RPS Modeling Approach

- Our overall framework for describing the economics of state RPS requirements is similar to (but more simple than) an energy market economic dispatch model.

- The basic economic supply/demand framework that underpins structural energy market models also exists for renewables markets:
  - Demand = state RPS requirements
  - Supply = quantity and quality of renewable resources in different locations.
    - Supply is priced based on the breakeven renewable energy credit price (“REC”) necessary to induce entry by a given renewable resource
  - Tradeability within broad regional areas in the form of renewable attributes products (RECs) that are often unbundled from the physical energy output of the facility and can be utilized to satisfy out-of-state RPS requirements

- Describing and then clearing this supply and demand framework tells us how much renewables supply is developed where and at what cost.

- The challenge in implementing this approach is threefold:
  1. Appropriately defining regional “RPS markets” that broadly respect state-level renewable resource eligibility rules (e.g. RECs from IL can supply the NJ RPS, but RECs from ERCOT cannot)
  2. Accurately describe the supply and demand for renewable resources in each region through time
  3. Address special cases and complications as necessary – in-state requirements, carve-outs, REC multipliers, net metering, etc.
Wind supply is built up from existing renewables and different categories of wind and solar in each state [Illustrative]

### N. Ill 2015 REC Supply Curve
- **Utility-scale solar @ >$100/MWh**
- **“Good” New Build N. Ill wind (34%), limited by transmission through 2018**
- **Existing wind + non-wind/solar renewables**

### Eastern PJM* 2015 REC Supply Curve
- **“Bad” Wind in PA, OH, MD, WV, VA (26-28%)**
- **Utility-scale solar in VA**
- **IA Imports into N. Ill**
- **IA imports are capped by N. Ill RPS demand (~8.3 TWh in 2012)**
- **Good IA New Builds (37%)**

### PJM Composite 2015 Residual REC Supply Curve
- **“Bad” Eastern Wind (26-28%)**
- **“Good” New Build N. Ill wind (34%)**
- **(25TWh = ~8GW of Capacity)**

*Assumes full subsidies to wind*
Demand is segmented state-by-state into solar carve-out and total “residual” demand, assumed to be supplied by wind or more solar

Ohio - “Alternative Energy Resource Standard” of 25% by 2025
(12.5% renewable minimum, including 0.5% solar-electric)

- Mandatory 0.5% solar-electric
- Energy Efficiency allowed; assume 5% is economic but 1% already accounted for through separate EE mandates
- Renewables include solar PV & thermal, wind, biomass, LFG & other organic gas, fuel cells, low-impact hydro, others
- “Advanced energy” includes clean coal, Gen 3 nuclear power, distributed CHP, fuel cells, others

2010 retail sales of 154.1 TWh, projected to be 188.1 TWh by 2030 with 1% load growth; 88.6% of this load is currently served by utilities and retail electric providers = 166 TWh baseline

<table>
<thead>
<tr>
<th>Solar Carve-Out</th>
<th>Residual (Supplied by wind or solar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Contribution to RPS before Rate Caps</td>
<td>0.5%</td>
</tr>
<tr>
<td>In-state Requirement</td>
<td>50%</td>
</tr>
<tr>
<td>ACPs</td>
<td>$400/MWh for 2011, falling to $50/MWh by 2024</td>
</tr>
<tr>
<td>Rate Caps</td>
<td>Utilities are not required to comply with the annual benchmarks if it is &quot;reasonably expected&quot; to raise their costs by 3% or more above what they would have otherwise been</td>
</tr>
<tr>
<td>Total Demand by 2030</td>
<td>833 GWh / ~1 MW&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
Each incremental year is cleared in succession, taking into account results of prior years [Illustrative]

- When we move forward one year, several things happen to change the RPS supply and demand landscape
  - Demand increases due to upward ratchet of RPS targets and load growth
  - Supply built in prior years is now sunk and bids into REC markets at zero
  - Market prices are depressed due to new builds, raising the required REC price for new entrants
    - We assume that new solar depresses prices considerably less than new wind (about 25% of the impact of wind), because it largely displaces marginal new resources

- We clear each year incrementally out to 2030

Assumes full subsidies to wind
Increases in demand, subsidy changes, and technology cost trends all greatly influence the ultimate outcome [Illustrative]

Assumes full subsidies to wind; Solar carve-outs and in-state residual RPS preferences are cleared separately and are not shown on this chart.
Key takeaways:

- Wind is uneconomic and is not built out significantly
- Major PJM RPS programs go through ~5 year period in which suppliers pay ACP rather than purchase RECs from new builds
- Eventually solar is able to beat the ACPs and allows states to meet RPS goals in the long run

Note: REC price for 2012-14 set by banking economics (15% discount rate); would be zero without banking
Key Wind/Solar Assumptions

- Starting real technology capital costs (2012)
  - Wind: $1,800/kw (with regional variation)
  - Solar: $3,125/kw utility scale, $4,220/kw distributed commercial, $5,150/kw distributed residential (with regional variation)

- Projected real costs (can be toggled):
  - Wind: 0.5% annual decline through 2030 ($1,900/kw to $1,735/kw)
  - Solar: 6.8% annual decline through 2020, 3.4% annual decline thereafter

- O&M:
  - Wind: $35/kw-yr flat real
  - Solar: $13/kw-yr flat real

- Subsidies (can be toggled):
  - PTC: $22.89/MWh through 2030
  - ITC: 30% through 2030
  - MACRS: 5-year, with 50% bonus depreciation for solar
  - Net metering: current state policies

- Useful Life:
  - Wind: 25 years (no degradation)
  - Solar: 25 years (1%/year degradation)

- 10% WACC for both wind & solar