The Consideration of PV Curtailments in NEMS: Addressing the Duck Problem

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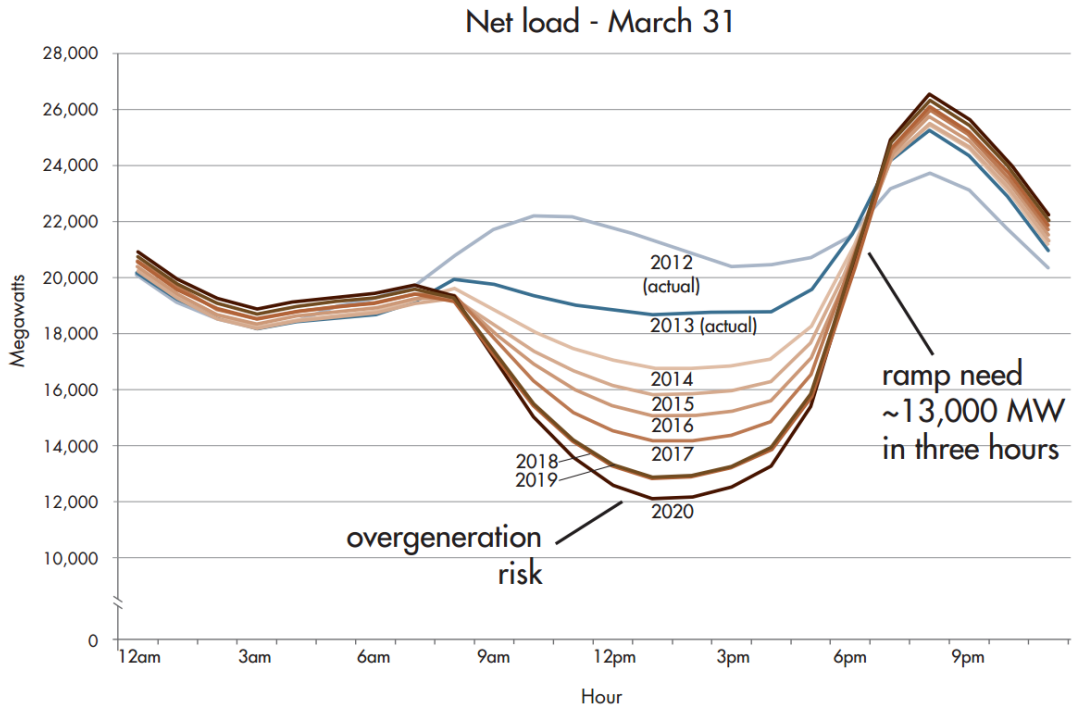
July 11, 2016

The "Duck" Problem

- As PV costs decline and greater PV capacity deployment is projected, NEMS and other models need to address the potential for PV overgeneration and curtailments.



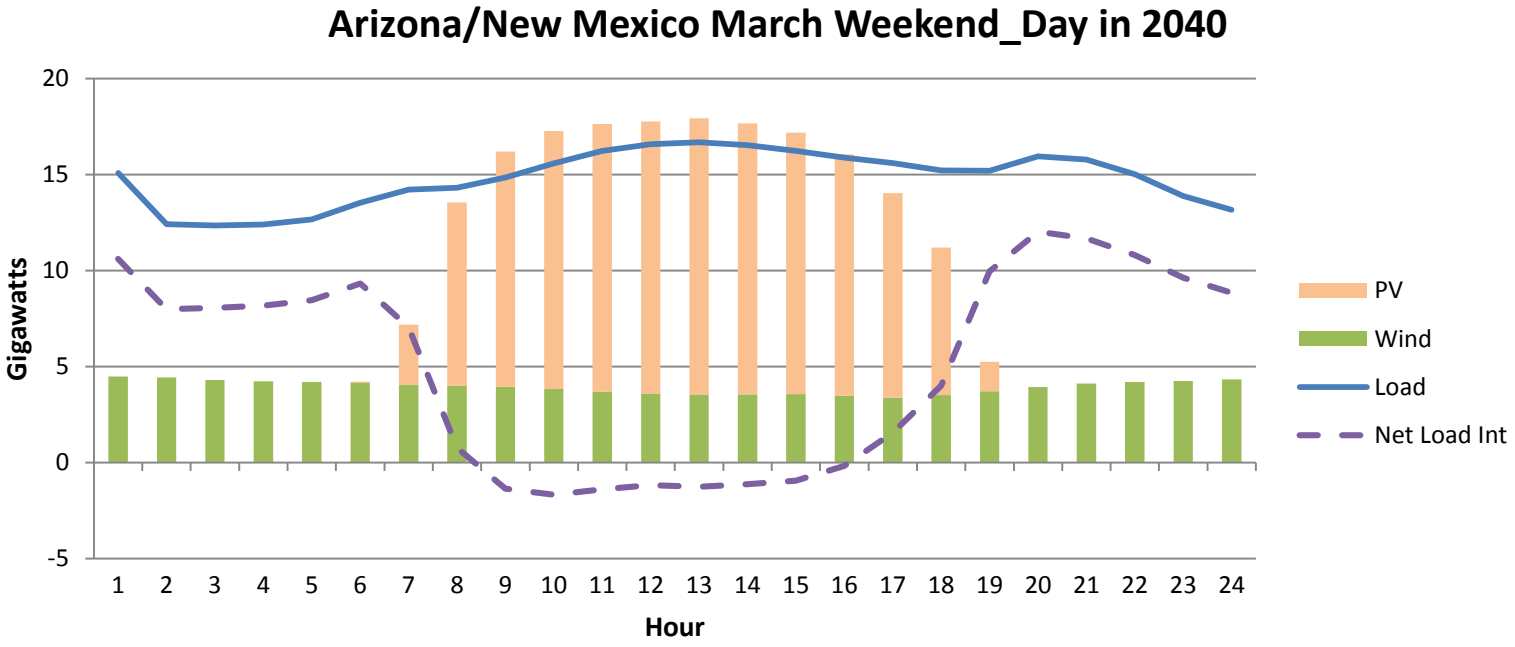
CAISO, *What the Duck Curve Tells us about Managing a Green Grid*.
https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

PV Issue in NEMS

- The Electricity Market Module (EMM) of NEMS includes several features to represent grid issues related to variable renewable generation sources:
  - Capacity reserve requirements with declining capacity credits for variable renewable capacity as penetration rates increase
  - Spinning reserve requirements that are impacted not only by load variability but also variable renewables
- However, the aggregation of time slices in the model means that the model likely overestimates the value of PV at high levels of PV adoption.
- In particular, the model does not accurately see potential PV curtailments.

Example of Negative Net Load

- An examination of the implied hourly loads and PV generation from a case with low cost PV illustrates that net load may become negative in some regions and hours - even without consideration of necessary spinning reserves.



Potential Solutions

- Two possible solutions include
  - Redefinition of the time slice aggregation
  - Use of hourly loads and renewable availabilities to inform the capacity planning and dispatch algorithms of PV curtailments
- Increasing the number of time slices to accommodate the diurnal pattern of solar generation as well as load variability is straightforward but comes with a significant runtime penalty.
  - Depending on the number of slices added, some residual aggregation problems may persist
- As an alternative, we have developed a method to add explicit consideration of PV curtailments within the current time slices.
- The curtailment development work was sponsored by DOE-EPSA and is not included in the AEO2016.

EMM Background

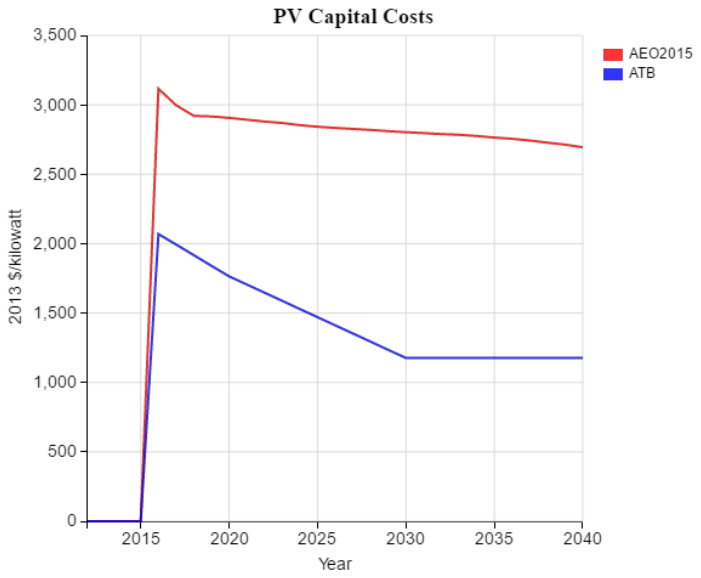
- The EMM aggregates the hours in a year into 3 declining load blocks in each of 3 seasons (total of 9 slices).
  - Loads are originally computed for 864 hours/year (24 hours by 12 months by 3 day types) and then sorted within each season to construct 3 blocks of declining loads
  - PV and wind capacity factors are provided by 24 hours for each month and then averaged according to the hours in each load block
- Power plants are dispatched using a linear program (LP) to meet load and spinning reserve requirements and have 6 operating mode options for generation in each season
  - Maximize electricity generation (run at max level)
  - Load following
  - Maximize spinning reserves (run at min level)
  - Each of these 3 modes can be applied either to all 3 load blocks or to the first 2 blocks with no generation in the 3rd block.

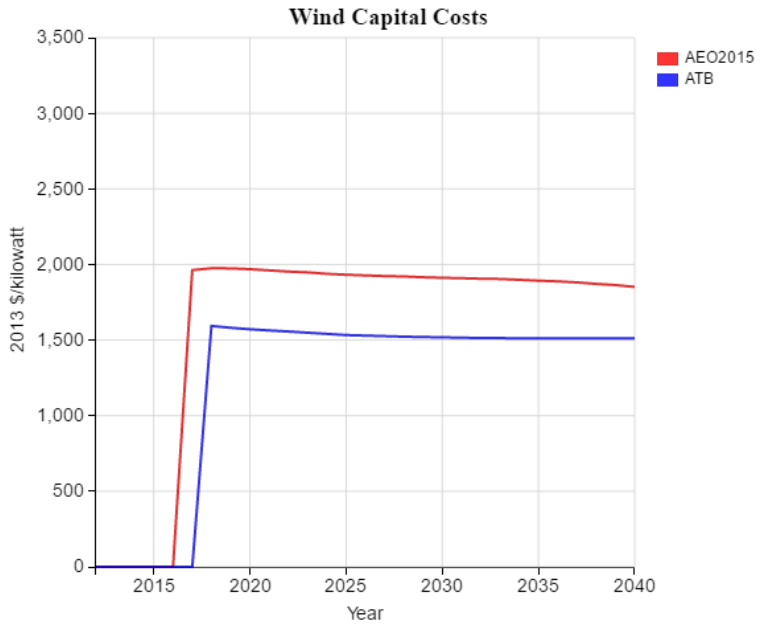
Modifications to Address PV Curtailments

- The goal was to determine necessary PV curtailments endogenously within the model taking into account the need for some minimum amount of dispatchable capacity to provide ramping response and at the same time allow other capacity additions and generation to adjust to make room for more PV capacity if it would be cost-effective.
- Creation of a new capacity-only constraint for the most PV constrained hour each season when the lowest net load occurs coincident with high PV availability
  - Identifies required minimum amount of non-variable renewable generation as well as PV that is feasible without curtailments
- Creation of a new bounded capacity build for curtailed PV
- Curtailments are used as coefficients in the LP that indicate the amount of curtailments associated with each GW of PV capacity beyond the amount of feasible uncurtailed PV.

Test Cases

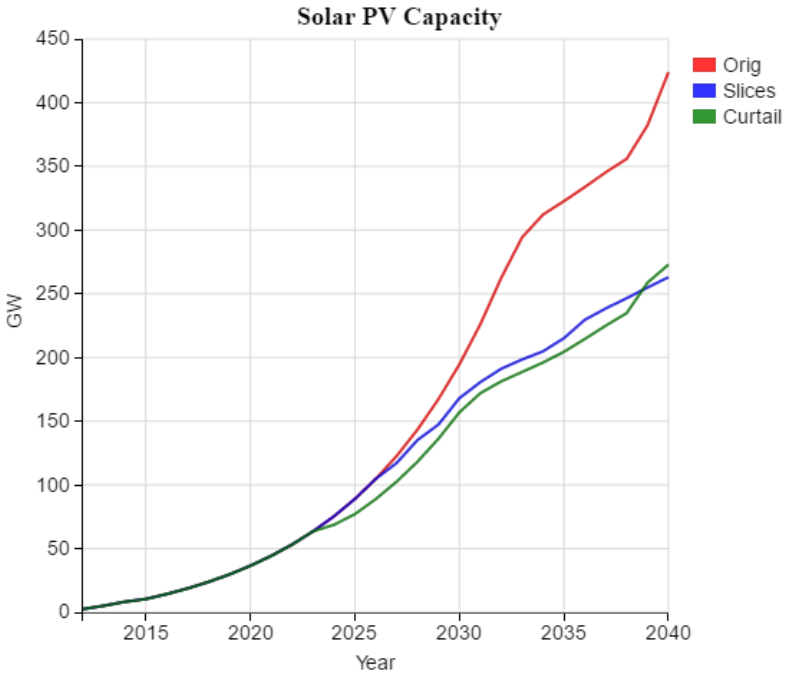
- Three test cases were constructed using EPSA-NEMS that include PV and wind technology assumptions from NREL's Annual Technology Baseline (ATB) and the renewable PTC/ITC credit extensions
  - Original methodology (Orig)
  - Revised load slices with 5 time slices per season: 3 daytime slices and 2 night slices (Slices)
  - PV curtailment methodology (Curtail)

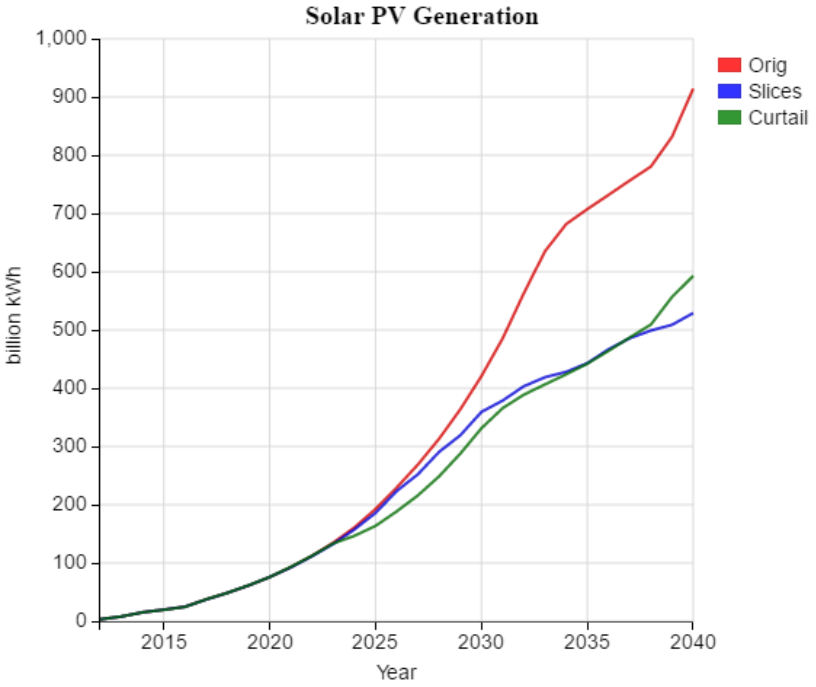




Solar PV Capacity and Generation

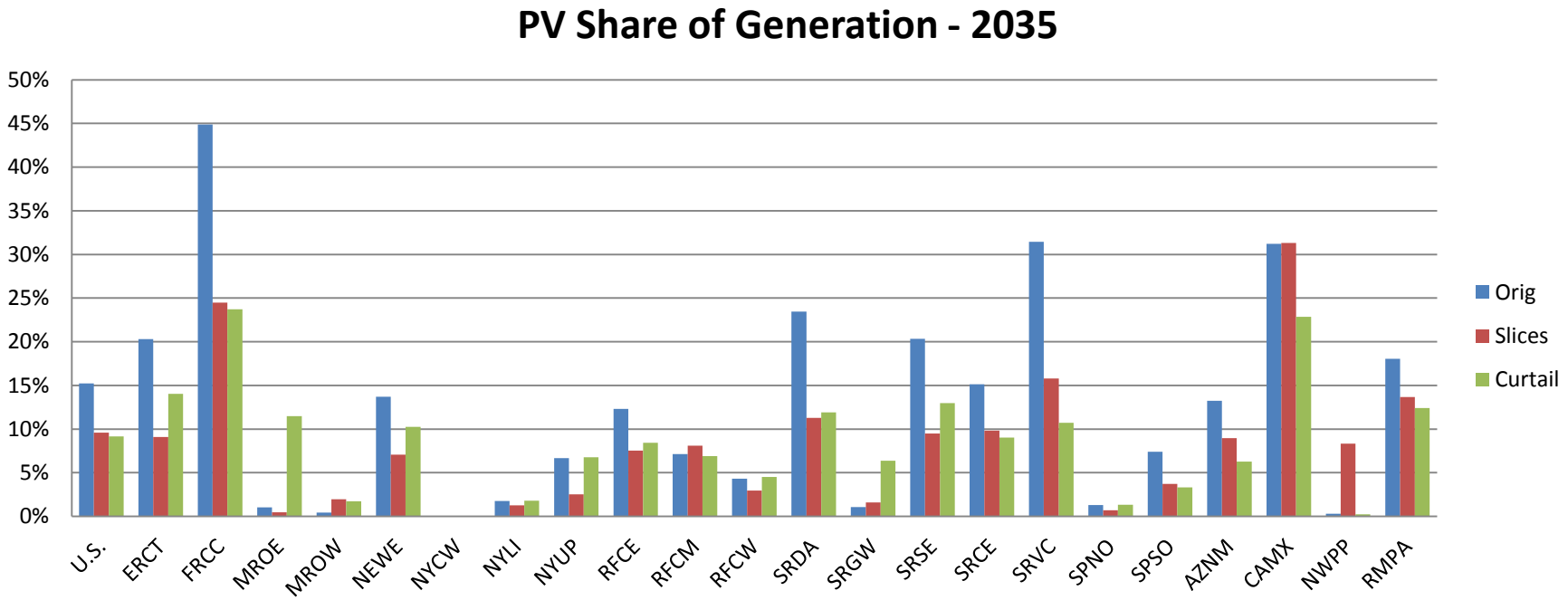
- Projected utility-scale PV capacity and generation are significantly reduced when the load slices are modified or curtailments are explicitly considered.





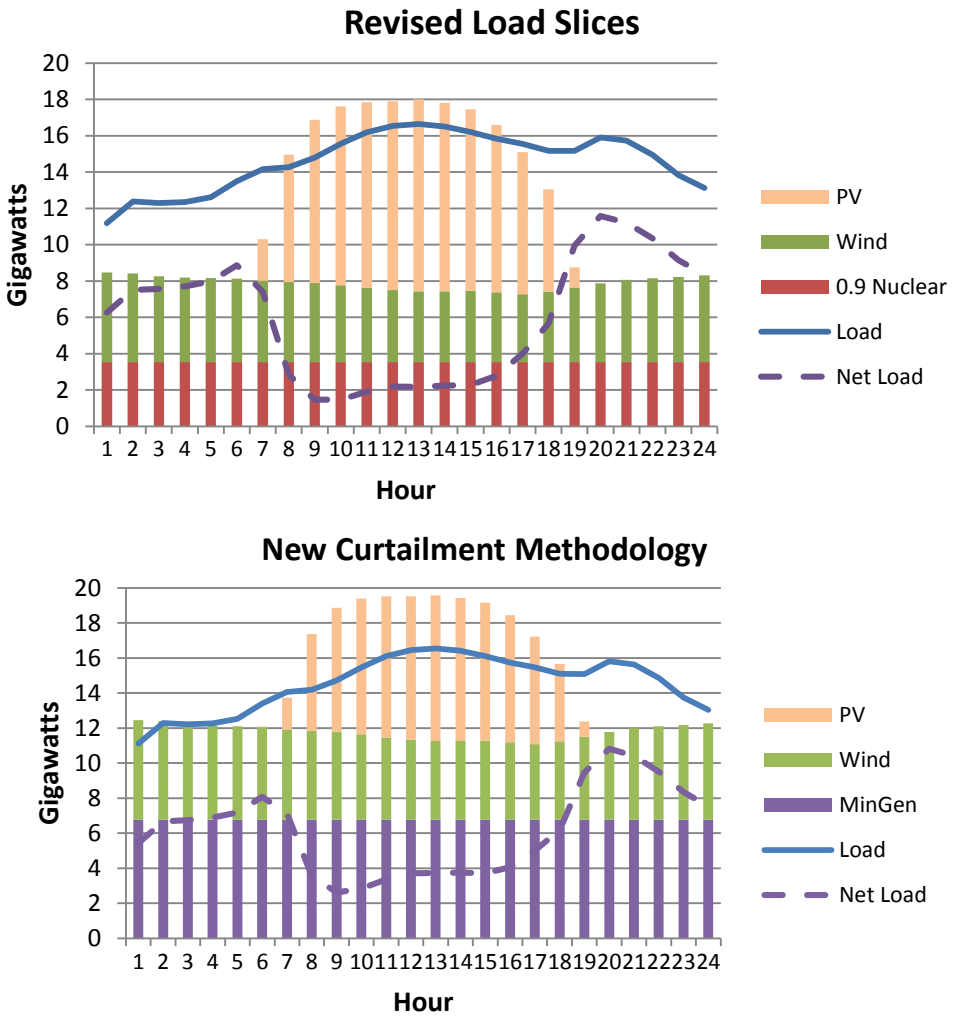
Regional PV Projections

- PV generation in the revised cases is much lower than the original in most regions with high PV shares.
- There is some variation across regions between the curtailment methodology and the change in load slices.



Arizona/New Mexico Revisited

- With revised load slices, AZNM likely still experiences PV over generation in some periods without economic considerations.
  - Other regions likely experiencing over generation in the Revised Slices case include ERCOT, Florida, SERC-VC, and CA.
- When PV curtailments are explicitly modeled, projected PV is still significant and some curtailments are economically viable.
  - Overall 2 percent of PV generation is curtailed nationally by 2040, with the greatest share in Florida at 7 percent.



Example for AZNM 2040 March Weekend Day

Conclusions

- The current load slice configuration in NEMS tends to over value PV capacity at high levels of deployment.
- Modifying the load slice definition leads to more reasonable results but causes longer model run times and does not completely resolve the over valuation problem.
- The new algorithm that explicitly represents potential curtailments gives the model flexibility in adjusting operations to accommodate PV as well as account for the expectation of curtailments at high levels of deployment.
- This methodology could be extended to wind capacity as well.