The SB100 Pathways Project: Reaching a Net Zero Carbon Grid in California

SCCS Affiliates Meeting
November 5th, 2020

**EJ Baik, Sally M. Benson**
Department of Energy Resources Engineering, Stanford University

In collaboration with Jane Long (EDF), Steven Hamburg (EDF), Armond Cohen (CATF), Clea Kolster (E3), Kiran Chawla (E3), Arne Olsen (E3), Jesse Jenkins (Princeton), Michael Colvin (EDF), David Victor (UCSD), and Rob Jackson (Stanford)
Key Takeaways

• **SB100 Pathways Project (Long et al. 2020, *in review*)**
  
  • Reaching a net zero carbon grid in 2045 in California can be done cost-effectively if we develop ~30 GW of Clean Firm Resources

• **An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions (EFI and Stanford University, 2020)**
  
  • Utilizing NGCC-CCS in the electricity grid as early as 2030 to meet emissions reductions goals is cost-effective and puts California on path to meet its 2045 goals
Executive Order (B-55-18) commits California to a carbon-neutral economy by 2045
Decarbonizing the electricity grid and electrifying other end-uses of energy has significant implications.
One of California’s key climate policy is Senate Bill 100

**SB 100**

- **2030**: 60% Renewable Portfolio Standard (RPS)
- **2045**: Zero-Carbon Grid
California currently gets over 30% of its electricity from natural gas.

California’s Generation Mix

- Natural Gas: 31%
- Imports: 28%
- Solar: 10%
- Hydro: 12%
- Nuclear: 6%
- Other Renewables: 8%
- Wind: 5%

Source: CEC, 2019
2045

The SB100 Pathways Project utilized three independent capacity expansion and dispatch models to assess several different pathways of reaching a net zero carbon grid in California to meet its SB100 and carbon neutrality goals in 2045.
Three distinct capacity expansion and dispatch models were used for The SB100 Pathways Project.

Capacity expansion and dispatch models find the cost-optimal grid subject to meeting future annual load and policy goals (cost-optimal indicates minimizing both the capital cost of building new resources and annual operating costs).
Three distinct capacity expansion and dispatch models were used for The SB100 Pathways Project.

<table>
<thead>
<tr>
<th></th>
<th>E3 RESOLVE</th>
<th>Stanford urbs</th>
<th>Princeton GenX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>3 zones: CA, SW, NW</td>
<td>10 CA zones; 2 out of state zones</td>
<td>2 CA zones; 7 out of state WECC zones</td>
</tr>
<tr>
<td><strong>Zones Optimized</strong></td>
<td>California</td>
<td>California</td>
<td>WECC-wide</td>
</tr>
<tr>
<td><strong>Temporal Resolution</strong></td>
<td>37 representative days</td>
<td>1 year in hourly time steps (8760)</td>
<td>16 representative weeks with hourly resolution time steps (2,688 hours)</td>
</tr>
</tbody>
</table>
Technologies considered in the analysis include:

- Solar (Re)
- Onshore Wind (Re)
- Offshore Wind (Re)
- Energy Storage (B)
- Nuclear Power (N)
- Natural Gas with Carbon Capture and Storage (C)
- Zero Carbon Fuel (F)

Renewable Resources

Clean Firm Resources
With the development of clean firm resources, California can build a net zero carbon grid at approximately historic generation and transmission rates.
With the development of clean firm resources, California can build a net zero carbon grid at approximately historic generation and transmission rates.

Current California IOU Generation & Transmission Rates (9.1 cents/kWh)

Cases with Clean Firm Capacity

- **GenX**
- **urbs**
- **RESOLVE**

<table>
<thead>
<tr>
<th>Model</th>
<th>GenX</th>
<th>urbs</th>
<th>RESOLVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ReBC</td>
<td>9.7</td>
<td>8.4</td>
<td>9.4</td>
</tr>
<tr>
<td>ReBN</td>
<td>9.4</td>
<td>8.2</td>
<td>8.0</td>
</tr>
<tr>
<td>ReBF</td>
<td>10.2</td>
<td>8.5</td>
<td>8.2</td>
</tr>
<tr>
<td>ReBCN</td>
<td>9.3</td>
<td>7.8</td>
<td>7.7</td>
</tr>
<tr>
<td>ReBCF</td>
<td>9.7</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>ReBCNF</td>
<td>9.4</td>
<td>7.6</td>
<td>7.1</td>
</tr>
</tbody>
</table>
With the development of clean firm resources, California can build a net zero carbon grid at approximately historic generation and transmission rates.
Without clean firm resources, California’s PV capacity will have to grow at unprecedented rates and reach more than double the PV build in the scenarios with clean firm resources.
So how much clean firm resources do we need? – approximately 30 GW

*Current California Firm Capacity* (48 GW)

*Dotted boxes indicate imported firm capacity*
Developing ~30 GW by 2045 will require action before 2030

Natural Gas grew at 1.4 GW/yr in CA 2001-2013
2030

An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions (EFI and Stanford University, 2020)

We assess the role of NGCC-CCS in California’s grid in 2030 in meeting California's climate goals
One of California’s key climate policy is Senate Bill 100

<table>
<thead>
<tr>
<th>Year</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>60% Renewable Portfolio Standard (RPS)</td>
</tr>
<tr>
<td>2045</td>
<td>Zero-Carbon Grid</td>
</tr>
</tbody>
</table>

**SB 100**
In addition to meeting the RPS, cost-effective decarbonization of the economy will need meeting emissions reduction goals for the electricity sector in 2030 as well.
Given climate goals for 2030, what does an optimized California grid look like?
Meeting California’s 2030 RPS and emissions reduction goals for the electricity sector with NGCC-CCS in the system saves ~$750 Million/year relative to a scenario without NGCC-CCS.

**FIGURE 3-6**
CAPACITY OF CALIFORNIA’S ELECTRICITY SYSTEM IN 2030 WITH AND WITHOUT CCS

$750 million/year Cost Savings

<table>
<thead>
<tr>
<th>Capacity (GW)</th>
<th>2018 Baseline</th>
<th>2030 No CCS</th>
<th>2030 CCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio+Geo+Nuc</td>
<td>2</td>
<td>17</td>
<td>27</td>
</tr>
<tr>
<td>Hydro</td>
<td>17</td>
<td>51</td>
<td>43</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>31</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>CCS</td>
<td>8</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A decrease in natural gas generation relative to 2018 is made up largely with more PV generation.
Developing CCS in 2030 can put California on path to meet its 2045 goals effectively.

**No CCS**

- 2018 Baseline: 77 GW
- 2030 No CCS: 37 GW
- 2045 No CCS: 103 GW

**CCS**

- 2018 Baseline: 77 GW
- 2030 CCS: 31 GW
- 2045 CCS: 55 GW
Key Takeaways

• **SB100 Pathways Project (Long et al. 2020, *in review*)**
  • Reaching a net zero carbon grid in 2045 in California can be done cost-effectively if we develop ~30 GW of Clean Firm Resources

• **An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions (EFI and Stanford University, 2020)**
  • Utilizing NGCC-CCS in the electricity grid as early as 2030 to meet emissions reductions goals is cost-effective and puts California on path to meet its 2045 goals
Thank you for listening!
I’d be happy to take Questions:
@ebaik@stanford.edu