Decarbonizing Rhode Island Space Heating in a Managed Carbon Future

Daniel S. LeFevers
Director, State and Consumer Programs
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Space heating is the dominant space conditioning load in all regions. Ratio of heating to cooling is high in northern regions (over 10:1).

Source: DOE EIA (RECS, 2015)
Rhode Island power generation is highly reliant on natural gas generators for baseload power.

Natural gas generators are used nearly exclusively to meet seasonal demand increases – for example, for space cooling or heating.

EPA eGRID data shows Rhode Island natural gas power plants have an overall efficiency of 44.6% (HHV basis). Coupled with electric transmission and distribution line losses, delivered electric efficiency is less than 40%.

<table>
<thead>
<tr>
<th>Rhode Island Power Generation</th>
<th>Baseload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>91.7%</td>
</tr>
<tr>
<td>Oil, Coal</td>
<td>0.3%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.0%</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.1%</td>
</tr>
<tr>
<td>Wind</td>
<td>3.0%</td>
</tr>
<tr>
<td>Solar</td>
<td>1.6%</td>
</tr>
<tr>
<td>Other</td>
<td>3.3%</td>
</tr>
</tbody>
</table>

Note: wind and solar are not seasonally dispatched generation resources.

Source: GTI analysis of DOE-EIA and EPA eGRID data.
Today a shift to electric heat pumps in Rhode Island would lead to a 79% increase in consumer’s space heating annual energy costs with virtually no change in GHG emissions.

Seasonal electricity heating loads and associated peaks, based on today’s grid, would largely be met by dispatchable natural gas power generation.

Wind will not able to ramp up in the winter, solar PV output drops substantially during short winter days, and batteries are insufficient to deal with winter heating storage needs for peaks.

Source: GTI analysis, including DOE-EIA data.
Impact of Cold Temperature on Electric Heat Pump Efficiency (and Output)

Cold ambient temperatures lower electric heat pump efficiency (COP) by 30-50% (or more).

Diminished 2015 performance partly attributed to high levels of snow & ice accumulation.

Testing conducted on homes in Massachusetts and Rhode Island.
Rhode Island: Seasonal Patterns In Residential Use of Electricity and Natural Gas

<table>
<thead>
<tr>
<th>2013 - 2018</th>
<th>Residential Electric</th>
<th>Residential Natural Gas</th>
<th>Natural Gas: Electric Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td></td>
<td></td>
<td>210%</td>
</tr>
</tbody>
</table>

Data show monthly peaks. Peak day ratios even higher.

Source: DOE EIA. Six years of monthly data on equal scales.
Large Increases In Peak Month Electricity Use Shifting From Natural Gas To Electric Heat Pumps

Switching from gas heating to electric heating would (on average) increase peak residential month electricity 150% in most states.

In Rhode Island, winter month peak with electric heat pumps would be 185% higher than the current summer peak.

Source: GTI analysis, including DOE-EIA data.
Energy Storage Realities

Former Secretary of Energy Professor Steven Chu as cited by the Australian on 1-30-18

- While the costs of building battery plants were likely to halve over the next decade, the approach would never be cheap enough to accommodate the big seasonal shifts in renewable power production.
- Batteries could prove viable for storing power produced during the day for use during night hours, and “maybe” up to a week later, but not over seasonal timeframes.
- You need other new technologies to convert cheap renewable energy into chemical fuel when the sun is shining or the wind is blowing, he told The Australian. “If you make really cheap hydrogen from renewables and store it underground, then you have something very different.”

Source: GTI analysis of DOE EIA data (nominal). Based on underground gas storage and pumped hydro storage data; estimated battery performance assuming 1 GW installed capacity and 25% annual capacity factor.
Reducing full-cycle natural gas methane emissions

Natural Gas Low Greenhouse Gas Pathways

**Near-Term (25-50+%)**
- Expanded use of high-efficiency gas equipment
- Hybrid natural gas furnace/boilers and electric heat pump systems
- Building envelope improvement

**Next-Gen (40-60+%)**
- Natural gas heat pumps for space & water heating
- Micro CHP systems
- Deep building retrofits

**Renewables (Added 10-30%)**
- Renewable gas blends (bio-methane, hydrogen)
- Solar thermal/natural gas space & water heating systems
- Lower Methane Emissions (5-10%)

* Numbers indicate nominal GHG reduction potential
Near-Term Thermally Driven Gas Heat Pump Developments
130-140% Efficiency

- Residential Heat Pump Water Heater (10 kBtu/hr)
- Residential Low-Capacity Combination Space & Water Heating System (20 kBtu/hr)
- Residential Large-Capacity Combination Space & Water Heating System (80 kBtu/hr)
- Light Commercial Combination Space & Water Heating System (140 kBtu/hr)

Multiple product platforms in development by SMTI, GTI, and partners.
Past, Present, Future
Natural Gas Low Carbon Pathways

• The nearly 30% reduction in annual per-home CO₂ emissions is complemented by a nearly 60% reduction in annual methane emissions per home (full-fuel-cycle) since 1990

• Where will be in 2040? Further potential to improve efficiency and lower GHG impacts
  – Gas heat pumps
  – Improved building envelopes
  – Renewables (biomethane, H₂, solar)
  – Lower methane emissions

Source: DOE-EIA, EPA, GTI analysis