the claim of a modeling error.

Dr. Clack asserts that the statement in the article that he and his co-authors "hope there is another explanation for the discrepancy" is a question not capable of being defamatory. In support he cites *Abbas v. Foreign Policy Group, LLC*, 783 F. 3d 1328, 1338-39 (D.C. Cir. 2015). Clack Memo. at 18. The Clack Article, unlike *Abbas*, did not ask a question; it made a statement. Moreover, as even the *Abbas* Court noted, the reason questions are not usually capable of defamatory meaning is that they "indicate a defendant's 'lack of definitive knowledge about the issue.'" *Abbas*, 783 F.3d at 1338 (quoting *Partington v. Bugliosi*, 56 F.3d 1147, 1157 (9th Cir.1995). Here, of course, Dr. Clack did have definitive knowledge about the issue – Dr. Jacobson disclosed the underlying assumption to him and Dr. Clack explicitly lied by pretending he did not know the exact explanation.

The published version of the Clack Article's states that the modeling for the Jacobson Article might have included additional hydropower. Clack Memo. at 19. This revision (regarding the turbines) did not rectify the original statement because Dr. Clack knew for a fact that more turbines were added as part of Dr. Jacobson's analysis (because Dr. Jacobson told Dr. Clack), and the additional turbines explain exactly why there is a difference between the peak discharge rate seen in Figure 4B of the Jacobson Article (Figure 1 of the Clack Article) and the average hydropower discharge rate seen in Table S2 of the Jacobson Article. Because the added turbines explains this difference, it also proves there is no model error. By refusing to remove the claim of model error while admitting turbines were added, Dr. Clack knew he was lying about the model error.

Finally, the fact that Dr. Jacobson published a clarification of the record regarding the assumption (Clack Memo. at 18-19) does not excuse Dr. Clack from publishing a paper he knew included a false assertion regarding the assumption. The clarification was published to make it clear to other readers what Dr. Clack had already known since February 29, 2016.

Dr. Clack was informed on Feb. 29, 2016 of the Jacobson Article hydropower assumption and its estimated cost and that the cost would be included in a followup study that Prof. Jacobson had asked Dr. Clack on June 27, 2015 to collaborate on. Dr. Clack began collaboration on the followup study on July 1, 2015.

Subject: Re: Time to talk today?
Date: Mon, 29 Feb 2016 17:41:58 -0800
From: Mark Z. Jacobson <jacobson@stanford.edu>
Reply-To:jacobson@stanford.edu
Organization: Stanford University
To: Christopher Clack - NOAA Affiliate <christopher.clack@noaa.gov>

Hi Chris,

Thanks for calling today.

I looked into the issue of the high discharge rate of conventional hydro, and it turns out the numbers in the figure are correct as simulated; however, I did neglect to clarify that we increased the number of generators/turbines for each hydro plant (without increasing the dam capacity) and neglected to include the additional cost for turbines/generators; however, the additional costs are relatively minor in comparison with other costs as shown here.

The result is based on the assumption that we would increase the discharge rate conventional hydro while holding the 2050 annual energy output constant (as stated in Footnote 4 of Table S.2 of the paper).

More specifically, the 2050 annual energy output rate converted to power for the CONUS from our 50-state plans is ~ 46.67 GW (multiply by 8760 to obtain annually-averaged energy we used as a constraint). Since the current installed capacity is 87.48 GW, the capacity factor of hydro is ~53.3%.

For the study, we assumed that the discharge rate of hydro would be increased as needed by adding turbines+generators+transformers in the hydro stations thereby increasing the discharge rate.

The additional cost of such electromechanical equipment for 1 TW discharge is approximately $0.2-0.3 trillion (See cost per 1000 MW in Figure 4.7 of

http://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf

This additional cost compares with the capital cost of the rest of out system of $14.6 trillion, so is ~1.4-2% of the total cost, thus is relatively minor.

For the future study, I will add a discharge rate limit and add the costs of equipment.

Please also note, that, even if we could not add 1 TW of discharge to current hydro plants, the solution could still be obtained with more CSP albeit at higher cost than the present solution.

Since CSP costs have dropped since our study, we think that would be more competitive with increasing hydro discharge rates.

Please let me know what you think.

Best regards,
Mark

--
Mark Z. Jacobson
Professor of Civil and Environmental Engineering
Director, Atmosphere/Energy Program
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www.stanford.edu/group/efmh/jacobson/

On March 2, 2016, Dr. Clack replied, "I am not disagreeing with the possibility that it can be done with CSP and hydro, etc, I just think that the costs are skewed quite badly..." Thus, Dr. Clack did not disagree with the Jacobson Article hydropower assumption (increasing the number of turbines per reservoir while keeping annual energy output constant) or claim there was a model error. He just disagreed with costs.

Subject: Re: Time to talk today?
From: Christopher Clack - NOAA Affiliate <christopher.clack@noaa.gov>
Date: 3/2/16, 10:25 AM
To: jacobson@stanford.edu

Hi Mark,

Great points, but please see my comments below.

I am not disagreeing with the possibility that it can be done with CSP and hydro etc, I just think that the costs are skewed quite badly by getting all this free dispatchable power,

--

Christopher Clack PhD BSc (Hons) FRAS FEAS
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Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar

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In particular, we point out that this work used invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions..

Significance

We find that their analy-sis involves errors, inappropriate methods, and implausible assumptions.

Modeling Errors

As we detail in *SI Appendix*, section S1, ref. 11 includes several modeling mistakes that call into question the conclusions of the study. For example, the numbers given in the supporting information of ref. 11 imply that maximum output from hydroelectric facilities cannot exceed 145.26 GW (*SI Appendix*, section S1.1), about 50% more than exists in the United States today (15), but figure 4B of ref. 11 (Fig. 1) shows hydroelectric output exceeding 1,300 GW. <---

Fig. 1. This figure (figure 4B from ref. 11) shows hydropower supply rates peaking at nearly 1,300 GW, despite the fact that the proposal calls for less than 150 GW hydropower capacity. This discrepancy indicates a major error in their analysis. <---

Conclusions

From the information given by ref. 11, it is clear that both hydroelectric power and flexible load have been modeled in erroneous ways and that these errors alone invalidate the study and its results. <---

Supporting Information

Both Figures S4 and S5 of its SI, for example, depict hydroelectric generation rates exceeding 700 GW. This error is so substantial that we hope there is another explanation for the large amounts of hydropower output depicted in these figures. <---

One possible explanation for the errors in the hydroelectric modeling is that the authors assumed they could build capacity in hydroelectric plants for free within the LOADMATCH model. <-

Main Text

Furthermore, the conclusions in ref. 11 rely heavily on free, nonmodeled hydroelectric capacity expansion (adding tur-bines that are unlikely to be feasible without major reconstruc-tion of existing facilities) at current reservoirs without consid-eration of hydrological constraints or the need for additional supporting infrastructure (penstocks, tunnels, and space);

The authors finally admit turbines were added, contradicting their other claims, but show their continued intent to fabricate by keeping their concocted claim that the difference between peak and average discharge is due to "model error" when they now admit it is not.

Despite full knowledge (as evidenced by the Feb. 29 and March 2, 2016 letters above and a letter to the Clack Authors before publication) of the Jacobson Authors' hydropower assumption (whereby turbines were intentionally added to existing dams to increase hydropower's peak discharge rate without increasing its annual energy output or average discharge), the Clack Authors itentionally pretend twice they are unaware of the assumption and concoct a false claim that because Fig. 4B of the Jacobson Article has a peak discharge rate exceeding 1,300 GW, but the installed capacity given in the Article is less than 150 GW, that the Jacobson Authors made a "modeling mistake

The Clack Authors then use their own concocted false claim plus a second factually false claim to state, as their main conclusion, that the Jacobson Article is invalid.

The Clack Authors demonstrate their intention to fabricate the "modeling error" when they state, "we hope there is another explanation," pretending they are unaware of the Jacobson Article hydropower assumption provided to Dr. Clack on Feb. 29, 2016.

This intention is solidified when they state, "One possible explanation..." instead of truthfully admitting the exact explanation, which they had full knowledge of, and without withdrawing their false claim of model error

EXHIBIT 5

<u>THE STATEMENT REGARDING U.S. ANNUAL HYDROPOWER OUTPUT IS FALSE</u>

Dr. Clack's third major falsification is found in Figure 3 of the Clack Article. *See* attached infographic summary of this issue prepared by Dr. Jacobson. Figure 3 compares actual U.S. only annual hydropower output data during a fifteen year period with Dr. Jacobson's estimates of proposed annual hydropower output data. Dr. Clack used this false comparison to claim that Dr. Jacobson's projected numbers were unrealistically high compared with historic data.

Dr. Jacobson used a combined total of U.S. plus imported Canadian numbers, and this fact was clear from the paper that the Jacobson numbers originated from, which was referenced in Footnote 1 of Table S2 of the Jacobson Article, which is the table listing the total hydropower installed capacity in the Jacobson Article. The referenced paper states, "Canadian hydro currently provides ~9.036 GW worth of installed capacity to the U.S. This is included as part of existing hydro capacity in this study to give a total existing...of 87.86 GW." Jacobson EES Paper at 2102.

Thus, Figure 3 in the Clack Article Figure falsely compares historical U.S. only data with proposed hydroelectric generation data and uses the resulting difference to falsely describe Dr. Jacobson's projection as implausible. Clack Article at p. 6725. In fact, the Jacobson Article did not use U.S. only generated historic data; rather, Dr. Jacobson's historic data of actual hydropower output was based on U.S. plus Canadian imported hydropower output. As such, the percentage difference between the historic number and the projected number is demonstrably smaller than the number used by Dr. Clack.

It was misleading to ignore the data that Dr. Jacobson actually used (U.S. plus Canada) in favor of data Dr. Jacobson did not use (U.S. only) to "illustrate the implausibility of the assumed increase in hydroelectric net generation . . ..” Clack Article at p. 6725. Dr. Clack’s argument that Dr. Jacobson’s projections were implausible was based on a false comparison. For the same reason, it is no answer for Dr. Clack to assert that he is blameless because Figure 3 states that it references U.S. hydropower output. Clack Memo. at 19-20. Dr. Clack’s statements about, and characterizations of Dr. Jacobson’s projections were demonstrably false because they were not based on the data Dr. Jacobson actually used (U.S. plus Canadian). *See* Complaint at ¶¶63-64.

Dr. Clack states: “To the extent that Dr. Jacobson’s complaint is that Dr. Clack does not state that the Jacobson paper allegedly adds imported power from Canada, that information is not contained anywhere in the Jacobson Paper.” Clack Memo. at 19. This is false because the source of the data is clearly incorporated by reference and data incorporated by reference are part of a paper. Moreover, Dr. Clack even cited and critiqued the paper the data originated from, demonstrating that he was fully aware of the data. Dr. Clack thus knew that Dr. Jacobson’s data included Canadian output. Footnote 1 to the Jacobson Article’s Table S2 states that the data are from reference (4) which is the Jacobson 2015 EES Paper, which Dr. Clack also references and critiques in his Article. Thus, Dr. Clack knew before submitting the Clack Article for publication that Dr. Jacobson was relying on U.S. plus Canadian data. , Moreover, on the day the Clack Article was published online, Dr. Jacobson told him via twitter that he was using U.S. plus Canadian data. Compl. ¶62. Dr. Jacobson told Dr. Clack again via twitter on July 26, 2017 when Dr. Clack made another misleading comparison of the data on twitter. Compl. ¶62.

The issue with respect to Figure 3 was not a mere difference in methodology; it is an issue of fact, not science. Comparing U.S. with U.S. plus Canadian values is factually incorrect. Even if Dr. Clack had made a mistake initially, once he and NAS were informed of this mistake, it should have been corrected in the Article instead of excused as a “difference in methodology.”

Further, in the context of NAS allowing Dr. Clack to critique the Jacobson Article, Dr. Clack was required to accurately represent the data from the Jacobson Article on which he was commenting. This he did not do because he did not make clear in comparing his Figure 3 to Jacobson Article Table S2 that Table S2includes Canadian output. Only by omitting this fact was he able to show another purported modeling error.

In sum, the three issues discussed are issues of provable falsifications of fact, not issues of scientific opinion.

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In particular, we point out that this work used invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions..

To illustrate the implausibility of the assumed increase in hydroelectric net generation (dispatched from the plants to the electricity grid) in the face of limited water supply, we plot in Fig. 3 the last 25 y of generation from hydropower in the United States along with the average for the studies in refs. 11 and 12. The data used for Fig. 3 can be found in Datasets S1 and S2. Average future generation assumed by refs. 11 and 12 is 13% higher than the highest peak year in the last 25 y and 85% higher than the minimum year in the last 25 y. Therefore, in addition to needing 1,300 GW of peak power from 150 GW of capacity, there also needs to be an extra 120 TWh of hydroelectric gener-

<--- **The Clack Authors falsely claim that their Figure 3 compares "the last 25 y of generation from hydropower in the United States along with the average for the studies in refs. 11 and 12 (Jacobson et al., PNAS, 2015 and EES, 2015, respectively)."**

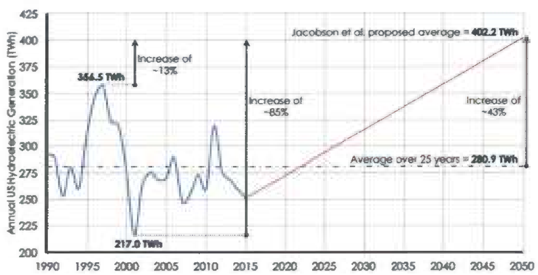

Fig. 3. Historical and proposed hydroelectric generation per year. The historical data (www.eia.gov/todayinenergy/detail.php?id=2650) show generation averaging 280.9 TWh/yr; generation proposed in ref. 11 is 402.2 TWh, 13% higher than the 25-y historical maximum of 356.5 TWh (1997) and 85% higher than the historical minimum of 217 TWh (2001).

<--- **In fact, the values in Refs 11 and 12 are NOT United States only values but United States plus 44.7 TWh (over 11% of the total) imported Canadian hydropower, as quantified in Section 5.4 of Ref. 12.**

Since, the authors of ref. [11] assume an increase of 43% from historical average values (see our Fig. 3), then Hoover Dam must produce 43% more electricity for a total of 6.01 TWh[10]. Using the calculation above, the increase in electricity production would require an additional 4.6 km^3 of water. Thus, on average Hoover Dam would be required to use 78.2% of the active capacity of Lake Mead.

<--- **The Clack Authors then concoct several erroneous claims based on their false comparison in Figure 3.**

The calculation above is simply one of water use. It is clear that more water would need to be passed through the turbines at hydroelectric power plants, regardless of the capacity. The additional need for water is not explained in [11] or [12]. Further, to compound the issues, the higher capacity is used to generate more power when necessary. This extra power results in more water moving downstream. From the calculations above, for Hoover Dam to have 21 GW capacity the maximum flow rate would be 14,724 m^3/s, which is greater than the capacity of the spillways at Hoover Dam. The extra water will cause issues downstream for all the other uses of the water, particularly irrigation. At other times, the power plants will be shutdown to store the water, presumably leaving the river to dry up downstream.

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Finally, on p. 16 of NAS's Nov. 27, 2017 "Memorandum in Support of Motion..," NAS claims that comparing U.S.+ Canadian with U.S. only data is "a simple disagreement over scientific methodology..." No, comparing apples with oranges, using the comparison to falsely denigrate another paper, and refusing to correct such an error is scientific dishonesty.