Consumer/Societal Needs and Advanced Natural Gas Energy Technologies

William E. Liss

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Company Overview

ESTABLISHED 1941

> Independent, not-for-profit established by the natural gas industry

> GTI tackles tough energy challenges turning raw technology into practical solutions

> Downhole to the burner tip including energy conversion technologies
Energy Supply & Security

U.S. Primary Energy Production (Quadrillion Btu)

Residential Energy $/MMBTU
Electricity ($0.1267/kWh) 37.12
Natural Gas 10.38
Ratio 3.58

Environment

Trends in Radiative Forcing (watts/meter²)

2.5
2
1.5
1
0.5
0
1985 2000 2015

NOAA (AGGI)

Consumer Choice

National: Current vs. Preferred Energy Source

Energy Economics

Residential Energy $/MMBTU
Electricity ($0.1267/kWh) 37.12
Natural Gas 10.38
Ratio 3.58
Natural Gas
Clean Burning Domestic Resource

> **Natural Gas** is the leading U.S. produced energy source, with an increasingly bullish domestic resource base outlook.

> Shale gas success is remarkable in an historical context. It has driven down consumer prices substantially (over $75 billion in annual savings) while enabling benefits for the manufacturing sector, and cost-effective reductions in power sector carbon emissions.

> Natural gas technologies are a great complement to renewable resources.

DOE-EIA AEO 2016
Consumer Energy Economics, Preferences, and Public Policies

> Natural gas used in about 65 million locations in the U.S.
  - 61 million homes (up from 47 million homes in 1990)
  - 4.6 million commercial businesses
  - 120,000 industrial facilities

> Natural gas a good value for consumers
  - Surveys demonstrate they know that…

> Seeing instances of policies advocating, for example, a future ban on gas use in homes due to climate concerns
  - Seems like a poor policy position and certainly runs counter to what people want

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![Bar chart comparing Electricity to Natural Gas costs]
Residential Natural Gas Use

Residential Gas Consumption:
Regional breakdown (billion therms):
- Space Heating
- Water Heating
- Other (drying, cooking, etc.)
ONTARIO CLIMATE CHANGE LEGISLATION CALLS FOR PHASE OUT OF RESIDENTIAL NATURAL GAS USE

Section: News
Post Date: 25/05/2016, 10:03

By Barb McKay

Ontario’s Climate Change legislation is raising questions about the future of proposed natural gas projects in the province, including one in southern Bruce County.

The Climate Change Action Plan was reportedly leaked to the Globe and Mail newspaper last week and outlines a strategy for reducing greenhouse gas emissions by 80 per cent by 2050, and targets natural gas use in homes and businesses.

On Thursday, The Independent received a media release from the Ministry of the Environment and Climate Change announcing that the province has passed the Climate Change Mitigation and Low-Carbon Economy Act, which will support Ontario’s cap and trade program. The program sets out strict timelines for reducing carbon emissions by relying more heavily on green and low-carbon energy sources, such as nuclear, wind, solar and biomass, and moving away from fossil fuels. Under the Act, money raised from the cap and trade program will be deposited into a new Greenhouse Gas Reduction Account, all of which will be invested in green projects and initiatives that reduce emissions.

Kathleen Wynne says Ontario will not phase out natural gas for home heating

Critics have warned that phasing out natural gas, which is used to heat more than three-quarters of the homes in this province, would drive up energy costs for everyone.

http://www.independent.on.ca/site/?q=node/5930

Residential natural gas use a small slice of U.S. carbon emissions.

Continued advancements in efficiency & home weatherization will lower future emissions.

Largest opportunities for residential carbon savings are (1) continued decarbonization of electricity and (2) replacing electric resistance heating devices (e.g., space and water heating)
State Example: Pennsylvania
Benefits of Moving Away From Electric Resistance Heating

> Estimated 1.68 million homes using low-efficiency electric resistance devices for space heating

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<thead>
<tr>
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<th>Source Energy Use (Trillion Btu)</th>
<th>Annual Energy Costs ($Billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Resistance</td>
<td>326</td>
<td>3.89</td>
</tr>
<tr>
<td>Electric Heat Pumps (8.1 HSPF)</td>
<td>205 (-37%)</td>
<td>2.45 (-37%)</td>
</tr>
<tr>
<td>Gas Furnace (92% efficiency)</td>
<td>119 (-63%)</td>
<td>1.28 (-67%)</td>
</tr>
</tbody>
</table>
State Example: Tennessee
Benefits of Moving Away From Electric Resistance Heating

> Estimated 833,000 homes using low-efficiency electric resistance devices for space heating

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<th>Source Energy Use Trillion Btu</th>
<th>Annual Energy Costs ($Billion)</th>
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<tr>
<td>Electric Resistance</td>
<td>72</td>
<td>0.67</td>
</tr>
<tr>
<td>Electric Heat Pumps</td>
<td>34 (-52%)</td>
<td>0.32 (-52%)</td>
</tr>
<tr>
<td>Gas Furnace</td>
<td>26 (-63%)</td>
<td>0.25 (-63%)</td>
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> Electric heat pump benefits improve in this Southern climate, but natural gas remains favorable
   — Going further south improves the benefit of electric heat pumps
Natural Gas & Electric Heat Pumps
ACEEE Report on Space Heating

ACEEE findings point to natural gas being a better consumer value and energy option for space heating, particularly in mid to upper continental portions of the U.S.

Requiring use of electric heat pumps in these regions would saddle consumers with much higher annual energy costs and increase total energy use in most cases – and stress electric utility systems.

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<tbody>
<tr>
<td>Upper Midwest (IL/MI/WI)</td>
<td>$10,518</td>
<td>$22,785 (+166%)</td>
<td>-22%</td>
</tr>
<tr>
<td>Middle U.S. (VA/TN)</td>
<td>$8,401</td>
<td>$12,260 (+46%)</td>
<td>-3.4%</td>
</tr>
<tr>
<td>U.S. Average</td>
<td>$8,964</td>
<td>$14,524 (+62%)</td>
<td>-1.9%</td>
</tr>
</tbody>
</table>

ACEEE, Comparative Energy Use of Residential Gas Furnaces and Electric Heat Pumps (May 2016)
Gas furnace (95% efficiency) electric heat pump (8.5 HSPF), power plant heat rate of 7,658 Btu/kWh
2016 Consumer Preference Survey
National Results

From Energy Solutions Center Report:
### GTI’s Technology Developments

#### Energy Delivery & Utilization

<table>
<thead>
<tr>
<th>Natural Gas Delivery Systems</th>
<th>Clean Transportation Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pipeline Safety &amp; Risk Management</td>
<td>• Natural Gas for Medium/Heavy-Duty Vehicles and Off-Road Uses</td>
</tr>
<tr>
<td>• Tools for Operations Improvement and Data Automation</td>
<td>• Hydrogen Fuel Cell Vehicles</td>
</tr>
<tr>
<td>• Minimizing Methane Emissions</td>
<td>• Fueling Infrastructure and Storage</td>
</tr>
<tr>
<td></td>
<td>• Fuel Efficiency and Emissions</td>
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<thead>
<tr>
<th>Direct Gas Use in Homes &amp; Businesses</th>
<th>Clean Distributed Power Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building Codes &amp; Standards/Regulations</td>
<td>• Microgrids and Natural Gas CHP Systems</td>
</tr>
<tr>
<td>• Source Energy &amp; Direct Gas Use</td>
<td>• Emergency Power &amp; Energy Storage</td>
</tr>
<tr>
<td>• Impact of New Technology &amp; Power Sector Decarbonization</td>
<td>• Interconnection &amp; Smart Controls</td>
</tr>
</tbody>
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<tr>
<th>New Energy Efficiency Solutions</th>
<th>Renewable Energy &amp; the Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Advanced Gas Use &amp; Heat Pump Solutions</td>
<td>• Renewable Natural Gas &amp; Low Carbon Strategies</td>
</tr>
<tr>
<td>• Hybrid Gas/Electric and Gas/Solar Thermal Systems</td>
<td>• Methane Emissions: Insights &amp; Mitigation</td>
</tr>
<tr>
<td>• Industrial process solutions</td>
<td>• Ultra-low NOx Solutions</td>
</tr>
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</table>
High-Efficiency Natural Gas Heat Pumps for Homes & Businesses

> Multiple efforts to develop next-generation gas heat pump solutions for space heating and water heating
  – Near-term and longer-term options

> Hold the potential to substantially raise efficiency levels compared to current consumer choices
Natural Gas Heat Pumps

**Near-Term**
Commercially-available in US market or undergoing field trials

**Mid-Term Tech-Transfer**
Products recently or soon-to-be introduced overseas, may transition product to NA if GHP market develops

**Long-Term**
Technology at or near proof-of-concept/bench-scale stage, may have potential for non-incremental improvement over established GHP

Binary-Fluid Ejector
Thermoelastic HP
Adsorption HP
Gas Engine Heat Pump

IntelliChoice Energy (ICE) NextAire™ 1st GEHP in U.S. for HVAC

- 8-ton and 15-ton Multi-Zone VRF units, 11-ton packaged rooftop
- COP >1.4 (140% efficient)
- Variable refrigerant flow (VRF) provides heating and cooling for up to 33 zones
- Adapted from established technology used in Japan…100s of units deployed in US

> Residential GHP (3 to 5-ton) in development

Source: Intellichoice
Gas Absorption Heat Pump Development

Low-Cost Gas Absorption Heat Pump
Direct-fired single-effect absorption cycle with integrated heat recovery for space and water heating.

Initial field testing in Tennessee and California.
Collaborative effort with Stone Mountain Technologies, USDOE, CEC, and commercial partners (A.O Smith/Lochinvar)

<table>
<thead>
<tr>
<th>Heat Pump Output</th>
<th>80,000 Btu/hr (23 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Efficiency</td>
<td>COP &gt; 1.4 at 47°F 140% AFUE</td>
</tr>
<tr>
<td>Estimated Unit Cost</td>
<td>Competitive with condensing boilers</td>
</tr>
</tbody>
</table>
Natural Gas Heat Pump Water Heater

> Next-generation high-efficiency water heating solution
  ‒ Equivalent to over 130% efficiency (or higher)

> Targeting use in residential and light-commercial applications
  ‒ Support from USDOE, CEC
  ‒ Working with A.O. Smith, GE Appliances

> Double the efficiency of conventional storage water heaters

> Most efficient option on a source (primary) energy basis
Water Heating Efficiency Improvements With Natural Gas Heat Pumps

Source Energy Water Heating Efficiency

- Gas Heat Pump: 138%
- Gas Tankless Condensing: 88%
- Gas Storage Energy Star: 62%
- Electric Storage: 29%
- Electric Heat Pump: 70%

Source: GTI (source to site, natural gas source to site: 91.9%, electric: 31.8%)

Natural gas heat pump water heater provides highest-rated source energy efficiency – over 50% advantage over electric heat pump water heaters.
U.S. CHP Market

- **Over 82 GW of installed** CHP at almost 4,000 industrial and commercial facilities
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO₂** as compared to traditional separate production
- Majority of CHP Capacity Currently In Industrial Sector
- Continued growth potential in industrial as well as commercial and institutional sectors.
- Residential products available, but economics are challenging

Source: EEA, Inc. CHP Installation Database.
ACEEE 2012-2013 CHP Scorecard
Total Additions: 1,588 MW, 374 Units
Average Size: 4.25 MW

Top States by New Capacity

<table>
<thead>
<tr>
<th>State</th>
<th>Total New CHP Units (2012-2013)</th>
<th>Total New CHP Capacity, kW (2012-2013)</th>
<th>Average Size (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>6</td>
<td>343,630</td>
<td>57,272</td>
</tr>
<tr>
<td>California</td>
<td>94</td>
<td>264,827</td>
<td>2,817</td>
</tr>
<tr>
<td>Delaware</td>
<td>1</td>
<td>104,000</td>
<td>104,000</td>
</tr>
<tr>
<td>Michigan</td>
<td>4</td>
<td>102,095</td>
<td>25,524</td>
</tr>
<tr>
<td>Virginia</td>
<td>4</td>
<td>79,380</td>
<td>19,845</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>16</td>
<td>73,041</td>
<td>4,565</td>
</tr>
<tr>
<td>Maine</td>
<td>6</td>
<td>54,240</td>
<td>9,040</td>
</tr>
<tr>
<td>Louisiana</td>
<td>2</td>
<td>51,400</td>
<td>25,700</td>
</tr>
<tr>
<td>Georgia</td>
<td>3</td>
<td>47,600</td>
<td>15,867</td>
</tr>
<tr>
<td>New Jersey</td>
<td>22</td>
<td>43,005</td>
<td>1,955</td>
</tr>
<tr>
<td>South Carolina</td>
<td>6</td>
<td>40,608</td>
<td>6,768</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>23</td>
<td>38,715</td>
<td>1,683</td>
</tr>
<tr>
<td>Florida</td>
<td>4</td>
<td>37,900</td>
<td>9,475</td>
</tr>
<tr>
<td>New York</td>
<td>63</td>
<td>35,201</td>
<td>559</td>
</tr>
<tr>
<td>Colorado</td>
<td>5</td>
<td>33,330</td>
<td>6,666</td>
</tr>
<tr>
<td>Washington</td>
<td>4</td>
<td>26,350</td>
<td>6,588</td>
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<tr>
<td>Maryland</td>
<td>1</td>
<td>24,500</td>
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<tr>
<td>Connecticut</td>
<td>21</td>
<td>21,560</td>
<td>1,027</td>
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<tr>
<td>Missouri</td>
<td>2</td>
<td>21,000</td>
<td>10,500</td>
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<tr>
<td>Oregon</td>
<td>8</td>
<td>20,200</td>
<td>2,525</td>
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Top States by New Units

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<tr>
<th>State</th>
<th>2013 industrial electricity price (cents/kWh)</th>
<th>Total New CHP Units (2012-2013)</th>
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<td>5.93</td>
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<tr>
<td>Idaho</td>
<td>6.12</td>
<td>4</td>
<td>10,765</td>
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State programs incentivize CHP in CA, NY and other leading states.
Natural Gas CHP Products

Gas Engines

Strong competition in the 0.5-10 MW range from multiple suppliers and relatively high electrical efficiency.

Gas Turbines

Mainly used above 10 MW, with limited options in smaller sizes.

Fuel Cells

High efficiency, ultra clean power. High first costs are a market challenge.

Microturbines

1 MW and lower units, with limited suppliers (mainly Capstone).
Micro CHP

> Broad range of potential technologies and products in development or commercialized in the U.S. or worldwide

> Market activity on the small end has been mainly in Japan and Europe

> Market opportunities exist in the U.S. residential (single and multi-family) and light-commercial market segments

> First cost remains a primary challenge
  — Along with other market factors and institutional barriers (e.g., interconnection, standby rates, etc)
Market Landscape

Electrical Efficiency (LHV) vs. System Capacity (kW)

- **Internal Combustion Engine**
- **Solid Oxide Fuel Cell**
- **Microturbine**
- **Stirling Engine**
- **Organic Rankine Cycle**
- **Thermal Acoustics**

- SOLIDPower BlueGen
- SOLIDPower EnGen
- Be Power (CCHP)
- Kyocera, Bosch, Aisin
- Nirvana Thermo Acoustic Power Stick
- Aisin Coremo
- Marathon ecopower
- Yanmar CP5WN
- Flat/Crysler Totem
- Yanmar CP10WN
- EC Power, XRG1 25
- AO Smith/Lochinvar
- Climate Energy freewatt
- Qnergy Stirling/ITC
- M-Trigen PowerAire (CCHP)
- Tecogen/Tedom Micro T35
- Navien Hybrigen SE
- MTT Ener Twin
- Green Turbine (EnviroPower) GT
- iGEN Technologies iGEN Furnace
- Tecogen Tedom Micro T35

- Commercially available within
the US market
- Commercially available abroad,
and/or certifying for US
- Under development, with plans
for US market
- Commercially available abroad,
may consider US

There are others not considering
the US market or in very early-
stage development
AO Smith/Briggs & Stratton Micro-CHP

> Near commercial with $2,000/kW target

> Major US manufacturers in the hot water and engine industries with networks of installers and trainers to drive market acceptance

> 21kW synchronous, 240V split-phase

> Multiple units undergoing field test across the U.S. prior to full commercial launch
Summary

> Natural gas relied upon by nearly 65 million consumers – homes, businesses, manufacturing operations

> U.S. energy consumers (and economy) benefitting from our abundant and low-cost natural gas supplies

> Residential users favorable about natural gas and the fundamentals support this viewpoint. Policies should consider extending natural gas benefits to others (e.g., rural communities)

> New gas technologies (e.g., heat pumps, micro CHP) and home weatherization offer potential for continued efficient use of gas

> Policies based on switching homes from gas to electric are, for the vast majority of the country, counterproductive on a consumer cost, total energy, and carbon emissions basis
  
  — Focus should be shifting away from electric resistance space and water heating to electric heat pumps or natural gas