Comments on Independence Institute 2019 Recent Op-eds and Report on the Topic "Massive Cost of 100% Renewables"

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Executive Summary:

The Independence Institute has a long record of disparaging renewables, especially if they are supplied by the regulated monopoly, Xcel. Recent legislation in Colorado and Xcel announcements have both been in the direction of replacing fossil fuels with renewables. In these recent reports and press releases, the Independence Institute is trying to counter this trend with warnings about the "massive cost" of renewables. They present arguments based on approximate internal calculations that they have done themselves which are intentionally designed to show high costs. These are used in tandem with an emphasis on the difficulty and expense of perfection—100% renewable electricity—in contrast to the well-established cost-effectiveness of short-term progress to 80% carbon reduction by 2030 or earlier.

Comments on their study and recent opinion editorials:

In 2017, the Independence Institute hired Energy Ventures Analysis to do a report on the cost of 100% renewables to use in the Governor's race. It was designed to result in a high apparent price of renewables by:

- Not accounting for savings from not buying and burning coal and gas.
- Assuming that Colorado would not take advantage of federal tax breaks for PV or wind.
- Assuming that a renewables scenario would need to pay remaining fossil fuel debt, while a fossil fuel scenario would not.
- Assuming that renewable power plants need to be paid in advance in cash (rather than over the life of the plant, as is actually done).
- Assuming that before 2040, no new fossil fuel plants would be needed to replace retiring ones.
- Assuming that Colorado is an island without electricity imports or exports.

The resulting report was not technically defensible, given these deliberately skewed assumptions. Doing the same calculation for the fossil fuel grid (which they did not do) resulted in a cost estimate higher than for the renewables case when using their methodology (Sinton Comments on 2017 Energy Venture Analysis report).

Since none of these assumptions are actually true in practice, the study was not useful. In PUC hearings to compare the costs of retiring 2 coal plants with building renewables, the Independence Institute's expert witness did not use any results from the Energy Ventures Analysis study, although this study was central to the political race for governor in the same time period. It seems that the study had been created to support a political talking point rather than to provide information relevant to a practical decision.

The PUC decision (Sept. 2018) will increase the renewable fraction of energy on Xcel's grid in Colorado from 25% (now) to 55% after 2023. The PUC hearings determined that this plan will save money compared to running the 2 coal plants out to the original retirement dates.

The new studies and op-eds from the Independence Institute are based on this Energy Venture Analysis study from Dec. 2017. They take those results, which included Energy Ventures estimate of required battery storage and cost, and simply claim that $900B of batteries (or more) would need to be added. They do not explain why the previous study was wrong. The fantastical number of $900B for batteries is based on another simplistic calculation that the Independence Institute commissioned. The analyst that did the 2017 Energy Ventures study has now moved on to the American Petroleum Institute—so I did not approach him for a comment. Besides adding $900B to the previous $45B number from the Energy Ventures Analysis report, no updates were done to account for the actual renewable prices from the Colorado Energy Plan, the new baseline where Xcel will have 55% renewables, or the new laws such as one that reduces

the cost of retiring coal plants. It does not account for the Energy Imbalance Market that several utilities in Colorado recently joined to trade electricity between states and regions.

There is a broad consensus that PV + Wind + batteries is not the lowest-cost solution to low carbon electricity. PV + Wind + batteries + a variety of other options (demand response + other storage solutions + other low or no-carbon generation solutions + energy efficiency) will always be lower cost than the overly-constrained case of PV + Wind + batteries. The Independence Institute is setting up a straw man that is not indicative of anything real—and even then overestimating the costs in order to show a big, scary number that they attribute to being the governor's plan for 100% renewable energy by 2040. (Colorado law indicates Xcel should be 100% carbon-free by 2050 "…SO LONG AS DOING SO IS TECHNICALLY AND ECONOMICALLY FEASIBLE, IN THE PUBLIC INTEREST…", SB-236, signed by the Governor, Jan. 2019).

The cost assumed for the batteries in the Independence Institute study is already 4 times higher than the actual costs in 2019 (NREL 2019). The amount of storage required is also over-estimated, by about a factor of 4. So this calculation is likely to be high by at least a factor of 16. Battery prices are falling rapidly, and this is expected to continue so that the price of batteries will be much lower before they are actually needed in large numbers on the grid. The technology is in an early stage with rapid progress.

The tactic used here is to scare people that the transition to renewables is very risky and extremely costly. Since this has not been shown to be the case in a step by step progression replacing fossil fuels with renewables, the Independence Institute is highlighting the cost and difficulty the last little bit using perfection as the end point, 100% renewables, in hopes of confusing the issue and slowing real progress in the present.

What is known is this:

- Moving from 25% to 55% percent renewables on Xcel's grid, as is now being done, will save money.
- Continuing this trend up into the range of 80% reduction in emitted Carbon dioxide is projected to save money in Colorado due to our great sun and wind resources. Many studies are indicating this result (see Clack).
- The studies cited by the Xcel presentation show that as we reach 90% to 100% reduction in CO_2, we will likely start to see a steep increase in the cost of providing electricity if we were to do this with existing off-the-shelf technology. This general result is well recognized in the technical literature. This is the topic of much research to obtain the last bit of carbon reduction at reasonable cost *when we hit this limit*.
- In Xcel's slide deck, the sources for some of the slides are from proponents advocating for nuclear power or carbon capture and sequestration to aid in achieving the last few percent. In general, these papers show that the cost increase in using a 100% renewable solution usually comes primarily in the last 10% to 20%, with much of it in the last 1% to 5% towards 100% renewables. These studies do not contradict a rapid implementation of PV + wind in the near term.
- For example, the citation on one Xcel slide is from a paper by Jenkins. This review paper gives many estimates for the capacity of renewables that would need to be built to achieve 100% renewable. The citation in this review paper to an estimate of 3x to 8x is to a paper by Schlachtberger with some calculations for the European grid. However, the 8X figure is pulled out of context. This is not a conclusion of the paper and was a teaching example for the case of *if PV were free* with *no transmission between countries in Europe*. There are some sloppy citations and misrepresentation of technical papers by both Jenkins and Xcel here. In any case, the 8x number is absurd for the specific case of electricity in Colorado where the renewable resources as so favorable. This figure also seems to imply that traditional power systems only build the nameplate capacity (1x). In current systems, summing up the nameplate capacity of all of the power plants would be much greater than the peak demand, and this is not shown in the figure. This ratio is also irrelevant since having nameplate capacity greater than peak demand is often the lowest-cost solution for meeting demand.
- Jenkins has published papers showing that some sources of firm power, such as nuclear or gas with carbon sequestration, need to be a fraction of the electricity mix in order to achieve 100% carbon-free electricity in

some cases. However, this option is useful primarily in the last 20% of de-carbonization (from 80% to 100%), and does not change the necessity to make progress with wind and solar today towards 80%. Essentially, he is arguing that research money should be available for these alternative firm technologies, should wind and solar fall short of achieving 100% renewable goal. The two technical papers use assumptions for the cost of nuclear that are out of date. The price tag that it cited for the cost of a power plant being built in Georgia has recently been updated and nearly doubled (to $13/W) from the assumptions used in the work by Jenkins reported in the two papers in Joule in 2018. Other authors (Breyer) are calculating the costs of supplying this firm power in off-season with renewable fuels such as PV-produced hydrogen used in combustion turbines to produce power in winter or other peak periods when renewables fall short.

- Another slide is from a non-profit promoting both nuclear and carbon sequestration technologies. They use PV + wind + batteries to show a high cost, beginning at renewables exceeding 80%. However, this slide is for a deliberately high-cost example, in order to illustrate the "need" for additional technologies in the electricity mix. The calculation is not for Colorado, and once again, is using the case of exclusively using batteries rather than a mix of balancing options.
- Technical papers often give, as a teaching example, the costs of 100% renewables with PV + Wind + batteries, which can be a high-cost solution, in order to contrast this with whatever scenarios are being advocated.
- There is wide agreement that PV + wind + batteries + the variety of other options always gives lower cost than PV + wind + batteries alone. This sort of complete solution will be the likely result of a grid in the 2030 to 2040 time frame.
- Colorado has a unique situation with PV and Solar that the combination is relatively constant over the course of the year, without major seasonal variation. This makes renewable solutions less expensive here than in many places, such as northern Europe or California. Many of the referenced papers do not specifically take Colorado's unique advantages into account.
- Rather than spending ~$1T to achieve 100% renewables, it is much more likely that we will actually save money while moving to an 80% to 90% renewable electricity grid, and then continue towards 100% as advancing technologies enable higher fractions of low-cost, low-carbon power. This is a conservative strategy. Doing nothing is the risky strategy.

The Independence Institute also has sections in their study advocating for nuclear power and microgrids as alternatives to a utility renewable grid. Microgrids are said to cost more than the $940B that they estimate for utility renewables, and nuclear is said to be a preferred option based on numbers that the Independence Institute says it calculated itself. These sections of the report are not well developed and seem to be placeholders to support the results presented in the Executive Summary. The arguments do not seem to be targeted at Colorado's particular case in any way.

For example, instead of doing a simple parallel calculation for nuclear like they did for batteries with similar assumptions, they use a study from the Institute of Energy Research that compared the LCOE (Levelized Cost of Electricity) from nuclear to a "modified" LCOE for Wind and PV where they did an ad-hoc calculation to penalize PV and wind, giving numbers "including costs imposed on combined cycle and combustion turbine gas". Interestingly, the Institute for Energy Research has multiple versions of this calculation on their website. A later IER report has different numbers than the figure in the Independence Institute report, and shows both PV and Wind to be *less* expensive than new nuclear, even with their penalty imposed on PV and wind. No explanation is given although they cite the previous paper as the source of the calculation. The Independence Institute uses the version that supports their story. The assumptions used in this sort of analysis are not published in a journal, not peer reviewed, do not use Colorado data, and have been contradicted by the real costs evaluations done in the Colorado PUC proceedings for the resource plan for Xcel.

If they had done a parallel calculations for nuclear to their calculation for batteries, it might look like this.

To cover a 13 GW peak electricity load (their assumption for the battery calculation) would require building 13 GW of nuclear at $13/W (the current estimate for Vogtle in Georgia, the only plant currently under construction in the US).

13 GW * 13 $/W = $169B in capital cost just to build the required nuclear capacity. These nuclear plants, sized for the peak demand (as assumed for the case of batteries) would run at a low capacity factor at a high LCOE, since they would be cycled up and down with demand. On which river or lake in Colorado would they propose to site 13 GW of nuclear? The content in this report is pretty thin with respect to the Independence Institute assertion that nuclear is a serious option for de-carbonizing Colorado in preference to PV + wind.

Annotated Bibliography

Independence Institute 2019 Op-ed

Op-ed from Brit Naas at Independence Institute with links to their previous op-eds and studies. I would judge these contributions to be carefully-curated misinformation. They are heavily dependent on the climate change skeptic and renewables-opposition ecosystem for methods and sources (Energy Ventures Analysis, American Experiment, Heartland Institute, Institute for Energy Research).

Xcel presentation on 100% Carbon Free

Xcel presentation cited in Naas as supporting "massive cost" of renewables hypothesis. Mostly on target with a reasonable plan towards de-carbonization, but a few slides out of context to emphasize difficulty of 100% renewables and perhaps used to defend continued operation of their nuclear plant in Minnesota. Could be misleading depending on the commentary that went with the slides. Overall presentation is remarkably good as far as utility presentations go with respect to addressing climate change directly.

Slide 18: "Costs increase steeply over 60% renewables". I doubt that the 60% threshold applies to the Colorado case. It is probably from a general assessment from somewhere with less favorable resources. For example, Clack (linked below) finds a lowest-cost optimum at 83% renewables for the specific case of Colorado. The cost would be declining out to 83% and then rise as 83% is exceeded.

Slide 19: Need for seasonal storage using California data. Colorado has a rather unique advantage that makes it much easier to balance high fractions of PV and wind than in California. In California, wind and solar have a strong peak in summer, and both are much lower in winter. Lithium-ion batteries are not yet cost effective for seasonal storage so regions that require it are at a significant cost disadvantage for higher percentage renewables.

Slide 20: I have seen this slide many times in Xcel presentations. It is misleading and incorrectly sourced. I will ask Xcel to defend this slide or quit using it. Objections to this slide were raised by several audience members at a recent CRES meeting in Boulder, for example. It has also been presented at a "Switch" event in Boulder. It implies that for 100% renewables, you have to overbuild the grid by 8 times (implying great expense) to get reliability to deal with the intermittency of wind and solar.

Slide 21: Here is where they say that "Storing all excess generation to avoid curtailment would cost trillions". Nobody would do this for this very reason. So this off-hand comment is irrelevant, but was picked up by the Independence Institute and presented as Xcel's master plan for spending too much of their customers' money. Hence the title of the op-ed "Xcel acknowledges massive cost of 100 percent renewables".

Slide 22: The paper cited here is a serious paper, but the main results need to be updated because they are obsolete. The costs of nuclear cited in this paper has since doubled. In any case, this paper addresses mostly 2040, and advocates for rapid adoption of PV & wind in the short term while keeping other options open for the long-term goal of 100% carbon-free electricity.

Getting to Zero Carbon Emissions in the Electric Power Sector (Jenkins review paper)

Serious technical paper arguing for keeping options open for technology R&D for achieving de-carbonization of electricity supply at the 80% to 100% level. Advocates for "firm low-carbon resources" with nuclear as the example.

Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation (Sepulveda, Jenkins et al.)

Technical paper advocating keeping options open for “firm low-carbon resources” for long-term 100% de-carbonization. Mostly relevant to the last 20% of de-carbonization of electricity. More detailed than the Jenkins review paper.

Cost Optimal Scenarios of a future highly renewable European electricity system... (Schlachtberger et al.)

Cited as the source for the conclusion that 100% renewable systems require 8x the capacity compared to fossil fuels in the review paper by Jenkins. In one of the graphs, Power capacity vs. Solar Capital Costs, it is shown that you would install 6X the demand of nameplate PV *if PV were free and no there is no transmission between countries in Europe*. Including the battery storage as capacity brings the number up to 8X. The case of no transmission is not even true for today’s system where power flows quite freely between countries. Obviously, PV will never be free. The 8x figure was subsequently used in the Xcel slide and sourced to the Jenkins review paper above. The Independence Institute then showed the Xcel slide in their latest op-ed. Using this teaching example (if PV were free) to show that renewables would be overbuilt by 8X and imply that this means that they would be expensive is nonsense. If PV were free, this might be the lowest-cost alterative (not expensive). In the same figure, Schlachtberger shows that with optimized transmission and the most probable PV cost, the system would have 3 times the peak demand as capacity, mostly consisting of equal amounts of wind and PV. The amount of battery storage is just a few percent of capacity. This is the case that is most relevant to a planning discussion.

Baseload Electricity from Renewables (Fasihi and Breyer)

Serious technical paper from Breyer’s group in Finland that models carbon reduction for entire economy, worldwide. Good source of projected costs of batteries and alternative strategies including hydrogen.

Worldwide Renewable Economy (Jacobson et al.)

Serious paper from Jacobson at Stanford advocating a comprehensive approach to carbon reduction in the entire economy. The need for “storage”, if you look at electricity as an isolated industry, can be addressed by integrating all other parts of the economy, such as transportation, to help match electricity supply and demand. The paper discusses perceived shortcomings in the above papers from the journal “Joule” from Jenkins.

Study of Decarbonization in Colorado (Clack for Community Energy Inc.)

Study specific to Colorado, by a Colorado company founded by Christopher Clack, a scientist that had done work on renewables using weather forecasting at NOAA in Boulder. This study includes de-carbonization of the transportation sector. Similar to Jacobson in taking a comprehensive approach to using complementary aspects of the wider economy to balance the grid and obtain the lowest cost, lowest CO_2 solution. Clack has had disagreements with Jacobson on the details in the past, but they seem to be converging on solutions in the present.

Cost Projections for Utility-Scale Battery Storage, NREL

An NREL 2019 study of battery costs now and projections for the future.

This is not a representative cross section of the literature on eliminating carbon from the electricity supply. The citations from the Xcel slide presentation may skew towards sources supporting nuclear due to the nuclear reactor in Minnesota. Jenkins worked on Nuclear at MIT, and is making a case for continued R&D in that area in his position at Harvard. I added Breyer and Jacobson as alternative viewpoints. Breyer and Jacobson have found that nuclear is too expensive and too difficult to construct on time and within budget to be useful in a rapid de-carbonization of the economy. Clack does not specify the nature of his carbon-free firm generation.