Catalyst Cooperative
Observations from the PRPA Zero Net Carbon Portfolio Analysis
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The Platte River Power Authority (PRPA) exploration of a zero net carbon generation portfolio is an important first step towards implementing a no or low carbon electricity system. The study was initiated in response to PRPA members' requests. PRPA contracted Pace Global to conduct a Zero Net Carbon (ZNC) Portfolio Analysis, which was released in December 2017.

The ZNC portfolio examined in the PACE Global study had a net cost (valued in the present) only 8% higher than that of PRPA's baseline 2016 Integrated Resource Plan (IRP) portfolio over the planning horizon considered (2018-2050). This 8% additional cost is relative to only the generation and transmission portion of PRPA's operations, and so we would expect potential rate impacts to be smaller than that, as rates also cover distribution and administrative costs, which are substantial.

The electric utility industry is changing rapidly, and it is difficult to accurately predict the future. The ZNC portfolio analysis adopted many conservative assumptions from PRPA's 2016 IRP, especially with regard to the future price of solar power and electricity storage, and how the generation mix of the regional grid will evolve. We think it is worth revisiting some of those assumptions in a future study, and offer some alternatives below.

Resource Assumptions

Many of the outcomes of a modeling exercise like this one are largely determined by the input assumptions. Here we highlight some of the explicit and implicit assumptions about resources, which underlie PRPA's ZNC Portfolio Analysis, and offer references which support alternative scenarios.

Future Renewable PPA Prices

Observations:

- Over the planning horizon, the all-in costs for wind and solar appear to be very gently declining in real terms (i.e. when adjusted for inflation).

Discussion:

- The assumptions underlying the evolution of the all in wind & solar PPA prices could be spelled out in more detail. Especially given current uncertainty about renewable energy tax credit policy at the federal level, it would be useful to have the full time series for the individual cost components -- especially breaking out the assumed tax credit impacts on a $/MWh basis annually.
- Renewable energy PPA prices have continued to decline nationally for years, much more quickly than is assumed in the ZNC study (LBNL Utility Scale Solar, 2016; LBNL Wind Market Technology Report, 2016). In the short term, US tax credit policy will have a significant impact on PPA prices, but over the longer term envisioned by the study, most industry analysts expect technology prices to be driven down by economies of scale globally (BNEF New Energy Outlook, 2017). When technology becomes a small portion of the overall cost, the soft costs of renewable energy deployment will face more downward pressure.

- Direct comparisons of PPA prices in $/MWh globally aren't easy because of different solar resource quality and policy regimes, but the trend in module and balance of system costs should apply globally, as those components are largely commoditized, and those costs have declined rapidly over the last decade (BNEF New Energy Outlook, 2017).
- Global solar deployments continue to grow rapidly. Megaprojects are going forward in China, India, the Persian Gulf, Mexico, Chile, and other developing nations, where high quality resources, along with low labor, land, & permitting costs have resulted in large PPAs at prices below $30/MWh. The resulting economies of scale should drive down the cost of commoditized solar components for everyone, potentially for many years.

Questions:

- What are the assumptions underlying the wind and solar PPA price forecasts? Why does the all-in cost of solar shown in Exhibit 9 decline between 2023 and 2036 in nominal terms, and then flatten out? Is the assumption that beyond 2036 there will no longer be cost reduction opportunities in the technology?

Renewable Capacity Factors

Observations:

- The ZNC Portfolio Analysis assumes a solar PV capacity factor of 20%, and a wind capacity factor of 40%.

Discussion:

- PRPA's 2016 IRP (pp. 26-27) assumes commercial & industrial single axis PV tracking systems would have capacity factors of 25%.
- PRPA's quoted capacity (30 MW) and expected annual net generation (65,000 MWh) for the single-axis tracking Rawhide Flats Solar facility suggests a capacity factor of 25%. For locally deployed utility scale solar, this facility seems like the best benchmark to use (PRPA annual report, 2016).
- Solar PV capacity factors have increased as single-axis tracking systems have become more common in utility-scale facilities (67% of all utility scale projects built in 2015), and as inverter load ratios (ILR) have increased (LBNL Utility Scale Solar, 2016, pp. 24-26, Figs 14-16)
- Facilities with solar resource quality comparable to NE Colorado (Global Horizontal Irradiance in the 2nd quartile, between 4.52-5.37 kWh/m^2/day), single-axis tracking, and better than median ILR have average capacity factors of ~30% (LBNL Utility Scale Solar, 2016, pp. 24-26, Figs 14-16).
- A 2015 study conducted by EnerNex for Public Service Company of Colorado found expected capacity factors of ~30% for utility scale single-axis tracking PV systems in the Denver metro area (EnerNex/Brattle Group for Xcel Energy, 2015).
- A wind capacity factor of 40% appears consistent with recently completed projects in the region (LBNL Wind Technologies Market Report, 2016, p 45, Fig 38), for example the recently completed Spring Canyon wind farm in NE Colorado.

Questions:

- What has the observed capacity factor of PRPA's Rawhide Flats Solar facility been over its first full year of operation?
- When Rawhide Flats Solar is fully commissioned, what capacity factor does PRPA expect to see at that facility?

Firming of Forecastable Renewables

Observations:

- Under the PRPA ZNC study assumptions, both gas-firmed wind and gas-firmed solar are cheaper than gas alone on a $/MWh basis.
- In the ZNC portfolio for every MW of intermittent resources (wind and solar) there are 0.735 MW of dispatchable capacity.

Questions:

- The cost per MWh and dispatchable capacity required to firm either wind or solar in isolation ought to be higher than for a diversified portfolio of wind and solar. How are the firming costs of wind and solar being attributed in the ZNC portfolio? Are the firming costs presented for wind and solar in Exhibit 10 associated with each type of resource in isolation, or do they reflect a particular mix of wind and solar, and the gas required to firm that mix? If the latter, how are the firming costs attributed to one resource vs. the other?

Electricity Storage

Observations:

- Energy storage is an emerging technology that is increasingly gaining regulatory and economic traction in the electric utility landscape.
- The PRPA ZNC study assumed a 20% decrease in price over the next 5 years (pg. 17, referring to an earlier HDR Engineering study commissioned by PRPA).
- The ZNC study indicated that it only attempted to value batteries through the lens of resource adequacy, not frequency regulation or other ancillary services.

Discussion:

- The assumed price trajectory is conservative compared to other market studies.
- Electric vehicles are still a small portion of the global transportation system. Nevertheless, they are already driving enormous economies of scale in battery manufacturing.
- Lithium ion battery costs declined by an average of 19% per year between 2010 and 2016 (BNEF Lithium Ion Battery Cost & Market Report, 2017). Forecasts suggest battery capital costs per MWh of storage dropping by more than 50% between now and 2030, as deployment scales up substantially (BNEF Lithium Ion Battery Costs & Market, page 7).
- Preliminary numbers for 2017 indicate a 24% decline in costs over the last year (Bloomberg Technology News, 2017).
- Similarly, Lazard projects future capital cost for lithium ion batteries will decrease 10% per year resulting in a 36% decrease between 2017 and 2021. (Lazard LCOS 2017, p16)
- A recent NextEra solar project including battery storage offered 100MW of solar capacity plus 30MW of battery capacity available for 4 hours via a PPA at $40-45/MWh, which included a $15/MWh adder to cover the storage component. (LBNL Utility Scale Solar 2016, p37).
- Given that PRPA's reported cost (Exhibit 10) to firm solar resources using gas is ~$10/MWh, it seems possible that continued storage cost declines similar to what we have seen over the last decade could make zero carbon firming with batteries cost effective well within the planning horizon of the study, and potentially within the suggested 2025-2030 transition period.

Questions:

- Can PRPA provide the details of its battery cost assumptions from the HDR Engineering study?
- Is there a plan to integrate battery cost declines into future planning? Will PRPA reevaluate the levelized cost of batteries before investing in new dispatchable generation?

Fossil Fuel Prices

Observations:

- The ZNC Portfolio Analysis assumes that fuel prices will remain low and stable:
  - Gas (Exhibit 22):
    - PRPA delivered gas in 2017: $3.60/mmBTU. In 2040: $7.50/mmBTU
    - Equivalent to average increase of ~3.25% per year, slightly outpacing inflation.
  - Coal (Exhibit 23):
    - Rawhide coal in 2017: $1.25/mmBTU. In 2050: $2.40/mmBTU
    - Equivalent to average increase of ~2.0% per year, roughly equivalent to inflation.
    - According to the US EIA Form 923, between 2009 and 2016 the delivered price of coal increased:
      - Craig: from $1.63 to $2.29/mmBTU (~5.0%/yr)
      - Rawhide: from $1.03 to $1.32/mmBTU (~3.6%/yr)
- The ZNC analysis points out PRPA members could think of the ZNC Portfolio investment as a way to mitigate exposure to future fuel price risks.

Discussion:

- Fuel free power and demand side management (DSM) are currently the only effective ways to avoid exposure to long-term fuel price volatility, as the futures markets do not offer hedging contracts for more than 10 years, and even those contracts are extremely expensive (The Value of Renewable Energy as a Hedge Against Fuel Price Risk, NREL, 2013)

Questions:

- Fuel prices are volatile, and impossible to predict over decades. To what extent is the net cost of the overall plan sensitive to this particular set of fuel price projections?
- How much risk would PRPA members be able to avoid in exchange for the estimated 8% higher NPV of the ZNC Portfolio?
- What fuel price scenarios would result in the ZNC portfolio breaking even vs. the IRP?
- How valuable is electricity price stability to PRPA members?
- To what extent does the shift from coal to gas in combination with the reduction in overall fuel consumption change PRPA member exposure to future fuel price risk?

Demand Side Management

Observations:

- The ZNC Analysis incorporated DSM insofar as DSM was incorporated into PRPA's 2016 IRP, but it was not studied further.

Discussion:

- It is becoming common industry practice to incorporate DSM into utility planning processes as if it were a resource. This is largely because energy efficiency and demand response are usually more cost effective than comparable supply side options. This is especially true when DSM is deployed so as to mitigate the need for distribution system investments and additional peaking resource purchases.

- Navigant found that four-fifths of the Xcel Energy of Colorado (PSCo) achievable DSM savings cost less than $50/MWh, which is below the cost of all of the resources presented in the ZNC study, other than intermittent renewables and the combined cycle gas-firmed renewables (PSCo DSM Potential Study, 2016, pg. 84).
- In comparing PSCo's and PRPA's DSM potential studies, we found that the PSCo is projecting its achievable DSM to be 38% of its technical potential, whereas PRPA is projecting its achievable DSM to be 28% of its technical potential. (PSCo DSM Potential Study, 2016; PRPA 2016 IRP).

Questions:

- Are there any plans to examine how an expanded DSM portfolio, including dispatchable demand response elements could alleviate the need for more costly generation facilities or electricity storage in a ZNC portfolio?

Systemic Assumptions

An Evolving or Static Grid?

Observations:

- The ZNC analysis imagines PRPA's energy supply changing substantially, but assumes that the carbon intensity of the regional grid will not decline.
- In order to offset the emissions produced by gas-fired generation, the ZNC portfolio proposes selling renewables back to the grid. The carbon credits resulting from selling excess generation to the grid depend on the carbon intensity of the electricity those resources would be displacing. The ZNC portfolio assumes a regional grid with an emissions intensity for non-baseload generation of 1,803 lbs/MWh (US EPA eGrid database, 2014).
- Exhibit 2 shows that this plan is not robust against broader decarbonization of the grid. With even a ~20% decrease in intensity by 2050, there is insufficient excess renewable generation available in the proposed ZNC portfolio to net out the emissions from the natural gas required to firm PRPA's intermittent resources.

Discussion:

- Based on 2016 EIA 860 data, between 2014 and 2030, Colorado will see the closure of 24% of its existing coal-fired generation capacity. PSCo is moving forward with its Energy Future plan, which would bring that utility to 55% renewable energy by 2025 (US EIA Form 860, Xcel Energy Colorado "Energy Future" plan, 2017).
- California's investor owned utilities are on track to achieve 50% renewable generation by 2020, ten years before the legislatively required date (CA RPS Annual Report, 2017).
- One of the largest coal plants in the west, Colstrip in Montana, is now slated for early closure due to economics (Billings Gazette, 2017).
- In Indiana, Northern Indiana Public Service Company filed their 2016 IRP with a request for early retirement for half of its coal fleet (NIPSCO 2016 IRP Application).
- Overall, it seems entirely possible that the regional grid will decrease its carbon intensity by more than 20% over the study's planning horizon, impacting PRPA's ability to net out the carbon emissions from any natural gas-fired generation they acquire.

- Declining renewable energy and storage costs would likely both accelerate regional decarbonization and make it cheaper for PRPA to acquire more zero carbon resources.
- Additional modeling of scenarios exploring different rates of renewable energy and storage cost reductions, in combination with different rates of regional grid decarbonization will be required to assess the robustness of the proposed strategy of netting out PRPA's carbon emissions.

Questions:

- Does PRPA envision making any sales of natural gas-fired electricity into the regional grid? If so, under what circumstances? If such sales did take place, how would PRPA attribute the resulting emissions?
- Would a ZNC portfolio dominated by gas satisfy PRPA members? If not, to what extent are they willing to accept the netting out of emissions as a climate strategy?

Conclusions

The type of emissions goal used for the study -- of reaching a particular rate of emissions by a given future date -- creates an incentive to use cheap fossil fuels for as long as possible, and we see that in the study's outcome. The ramp up of renewable power begins in 2025, and the switch to renewables + natural gas firming happens as late as possible given the stated goal. An alternative emissions goal that could avoid this dynamic would be to seek the least cost portfolio and transition plan allowing the utility to remain within a given fixed net carbon budget over the study period. This type of goal avoids the incentive to delay, rewarding cost-effective early acquisition of renewable resources and aggressive demand side management measures. The ZNC portfolio results in roughly 20M net tons of CO_2 being released. Is there a lower cost path that limits PRPA's net emissions to 20M tons between now and 2050, and results in a net zero emissions electricity system in 2050? Alternatively, for the same marginal cost, are there portfolios and transition plans that result in lower overall emissions?

Based on industry trends, we feel that many of the inputs provided to PACE Global by PRPA are very conservative. Even with these conservative assumptions, the net present valuation of the generation portion of the ZNC portfolio is only 8% higher than the baseline 2016 IRP. For many customers this is likely to be a negligible difference in overall energy costs. We believe that impacts on the most economically vulnerable customers can be mitigated cost effectively.

A dramatic shift from fuel dependent to renewable electricity means a shift from potentially volatile operating expenses to stable capital expenses, and thus much more stable energy prices long term. PRPA members who do not find the need to mitigate climate change compelling may still be supportive given this purely financial benefit of the proposed transition.

Based on the reported difference in the net present value (NPV) of the two portfolios evaluated (Exhibit 18), and an estimate of the total carbon emissions based on Exhibit 25 in the ZNC Portfolio Analysis, we calculated an equivalent mitigation cost per ton of CO_2 emissions avoided:

2016 IRP Emissions			
Years	**Number of Years**	**Emissions Rate**	**Carbon Emissions**
2018-2030	13 years	2.6 Mt/year	33.8 Mt
2031-2046	16 years	2.5 Mt/year	40.0 Mt
2047-2050	4 years	1.3 Mt/year	5.2 Mt
NPV of generation & transmission: $2.718 billion			**Total: 79.0 Mt**

ZNC Portfolio Emissions			
Years	**Number of Years**	**Emissions Rate**	**Carbon Emissions**
2018-2024	7 years	2.6 Mt/year	18.2 Mt
2025-2029	5 years	1.2 Mt/year	6.0 Mt
2030-2050	21 years	-0.2 Mt/year	-4.2 Mt
NPV of generation & transmission: $2.938 billion			**Total: 20.0 Mt**

Based on the numbers reported in the study, the ZNC portfolio avoids the emission of 59.0 million tons of CO_2, and has an additional cost (valued in the present) of roughly $220 million. This implies a mitigation cost of $3.73/ton of CO_2. If we think of this mitigation cost as analogous to a price on carbon, it would be roughly equivalent to adding a 3.7 cent/gallon carbon tax on gasoline.

Spreading the same $220 million out over the 132 TWh of electricity generation PRPA projects over the study period (roughly 4 TWh / year * 33 years = 132 TWh), would yield an additional cost of 0.167 cents/kWh. Both of these cost measures are simplistic, and much more study of the economic impacts and benefits of moving to a ZNC portfolio are obviously required, but they suggest that the cost of avoiding these emissions is extremely modest.

Our primary suggestions for future analysis would be to explore the sensitivity of the ZNC portfolio's cost and viability to the following variables:

- Fuel prices for coal and natural gas.
- Cost reductions for wind, solar, and electricity storage.
- Decarbonization of the regional grid.
- Expanded, early investments in energy efficiency and demand response.
- Adoption of a fixed net future carbon budget for PRPA as the goal, rather than attaining a net zero emissions rate in a particular year.

It would also be worthwhile to quantify the climate impacts of fugitive methane from upstream natural gas production and distribution, as well as the hydroelectric reservoirs serving PRPA members. This would allow an assessment of how much additional renewable generation would be required to offset those emissions.

Given a more extensive exploration of a variety of scenarios, we hope that several viable and cost effective paths forward can be identified. Ideally these paths would both preserve future options for emissions reductions, while allowing early, aggressive, and cost effective investments to be made in the service of a variety of potential zero carbon futures.

As we completed our review of the ZNC portfolio analysis, we were excited to hear that PRPA is moving forward with the acquisition of 150-225 MW of new wind capacity and the transmission required to deliver it to their service territory from Wyoming. We look forward to a robust dialogue between PRPA and their members on the topic of decarbonization, and hope that PRPA can help set an example for other public power providers nationwide.

References

1. Utility-Scale Solar 2016: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States, LBNL-2001055, 2017
https://goo.gl/3CmVUo
2. 2016 Wind Technologies Market Report, LBNL-2001042, 2017
https://goo.gl/Rrt9Bt
3. The Use of Solar and Wind as a Physical Hedge against Price Variability within a Generation Portfolio, NREL/TP-6A20-59065, 2013
https://goo.gl/ZavNW2
4. Lazard Levelized Cost of Energy (2017)
https://goo.gl/gg14Bi
5. Lazard Levelized Cost of Storage (2017)
https://goo.gl/j7X2aT
6. Bloomberg New Energy Finance New Energy Outlook 2017
https://goo.gl/UYjBsa
7. Comparative Generation Costs of Utility-Scale and Residential-Scale PV in Xcel Energy Colorado's Service Area (2015)
https://goo.gl/aX6Xg3
8. Bloomberg New Energy Finance Lithium Ion Battery Costs and Market (2017)
https://goo.gl/XRPozX
9. PRPA Integrated Resource Plan (2016)
https://goo.gl/PDXGkJ
10. PSCo Demand Side Management Potential Study (2016)
https://goo.gl/aJo5XD
11. PRPA Annual Report, Rawhide Flats Solar, 2016
https://goo.gl/vQeZYH
12. US Energy Information Administration Form 923
https://goo.gl/nytcQh
13. Bloomberg Technology News, "The Latest bull Case for Electric Cars: the Cheapest Batteries Ever," December 5, 2017, reporting on a Bloomberg New Energy Finance industry survey
https://goo.gl/YjJZhw
14. US EPA eGrid2014v2 Database, Annual Output Emission Rates, released 2017
https://goo.gl/xA9tCG
15. Xcel Energy Colorado / Public Service Company of Colorado "Our Energy Future" stipulation, proceeding 16A-0396E, August, 2017
https://goo.gl/BWALi1
16. US Energy Information Administration, Form 860
https://goo.gl/pJ8wfn
17. California Renewable Portfolio Standard Annual Report, 2017
https://goo.gl/sVPUio
18. Plan to close Colstrip power plant by 2027 approved, leaving $10M for community transition, Billings Gazette, December 5, 2017
https://goo.gl/RMmq9D
19. NIPSCO 2016 IRP Application
https://goo.gl/WfE478