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100% renewables study has limited relevance for carbon policy

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ABSTRACT

This paper compares the work by Mark Jacobson et al. of 100% renewables to the rigors of long-run utility system planning. This comparison to integrated resource planning (IRP) allows comparison between assumptions used by Jacobson to results from real-world planning studies. Seven criteria are proposed for designing such a study.

1. Introduction

According to the Sierra Club, 36 cities are working towards 100% renewable energy; 25 more have committed themselves to that goal, and five have reached it.[1] In addition, one county and one state have made that same commitment.[2] Sen. Jeff Merkley of Oregon is one co-sponsoring a bill titled "100 by '50 Act.[3]; This movement also goes by the slogan "100 by 50." Part of the momentum arises from research, including The Solutions Project, that argues for the wholesale transformation of the entire energy system (not just electric utilities) of the United States and 138 other countries to one that relies only on a limited set of 100% renewables, referred to as wind, water, and sunlight (WWS-only), by 2050.

Heard et al. (Heard) paints a challenging picture for deep reductions in carbon emissions. Calling on multiple sources, he notes that more than 1.2 billion people lack access to electricity. That, in addition to population growth of around 2 billion more people by century's end, primarily outside Organization for Economic Co-operation and Development (OECD) countries, where projected gains in electrification is more than triple that of OECD countries, will make accomplishing deep cuts in carbon emissions challenging.

We've been allowed to ignore how electricity is produced and delivered. Our indifference to the complexity of the electric power system is a barrier to informed public policy on greenhouse gas (GHG) related emissions, especially CO_2. The importance of reliable power has risen with the increase in digital communication. As a result, studies that argue that it's prudent to rapidly shift wholly out of fossil fuels and into WWS-only for all our electricity needs must be held to a very high standard.

This paper compares a set of implicit and explicit assumptions in research by Jacobson et al. (Ref4)[4] and in [20] to system planning work by Portland General Electric (PGE) and the Northwest Power Planning Council (NWPPC). These are but two examples of how utilities and the NWPPC do utility expansion planning using integrated resource planning (IRP).

Data on existing generation capacity and projected additions will also help broaden the real-world context for the policy recommendations in Ref4. Sections 2 and 3 together will examine Ref4 to utility planning in Oregon and the Pacific Northwest (PNW). In particular, important implicit and explicit assumptions required by Ref4's conclusions are compared to results from PGE's 2016 IRP and to the most recent power plan from the NWPPC. These planning analyses are both long-term and representative of current practice for both utility-level and regional electric power planning efforts. Augmenting those studies are selected research papers. The selected research papers are a subset of the rather large body of work that currently exists that address assumptions and results in Ref4. Finally, Section 4 presents a set of conclusions and recommendations.

2. An overview of Ref4

Ref4 argues that it is both technically and economically feasible to

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[1] Is Your City #ReadyFor100? *See*: http://www.sierraclub.org/ready-for-100/cities-ready-for-100.

[2] Ibid.

[3] Transitioning America to Clean 100% Renewable Energy for All by 2050. *See*: https://www.merkaey.senate/100by50.

[4] Mark Z. Jacobson et al. 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All- Sector Energy Roadmaps for 139 Countries of the World, June 2017, *See*: http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf.

https://doi.org/10.1016/j.tej.2017.11.010

switch to a WWS-only portfolio in every application where fossil fuels are currently used. To be clear, the argument is that every current use of fossil fuels would be replaced by either electricity or hydrogen in every sector of the economy of 139 countries simultaneously. Industrial processes would no longer use fossil fuels. Products would no longer contains fossil fuels. All transportation, including trains, planes, and ships, would no longer use fossil fuels. Natural gas would no longer be used for heating or cooking. Same with propane and all other fuel oils. In addition, we would stop burning wood and other biomass to generate electricity and/or heat.

Conceptually Ref4's analysis presumes there is one utility spanning the lower 48 states with new high-voltage direct-current transmission that forms a super-grid across which electricity flows from generators anywhere to loads everywhere. To accomplish coast-to-coast co-ordination of the power system, Ref4 implicitly assumes the existing institutional framework (organizations, balancing authorities, state-level utility requirements, state statutes, and administrative procedures) have been costlessly transformed to allow one entity to manage operations that spans the continental U.S. As a result, he essentially presumes that the contiguous 48 states comprise one coast-to-coast utility balancing authority (BA).[5]

His estimates of the levelized cost of energy (LCOE) of WWS-only and business-as-usual (BAU) for the United States appear in Table 1. However, Ref4 notes, "The electric power cost of WWS [-only] in 2050 is not directly comparable with the BAU electric power cost, because the latter does not integrate transportation, heating/cooling, or industry energy costs.[6]

In addition to his observation that comparing the LCOE's of WWS-only to BAU is an apples-to-oranges comparison (which he then does), we will see that numerous costs have either not been counted or have been assumed away. Further, a difference of $0.42/MWh over the long time horizon used in that study is insignificant, and well within the range of uncertainty that exists in the real-world, even though Ref4 implicitly assumed perfect information. Assuming that all states can rapidly shift to WWS-only is hypothetical. While bench research can be used to assess how various technologies interface or when alternative policies may be effective/ineffective, analysis such as that in IRP is essential to examining how to modify an existing utility power system.

Those trained in neoclassical price theory will note the positive correlation between key assumption made in the partial-equilibrium comparative statics (PECS) model of price theory and the structure of Ref4's methodology. PECS provides a powerful tool to help structure policy analysis. However, blindly applying it without examining how the results are altered when its assumptions of perfect information, zero transactions costs, instantaneous transformation, and infinite divisibility do not hold forms a shaky foundation upon which to base policy.

To be clear, LCOE under BAU and WWS-only portfolios are not estimates of a utility's revenue requirements (revenues it needs to cover costs), nor are they prices (rates) customers would pay for electricity. Rather, they are estimates of the cost of two competing stand-alone generation portfolios at the customer's meter (Ref4 claims transmission and distribution costs and lines losses have been included). Why stand-alone? Typically, LCOE for different generation technologies are an input to an analysis that examines ways a utility can go about meeting future loads. These stand-alone costs are estimates of the stand-alone production costs of the new technology. Below we will see that least cost utility planning required of investor-owned utilities in Oregon and by the NWPPC (and in other states) requires that the analysis account for all the costs arising from changing the existing power system, which is different than the LCOE of various technologies.

Table 1
LCOE for BAU and WWS-only portfolios – US. ($/MWh).

(a) 2013 LCOE of BAU (Electricity only)	(b) 2050 LCOE of BAU (Electricity only)	(c) 2050 LCOE of WWS (All energy)
10.19	10.04	9.62

Jacobson (June 2017), pp. 123–125.

Ref4 at times assumes an extant utility exists (he notes that new wind turbines would be located near existing ones) that needs modifying, while at other times he argues no such entity exists (as when he asserts that integration costs are zero under the WWS-only). To be credible, adding renewable generation to an existing power system needs to account for risk and the costs of altering the existing power system. More will be said about this and related issues in Section 3.

Turning to an overview of Ref4's modeling, Loftus et al. (Loftus) described it as "Top–down, scenario-based back-casting.[7] A goal for reducing carbon emissions is pre-selected and the acceptable technologies are pre-defined. The analysis results in an energy system that is consistent with the pre-selected target using the pre-determined types of generators. What Loftus points out is that Ref4 begins with the result that is sought.

Ref4 identified reduced expenses for health care due to switching to WWS-only of $1425/per person per year, and climate cost savings of $7434/per person per year (those cost savings are taken at face value herein). Avoiding these externalities is the basis of his argument that the WWS-only portfolio is economic. However, these health care and climate costs do not constitute a thorough examination of social costs and benefits of the two portfolios. First, there is no substantive treatment of externalities from WWS-only, from resource extraction to fabrication, shipping, construction and operation, and decommissioning. Second, Ref4 implicitly assumes the accounting costs used to calculate LCOE are reasonable estimates of the shadow prices of those factors of production. Third, as we will see, numerous costs have been assumed away when evidence suggests they in fact are positive.

As I was completing the draft of this paper, the paper by Clack et al. at [14] became available. While there are several references to that work in this paper, my focus is on a comparison between the structure of Ref4's analysis and how utilitiy planning is practiced in Oregon and by the NWPPC.

It's puzzling that Ref4 argued so forcefully for a WWS-only energy system considering arguments made in a paper he co-authored with two students (hereafter, HFJ). HFJ noted, "Because the approaches that have been employed in moderate penetration [of renewables] regimes may not be extendable to systems with very high penetrations, care must be taken to place these methodologies into the proper context and to formulate methodologies that can be applied to systems with very high penetrations of intermittent renewables[8]

3. Further examination of Ref4's analysis

This section examines Ref4 across eight aspects of utility planning. These are: risk and adequacy of utility resource planning; commercial availability; electricity demand; generation supply; costs; transmission & distribution; system operation and reliability, and carbon policy.

[5] For an explanation of Balancing Area or Authority, refer to: Glossary of Terms Used in NERC Reliability Standards, Revised Aug. 1, 2017. *See*: http://www.nerc.com/files/glossary_of_terms.pdf.

[6] Jacobson (June 2017), p. 122.

[7] Peter J. Loftus, Armond M. Cohen, Jane C. S. Long, and Jesse D. Jenkins, A critical review of global decarbonization scenarios: what do they tell us about feasibility? Climate Change, Nov. 6, 2014 p. *See*: http://onlinelibrary.wiley.com/doi/10.1002/wcc.324/full.

[8] Elaine K. Hart, Eric D. Stoutenburg, and Mark Z. Jacobson, The Potential of Intermittent Renewables to Meet Electric Power Demand: Current Methods and Emerging Analytical Techniques, Proceedings of the IEEE, Vol. 100, No. 2, February 2012, p.323. *See*: https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/HartIEEE2012. pdf.