Rhode Island Energy Efficiency and Resources Management Council (EERMC):

Opportunity Report – Phase I

Submitted on July 15, 2008 to:

the RI Public Utilities Commission, the General Assembly,
the RI Office of Energy Resources, and National Grid

Attachment II:

The Potential for Cost-Effective Combined Heat and Power in Rhode Island

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Opportunity Report to the Energy Efficiency & Resources Management Council:

Submitted on July 15, 2008 – Phase I

The Potential for Cost-Effective Combined Heat and Power in Rhode Island

BACKGROUND

In 2006, the Rhode Island legislature approved the ground-breaking "Comprehensive Energy Conservation, Efficiency and Affordability Act of 2006.[1]" The Comprehensive Energy Bill was designed to systematically maximize ratepayers' economic savings by placing a requirement on the distribution utility to procure all energy efficiency that is less costly than supply. Combined heat and power (CHP) is a proven energy technology that, in addition to providing clear opportunities for reducing greenhouse gases and other air pollutants, is also an economically attractive option for Rhode Island. The 2006 Act explicitly identifies distributed generation under system reliability resources to be procured by the distribution "including, but not limited to…thermally leading combined heat and power systems."[2] In addition, the Least Cost Procurement and System Reliability Standards proposed by the Council and finalized by the RI PUC define CHP as an Alternative Resource Technologies (ART) that the electric and gas efficiency programs should target, as long as CHP applications are "…cost-effective, deliver net reductions in energy consumption, and provide environmental benefits."[3]

In addition, the deployment of cost-effective CHP can also help Rhode Island in meeting its ambitious goals for cost-effective clean energy and climate change reductions, including the greenhouse gas (GHG) reduction goals set out in the 2001 Climate Action Plan of the New England Governors/Eastern Canadian Premiers.[4] CHP could bring significant reductions in energy use and CO_2 emissions that will need to occur in the power generation, commercial, and industrial sectors. Rhode Island's commercial and industrial sectors, ideal settings for CHP applications, are responsible for significant portions of the state's GHG footprint. In 2003, these sectors combined contributed over 20 percent of the state's total GHG emissions.[5]

This analysis is designed to inform and be a part of Phase 1 of the Energy Efficiency Resource Management Council's (EERMC) Opportunity Report that identifies opportunities to procure

[1] *Comprehensive Energy Conservation, Efficiency & Affordability Act of 2006.*
[2] *Section 39-1-27.7 of the Comprehensive Energy Conservation, Efficiency & Affordability Act of 2006*
[3] Rhode Island Energy Efficiency and Resource Management Council, *Draft Proposed Standards for Energy Efficiency and Conservation Procurement and System Reliability*, February 29, 2008.
[4] Conference of the New England Governors/Eastern Canadian Premiers Conference, August 2001. *Climate Change Action Plan of 2001*, prepared by the Committee on the Environment and the Northeast International Committee on Energy of the Conference of New England Governors and Eastern Canadian Premiers (Boston, MA/Halifax, NS). The plan is accessible at: http://www.negc.org/documents/NEG-ECP%20CCAP.PDF
[5] Based on NESCAUM calculations using data derived from US EPA's *State Inventory Tool (SIT).* For more information on the tool, see: http://www.epa.gov/climatechange/wycd/stateandlocalgov/analyticaltools.html

efficiency, distributed generation, demand response, and renewables. The Opportunity Report will in turn guide the distribution utility, National Grid, in developing an Energy Efficiency Procurement Plan and System Reliability Procurement Plan for submission to the Rhode Island Public Utility Commission by September 1, 2008.

The primary purpose of this analysis is to generate an estimate of the technical and economic potential for CHP resources in Rhode Island, and to evaluate the economic, environmental, and system reliability benefits of associated with that potential. In developing these estimates, NESCAUM and Pace Energy have conferred with a variety of key energy and utility experts, relevant Rhode Island state agencies, and industry leaders in Rhode Island. We also provide sensitivities of these estimates to key variables and to potential policy incentives, and using our best expert judgment, we suggest a reasonable target for achievable CHP in Rhode Island based on the analysis.

METHODOLOGY AND DATA

Technical Potential for CHP

Technical potential for CHP is defined as the technological feasibility of CHP, based on consumption characteristics for electricity and thermal energy at a given facility type. Technical potential is an estimate that accounts for CHP's feasibility on an engineering basis only. Non-technical factors such as interest in CHP, availability of natural gas, ease of integrating CHP with existing systems, and system or facility economics are not considered.

No recent bottom-up engineering studies of the technical potential for CHP specific to Rhode Island exist. So to derive an estimate of the technical potential for CHP in Rhode Island, we relied primarily on a recent study of the technical potential for CHP in Massachusetts. A 2005 white paper by the University of Massachusetts-Amherst (UMass) showed that the technical potential for CHP systems in Massachusetts is approximately 4,700 MW for new CHP units at over 18,000 sites in the commercial and industrial sectors.[6] Technical potential for CHP in Massachusetts was estimated using energy consumption data collected at the state level by the U.S. Department of Energy's (DOE) *Energy Information Administration (EIA)*.

Based on input from industry and utility experts in Rhode Island and regional CHP experts, we assumed that the commercial and industrial sectors in Rhode Island were similar in composition to those in Massachusetts (MA) and that a ratio applied to the MA estimate based on relative energy consumption between the corresponding sectors in the two states would be a reasonable

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[6]Mattison, Lauren, May 2006. "*Technical Analysis of the Potential for Combined Heat and Power in Massachusetts*," University of Massachusetts Amherst, Department of Mechanical and Industrial Engineering, Center for Energy Efficiency and Renewable Energy.

approximation of the technical potential in Rhode Island, given the lack of primary research for Rhode Island. So, we downscaled the Massachusetts estimate to Rhode Island using RI's relative energy consumption levels as a percentage of MA energy consumption in 2005. Using these percentages of 16.7 percent and 7.6 percent for relative energy consumption in the commercial/institutional and industrial sectors, respectively, we estimate that the technical potential for CHP in Rhode Island to be 654MW in the commercial/institutional sector and 59 MW in the industrial sector, respectively, for a total of 713 MW in CHP technical potential.

The estimate of technical potential plays a critically important role in this analysis, because it is used as a constraint on the economic potential for CHP in the modeling methodology. In other words, economic potential cannot exceed the technical potential for CHP because CHP is not physically achievable in certain building types, no matter how attractive economic parameters may be.

According to a few RI industry experts, our estimate above of technical potential of 714MW may be an overstatement of the technical potential for CHP in Rhode Islands, so we assume this to a high-end estimate of technical potential to bound the analysis of economic CHP potential.[7] For a low-end estimate of CHP technical potential, we use the only published estimate of technical CHP potential that is specific to Rhode Island, from a 2000 US DOE on CHP potential in the US. [8] The DOE study finds that technical for CHP in Rhode Island's commercial and institutional sectors may be as low as 289 MW. This estimate was based on 1995 EIA data, so assuming relatively steady growth over time in the size of this sector since the mid-1990s, we estimate that 350MW is a reasonable lower bound for CHP technical potential. Through the remainder of the analysis, we use 350MW as a low-end estimate and 714MW as high-end estimate of the technical potential for CHP.

Obviously, this is a relatively wide range of uncertainty for CHP technical potential. In the absence of a recent detailed, bottom-up assessment of the technical potential for CHP in Rhode Island that evaluates CHP opportunities at the building level, however, technical potential will continue to be a source of significant uncertainty in evaluating the economic potential for CHP.

In the next sections, we describe our methodology for modeling economic and achievable potential for CHP in RI.

Economic Potential for CHP

Economic potential for CHP is defined as a subset of technical potential that represents CHP opportunities whose economic benefits outweigh costs (i.e., benefit-cost ratio of 1.0 or greater).

[7] Personal communication with John Farley, TECH-RI, June 20, 2008.

[8] US Department of Energy, Energy Information Administration. "The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector," prepared for US DOE by ONSITE SYCOM Energy Corporation (Washington, DC), January 2000.

Because Rhode Island's least-cost procurement legislation is designed to identify energy efficiency, renewable energy, and CHP resources whose costs are less than that of traditional generation resources, the evaluation of economic potential considers total costs and benefits of CHP, regardless of which entities may incur those costs and benefits. In the context of this analysis, economic potential does not address considerations that are specific to individual potential customers for CHP, such as a preferred payback period for investment in a CHP system. This analysis only evaluates the opportunity for economically viable CHP at the sectoral level (i.e., for the entire commercial sector), rather than from the more disaggregated viewpoint of individual customers.

Economic potential also does not account for various non-economic factors that affect CHP's actual penetration into the market, such as the fact that some potential CHP customers may not have the staff expertise to operate a system, may not have credit worthiness to consider investment, or are simply unaware of the opportunity to use CHP in their building. These factors influence the achievable potential for CHP, which will be addressed later in this report.

NE-MARKAL Energy Model

To evaluate the economic potential for CHP in Rhode Island, we applied the NE-MARKAL energy model to the commercial and industrial sectors in Rhode Island. Owing to the MARKAL model's strong basis in least-cost optimization and technological detail, NE-MARKAL is well-suited to assess the economic potential for CHP in Rhode Island in the context of least-cost procurement planning.

Based on the MARKAL family of energy models, NE-MARKAL is a least-cost linear optimization model of the Northeast's energy system which includes detailed representations of power generation and the end use transportation, commercial, industrial, and residential sectors.[9] The model is based on a large database including detailed engineering and economic descriptions of energy technologies, currently available fuel sources, alternative fuels available in the future and the end-use demand for different forms of energy in each sector. Based on this detailed representation of the region's energy infrastructure, NE-MARKAL calculates the least-cost combination of energy technologies and fuel sources that meet the demand for energy in each end-use sector.[10] For example, to meet demand for thermal energy in the commercial and industrial sectors, the model evaluates the costs and capabilities of CHP in comparison to other technologies capable of meeting those same thermal energy needs, such as boilers and furnaces. NE-MARKAL optimizes the costs of the entire energy system (i.e., all energy demand for all sectors) over the model's entire time horizon on a net present value basis.

[9]States included in the NE-MARKAL modeling framework include the six New England states, New York, New Jersey, Pennsylvania, Delaware, Maryland, and the District of Columbia. Documentation on the MARKAL family of models can be found at: http://www.etsap.org/MrklDoc-I_StdMARKAL.pdf. NESCAUM can make available detailed documentation for the NE-MARKAL model upon request.
[10]Energy demand by sector is endogenous to the NE-MARKAL model, and are derived from state energy data in the US DOE Energy Information Administration's *Annual Energy Outlook* (AEO).

As a linear programming model, NE-MARKAL conducts this least-cost optimization subject to whatever constraints or parameters are provided by the user. For example, we impose constraints on the modeling system to represent federal limits on criteria pollutants as well as regional limits on GHG emissions under the Regional Greenhouse Gas Initiative (RGGI).

We use a single-state Rhode Island version of the regional NE-MARKAL model to conduct this analysis. The model's detailed characterizations of CHP technologies (i.e., costs, technical parameters) were refined for an earlier analysis of economic potential in Massachusetts and carried over to this analysis of CHP potential for Rhode Island.

Reference Case

In order to develop an estimate of the potential for CHP in Rhode Island assuming all cost-effective CHP resources are deployed, we first estimate the baseline, or reference case, for CHP in Rhode Island, that is, the deployment of CHP that would occur in the absence of a least-cost procurement approach. To do so, we rely on a 2006 estimate of existing CHP systems in Rhode Island from the Energy and Environment Analysis, Inc. (EEA) CHP state database. EEA's database estimates over 103 MW of existing CHP resources in the state.[11] This estimate was subsequently updated and modified by UMass researchers to reflect recent changes to 102.5 MW. **Table 1** below provides a description of individual CHP installations in Rhode Island as of 2006.

Table 1
Existing CHP Systems in Rhode Island, 2006

Organization/Developer Name	Facility Name	City	Capacity, kW
Pawtucket Power Associates, Inc.	Colfax, Inc.	Pawtucket	67,000
Rhode Island Hospital	Rhode Island Hospital	Providence	10,400
Ridgewood Power LFG	Ridgewood Power LFG	Johnston	6,400
State Of Rhode Island	Central Power Plant	Cranston	4,700
Ridgewood Pwr Mgmt Corp	The Worcester Company	Centerdale	4,260
Noresco	Rhode Island Howard	Kingston	3,500
Brown University	Brown University Central Heating Plant	Providence	3,200
Bradford Dyeing Associates Inc.	Bradford Dyeing Associates Inc.	Bradford	2,000
Amity Associates	25 Lincoln Center Blvd. - Office Bldg	Lincoln	960
Alliant Energy	Landmark Medical Center-Fogarty Unit	North Smithfield	60
Micro Cogenic Systems, Inc.	Cartie Nursing Home	Central Falls	22
Micro Cogenic Systems, Inc.	Orchard View Manor	East Providence	22
Micro Cogenic Systems, Inc.	Shalom Apartments	Warwick	22
Total Installed CHP in Rhode Island, 2006			**102,546**

Source: Energy & Environment Analysis (EEA) state CHP database (2006), modified by UMass.

[11] EEA's estimate of existing RI CHP resources in their CHP database is available at: http://www.eea-inc.com/chpdata/States/RI.html.

To project a reference case of actual market penetration for CHP from 2006 forward, we assume that the rate of penetration of new CHP systems in Rhode Island is similar to the rate of new CHP installations in Massachusetts over the last decade. Based on information in EEA's 2006 state CHP database, NESCAUM found that the rate of CHP penetration in Massachusetts was approximately 2.7 percent per year over the period 1996 to 2006. Applying this rate of penetration to Rhode Island, we generate a reference case of for CHP market penetration in Rhode Island of a cumulative 141 MW between 2006 and 2018, or an average of 3.2 MW of additional CHP per year.

Timeframe

The timeframe for this analysis is 2008 to 2018. The NE-MARKAL model evaluates the energy system periodically on three-year intervals, so we provide results over the full timeframe of 2008 to 2020.

Key Assumptions for Economic Potential

Below, we describe the key variables and assumptions used for the analysis of RI economic potential for CHP incremental to the reference case. Key variables and assumptions that are most influential in determining results include: CHP system costs and technical characteristics; natural gas prices; emissions factors for key pollutants; and, environmental requirements.

- **CHP System Characteristics**

Because NE-MARKAL is a bottom-up model driven by engineering costs, the assumptions characterizing specific energy technologies are a critical driver of the model's least-cost optimization calculations. **Table 2** below provides our assumptions about key technical parameters for CHP systems, including capacities, system efficiencies, heat rates, and availability factors for different CHP technologies.[12] Installed costs on a per kW basis are also represented, expressed in 2000 dollars. Note that these cost estimates are for the installed costs of equipment only, and do not include program costs or other costs incurred to develop and implement CHP projects.

[12]Regional CHP experts note that there are no commercially available microturbines in the 350kW capacity range—more typically, 75kW units are combined in sets of two or three to accommodate capacity needs in this range. We will continue to refine these assumptions for installed costs of CHP based on recent empirical data describing commercially available technologies.

Table 2
CHP System Costs and Technical Parameters

	Capacity (kw)	Heat Rate (BTU/kWh)	Total System Efficiency	Availability	Power-to-Heat Ratio	Installed Cost 2000 $s/kw
Recip Engine #1	100	4,063	74.6%	90%	0.60	$1,623
Recip Engine #2	5,000	4,914	67.4%	90%	1.11	$1,049
Microturbine #1	30	5,509	66.7%	90%	0.47	$2,624
Microturbine #2	350	4,668	70.2%	90%	0.60	$1,447
Gas Turbine #1	5,000	5,947	64.7%	90%	0.64	$1,139
Gas Turbine #2	25,000	5,164	67.4%	90%	0.89	$989
Steam Turbine #1	3,000	4,568	72.3%	90%	0.10	$514
Fuel Cell #1	200	4,860	63.7%	90%	0.95	$5,108

Source(s): US EPA CHP Partnership database (2006); NESCAUM analysis.

Table 3 below shows assumed emissions factors on a per MWh basis for both CO_2 and nitrogen oxides (NOx), by type of CHP technology.[13] These assumptions will drive the emissions results associated with economically viable CHP. Emissions factors for CO_2 and NOx were derived by NESCAUM using US EPA guidance for output-based emissions limits for CHP systems.[14]

Table 3
CHP Emission Factors, by Technology

	Capacity (kw)	Lbs CO_2/MWh	Lbs NOx/MWh
Recip Engine #1	100	535.0	44.30
Recip Engine #2	5,000	592.7	1.48
Microturbine #1	30	598.3	0.54
Microturbine #2	350	568.6	0.53
Gas Turbine #1	5,000	617.3	1.16
Gas Turbine #2	25,000	592.5	0.92
Steam Turbine #1	3,000	552.2	0.20
Fuel Cell #1	200	626.3	0.06

Source: NESCAUM calculations based on US EPA guidelines for output-based emissions standards (2007).

- **Natural Gas Prices**

Virtually all new CHP systems in Rhode Island will be natural gas-fired, so natural gas prices will be one of the most influential factors determining economic potential for CHP in Rhode

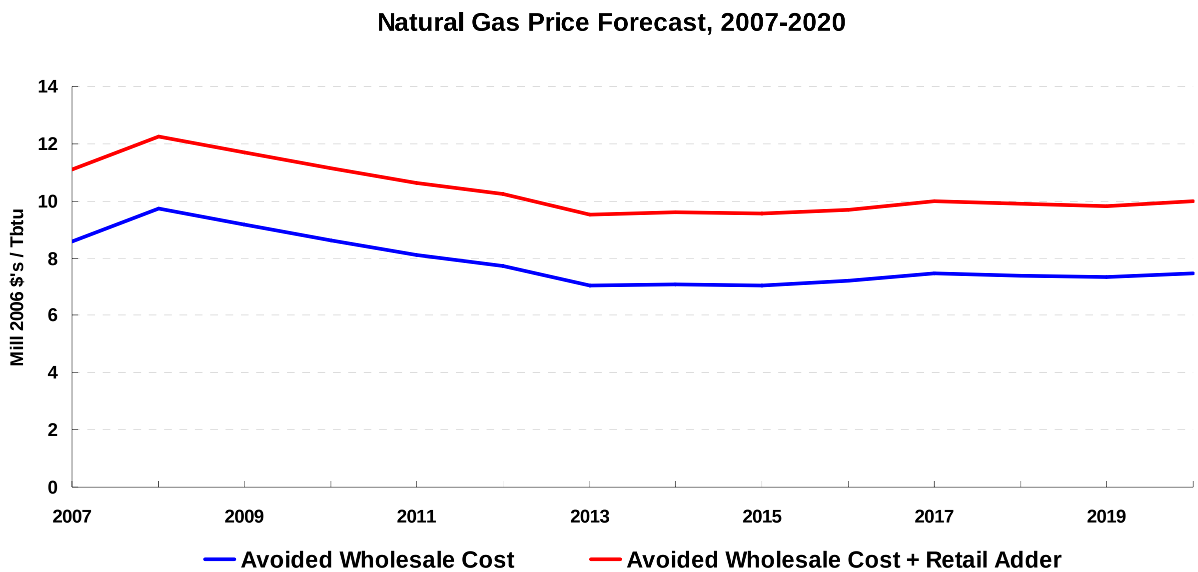
13 Because virtually all new CHP systems in Rhode Island are likely to use natural gas, and natural gas has low emissions for other pollutants such as particulate matter and volatile organic carbons, we do not provide emissions factors for these other pollutants.

14 NESCAUM calculations, based on output-based emissions factors for natural gas CHP systems provided by Tom Frankiewicz, Program Manager, US EPA CHP Partnership, June 2007.

Island. **Graph 1** below shows avoided wholesale natural gas costs, based on a 2007 analysis by Synapse Energy Economics of avoided energy supply costs, as well as the price of wholesale costs plus a "retail adder" to reflect retail gas costs to end-users in the commercial, industrial, and residential sectors.[15] The differential between wholesale and retail prices averages about 20 percent over the given timeframe.

Based on input from utility representatives and other industry experts, the majority of new CHP opportunities in Rhode Island will be for relatively small systems, most well under 1MW in capacity. As such, the commercial, institutional and small industrial sectors are likely to face retail prices rather than wholesale gas costs for the majority of potential new CHP installations, so we run the model using retail gas prices. However, we conduct a sensitivity run using the avoided wholesale gas costs as well.

Graph 1



Sources: Synapse Energy Economics, 2007; National Grid, 2008.

- **Environmental Requirements**

As described in the description of NE-MARKAL, the model optimizes for a least-cost solution to meet energy needs, subject to any other constraints on the energy system specified by the user. As such, we apply constraints within the NE-MARKAL model to represent environmental and energy regulations. These requirements include existing regulations as well as new regulations and/or requirements that will be applicable in the foreseeable future.

[15] Synapse Energy Economics, August 2007. "Avoided Energy Supply Costs in New England: Final Report," prepared for Avoided Energy Supply Component (AESC) Study Group, (Cambridge, MA).

In terms of emissions limits on criteria pollutants, NOx and carbon monoxide (CO) are the key pollutants of concern with respect to CHP systems. In May 2007, Rhode Island passed *Regulation No. 43*, which streamlines permitting requirements for smaller distributed generation and applies output-based emissions standards to reward CHP's overall efficiency in meeting both thermal and electrical energy demands.[16] We have applied *Regulation No. 43* limits for NOx emissions within NE-MARKAL by creating a constraint representing these emissions limits and applying it to CHP technologies.[17]

Each state participating in the Regional Greenhouse Gas Initiative (RGGI) program to limit CO_2 emissions from large power plants (i.e., larger than 25MW) has an assigned emissions budget which delineates its portion of the overall regional cap on CO_2 emissions. **Table 4** below shows Rhode Island's CO_2 emissions budget under RGGI, which we have built into NE-MARKAL as a constraint on the power generation sector. Note that RGGI does not actually take effect until January 2009—over the period 2009 to 2012, emissions are capped at 2006 levels. Over the period 2012 to 2018, CO_2 emissions are required to decline by 10 percent below 2006 levels.[18]

Table 4
Rhode Island CO_2 Emissions Budget under RGGI

	2008	2011	2014	2017	2020
Rhode Island CO_2 Budget (thousand metric tons of CO2)	2,412	2,412	2,392	2,231	2,171

Finally, we also apply a constraint to simulate requirements associated with Rhode Island's Renewable Portfolio Standard (RPS), which requires 16 percent of in-state generation to come from renewable energy resources by 2020.[19]

Achievable Potential

Achievable potential refers to the subset of economic potential that considers the influence of individual customer preferences as well as other, non-economic factors. Currently these non-

[16]In other words, a CHP system that meets Rhode Island's basic requirements for system efficiency (55%) and power-to-heat ratios can receive a compliance credit against its actual emissions based on the emissions that would have been created by a conventional separate system used to generate the same thermal output. The complete text of Regulation No. 43 can be accessed at: http://www.dem.ri.gov/pubs/regs/regs/air/air43_07.pdf

[17]Because we do not have CO emissions factors for the majority of combustion technologies included in NE-MARKAL, we do not apply the CO limits to CHP for this analysis.

[18]Although RGGI's requirements extend only to 2018, this table shows a continuation of the cap until 2020. Because NE-MARKAL operates in 3-year increments, we modeled RGGI until 2020 in order to show its impact on CHP potential through the study period of 2018.

[19] Rhode Island's RPS requirements allow for generation from numerous renewable resources (photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, ocean thermal, biodiesel, and fuel cells using renewable fuels) and are accessible at: http://www.rilin.state.ri.us/Statutes/TITLE39/39-26/INDEX.HTM

economic factors are cited as a key barrier to new CHP installations, not just in Rhode Island but elsewhere in New England as well. For example, a key barrier noted by an academic expert who has consulted with individual customers in Rhode Island is that many of these potential customers are discouraged from implementing CHP simply for lack of personnel qualified to operate these systems.[20] In other cases, it is customer preferences that limit the adoption of CHP, even for highly efficient systems. While non-profit institutions such as hospitals and universities can justify relatively longer "payback periods" (e.g.,2 to 5 years) for investments in new energy technologies, some private sector entities have payback requirements of less than one year, due to internal competition for funds from other capital projects.

Currently in Rhode Island, actual market penetration of CHP is low, probably close to an average of 2 to 3 MW per year. Additional policies and measures are needed to influence customer preferences and convert economic potential into achievable CHP. To examine the potential for bringing more economically viable CHP into actual deployment, we examine the impact of two observable, quantifiable measures that are amenable to the NE-MARKAL modeling framework. The measures that we model to examine achievable CHP potential include:

(1) Elimination of utility charges for stand-by power in the event of CHP system failure; and

(2) Introduction of revenues from the Forward Capacity Market (FCM), the market for electric capacity resources in the New England power pool.

Both of these measures are modeled by imputing a corresponding change in system cost for CHP technologies. In the case of back-up charges, we eliminate the back-up charge entirely to represent a change to achievable potential. **Table 5** below shows the back-up charge schedule for CHP systems of different sizes, eliminated under our sensitivity runs.

Table 5
Utility Back-Up Charges for CHP

	Rate B-62	Rate B-32
Customer Service Charge ($s)	$11,118.72	$236.43
Back up charge 2008 ($s per kw)	$2.24	$5.12
Back up charge 2009 ($s per kw)	$2.22	$5.11
Supplemental charge 2008 ($s per kw)	$2.24	$2.00
Supplemental charge 2009 ($s per kw)	$2.22	$1.99

Source: National Grid, 2008.

Forward capacity revenues are represented as negative costs to CHP systems based on their capacity. **Table 6** shows the schedule of estimated FCM revenues over the time period in the analysis.

[20] Personal communication with Dr. Vin Rose, Professor of Engineering, University of Rhode Island, July 3, 2008.

Table 6
Estimated Revenues for the Forward Capacity Market[21]

	2008	2011	2014	2017	2020
FCM Payment ($s/kw/year)	$45.0	$49.4	$54.0	$59.0	$64.5

Source(s): ISO New England, 2007 and National Grid, 2008.

These are just examples used for modeling purposes of measures targeted at achievable potential—other policy changes such as net metering or other program efforts, such as additional customer outreach and education, while less quantifiable within our modeling framework, are nonetheless very viable strategies and could be equally or even more effective than the two measures which we have modeled in this analysis.

RESULTS

The section below provides the results of our modeling and analysis of CHP's economic and achievable potential, respectively, in Rhode Island from 2008 to 2018. Key results for economic potential include: total capacity of CHP; shifts in electricity generation and consumption by the commercial/institutional sector and overall; changes in fuel consumption (natural gas, oil, and electricity) by the commercial/institutional sector and overall; and, changes in emissions of key pollutants (CO_2 and NOx). For achievable CHP under the two policy scenarios we explore, we provide total capacity as well as emissions results.

Note that these results to be dominated by the commercial/institutional sector—because the industrial sector in Rhode Island is relatively small and represents less than 10 percent of the total technical potential (i.e., 59 of 714 MW on the high end), the majority of economic potential and associated changes are driven by the commercial/institutional sector.

Finally, it is important to again note how important an influence on economic potential is played by the assumption of CHP technical potential, because technical potential acts as a constraint on economic potential. For the shorter timeframe of 2011, we provide only estimates corresponding with the high-end technical potential for CHP. Over the longer timeframe of 2020, we provide graphics below corresponding with our high-end estimate of technical potential for CHP (i.e., 714MW), but also provide figures and commentary corresponding with the application of the low-end estimate of technical potential (i.e., 350MW) as a constraint on economic potential.

[21] Based on input from National Grid, we adjusted ISO New England's estimates of FCM revenues downward in the latter part of the timeframe.

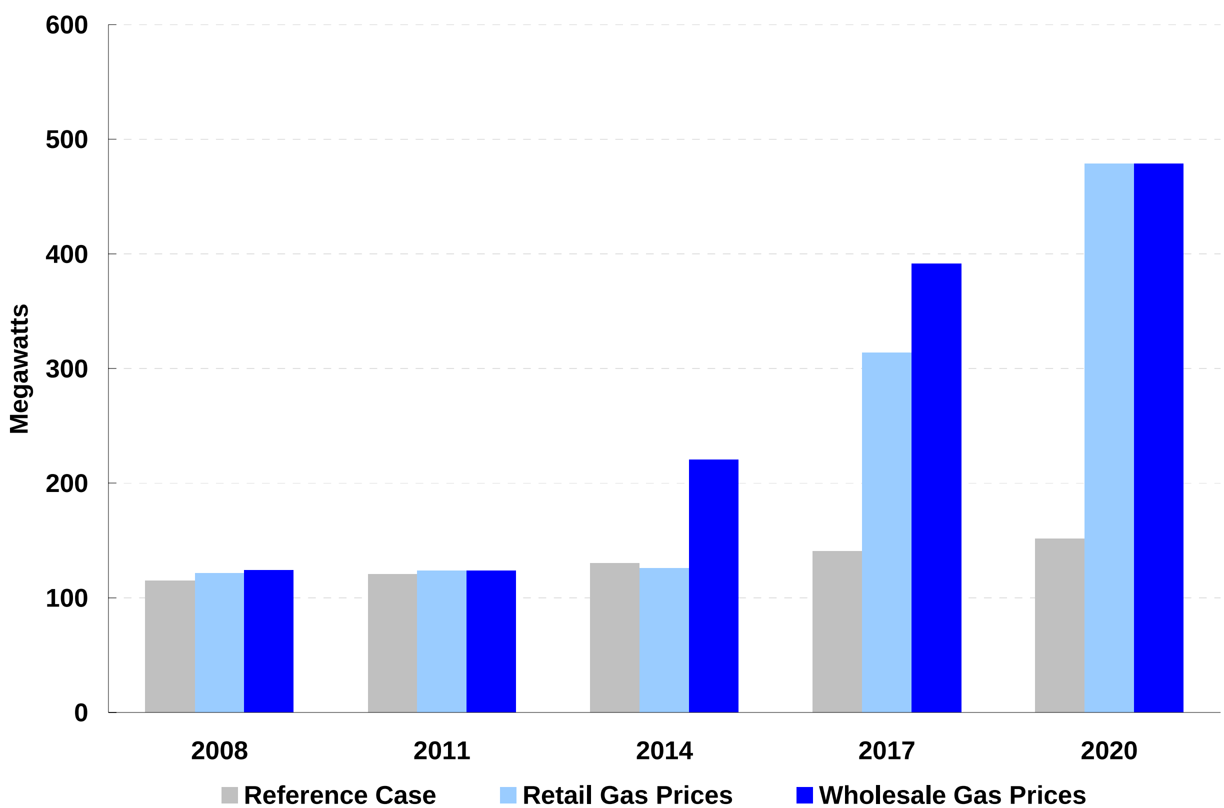
Economic Potential

- **CHP Capacity**

Graph 2 below shows that, under the high-end technical potential scenario, the capacity of CHP increases significantly over the reference case when considering all cost-effective CHP opportunities in the commercial/institutional sector. By then end of the timeframe, under the high-end technical potential, incremental CHP capacity is nearly 480 MW in total, or 330 MW above the reference case penetration of 150 MW.

In addition, the trajectory of new CHP capacity additions is more aggressive under the wholesale gas price scenario than under the higher retail rate scenario. This is because the differential between these two natural gas price scenarios—about 20 percent—makes a meaningful difference to overall CHP economics because of the role of gas costs in overall CHP operating expenses. Under the lower wholesale price¸ substantially more CHP is economically viable.

Graph 2
Economic Potential for CHP Capacity in Rhode Island

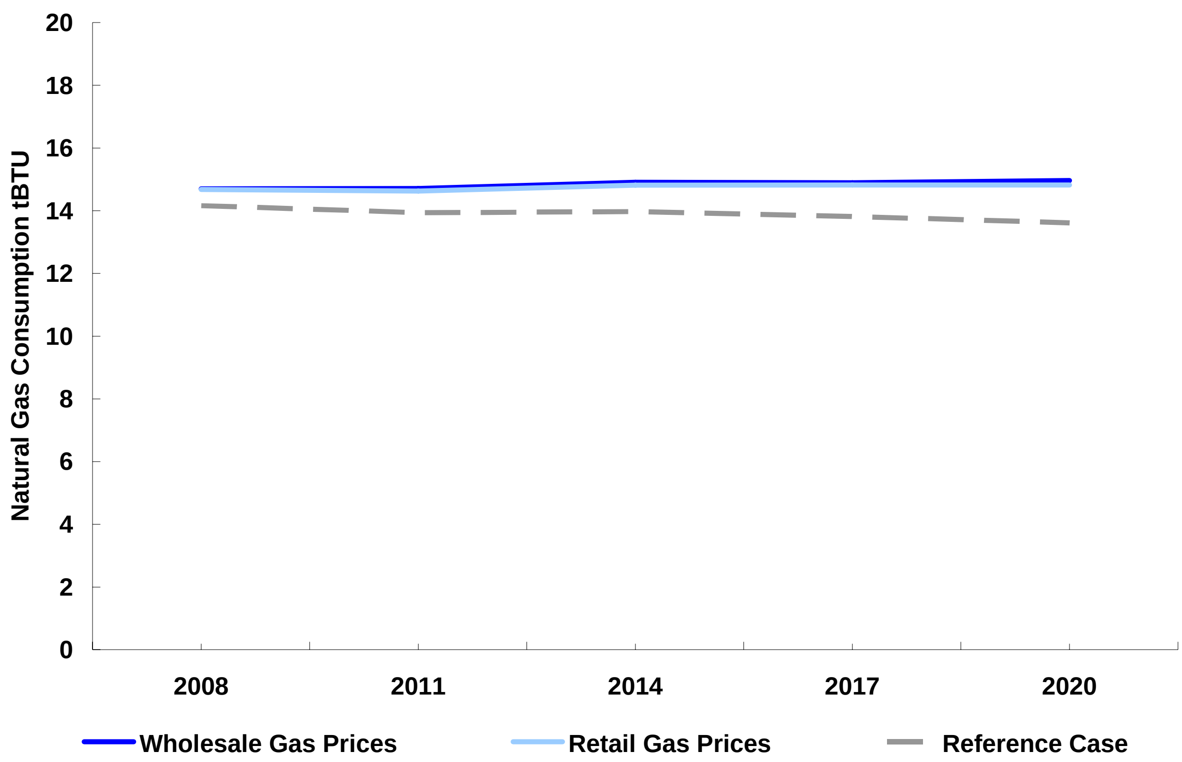


In comparison to the high-end technical potential, under the low-end technical potential where total capacity is limited to 350MW, new CHP capacity tops out at 350MW by the end of the timeframe, or just under 200 MW of incremental potential above the reference case. In other words, economic potential for new CHP is approximately 130MW less under the low-end technical potential than under the high-end technical potential scenario.

- **Natural Gas Consumption**

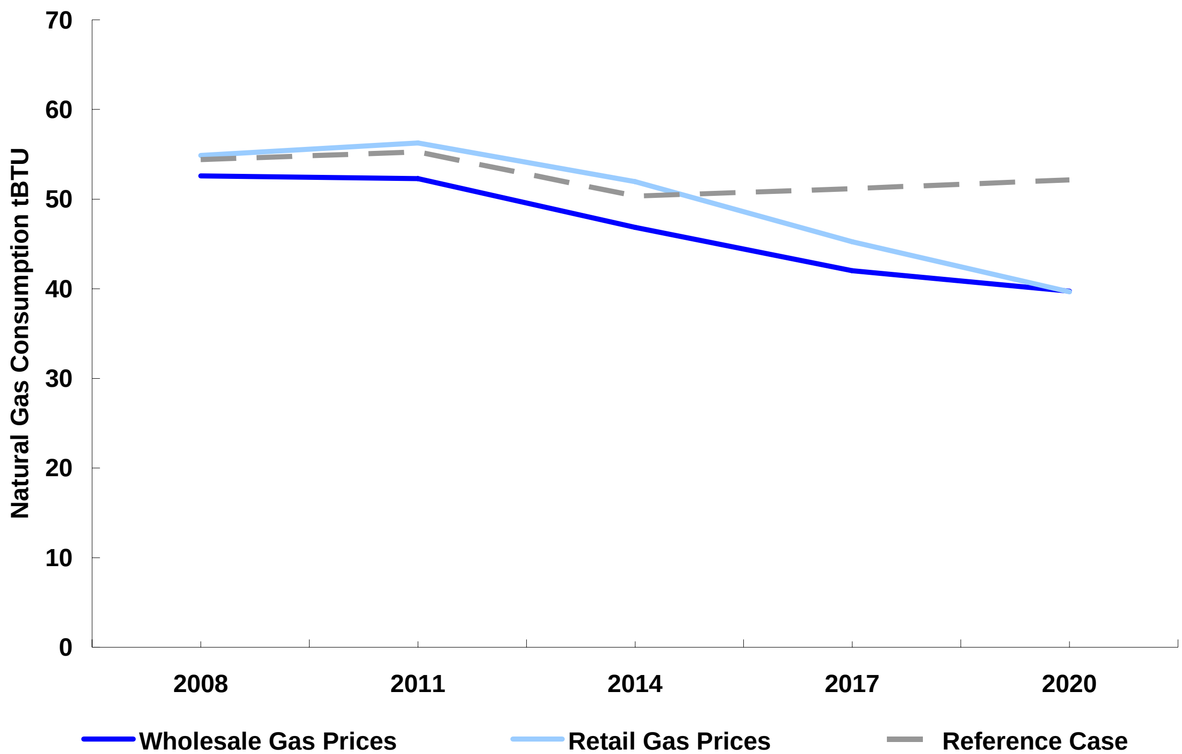
Graph 3 shows natural gas consumption associated with the incremental CHP capacity of 360MW under the high-end technical potential. Under both natural gas price scenarios (wholesale and retail), natural gas consumption in the commercial/institutional sectors increases by approximately 10 percent above the reference case, as the new CHP capacity causes a shift away from oil use by some thermal applications (e.g., boilers) and toward gas.

Graph 3
Commercial/Institutional Natural Gas Consumption



Although natural gas use increases somewhat in the commercial/institutional sector to accommodate the increase in gas-fired CHP capacity, **Graph 4** below shows that, over the entire timeframe, total natural gas consumption decreases from roughly 52 tBTU under the reference case, to 40 tBTU under the high-end technical potential scenario. This reduction results from a shift away from natural gas use by the power generation sector and to a lesser degree, by other thermal technologies in the commercial/institutional sector, to more efficient electricity and thermal energy production by new, gas-fired CHP systems.

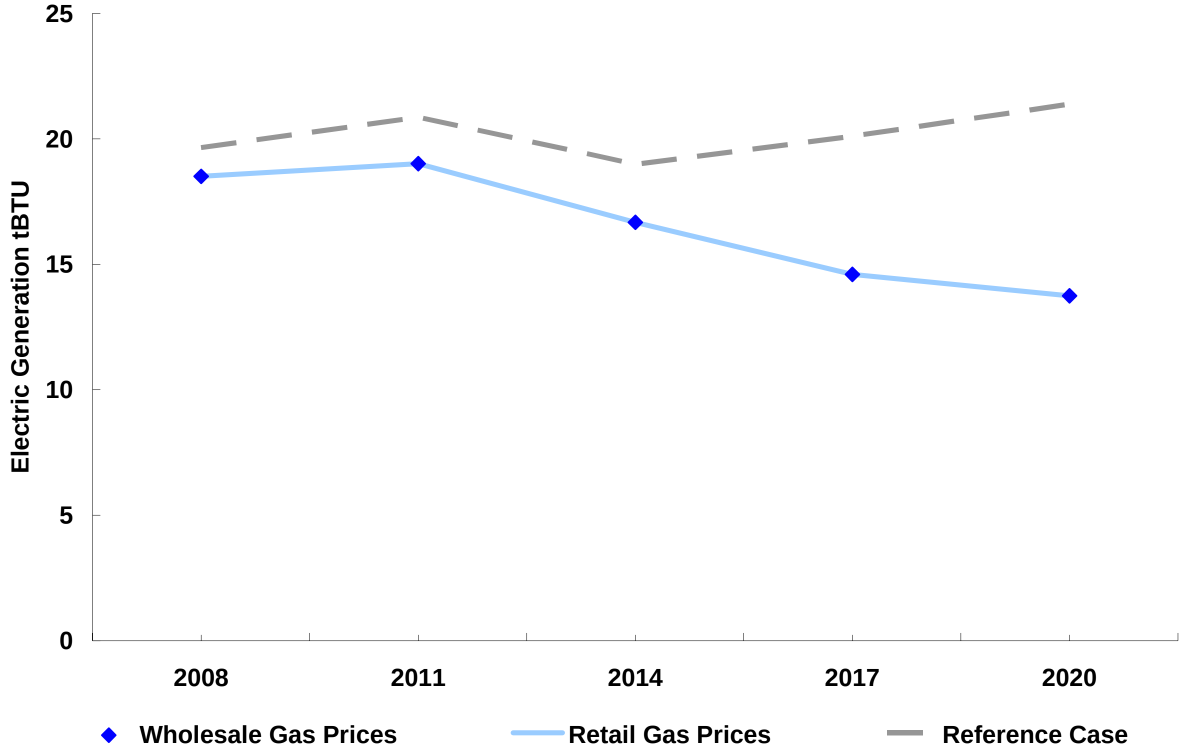
Graph 4
Total Natural Gas Consumption



- **Electricity Generation**

In accordance with a shift away from natural gas use by the power generation sector as new CHP capacity comes on-line, electricity generation by the power sector falls. As shown in **Graph 5**, under the high-end technical potential scenario, by the end of the timeframe, electricity generation by the power sector has decreased to about 14 tBTU, or a decline of nearly 20 percent relative to the reference case electricity use of 21 tBTU.

Graph 5
Power Sector Electricity Generation

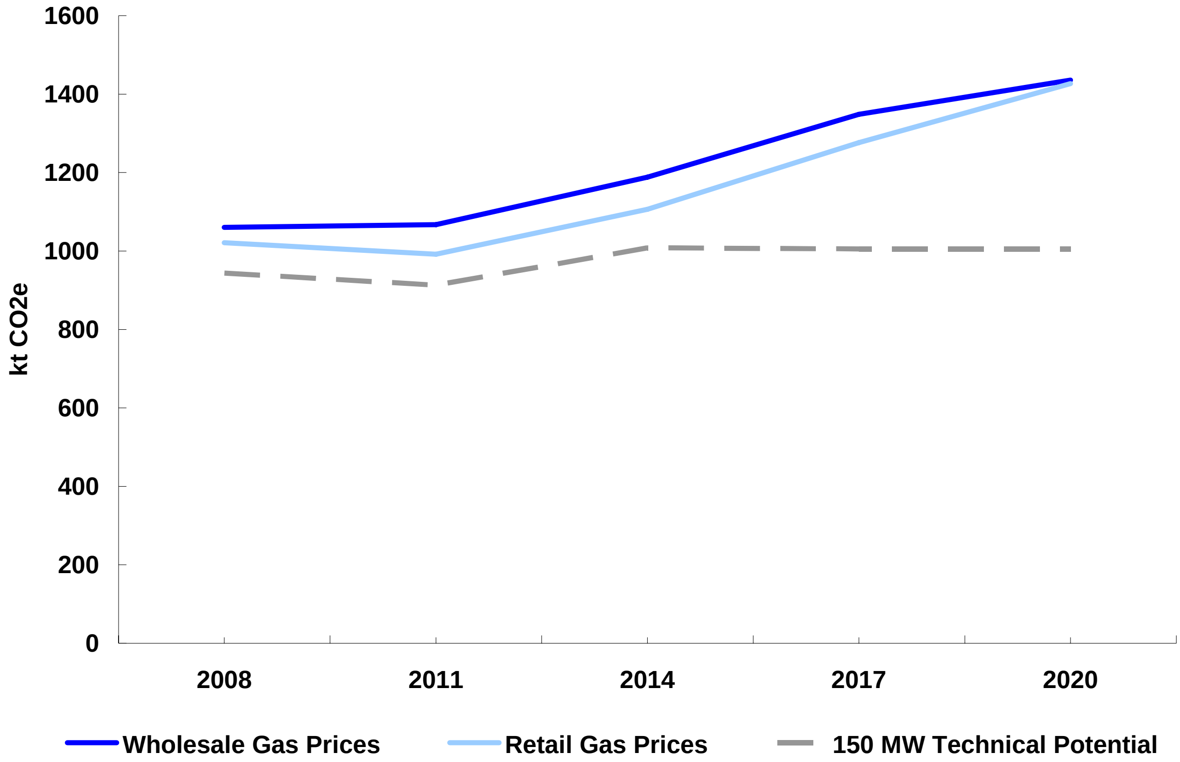


- **CO_2 Emissions**

In the commercial/institutional sector, CO_2 emissions under the high-end technical potential case increase over emissions in the reference case, at first gradually and then more aggressively after 2014, as more CHP capacity comes on-line. **Graph 6** shows that by 2018, CO_2 emissions in the commercial sector (1,427 kilotons of CO_2-equivalent) are 40 percent higher than in the reference case (1,000 kilotons of CO_2-equivalent).

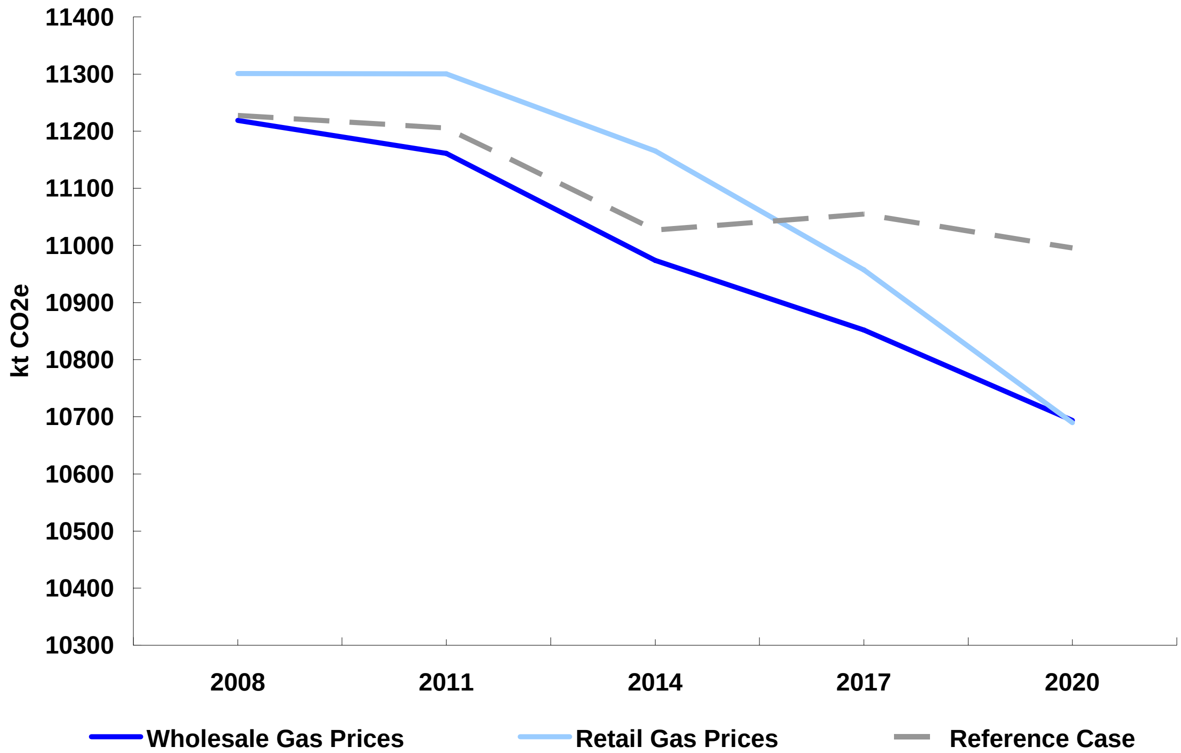
Under the low-end technical potential scenario, where total CHP capacity is constrained at 350MW, we see a similar outcome of a reduction in overall CO_2 emissions (10,515 kilotons of CO_2-equivalent) relative to the reference case. However, CO_2 emissions in the commercial sector do not increase above the reference case in this instance, because the increase in CHP capacity is not so significant relative to the reference case that gas use and emissions

Graph 6
Commercial/Institutional CO_2 Emissions in Rhode Island



Despite an increase in CO_2 emissions in the commercial/institutional sector, however, **Graph 7** shows total CO_2 emissions decline in comparison to the reference case, from 10,996 kilotons of CO_2-equivalent to 10,690 kilotons of CO_2-equivalent. This is because the increase in commercial/institutional sector emissions is counterbalanced by an even larger decrease in CO_2 emissions in the power sector, as overall electricity generation falls with the shift in generation capacity to CHP. Since electricity generation on average is more carbon-intensive than generation from newer, cleaner CHP, this shift results in a decrease in emissions.

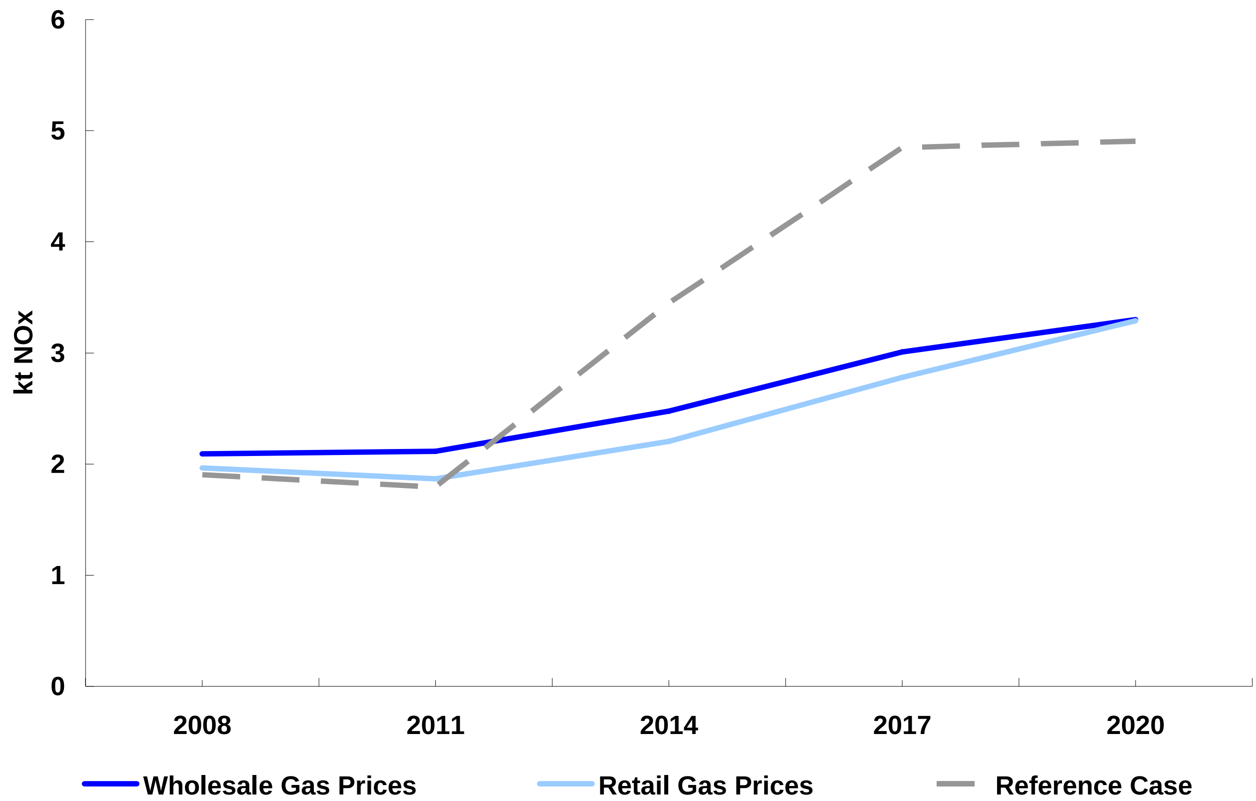
Graph 7
Total CO2 Emissions in Rhode Island



- **NOx Emissions**

Under the high-end technical potential scenario, NOx emissions in the commercial/institutional sector decline in a similar fashion to CO_2 emissions, relative to the reference case. As displayed by **Graph 8**, by the end of the timeframe, NOx emissions have decreased from almost 5.0 kilotons of NOx under the reference case to 3.3 kilotons. This reduction results from a shift away from relatively more NOx-intensive technologies in the electricity generation sector combined with cleaner CHP displacing some more NOx-intensive thermal technologies.

Graph 8
Commercial Sector NOx Emissions



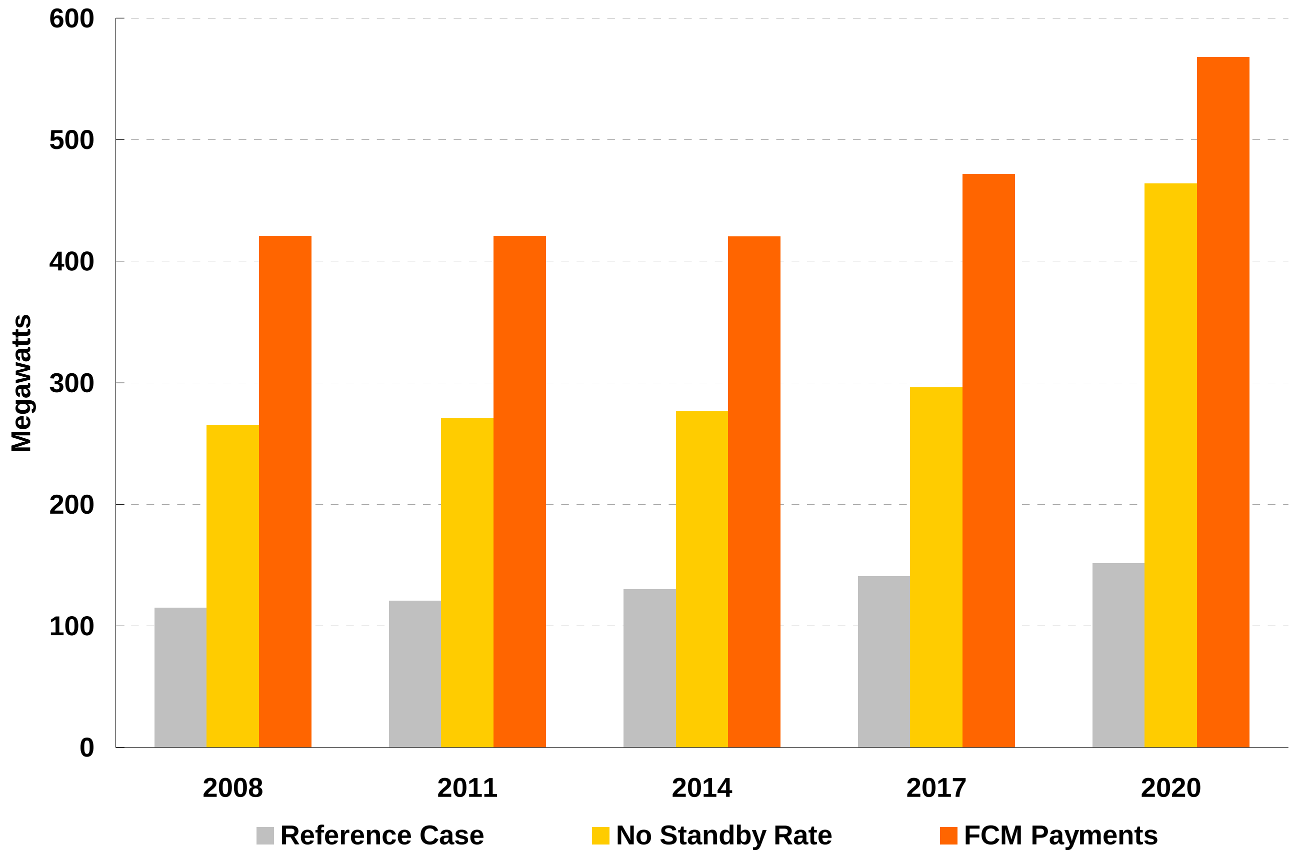
<u>Achievable Potential</u>

Because the two policy measures we have introduced to the analysis—eliminating CHP stand-by charges and introducing FCM revenues—both change the basic economics of CHP by reducing operating expenses (or increasing operating revenue), not surprisingly, these measures enhance the degree to which CHP is deployed as a economically viable strategy for the commercial/institutional sectors.

As **Graph 9** shows, under the high-end technical potential scenario, significantly more CHP is deployed as a result of both policy measures. Even in 2008, capacity of economic CHP is more than double that of the reference case capacity of 108MW under the no stand-by rate scenario, and over 400MW with the introduction of FCM revenues. By the end of the timeframe, both measures result in a cumulative CHP capacity more than three times that of the reference case, and runs well over half to the total high-end technical potential of 714MW.

Overall, the addition of FCM revenues has a greater impact on total CHP capacity than elimination of the stand-by charges, possibly because the elimination of the stand-by charge is more preferential to smaller capacity CHP systems, whereas the FCM revenue stream is equally beneficial to CHP systems of any capacity.

Graph 9
Economic Potential for CHP Capacity in Rhode Island



KEY FINDINGS AND NEXT STEPS

This analysis finds that CHP is a cost-effective resource for meeting electric and thermal energy needs in Rhode Island, particularly in the commercial/institutional sector. Under low-end and high-end assumptions of the technical potential for CHP, the estimates of potential capacity for economic CHP (i.e., where benefits exceed costs) are 200MW and 330MW, respectively, above the estimated reference case CHP penetration level by 2020.

Deployment of new CHP capacity in RI would likely result in an increase in natural gas use, CO_2 and NOx emissions in the commercial/institutional sector; however, total natural gas use and emissions of both CO_2 and NOx would decline as electricity generation by centralized power plants and the use of less efficient thermal technologies in the commercial/institutional sector decrease with the shift toward CHP.

The potential for economic CHP was evaluated under two price scenarios for natural gas—wholesale and retail gas rates. Over the relevant timeframe, the difference of approximately twenty percent between wholesale and retail gas rates does not result in significant cumulative differences in CHP capacity, natural gas use, or emissions. Note again, however, that this analysis considers the economic opportunity for the commercial/institutional sector in the aggregate, rather than from the perspective of individual CHP customers. Such a significant difference in the cost of an essential CHP operational variable like natural gas would indeed have a major influence on the evaluation of individual project economics.

In the event of a Phase II of the EERMC's evaluation of the opportunity for cost-effective CHP in Rhode Island, there are a number of refinements to this analysis that would enhance the understanding of the magnitude and nature of the potential opportunity presented by CHP resources. Refinements that we would consider to be high priority for additional effort include the following:

- **Generate a bottom-up RI-specific estimate of technical potential for CHP**: The assumption of technical potential is a key determinant of economic potential for CHP. Both the low- and high-end estimates of CHP technical potential used in this analysis were derived from studies in other contexts (i.e., Massachusetts, US) and scaled accordingly to Rhode Island. A bottom-up study of technical potential based on recent, Rhode Island-specific energy use and building data could substantially reduce the uncertainty range for economic potential of CHP.

- **Estimate near-term CHP opportunity:** Preliminary results suggest that if economic potential for CHP is optimized over a shorter timeframe, such as 2008-2011, it would be economic to invest in additional CHP immediately, rather than delaying investment in CHP in the latter part of the 2008-2020 timeframe when optimizing costs over the long-term. These initial results require additional verification, but they suggest that the availability of cost-effective CHP resources over the next three to five years is not insignificant.

- **Conduct quantitative evaluation of benefits:** With additional effort and information, we would provide a quantitative valuation of the suite of benefits of greater deployment of CHP, including the value of avoided electricity generation, avoided CO_2 and NOx emissions, more efficient use of natural gas, and system reliability benefits that could be realized if CHP is targeted toward areas of current or potential future transmission constraints.

- **Further investigate factors influencing achievable CHP potential:** Current annual rates of CHP penetration in Rhode Island are relatively low (i.e., less than 5MW per year, based on averaging of recent historical data), significantly lower than estimated economic potential even under the low-end assumption of technical potential. In order to drive achievable potential in RI to levels approximating economic potential for CHP, additional efforts such as policy changes, consumer outreach and education, and regulatory reform could be beneficial. While we have explored in this analysis the influence of measures that directly affect CHP system costs, including stand-by charges and the introduction of revenues from capacity markets, we would collect empirical information, such as a phone survey of potential CHP customers, to better understand current barriers to CHP implementation and design effective measures for increasing achievable potential in Rhode Island.