NEW JERSEY COMBINED HEAT AND POWER MARKET ASSESSMENT

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Prepared by:
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Policy Report

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Mid-Atlantic Clean Energy Application Center
Promoting CHP, District Energy, and Waste Heat Recovery

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Purpose: The purpose of this report is to provide economic, market, jobs and carbon reduction information regarding applying combined heat and power (CHP) and combined cooling, heating and power (CCHP) systems in New Jersey. It also assesses the impact of state incentives and rules changes on CHP and CCHP adoption rates, economic, environmental and employment impacts.

UPDATED VERSION: This report has been updated from the August 30, 2010 version to include modeling of a market based CHP Portfolio Standard approach on page 33.

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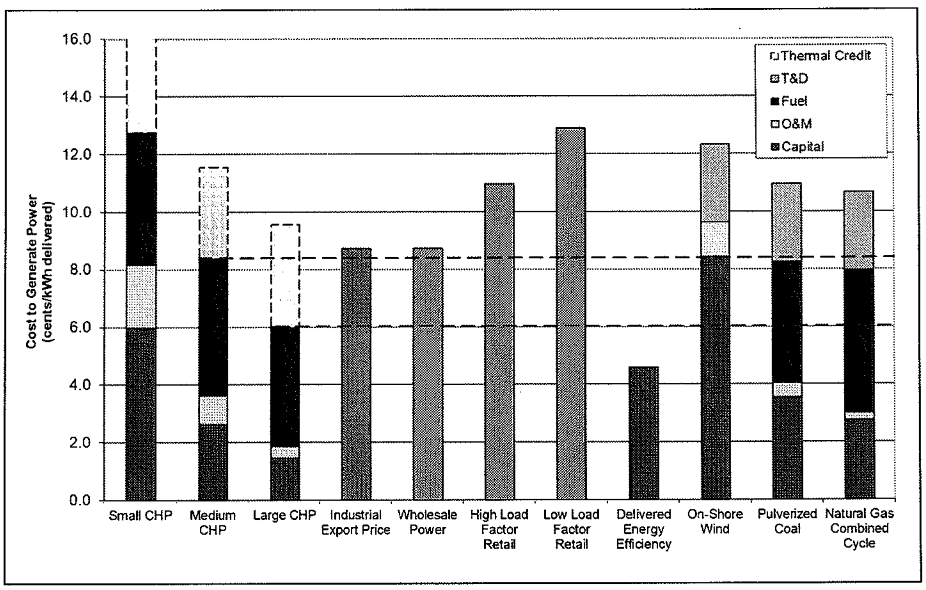
EXECUTIVE SUMMARY

The purpose of this report is to document the economic, environmental and societal benefits derived from instituting certain policies that will stimulate use of combined heat and power (CHP) systems in New Jersey.

CHP systems save energy by recovering heat during the power generation process and using it, on site, for heating, drying, cooling and/or humidity control and thus improving the efficiency of the fuel used to power the plant. Delivered fuel use efficiency of the electric grid has been about 31% for several decades. CHP can achieve fuel use efficiency[1] over 65% and as high as 85% in some cases. This high fuel use efficiency provides significant energy cost savings, primary energy savings and CO_2 emissions reduction. In addition, development of in-state CHP systems reduces the cost of otherwise required transmission infrastructure, creates jobs and improves New Jersey's competitiveness.

Energy Cost

The principle reason to consider providing policies and incentives supporting CHP in New Jersey is that it is the lowest cost means of providing additional power generation, as demonstrated in Figure 1. Medium and large scale CHP[2] including the thermal credit[3] provides power at a cost lower than the wholesale power price from the grid, lower than new coal or natural gas central station power plants and lower than onshore wind or solar photovoltaic (PV) systems[4].



Source: ICF for DOE

FIGURE 1: COST FOR ELECTRIC POWER PRODUCTION

[1] Fuel use efficiency (aka overall CHP efficiency) is defined by ASHRAE as the delivered power in Btu / (fuel used by the CHP system less the fuel that would have been required to produce the thermal energy provided by the CHP system)
[2] CHP in large and medium sizes ≥ 1MW in capacity with HHV efficiency of 36% or higher and using natural gas priced at $8.93 per million Btu's including NJ sales and use tax (SUT). SUT is removed for the CHP plant.
[3] Thermal credit applies the cost of generating the recovered (free) thermal energy from the CHP plant to reducing the power generation production cost. The credit is shown as a white column with dashed outline.
[4] Onshore wind has a production cost of 8.9¢/kWh, offshore wind is expected to be higher but the calculation unknowns are quite large at this point, utility based solar PV is about 22 ¢/kWh and non-utility scale plants are about 32¢/kWh.

Current Status of CHP in New Jersey

The next logical question is that if CHP is so cost effective, then why is it not being widely exploited today in New Jersey? The answer lies in studying New Jersey energy history. The simple answer comes down to a matter of financial risk tolerance. The bulk of New Jersey's CHP systems were installed between 1987 and 1995 largely resulting from two factors; low[5] natural gas prices relative to electricity cost and the ability to sell power at a profitable price (feed-in tariff). After 1995, federal and state policies were in flux or negative to CHP through 2008. Beginning in 2009 policy toward CHP was changing in New Jersey in recognition of its potential business and environmental friendly benefits. However, budget problems have left these recent state initiatives in limbo. There remain several significant impediments to widespread CHP deployment including high capital costs, air permitting processes, inability to raise capital, uncertainty of new Federal and State regulatory and/or policy changes, energy price uncertainty, lack of support by major utilities, etc.

Benefits to the State of New Jersey for Supporting CHP

Figure 1 provides a strong macroeconomic reason to support CHP to lower the marginal cost[6] of adding new electric capacity to the direct user and also the grid at large, by reducing the need to purchase high cost peak power and permanently reduce the need to build future power plants, transmission and distribution infrastructure. Table 1 shows CHP will also result in substantial primary energy savings 20 – 42 Trillion Btu/year, significant CO_2 reduction by 10 – 58 million short tons over 20 years and increase employment by 238 – 655 construction jobs plus retention of over 10,000 jobs by lowering energy prices.

TABLE 1: PROGRAM IMPACT

	Cumulative Market Penetration (MW)	Annual Primary Electric Energy Reduction (Trillion Btu/year)	Private sector investment ($ millions)	State investment ($ millions)	Total 20 Year CO_2 Reduced (million short tons)	Direct Sustained CHP Construction / Operating Jobs
10 Year Summary no Export[7]	743	20	$720	$297	10	328
10 Year Summary with Export	1,080	32	$1,023	$423	17	466
20 Year Summary no Export	1,102	28	$1,093	$449	38	497
20 Year Summary with Export	1,481	42	$1,429	$601	58	655

[5] Natural gas prices were low and also stable during this time period.

[6] In economics and finance, marginal cost is the change in total cost that arises when the quantity produced changes by one unit. That is, it is the cost of producing one more unit of a good. In general terms, marginal cost at each level of production includes any additional costs required to produce the next unit. In electrical terms, this means the cost of producing the next electron, which is highly time dependent. However, in the case of additional capacity referenced above, marginal cost merely means the cost of adding the next optimally designed power plant to meet the next electron's peak power needs above the current available grid capacity.

[7] Export refers to certain facilities like chemical plants where a CHP plant is designed to meet the 24/7 thermal load, it would have excess power to provide electricity to the grid at the wholesale power price.

Conclusion

As stated in New Jersey's Energy Master Plan; *"The economic, reliability, and environmental consequences of the "business as usual" scenario are unacceptable. Actions must be implemented to ensure that the state's future energy environment provides energy that is competitively priced, reliable and consistent with greenhouse gas targets."* CHP addresses these issues by lowering consumer power costs, increasing power reliability, creating jobs and private investment while also providing a low cost means of reducing greenhouse gas (GHG) emissions. Whereas building or 'load side' energy efficiency is recognized as the lowest cost method of reducing energy demand and GHG emissions, CHP is the lowest cost method on the 'supply side' to attain energy efficiency and GHG reductions.

In addition, the impending retirement of significant amounts of low cost coal-fired power plants due to age and their inability to compete when equipment to meet anticipated Federal EPA regulations are implemented gives rise to two concerns; how do we cost effectively replace this capacity to maintain reliability and, how do we deal with the cost increases implicit in retirement of low cost coal generation.

This report identifies that implementation of state level programs and policies to incentivize CHP and remove existing barriers to implementation of CHP will result in a significant increase in the development of CHP plants within the state. The report suggests specific policies and demonstrates the result of these policies in terms of MW's installed. Implementation of the suggested or similar policies is necessary in order for New Jersey to benefit from the many advantages offered by CHP as the lowest cost supply-side energy efficiency option available today. Inaction will force the state to invest in more expensive supply-side solutions and import more power from outside the state resulting ultimately in significantly higher energy costs for consumers.

1. INTRODUCTION

This report quantifies the long-term market penetration potential for combined heat and power (CHP), its economic impact and the degree to which CHP can reduce potential greenhouse gas (GHG[8]) emissions in support of the New Jersey Energy Master Plan. The report also examines how implementing various CHP financial and non-financial incentives would affect future CHP market penetration. The analysis covered the following five task areas:

- Characteristics of existing CHP in New Jersey
- Estimate of technical potential for CHP in New Jersey
- Market potential analysis under alternative scenarios
- Recommendations

1.1 Traditional CHP

Traditional CHP generates electric power and recovers the waste heat for useful purposes where the electrical output is produced to meet all or a portion of the electric load for a facility and the heat output is used to provide all or a portion of the facility's thermal load. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often have "excess" thermal load compared to their on-site electric load. Commercial facilities almost always have excess electric load compared to their thermal load. Two sub-categories were considered:

High load factor applications: This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such as colleges, hospitals, hotels, and prisons.

Low load factor applications: Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

1.2 Combined Cooling Heating and Power (CCHP)

All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration with the addition of a thermally activated cooling system. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round heating load to support a traditional CHP system. A typical system would provide the annual hot water load, a portion of the space heating load in the winter months and a portion of the cooling load during the summer months.

1.3 How CHP Saves Energy and Reduces CO_2 Emissions

Energy is one of the most significant driving forces of our economy. All buildings need electric power for lighting and operating equipment and appliances. One of the major consumers of energy in buildings is the equipment for space conditioning. Most commercial and institutional buildings for businesses, education, and healthcare require space conditioning for cooling, heating, and/or humidity control.

[8] There are a number of gases classified as "greenhouse gases" including carbon dioxide, methane, and nitrous oxide. This analysis only considers the impact on carbon dioxide, the principal GHG produced from the deployment of combined heat and power.

Two-thirds of all the fuel used to make electricity in the U.S. generally is wasted by venting unused thermal energy, from power generation equipment, into the air or discharging into water streams. While there have been impressive energy efficiency gains in other sectors of the economy since the oil price shocks of the 1970's, the average efficiency of power generation within the U.S. has remained around 31% since 1960. The average overall primary energy efficiency of generating electricity and heat by conventional systems is around 49%.

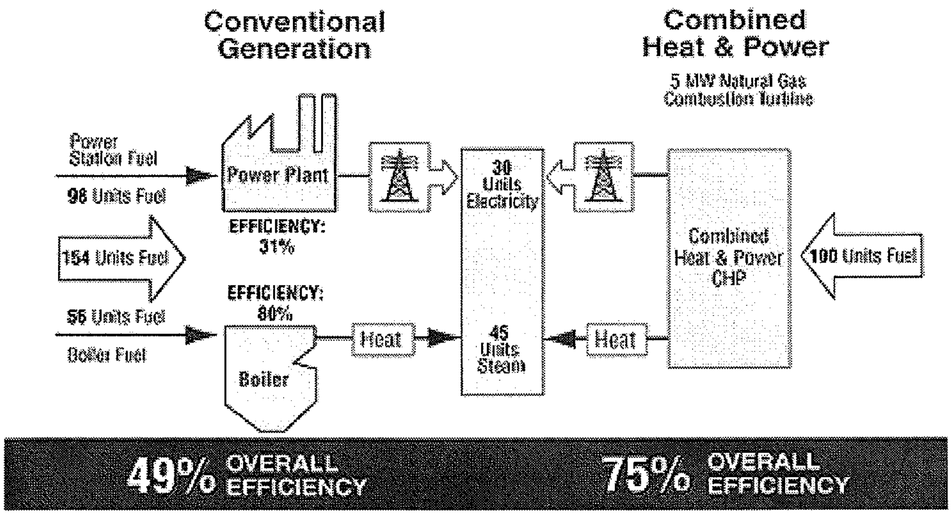


FIGURE 2: SEPARATE HEAT AND POWER VERSUS CHP – PRIMARY ENERGY [9]

CHP can increase primary energy efficiency to typically 75% and as high as 85%. This increase is accomplished by using thermal energy from power generation equipment, that otherwise would be wasted, for cooling, heating and humidity control. These plants are located at or near the facility's power and thermal distribution systems, and can save about 35% of the input energy required by conventional systems. In other words, conventional systems require 54% more energy than the integrated CHP systems, as shown in Figure 2 which demonstrates the efficiency gains of a 5 megawatt (MW) natural gas-fired combustion turbine CHP system compared to separate heat and power generation.

Industrial facilities, commercial buildings, college campuses, hospital complexes, correctional facilities and government facilities are good candidates for CHP.

Combined heat and power (CHP) systems also offer considerable environmental benefits when compared with conventionally generated electricity and onsite-generated heat. By capturing and utilizing heat that would otherwise be wasted from the production of electricity by remote large power plants, CHP systems require **less fuel** than equivalent separate heat and power systems to produce the same amount of energy.

Because less fuel is combusted, greenhouse gas emissions, such as carbon dioxide (CO_2), as well as criteria air pollutants like nitrogen oxides (NO_x) and sulfur dioxide (SO_2), are reduced. Figure 3 shows the magnitude of reduced CO_2 emissions of a 5 megawatt (MW) natural gas-fired CHP system compared with separate heat and power used to produce the same energy output. Figure 3 illustrates the CO_2 emissions output from power and thermal energy generation for two systems: (1) a separate heat and power system with a fossil

[9] Figure and efficiency calculations courtesy of EPA Combined Heat and Power Partnership http://www.epa.gov/chp/basic/environmental.html

fuel-fired power plant (emissions based on the U.S. fossil mix) and a natural gas-fired boiler; and (2) a 5 megawatt combustion-turbine CHP system powered by natural gas. The separate heat and power system emits a total of 49 kilotons of CO_2 per year (13 kilotons from the boiler and 36 kilotons from the power plant), while the CHP system, with its higher efficiency, emits 23 kilotons of CO_2 per year.

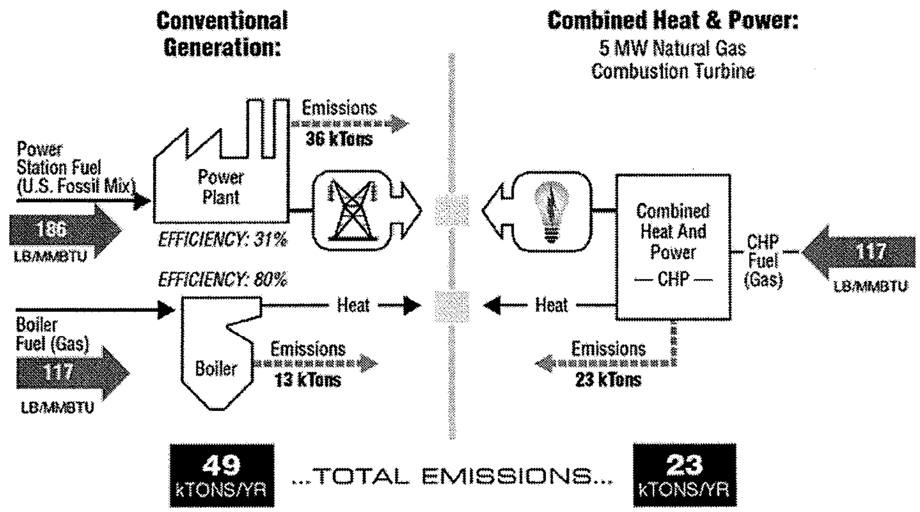
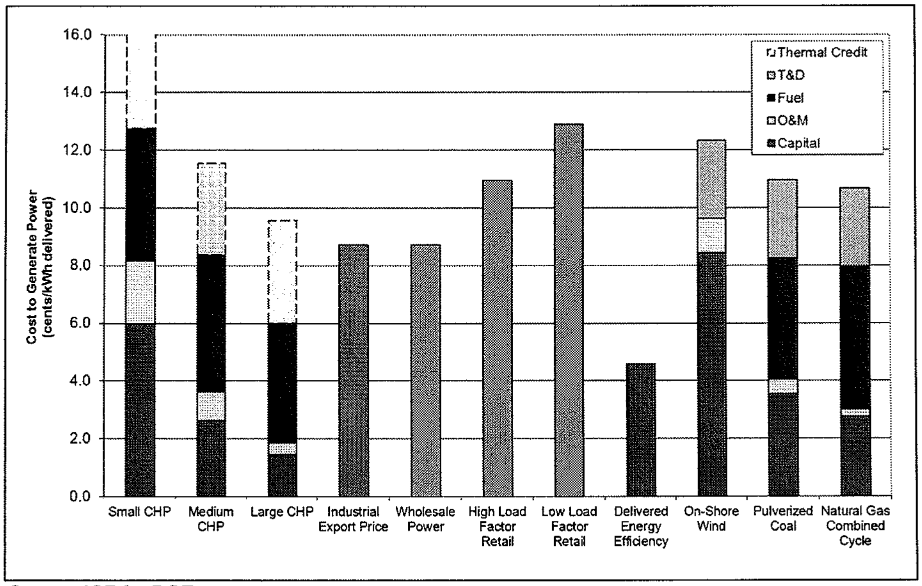


FIGURE 3: SEPARATE HEAT AND POWER VERSUS CHP – CO_2 EMISSIONS [10]

[10] Figure and emissions calculations courtesy of EPA Combined Heat and Power Partnership http://www.epa.gov/chp/basic/environmental.html

2. WHY CHP

The fundamental underpinning of this report is that there is indeed reason to consider removing barriers consumers face in applying CHP and CCHP systems. Furthermore, this report provides support for the notion that CHP[11] is a low cost method of increasing primary energy efficiency, reducing carbon emissions and affecting local marginal electricity price reduction.



Source: ICF for DOE

FIGURE 4: COST FOR ELECTRIC POWER PRODUCTION

Figure 4[12] presents the "all-in" electricity production cost in ¢/kWh for various sources that demonstrates providing delivered energy efficiency is the lowest cost means of providing electricity at the margin[6]. Large and medium size (1 to 40 MW range) CHP systems produce electricity at 6¢ to 8.4¢/kWh, which is lower than the current wholesale grid price of electricity and significantly less than the current retail price. Small (100 kW) CHP systems produce power at about the same retail cost for low load factor facilities or about same cost as on-shore wind does. Offshore wind is expected to be higher but the installation cost and capacity factor variables are very large at this stage, as there is little supportive data. Utility based solar PV is estimated to produce electricity at about 20 ¢/kWh and non-utility commercial scale plants at about 32¢/kWh.[13]

Figure 4 provides a compelling direct financial reason to promote CHP in New Jersey as the most economically efficiency supply-side electricity provider. In addition, CHP's low cost of electricity supply combined with its high fuel use efficiency yields low cost primary energy savings and carbon reduction. Furthermore, permanently reducing peak electric demand leads to reduced regional marginal electricity

[11] Reference to CHP throughout the remainder of the report means CHP and CCHP systems

[12] The central station data was derived from EIA AEO 2010, wind data is from internal DOE information and CHP data is from the DOE's MACEAC, DOE and the NJ BPU. Data used can be found in Appendix A. Note high load factor markets represent commercial facilities such as hospitals and universities that operate around the clock, providing energy loads for CHP systems to operate nearly continuously. Low load factor markets represent commercial and institutional market opportunities such as office buildings, schools, and laundries.

[13] Solar PV data from ICF calculations for Office of Energy Efficiency and Renewable Energy, DOE

pricing by lowering the demand for expensive wholesale peak electric power and reducing transmission and distribution costs.

Efficiently lowering the cost of electricity for all New Jersey consumers yields strong potential for economic growth, jobs creation and attracting new businesses to the state. According to an assessment by the American Council for an Energy-Efficient Economy, CHP projects provide one construction and/or operation job for every $155,000[14] of capital investment. Investing in CHP could yield between 497 and 655 new construction/operations jobs that would last over the course of the program. Furthermore, New Jersey's industrial base is at risk due to high energy prices and global competition. One recent estimate of three at risk plants from the manufacturing, pharmaceutical and food/beverage industries indicates that a $39 million investment in CHP has the potential to reduce the energy price risk enough to retain over 1,000 jobs. CHP's power to reduce energy cost and future risk could literally save well over 10,000 important manufacturing jobs in the state.

In summary, promoting CHP in New Jersey is business friendly and consumer friendly while also being environmentally friendly.

[14] Developed by John A. Laitner, Director of Economic Analysis, American Council for an Energy-Efficient Economy, email: jslaitner@aceee.org, phone: (847) 865-5106

3. INSTALLED CHP BASE AND SITUATION

The historical installed base for CHP and CCHP systems in New Jersey is presented in Figure 5. The base is dominated by industrial CHP installations accounting for over 3 GW[15] of electric capacity.

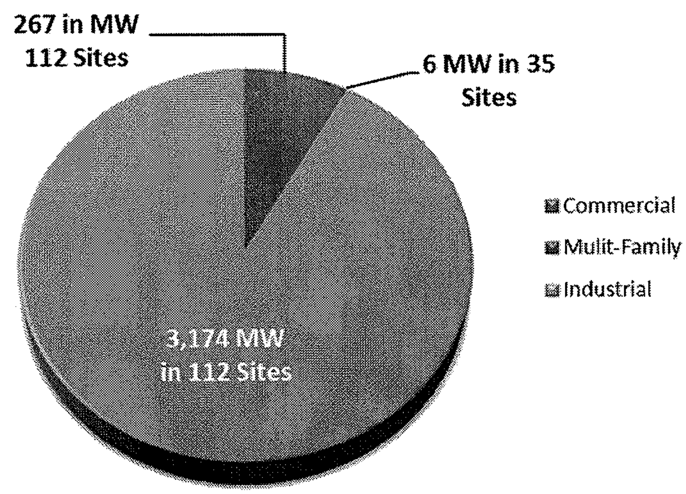


FIGURE 5: CURRENT INSTALLED CHP BASE IN MW BY APPLICATION

Dr. Carl Sagan reminds us that "You have to know the past to understand the present." To understand the current situation with CHP in NJ, it is important to understand the history of CHP in NJ. The Public Utility Regulatory Policies Act (PURPA) was passed in 1978 by the United States Congress as part of the National Energy Act. This law created a market for non-utility electric power producers forcing electric utilities to buy power from these producers at the "avoided cost" rate, which was the cost the electric utility would incur were it to generate or purchase from another source. Generally, this is considered to be the fuel costs incurred in the operation of a traditional power plant, associated variable operations and maintenance cost and new capital cost. Although a Federal law, the implementation was left to the States and a variety of regulatory regimes developed. The biggest result of PURPA is the prevalence of CHP plants, which produce electric power and steam. These plants were encouraged by the law, on the basis that they harness thermal energy (in the form of usable steam) that would be otherwise wasted if electricity alone was produced. These plants were known as 'Qualified Facilities' or QF's[16]. This act provided a federal incentive for states to implement regulations encouraging development of QF's that lead to substantial CHP installations in many states including New Jersey.

In addition, in the mid-1970s more than half of the nation was subject to state utility commission mandated moratoria on new customer hookups including utility power generation. CHP plants were exempt from these moratoria as long as they were certified QF's.

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[15] GW or gigawatt is equal to 1,000 megawats (MW) or 1,000,000 kilowatts (kW) or 1,000,000,000 watts.

[16] In order to become a qualified facility a power generation plant had to recover waste heat and meet a fuel use efficiency of 42.5% which was defined as the (power output in Btu added to 50% of the heat recovered) all divided by the fuel input.

The National Energy Act of 1978 also included legislation known as the Natural Gas Policy Act (NGPA) which was crafted in reaction to the then prevalent natural gas shortages. Realizing that those price controls that had been put in place to protect consumers from potential monopoly pricing had now come full circle to hurt consumers in the form of natural gas shortages, the federal government sought through the NGPA to revise the federal regulation of the sale of natural gas. Essentially, this act had three main goals:

- Creating a single national natural gas market
- Equalizing supply with demand
- Allowing market forces to establish the wellhead price of natural gas

Figure 6 below provides a long term historical overview of CHP installations in New Jersey. PURPA's impact on CHP in NJ did not substantively begin until 1988 largely due to lack of pipeline capacity from producing states to the region, uncertainty created by the natural gas hookup moratorium, a natural gas price spike beginning in 1979 (Figure 7) and to some extent market/regulatory assimilation of PURPA.

During the period of 1988 – 1995 over 3,297 MW of CHP systems were installed. The fundamental reason for this large impact was the certain return on investment provide by the QF feed-in tariff and stable natural gas prices. In the 1994/1995 timeframe it was understood that the FERC was going to "deregulate" the electric industry which created uncertainty that essentially stopped investment in CHP. Note that the regulatory/policy uncertainty essentially continues into today in New Jersey, which can be attributed to both Federal and State actions.

1. In 1997 New Jersey implemented a 7% sales and use tax on natural gas for CHP which essentially priced CHP out of the market place. (Note this was repealed by law in 2010.)
2. The Energy Policy Act (EPAct) 2005 removed the feed-in tariff requirements of PURPA, thus essentially removing a strong incentive for CHP[17] implementation.
3. In 2010 New Jersey applied all unspent discretionary funds, including the $60 million Retail Margin Fund which was intended to incentivize CHP projects, to balance the 2010 budget[18].

Furthermore, between 2002 and 2008 there was a period of volatile and high natural gas prices causing financial uncertainty for CHP developers. Given the high up front capital requirements and protracted payback, gas price volatility is an impediment to development of CHP projects.

[17] Section 1253 of EPAct 2005 amended PURPA, by adding a new section 210(m), to specify the conditions under which the obligation of an electric utility to purchase energy and capacity from QFs will be terminated. In Docket No. RM06-10-000, FERC issued a proposed rulemaking pursuant to which the mandatory purchase and sale obligations would be terminated if, in essence, QFs would have meaningful access to wholesale markets. Under the rules, electric utilities that are members of the Midwest Independent System Operator, PJM Interconnection, ISO-New England and the New York Independent System Operator qualified for relief from PURPA's mandatory purchase obligation.

[18] Source: NJ Board of Public Utilities (BPU)

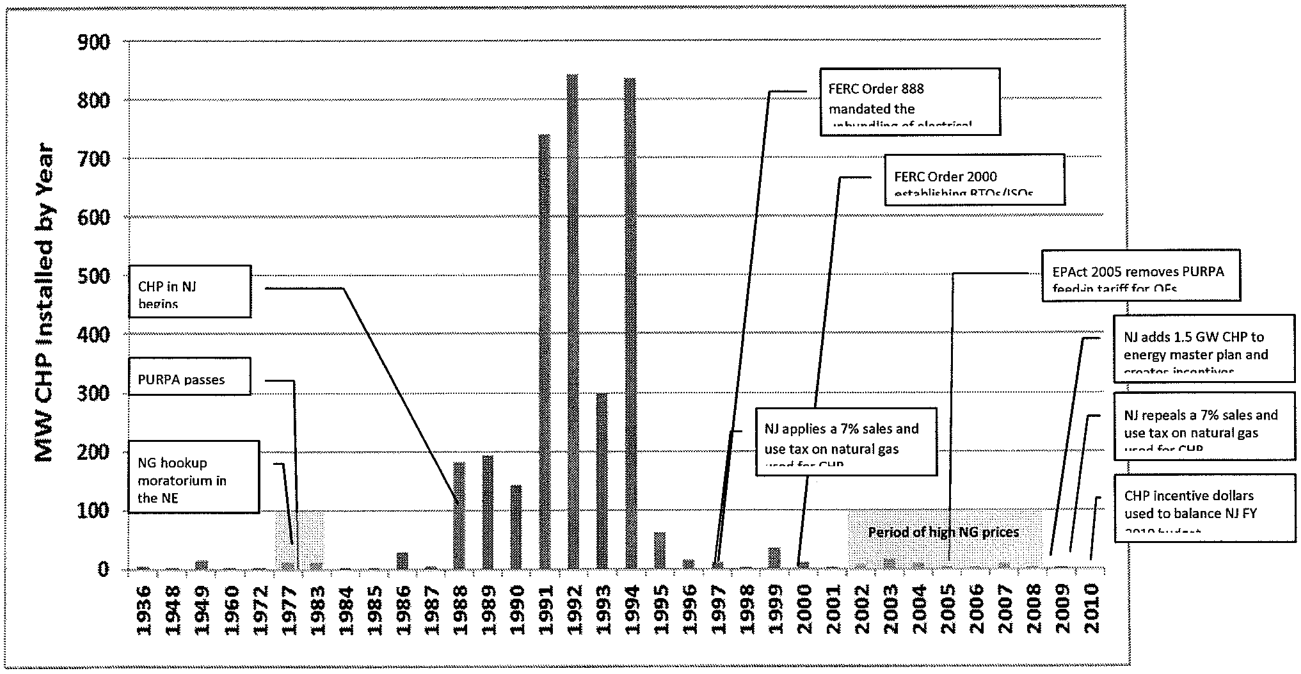

FIGURE 6: NEW JERSEY CHP INSTALLATIONS SINCE 1936

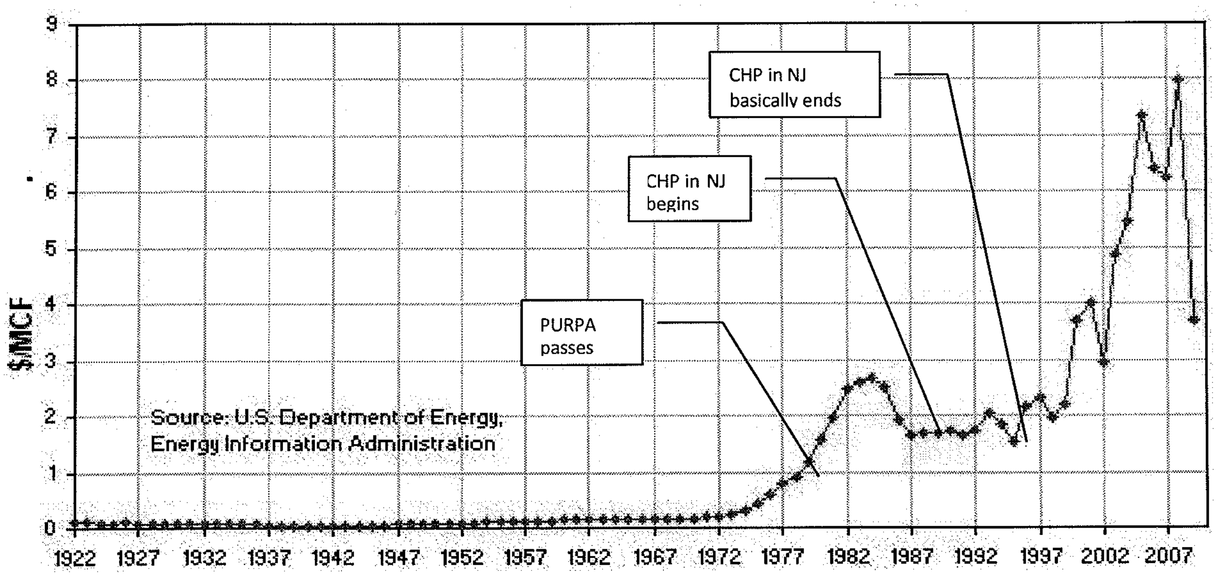

FIGURE 7: WELLHEAD NATURAL GAS PRICE SINCE 1922

Examining the beginning of CHP growth in New Jersey can be best understood by understanding the impact PURPA had on stimulating market adoption of CHP once the market understood two important factors:

1. NJ policy leaders desired to implement section 210 "qualified facility (QFs)" portions of PURPA in NJ providing a certain price structure and financial certainty
2. Natural gas price signals of the late 1970s (Figure 7) were turning positive.

Figure 8 examines CHP installations in New Jersey between 2000 and YTD 2010. These installations reflect natural gas price, price uncertainty and regulatory policy. In particular, virtually no CHP installations have occurred from 2008 onwards in spite of dramatically lowering of natural gas prices in 2009. There are four key reasons for this:

1. High natural gas prices in 2008 (Figure 9) creating uncertainty over future prices
2. The economic downturn slowing capital spending
3. Tight capital credit markets delaying good projects
4. In 2009 the Retail Margin Fund was to incentivize CHP at $450/kW through a competitive bid solicitation. Subsequent withdrawals of this fund lead to delay and/or cancellation of many potential CHP projects.

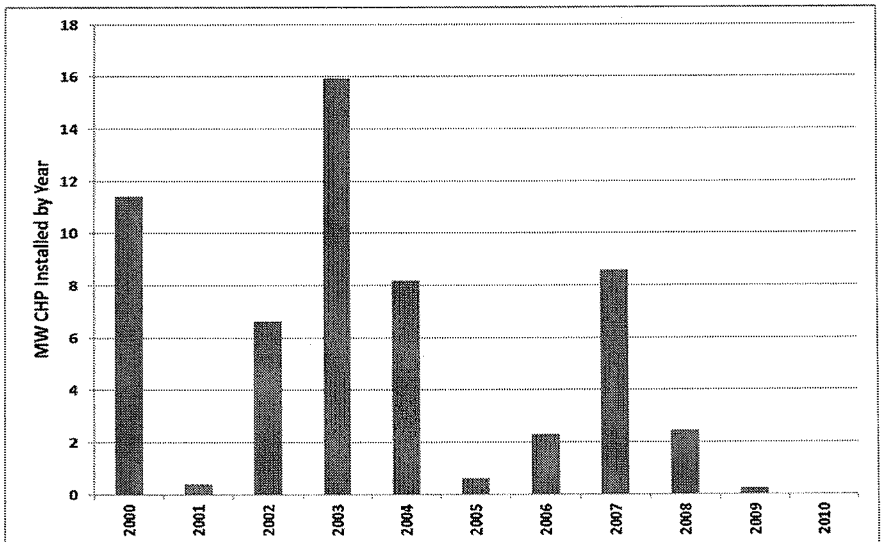

FIGURE 8: NEW JERSEY CHP INSTALLATIONS SINCE 2000

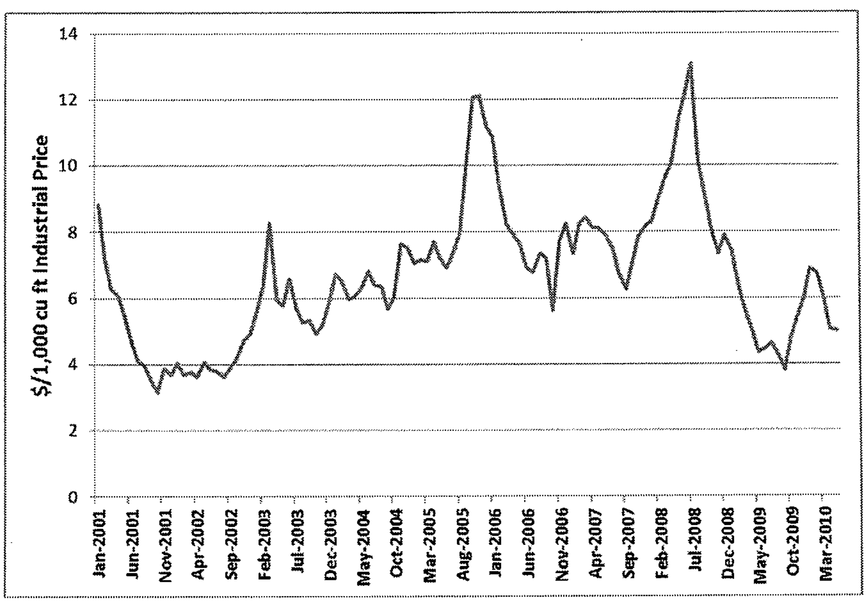

FIGURE 9: INDUSTRIAL NATURAL GAS PRICING (EIA)

The current market situation is that while many of the New Jersey Board of Public Utilities (BPU) financial incentives for CHP are technically available, the funding has been suspended or significantly reduced and utility programs retrospectively disallowed CHP as a fundable measure. Natural gas prices remain low and there exists a generally competitive spark spread. Project capital remains tight, environmental permitting remains a relatively long process, and utility attitude toward CHP remains unclear. The BPU is seeking reprogramming of about $18 million in DOE based American Recovery and Reinvestment Act of 2009 funding to jump start a number of CHP projects in an effort to demonstrate to stakeholders and the market place that CHP is a positive factor in energy cost reduction, fuel conservation and carbon reduction while avoiding deterioration of existing industry infrastructure. Nevertheless, the market for CHP remains confused and struggles to demonstrate acceptable risk parameters to the financial community.

Strong and sustained signals from the NJ government are required to move the industry forward and overcome a decade of high natural gas prices, regulatory issues and unclear policy signals, assuming the government recognizes the economic, environmental and job benefits offered by CHP.

Federal Energy Regulatory Commission (FERC), in its first major ruling[19] on state feed-in tariffs has ruled that (1) the Federal Power Act (FPA) does not preempt the States from requiring investor owned utilities (IOUs) to purchase wholesale electricity from combined heat and power generators (CHPs) that are not Qualifying Facilities (QFs) under Section 210 of the Public Utility Regulatory Policy Act (PURPA); (2) the FPA preempts the States from specifying the wholesale price for such purchases; (3) PURPA does not preempt the States from specifying the wholesale rates for purchases from CHPs that are QFs, provided such prices do not exceed the purchasing utilities' avoided cost rates; and (4) States are not preempted by the FPA from specifying wholesale prices for purchases from CHPs that are not QFs by publicly-owned utilities exempted from regulation under the FPA. In other words, states may require wholesale purchases by IOUs and publicly-owned utilities. States can set feed-in tariff rates for publicly-owned utilities. States can set feed-in tariff rates for IOUs provided the CHP plant is a QF and the feed-in tariff does not exceed the purchasing utilities' avoided cost rates.

[19] 132 FERC 61,047, issues July 15, 2010.

4. TECHNICAL MARKET POTENTIAL METHODOLOGY

Technical market potential is a statement of the number of MW's of power that could be produced from CHP plants assuming that all facilities with coincident electric and thermal loads would employ CHP. The estimation of technical market potential is generated by using multiple sources of data and various metrics as described below to identify and quantify in terms of size, sites suitable for the application of CHP. The existing CHP sites are subtracted from the identified sites to determine the remaining technical market potential.

The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and size distribution of the target CHP markets in the state. Identifying technical market potential is a preliminary step in the assessment of market penetration.

The basic approach to developing the technical potential is described below:

- *Identify existing CHP in the state.* This existing CHP capacity is deducted from any identified technical potential.
- *Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user* - Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the DOE EIA Commercial Buildings Energy Consumption Survey (CBECS), the DOE Manufacturing Energy Consumption Survey (MECS) and various market summaries developed by DOE, EPA's CHP Partnership, New Jersey Board of Public Utilities, and the Mid-Atlantic Clean Energy Application Center. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.
- *Estimate of CHP Technical Market Potential* - An estimate of the technically suitable CHP applications by size and by industry. This estimate is derived from the screening of customer data based on application and size characteristics that are used to estimate groups of facilities with appropriate electric and thermal load characteristics conducive to CHP.
- *Estimate CHP Technology Cost and Performance* - For each market size range, a set of applicable CHP technologies is selected for evaluation. These technologies are characterized in terms of their capital cost, heat rate, non-fuel operating and maintenance costs, and available thermal energy for process use on-site.
- *Estimate of Energy Price Projections* - Present and future fuel and electricity prices are estimated to provide inputs into the CHP net cost calculation.
- *Estimate Market Penetration* - Within each market size, the competition among applicable CHP technologies is evaluated. Based on this competition, the economic market potential is estimated and shared among competing CHP technologies. The rate of market penetration by technology is then estimated using a market diffusion model.

5. ICF MODEL

The ICF[20] CHP Market Model estimates cumulative CHP market penetration as a function of the competing CHP system specifications, current and future energy prices, and site electric and thermal load characteristics. The ICF CHP Market Model is a multi-layered integrated model that allows review of various measures against market assumptions including market potential and reports their impact on market penetration. The various incentive and policy measures, size segmentation, input assumption parameters and output parameters are summarized in Table 2. A breakout of assumptions and a more detailed review of the input data and results are provided in the following sections.

TABLE 2: ICF CHP MARKET MODEL

Forecast Periods	**2014, 2019, 2024, 2029**
Market Segmentation: Policies	\$225, \$450 & \$900 / kW Capital Cost Rebate
	Loan Guarantee
	0% Interest Loan
	Permit by Rule
	\$20/Ton CO_2
	CHP Portfolio Standard with Compliance Payment
	Export to Grid
Market Segmentation: Size	50-500 kW
	500-1,000 kW
	1-5 MW
	5-20 MW
	>20 MW
Major Input Assumptions	Technical Market Potential
	Technology Cost and Performance
	Energy Prices
	Application Load Profile
Economic Calculation Engine	CHP Economic Savings by Market and Size
	Payback Comparison
Market Penetration Estimation	Market Acceptance Curve vs. Payback
	Market Penetration of Economic Market
Model Outputs	Cumulative Market penetration in MW
	Electric, thermal and avoided AC Outputs
	Emissions Impacts

[20] ICF International partners with government and commercial clients to deliver professional services and technology solutions in the energy and climate change; environment and infrastructure; health, human services, and social programs; and homeland security and defense markets. ICF is the technical support contractor for the US EPA CHP Partnership and a US DOE support contractor for CHP programs.

6. RESULTS

The ICF model was used to assess the effect of implementing various incentive and policy measures as detailed in Section 9 below on the adoption of CHP. The results provide the expected total MW's of CHP installed as a result of implementing these measures. Figure 10 provides an overarching assessment of the 10-year potential to stimulate adoption of CHP systems in NJ through the various measures. Figure 11 provides an overarching assessment of the 20-year potential to stimulate adoption of CHP systems in NJ through implementation of these same measures.

The maximum penetration for any single initiative is through a $900/kW capital cost reduction which would add 1,671 MW over 20 years (with export). The 'Multiple Measures' scenario examines the impact of a $450/kW, 0% interest loan and permit by rule combined scenario over 20 years (with export and avoided cooling). The Multiple Measures scenario would result in:

1. 1,481 MW of CHP being implemented in New Jersey
2. Annual Primary Energy Savings of 101,182 billion Btu/year
3. Total investment to public investment leveraging of incentive funds by about 3.4 to 1
4. Annually reducing CO_2 emissions by 4,444,000 MT at a 20 year cumulative cost to the state of $10/MT
5. Increasing employment in the state by 655 construction/operations jobs and retaining significantly over 10,000 chemical, manufacturing, pharmaceutical, food and beverage jobs.

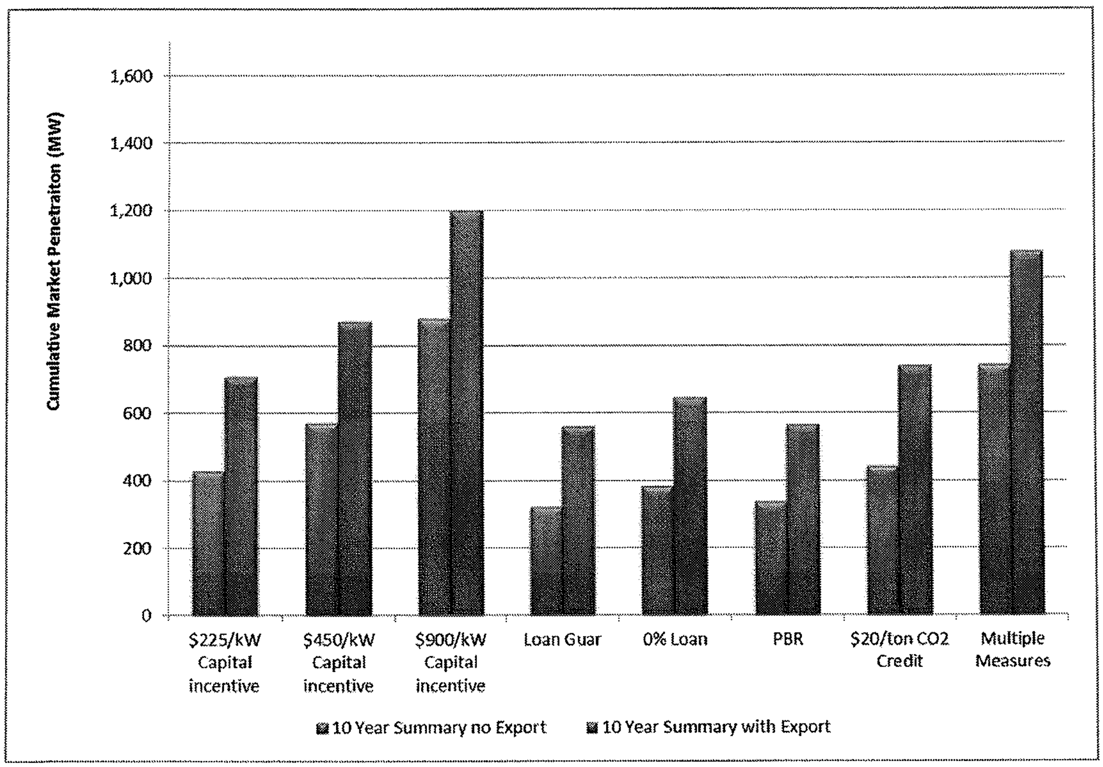

FIGURE 10: MW INSTALLED; 10-YEAR PROJECTION OF INCENTIVE SCENARIOS FOR CHP

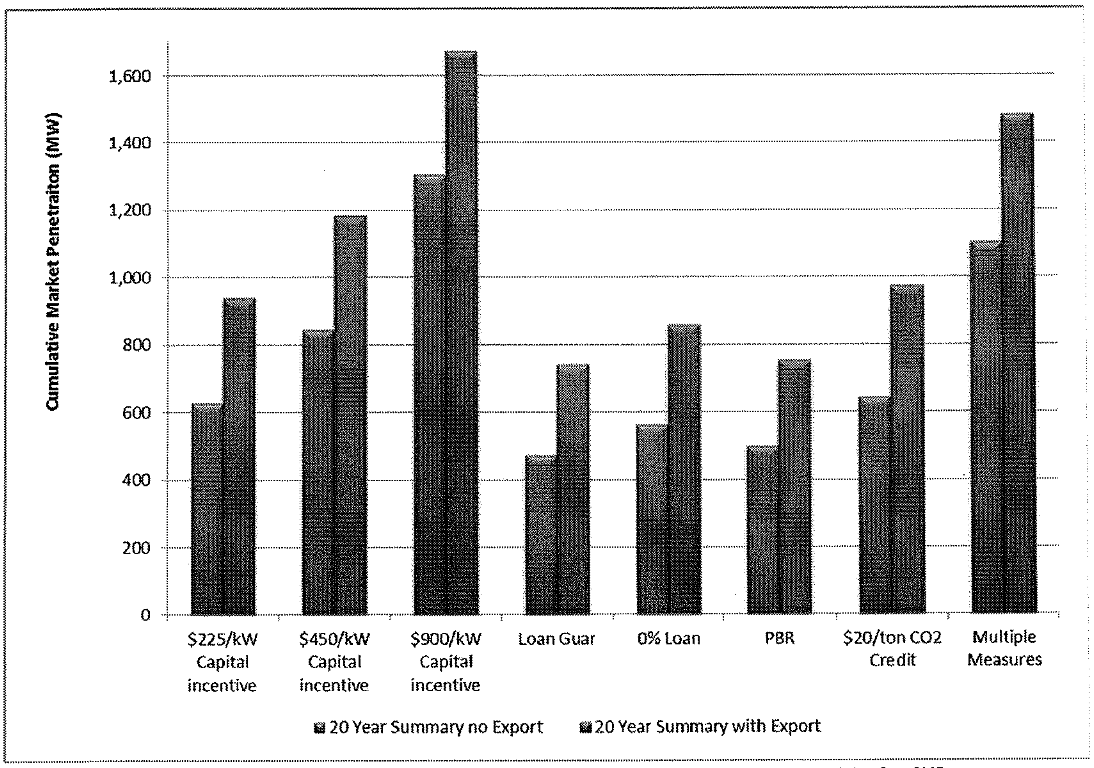

FIGURE 11: MW INSTALLED; 20-YEAR PROJECTION OF INCENTIVE SCENARIOS FOR CHP

The following tables 3 and 4 provide a detailed breakout of the model results for the first 10 years with and without power export respectively. Tables 5 and 6 provide a detailed breakout of the model results for the full 20-year review period with and without power export respectively.

TABLE 3: 10-YEAR CHP MARKET PENETRATION SCENARIOS WITH NO EXPORT

CHP Measurement	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	Loan Guar	0% Loan	PBR	$20/ton CO2 Credit	Multiple Measures
Economic Potential, MW	552	746	1,199	412	490	436	565	974
Cumulative Market Penetraiton (MW)								
Industrial	282	353	512	227	261	233	293	438
Commercial/Institutional	127	188	319	82	105	91	130	264
Total	409	542	830	310	366	324	422	702
Avoided Cooling	19	29	48	12	16	14	20	41
Scenario Grand Total	428	570	878	322	382	338	442	743
Delta CHP power	124	256	545	24	81	39	137	416
Delta with avoided cooling	132	274	582	26	86	42	146	446
Annual Electric Energy (Million kWh)								
Industrial	2,106	2,612	3,723	1,703	1,948	1,735	2,183	3,218
Commercial/Institutional	811	1,177	1,895	545	686	596	840	1,611
Total	2,917	3,788	5,618	2,247	2,633	2,331	3,023	4,829
Avoided Cooling	55	80	126	36	46	40	57	111
Scenario Grand Total	2,971	3,868	5,744	2,283	2,680	2,371	3,080	4,940
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	29,277	38,028	56,395	22,559	26,433	23,399	30,345	48,472
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	29,829	38,827	57,662	22,921	26,899	23,800	30,917	49,585
Incremental Onsite Fuel (billion Btu/year)								
Industrial	11572	14,395	20,619	9355	10,727	9,572	12,032	17806
Commercial/Institutional	5918	8,607	13,856	3937	5,001	4,342	6,125	11877
Total	17,490	23,003	34,475	13,292	15,728	13,914	18,157	29,682
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	11,787	15,026	21,920	9,267	10,706	9,485	12,188	18,790
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	12,339	15,824	23,187	9,629	11,171	9,886	12,760	19,903
Delta Annual Primary Savings (billion Btu/year) - CHP Power	3,178	6,417	13,312	658	2,097	876	3,579	10,181
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling	3,405	6,891	14,253	695	2,237	952	3,826	10,969
Financial Impact								
Cumulative Investment (million 2010 $)	$531	$615	$662	$453	$514	$486	$651	$720
Cumulative Capital Incentives (Million 2010 $)	$83	$207	$593	$2	$17	$0	$0	$297
Annual Operating Incentives (Million 2010 $)	$0	$0	$0	$0	$0	$0	$27	$0
Cumulative Operating Incentives (Million 2010$)	$0	$0	$0	$0	$0	$0	$132	$0
State Incentive Leverage	7.4	4.0	2.1	197	32			3.4
Annual Electric Energy (Million 2010 $)								
Industrial	209	261	380	168	193	173	216	325
Commercial/Institutional	85	125	205	56	72	62	87	173
Total	294	386	585	224	265	235	304	498
Avoided Cooling	8	12	19	5	7	6	8	17
Scenario Grand Total	302	398	604	230	271	241	312	514
Incremental Onsite Fuel (million 2010 $)								
Industrial	103	128	183	83	95	85	107	158
Commercial/Institutional	53	76	123	35	44	39	54	105
Total	155	204	306	118	140	124	161	264
Calculated Averages (2010 $)								
Average Capital Cost $/kW	$1,298	$1,135	$797	$1,463	$1,406	$1,501	$1,542	$1,026
Average Incentive Rate $/kW	$204	$382	$714	$7	$46	$0	$313	$424
Average Capital Cost $/kW	$1,502	$1,517	$1,510	$1,463	$1,406	$1,501	$1,542	$1,408
Equivalent Operating Incentive, $/kWh	$0.004	$0.007	$0.014	$0.000	$0.001	$0.000	$0.006	$0.008
Average Electric Cost Saved ($/kW)	$0.102	$0.103	$0.105	$0.101	$0.101	$0.102	$0.101	$0.104
Average Incremental Gas Cost ($/MMBtu)	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88
Average Incremental Heat Rate (Btu/kWh HHV)	5,886	5,947	6,002	5,821	5,869	5,869	5,895	6,009
Cumulative Market Penetration by Size and Year, MW								
50-500 kW	42	64	107	27	38	36	41	98
500kW-1,000kW	24	40	80	13	18	17	27	64
1-5 MW	117	177	382	82	101	94	116	247
5-20 MW	138	174	174	110	124	104	147	197
>20 MW	87	87	87	77	84	73	92	96
Total Market	409	542	830	310	366	324	422	702
CO2 Impact								
Avoided CO2 Emissions, Annual basis, thousand MT	1,312	1,695	2,501	1,016	1,185	1,049	1,358	2,148
Cost for MT CO2 Reduced	$64	$122	$237	$2	$14	$0	$0	$138
Cumulative Avoided CO2 Emissions, thousand MT	6,350	8,061	11,277	4,963	5,766	5,086	6,605	10,143
Cum Incentive Cost for Cum MT CO2 Reduced	$13	$26	$53	$0	$3	$0	$0	$29
Average unit Emissions savings, lb/MWh	973.3	966.1	959.7	980.8	975.2	975.3	972.2	958.9

TABLE 4: 10-YEAR CHP MARKET PENETRATION SCENARIOS WITH EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	Loan Guar	0% Loan	PBR	$20/ton CO2 Credit	Multiple Measures
Economic Potential, MW	648	884	1,104	1,584	697	804	709	913	1,374
Cumulative Market Penetraiton (MW)									
Industrial	438	561	653	832	465	524	461	589	775
Commercial/Institutional	74	127	188	319	82	105	91	130	264
Total	511	688	842	1,151	548	629	552	719	1,039
Avoided Cooling	11	19	29	48	12	16	14	20	41
Scenario Grand Total	522	707	871	1,199	560	645	566	739	1,080
Delta CHP power		177	330	639	36	118	41	207	527
Delta with avoided cooling		185	348	676	38	123	44	216	557
Annual Electric Energy (Million kWh)									
Industrial	3,375	4,306	4,968	6,220	3,586	4,030	3,539	4,523	5,858
Commercial/Institutional	491	811	1,177	1,895	545	686	596	840	1,611
Total	3,866	5,117	6,145	8,115	4,130	4,716	4,134	5,363	7,469
Avoided Cooling	32	55	80	126	36	46	40	57	111
Scenario Grand Total	3,899	5,172	6,224	8,241	4,167	4,762	4,174	5,420	7,579
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	38,812	51,370	61,683	81,459	41,462	47,338	41,502	53,832	74,971
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	39,137	51,921	62,482	82,726	41,824	47,804	41,903	54,404	76,084
Incremental Onsite Fuel (billion Btu/year)									
Industrial	18,080	23120	26,796	33,813	19226	21,650	19,029	24,324	31714
Commercial/Institutional	3,540	5918	8,607	13,856	3937	5,001	4,342	6,125	11877
Total	21,621	29,038	35,403	47,668	23,163	26,651	23,371	30,448	43,591
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	17,192	22,332	26,281	33,791	18,299	20,688	18,130	23,383	31,380
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	17,517	22,883	27,079	35,057	18,662	21,153	18,531	23,955	32,493
Delta Annual Primary Savings (billion Btu/year) - CHP Power		5,141	9,089	16,599	1,108	3,496	939	6,192	14,189
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		5,367	9,563	17,541	1,145	3,637	1,015	6,439	14,977
Financial Impact									
Cumulative Investment (million 2010 $)	$697	$825	$914	$957	$737	$811	$763	$1,013	$1,023
Cumulative Capital Incentives (Million 2010 $)	$0	$125	$270	$682	$4	$26	$0	$0	423
Annual Operating Incentives (Million 2010 $)	$0	$0	$0	$0	$0	$0	$0	$49	$0
Cumulative Operating Incentives (Million 2010$)	$0	$0	$0	$0	$0	$0	$0	$251	$0
State Incentive Leverage		7.6	4.4	2.4	197	32			3.4
Annual Electric Energy (Million 2010 $)									
Industrial	415	536	631	831	443	501	442	558	754
Commercial/Institutional	110	174	250	393	122	153	133	178	339
Total	525	710	881	1,224	565	653	575	737	1093
Avoided Cooling	11	17	24	36	12	15	13	17	33
Scenario Grand Total	536	727	905	1,260	577	668	588	754	1,126
Incremental Onsite Fuel (million 2010 $)									
Industrial	161	205	238	300	171	192	169	216	282
Commercial/Institutional	31	53	76	123	35	44	39	54	105
Total	192	258	314	423	206	237	208	270	387
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,364	$1,199	$1,086	$832	$1,345	$1,288	$1,382	$1,409	$985
Average Incentive Rate $/kW	$0	$182	$320	$593	$7	$42	$0	$349	$407
Average Capital Cost $/kW	$1,364	$1,381	$1,406	$1,425	$1,345	$1,288	$1,382	$1,409	$1,305
Equivalent Operating Incentive, $/kWh	$0.000	$0.003	$0.006	$0.011	$0.000	$0.001	$0.000	$0.006	$0.007
Average Electric Cost Saved ($/kW)	$0.097	$0.098	$0.100	$0.102	$0.098	$0.098	$0.098	$0.098	$0.101
Average Incremental Gas Cost ($/MMBtu)	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88	$8.88
Average Incremental Heat Rate (Btu/kWh HHV)	5,545	5,614	5,688	5,784	5,559	5,596	5,599	5,618	5,751
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	24	42	64	107	27	38	36	41	98
500kW-1,000kW	12	24	40	80	13	18	17	27	64
1-5 MW	79	129	195	421	90	111	103	128	273
5-20 MW	147	195	245	245	155	174	147	207	277
>20 MW	250	298	298	298	262	288	250	316	327
Total Market	511	688	842	1,151	548	629	552	719	1,039
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	1,792	2,358	2,813	3,683	1,912	2,176	1,906	2,470	3,400
Cost for MT CO2 Reduced		$53	$96	$185	$2	$12	$0	$0	$124
Cumulative Avoided CO2 Emissions, thousand MT	9,138	11,916	13,978	17,470	9,727	11,039	9,639	12,559	16,764
Cum Incentive Cost for Cum MT CO2 Reduced		$10	$19	$39	$0	$2	$0	$0	$25
Average unit Emissions savings, lb/MWh	1013.1	1005.1	996.5	985.2	1011.5	1007.2	1006.9	1004.6	989.0

TABLE 5: 20-YEAR CHP MARKET PENETRATION SCENARIOS WITH NO EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	Loan Guar	0% Loan	PBR	$20/ton CO2 Credit	Multiple Measures
Economic Potential, MW	555	772	1,022	1,527	604	710	629	775	1,292
Cumulative Market Penetraiton (MW)									
Industrial	261	351	445	664	281	324	290	360	554
Commercial/Institutional	147	236	343	552	164	205	178	241	469
Total	408	587	788	1,215	445	529	468	602	1,023
Avoided Cooling	25	40	58	90	28	35	30	41	80
Scenario Grand Total	433	627	845	1,305	472	564	498	643	1,102
Delta CHP power		179	380	808	37	121	60	194	615
Delta with avoided cooling		194	413	873	40	131	66	210	670
Annual Electric Energy (Million kWh)									
Industrial	1,942	2,599	3,270	4,803	2,090	2,401	2,149	2,673	4,051
Commercial/Institutional	965	1,503	2,140	3,302	1,067	1,320	1,146	1,549	2,869
Total	2,906	4,103	5,410	8,105	3,157	3,721	3,295	4,222	6,920
Avoided Cooling	66	103	146	217	73	91	79	107	197
Scenario Grand Total	2,972	4,206	5,555	8,322	3,230	3,813	3,374	4,329	7,116
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	29,174	41,185	54,304	81,357	31,687	37,357	33,079	42,384	69,460
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	29,836	42,220	55,765	83,537	32,420	38,274	33,869	43,454	71,433
Incremental Onsite Fuel (billion Btu/year)									
Industrial	10,736	14396	18,153	26,652	11571	13,332	11,953	14,853	22579
Commercial/Institutional	7,032	11043	15,741	24,203	7794	9,713	8,428	11,383	21242
Total	17,768	25,439	33,894	50,856	19,365	23,045	20,381	26,236	43,821
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	11,406	15,746	20,411	30,501	12,322	14,312	12,698	16,148	25,639
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	12,068	16,781	21,872	32,682	13,055	15,229	13,488	17,218	27,612
Delta Annual Primary Savings (billion Btu/year) - CHP Power		4,340	9,005	19,095	916	2,906	1,292	4,742	14,233
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		4,713	9,804	20,614	987	3,161	1,420	5,150	15,544
Financial Impact									
Cumulative Investment (million 2010 $)	$630	$794	$927	$982	$679	$776	$735	$962	$1,093
Cumulative Capital Incentives (Million 2010 $)	$0	$122	$311	$902	$3	$25	$0	$0	449
Annual Operating Incentives (Million 2010 $)	$0	$0	$0	$0	$0	$0	$0	$37	$0
Cumulative Operating Incentives (Million 2010$)	$0	$0	$0	$0	$0	$0	$0	$471	$0
State Incentive Leverage		7.5	4.0	2.1	197	32			3.4
Annual Electric Energy (Million 2010 $)									
Industrial	211	285	361	541	228	263	236	293	452
Commercial/Institutional	110	174	250	393	122	153	133	178	339
Total	321	459	611	934	350	416	369	471	791
Avoided Cooling	11	17	24	36	12	15	13	17	33
Scenario Grand Total	332	476	635	970	362	431	382	488	823
Incremental Onsite Fuel (million 2010 $)									
Industrial	105	140	177	260	113	130	117	145	220
Commercial/Institutional	69	108	153	236	76	95	82	111	207
Total	173	248	330	496	189	225	199	256	427
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,546	$1,353	$1,177	$808	$1,527	$1,467	$1,571	$1,598	$1,068
Average Incentive Rate $/kW	$0	$209	$395	$742	$8	$48	$0	$784	$439
Average Capital Cost $/kW	$1,546	$1,561	$1,572	$1,550	$1,527	$1,467	$1,571	$1,598	$1,464
Equivalent Operating Incentive, $/kWh	$0.000	$0.004	$0.007	$0.014	$0.000	$0.001	$0.000	$0.014	$0.008
Average Electric Cost Saved ($/kW)	$0.112	$0.113	$0.114	$0.117	$0.112	$0.113	$0.113	$0.113	$0.116
Average Incremental Gas Cost ($/MMBtu)	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75
Average Incremental Heat Rate (Btu/kWh HHV)	5,978	6,048	6,101	6,111	5,996	6,044	6,041	6,061	6,158
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	51	85	126	204	58	79	72	83	186
500kW-1,000kW	27	49	76	143	31	40	36	51	114
1-5 MW	107	170	254	537	121	148	138	168	351
5-20 MW	142	188	235	235	150	169	142	198	266
>20 MW	81	96	96	96	85	93	81	101	105
Total Market	408	587	788	1,215	445	529	468	602	1,023
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	1,298	1,821	2,389	3,574	1,407	1,651	1,462	1,871	3,039
Cost for MT CO2 Reduced		$67	$130	$252	$2	$15	$0	$0	$148
Cumulative Avoided CO2 Emissions, thousand MT	16,382	22,832	29,597	43,444	17,709	20,699	18,307	23,574	37,509
Cum Incentive Cost for Cum MT CO2 Reduced		$19	$11	$21	$0	$1	$0	$0	$12
Average unit Emissions savings, lb/MWh	962.5	954.3	948.1	946.9	960.4	954.7	955.2	952.8	941.4

TABLE 6: 20-YEAR CHP MARKET PENETRATION SCENARIOS WITH EXPORT

CHP Measurement	Base	$225/kW Capital Incentive	$450/kW Capital Incentive	$900/kW Capital Incentive	Loan Guar	0% Loan	PBR	$20/ton CO2 Credit	Multiple Measures
Economic Potential, MW	877	1,163	1,443	1,996	942	1,080	954	1,175	1,760
Cumulative Market Penetraiton (MW)									
Industrial	514	663	782	1,029	547	618	546	691	933
Commercial/Institutional	147	236	343	552	164	205	178	241	469
Total	661	899	1,125	1,581	711	823	724	932	1,402
Avoided Cooling	25	40	58	90	28	35	30	41	80
Scenario Grand Total	686	939	1,183	1,671	739	859	754	973	1,481
Delta CHP power		238	464	920	50	163	63	271	741
Delta with avoided cooling		253	497	985	53	173	68	288	796
Annual Electric Energy (Million kWh)									
Industrial	3,940	5,059	5,914	7,644	4,194	4,728	4,167	5,277	7,015
Commercial/Institutional	965	1,503	2,140	3,302	1,067	1,320	1,146	1,549	2,869
Total	4,905	6,563	8,054	10,946	5,261	6,048	5,313	6,826	9,883
Avoided Cooling	66	103	146	217	73	91	79	107	197
Scenario Grand Total	4,971	6,666	8,199	11,163	5,334	6,139	5,392	6,932	10,080
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	49,239	65,880	80,846	109,881	52,811	60,709	53,331	68,517	99,210
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	49,901	66,915	82,307	112,061	53,545	61,626	54,122	69,587	101,182
Incremental Onsite Fuel (billion Btu/year)									
Industrial	21,201	27295	32,061	41,658	22593	25,524	22,526	28,522	38188
Commercial/Institutional	7,032	11043	15,741	24,203	7794	9,713	8,428	11,383	21242
Total	28,234	38,338	47,801	65,862	30,387	35,238	30,954	39,905	59,430
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	21,006	27,541	33,045	44,019	22,424	25,471	22,378	28,612	39,779
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	21,668	28,576	34,506	46,200	23,158	26,388	23,168	29,682	41,752
Delta Annual Primary Savings (billion Btu/year) - CHP Power		6,536	12,039	23,013	1,419	4,465	1,372	7,606	18,774
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		6,909	12,838	24,532	1,490	4,720	1,500	8,015	20,084
Financial Impact									
Cumulative Investment (million 2010 $)	$936	$1,120	$1,259	$1,310	$995	$1,106	$1,044	$1,363	$1,429
Cumulative Capital Incentives (Million 2010 $)	$0	$170	$384	$1,010	$5	$36	$0	$0	601
Annual Operating Incentives (Million 2010 $)	$0	$0	$0	$0	$0	$0	$0	$62	$0
Cumulative Operating Incentives (Million 2010$)	$0	$0	$0	$0	$0	$0	$0	$832	$0
State Incentive Leverage		7.6	4.3	2.3	197	32			3.4
Annual Electric Energy (Million 2010 $)									
Industrial	415	536	631	831	443	501	442	558	754
Commercial/Institutional	110	174	250	393	122	153	133	178	339
Total	525	710	881	1,224	565	653	575	737	1093
Avoided Cooling	11	17	24	36	12	15	13	17	33
Scenario Grand Total	536	727	905	1,260	577	668	588	754	1,126
Incremental Onsite Fuel (million 2010 $)									
Industrial	207	266	312	406	220	249	220	278	372
Commercial/Institutional	69	108	153	236	76	95	82	111	207
Total	275	374	466	642	296	343	302	389	579
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,416	$1,246	$1,119	$829	$1,399	$1,343	$1,443	$1,462	$1,020
Average Incentive Rate $/kW	$0	$189	$341	$639	$7	$44	$0	$893	$429
Average Capital Cost $/kW	$1,416	$1,434	$1,460	$1,468	$1,399	$1,343	$1,443	$1,462	$1,361
Equivalent Operating Incentive, $/kWh	$0.000	$0.003	$0.006	$0.012	$0.000	$0.001	$0.000	$0.016	$0.008
Average Electric Cost Saved ($/kW)	$0.108	$0.109	$0.110	$0.113	$0.108	$0.109	$0.109	$0.109	$0.112
Average Incremental Gas Cost ($/MMBtu)	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75
Average Incremental Heat Rate (Btu/kWh HHV)	5,680	5,751	5,830	5,900	5,697	5,740	5,741	5,756	5,896
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	51	85	126	204	58	79	72	83	186
500kW-1,000kW	27	49	76	143	31	40	36	51	114
1-5 MW	116	185	278	589	131	161	149	184	384
5-20 MW	192	253	318	318	203	228	192	267	359
>20 MW	275	327	327	327	288	316	275	346	359
Total Market	661	899	1,125	1,581	711	823	724	932	1,402
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	2,249	2,990	3,644	4,920	2,408	2,758	2,422	3,108	4,444
Cost for MT CO2 Reduced		$57	$105	$205	$2	$13	$0	$0	$135
Cumulative Avoided CO2 Emissions, thousand MT	30,191	39,811	47,749	62,715	32,245	36,769	32,222	41,608	57,831
Cum Incentive Cost for Cum MT CO2 Reduced		$4	$8	$16	$0	$1	$0	$0	$10
Average unit Emissions savings, lb/MWh	997.4	989.0	979.8	971.6	995.4	990.4	990.2	988.4	972.1

7. MODELED TECHNICAL POTENTIAL FOR CHP

The CHP technical potential is an estimation of market size constrained only by technological limits – the ability of CHP technologies to fit customer energy needs. CHP technical potential is calculated in terms of CHP electrical capacity that could be installed at existing and new industrial and commercial facilities based on the estimated electric and thermal needs of the site as described in Section 4 above.

Figure 12 summarizes the technical potential for additional CHP in the state by market segment. The estimate includes both additional CHP (including CCHP) potential at existing businesses and CHP potential from the expected growth in new facilities over the next 10 years. The export market potential is composed solely of industrial sites that have large thermal loads. No CHP export potential was assumed to come from commercial or institutional facilities. The total technical potential is close to 6,000 MW. Most of this potential is in industrial and commercial facilities that exist today; only a small portion is due to the growth in new businesses.

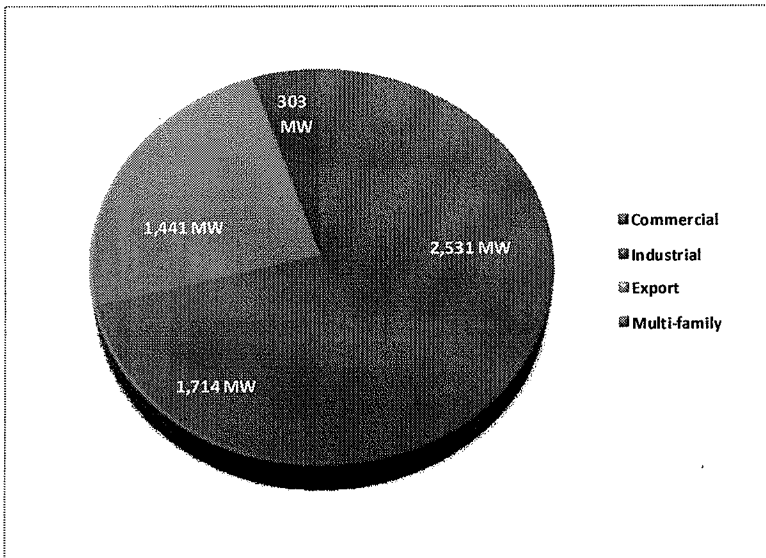

FIGURE 12: TECHNICAL NJ CHP MARKET POTENTIAL IN MW BY APPLICATION

The technical potential derived by ICF is based on EIA data updated with Hoover's data together with input from the NJ BPU and MA-CEAC. Tables 7, 8 and 9 provide a breakout of the technical market potential for commercial, industrial and export by standard industrial classification (SIC) code. Multi-family buildings are incorporated in the Commercial Potential table below.

TABLE 7: TECHNICAL MARKET POTENTIAL FOR COMMERCIAL CHP

SIC	Application	50-500 kW Sites		500-1 MW Sites		1-5 MW Sites		5-20 MW Sites		>20 MW Sites		Total	
		Total #	Total MW	Total #	Total MW	Total #	Total MW	Total #	Total MW	Total #	Total MW	Sites	MW
43	Post Offices	20	2.0	1	0.7	1	3.5	0	0.0	0	0.0	22	6.2
52	Retail	581	94.4	6	5.5	7	11.5	0	0.0	0	0.0	594	111.4
4222	Refrigerated Warehouses	33	5.3	4	2.9	0	0.0	0	0.0	0	0.0	37	8.3
4581	Airports*	6	0.7	1	0.8	0	0.0	1	12.4	0	0.0	8	13.9
4952	Water Treatment	100	14.7	10	6.5	2	2.4	0	0.0	0	0.0	112	23.5
5411	Food Stores	557	97.4	9	5.5	1	1.2	0	0.0	0	0.0	567	104.0
5812	Restaurants	640	77.4	1	0.6	0	0.0	0	0.0	0	0.0	641	78.0
6512	Commercial Buildings	1,593	318.6	796	477.6	318	477.0	0	0.0	0	0.0	2,707	1,273.2
6513	Multifamily Buildings	605	121.0	219	131.4	34	51.0	0	0.0	0	0.0	858	303.4
7011	Hotels	359	48.3	25	16.2	7	11.0	10	94.2	1	27.6	402	197.3
7211	Laundries	36	7.5	3	1.7	1	4.1	0	0.0	0	0.0	40	13.2
7374	Data Centers	96	14.4	8	5.2	10	15.2	2	21.2	0	0.0	116	56.0
7542	Car Washes	27	1.7	0	0.0	0	0.0	0	0.0	0	0.0	27	1.7
7832	Movie Theaters	2	0.4	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4
7991	Health Clubs	90	10.2	2	1.4	0	0.0	0	0.0	0	0.0	92	11.7
7997	Golf/Country Clubs	119	14.9	1	0.6	0	0.0	1	5.5	0	0.0	121	21.0
8051	Nursing Homes	285	51.2	14	9.4	0	0.0	0	0.0	0	0.0	299	60.6
8062	Hospitals	39	7.5	15	11.2	55	113.0	2	23.1	0	0.0	111	154.8
8211	Schools*	800	70.8	0	0.0	4	4.9	0	0.0	0	0.0	804	75.7
8221	College/Universities	39	6.6	11	7.5	15	20.8	1	5.8	0	0.0	66	40.7
8412	Museums	7	1.2	0	0.0	0	0.0	0	0.0	0	0.0	7	1.2
9100	Government Buildings	522	77.8	57	40.8	28	49.2	3	20.7	0	0.0	610	188.6
9223	Prisons*	11	2.4	6	4.4	14	35.9	7	46.9	0	0.0	38	89.6
Total		**6,567**	**1,046.5**	**1,189**	**729.9**	**497**	**800.7**	**27**	**229.8**	**1**	**27.6**	**8,281**	**2,834.5**

TABLE 8: TECHNICAL MARKET POTENTIAL FOR INDUSTRIAL CHP

SIC	Application	50-500 kW Sites	50-500 kW MW	500-1 MW Sites	500-1 MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
20	Food	284	44.9	48	34.4	37	67.6	3	26.3	1	35.8	373	209.0
22	Textiles	95	13.5	12	8.9	2	2.2	0	0.0	0	0.0	109	24.7
24	Lumber and Wood	54	6.1	2	1.8	3	8.3	0	0.0	0	0.0	59	16.2
25	Furniture	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	2	0.1
26	Paper	138	27.8	34	25.9	25	51.2	8	69.2	0	0.0	205	174.0
27	Printing	19	3.1	2	1.6	2	2.0	0	0.0	0	0.0	23	6.7
28	Chemicals	430	83.1	85	59.7	146	308.5	40	396.5	7	265.7	708	1,113.5
29	Petroleum Refining	36	6.1	8	5.4	6	11.8	1	8.3	1	26.3	52	57.8
30	Rubber/Misc. Plastics	187	28.5	7	4.2	4	8.9	1	5.8	0	0.0	199	47.4
32	Stone/Clay/Glass	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2
33	Primary Metals	28	5.4	5	3.4	4	8.5	2	28.1	0	0.0	39	45.5
34	Fabricated Metals	48	4.6	0	0.0	0	0.0	0	0.0	0	0.0	48	4.6
35	Machinery/Computer Equip	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
37	Transportation Equip.	28	4.4	1	0.9	2	3.0	0	0.0	0	0.0	31	8.3
38	Instruments	8	2.0	0	0.0	0	0.0	0	0.0	0	0.0	8	2.0
39	Misc. Manufacturing	25	3.1	1	0.5	0	0.0	0	0.0	0	0.0	26	3.7
	Total	**1,383**	**232.9**	**205**	**146.7**	**231**	**471.8**	**55**	**534.3**	**9**	**327.8**	**1,883**	**1,713.5**

TABLE 9: TECHNICAL MARKET POTENTIAL FOR EXPORT CHP

SIC	Application	50-500 kW Sites	50-500 kW MW	500-1 MW Sites	500-1 MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
20	Food	0	0.0	0	0.0	37	6.8	2	8.7	2	47.0	41	62.5
24	Lumber and Wood	0	0.0	0	0.0	0	0.0	3	18.0	0	0.0	3	18.0
26	Paper	0	0.0	0	0.0	16	31.3	12	76.9	5	132.8	33	241.1
28	Chemicals	0	0.0	0	0.0	132	71.4	40	213.3	23	573.4	195	858.2
29	Petroleum Refining	0	0.0	0	0.0	3	5.1	3	12.8	2	243.5	8	261.4
	Total	**0**	**0.0**	**0**	**0.0**	**188**	**114.6**	**60**	**329.8**	**32**	**996.8**	**280**	**1,441.2**

8. MULTI-INCENTIVE CASE MARKET PENETRATION

A multi-Incentive case based on combining the $450/kW capital reduction program, 0% interest loan program and permit-by-rule measures was estimated using the technical market potential combined with current and expected economic conditions, regulatory policies, energy prices, and technology cost and performance characteristics.

FIGURE 13 shows the estimated market penetration showing the impact of implementing the ability to export electricity when economically viable and the impact of adding cooling as a heat load to CHP systems over a 20 year period. The figure shows that the total CHP market penetration for the multi-Incentive case including export is equal to 1,402 MW. This total CHP capacity is composed of two components: 1,023 MW for systems that provide power for on-site use and 379 MW for export of power to the grid. The combined on-site and export components represent actual total CHP generating capacity. The avoided electric cooling capacity is central station capacity that would have otherwise been needed to supply the air conditioning now provided by the CHP thermal recovery systems (totaling 80 MW).

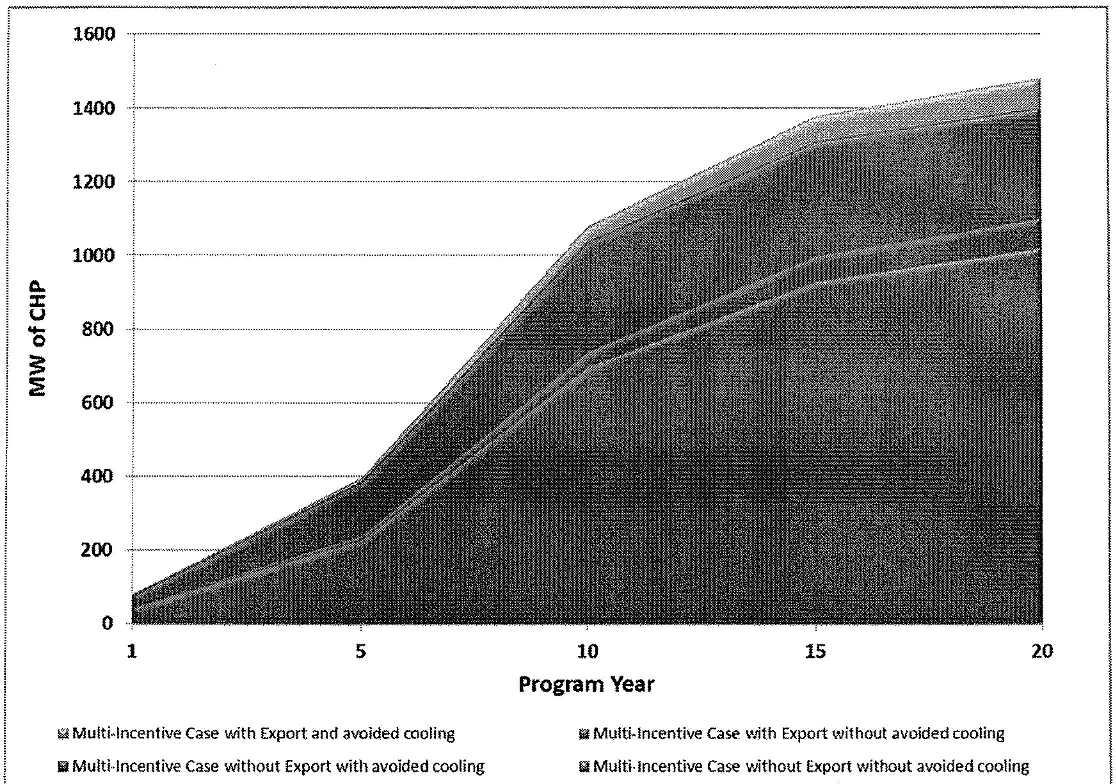

FIGURE 13: MULTI-INCENTIVE CASE CUMULATIVE MARKET PENETRATION BY MARKET TYPE
Source: ICF CHP Market Model

9. MARKET ANALYSIS UNDER ALTERNATIVE SCENARIOS

In order to achieve the benefits of higher CHP penetration it will be necessary for the state to support CHP implementation as well as address existing barriers. The study assessed seven state-based CHP incentive and/or regulatory changes that would significantly increase CHP installations in the State of New Jersey. These changes can be summarized as follows:

- **Capital Grant Program:** A capital cost reduction policy for efficient CHP has been in effect in NJ through a variety of programs. However many of these programs are currently suspended or difficult to access. The programs are generally funded with monies collected through dedicated funds such as a Societal Benefits Charge or other levy on electric rates and are paid to the developer of a CHP plant based on a dollar value per kW of plant capacity. This modeling assumed a $5 million cap on the capital reduction incentive and no limitation on installed capacity. The $450/kW case produces a 746 MW[21] (1,104 MW[22]) increase in total market penetration in the first 10 years.
- **Loan Guarantee:** This policy addresses the lack of suitable long term financing for CHP development. While the loan guarantee essentially is a zero cost option for the government, it can have significant impact on assisting the development of CHP through long-term amortization of development costs compared with the terms currently made available by commercial institutions. It also has some material effect on helping to reduce the cost of money. This case produces a 412 MW[21] (697 MW[22]) increase in total market penetration in the first 10 years.
- **0% Loan:** A qualified commercial, institutional, or industrial entity with end-use energy efficiency projects including CHP is eligible for interest-free loans and grants through the Clean Energy Solutions Capital Investment (CESCI) program. Due to the overwhelming demand and the availability of funding for the CESCI program, funds were depleted within months and the program is currently closed. A similar program without funding limitation is emulated by the model. This case produces an 490 MW[21] (804 MW[22]) increase in total market penetration in the first 10 years.
- **Permit-by-Rule regulation:** Currently CHP plants in NJ must undergo new source review. A long-term goal would be creating a NJ DEP "Permit by Rule" regulation in place that would apply to all CHP systems meeting the requisite EPA/DEP emissions requirements allowing substantial time and applications coat savings. This case produces a 42 MW[21] (709 MW[22]) increase in total market penetration in the first 10 years.
- **Carbon Emissions Reduction Credits:** Applying $20/ton CO_2 Credit for reduced emissions verses the EPA's eGRID sub-region average fossil emissions was assessed to understand the future potential of RGGI or Federal programs. This case produces a 565 MW[21] (913 MW[22]) increase in total market penetration in the first 10 years.
- **The "Multi-Incentive" Case:** This scenario is based on combining the $450/kW capital reduction program, 0% interest loan program and permit-by-rule measures. This scenario adds 974 MW[21] (1,374 MW[22]) in the first 10 years. Combining these measures provides an additional 8 to 11% increase over the three individual measures amounting to 45 MW[21] (42 MW[22]).
- **Export:** Export potential was developed based on power limited facilities. These facilities have large thermal loads that can be serviced by CHP systems; however, to meet these thermal loads excess electricity must be generated.

[21] This figure includes additional avoided cooling MW savings but does not include export potential

[22] This figure includes additional avoided cooling MW savings and includes export potential

Historically, CHP systems applied to these facilities were limited by the electric power requirements. In other words, the maximum power was generated by the CHP system designed not to export and all the CHP system thermal capacity was used to satisfy a portion of the thermal load, leaving the remainder to conventional means.

The deregulated environment provides an opportunity to provide electric power from CHP operating at these facilities to the grid. The export option modeled examines those facilities with high thermal loads, meets these thermal loads with the CHP systems and allows the excess electricity to be provided to the grid. The model uses the following PJM electric avoided costs:

Export Price $/kWh	2010-2014	2015-2019	2020-2024	2025-2029
New Jersey	$0.0872	$0.0943	$0.1012	$0.1021

These export prices were based on the PJM 2010-2013 capacity auctions and after that the Resource Pricing Model (RPM) net CONE (cost of new entry) prices for the Eastern region. This price track is meant to reflect the competitive price for new firm power generation. These export cases should be interpreted as the value of policy initiatives that provide CHP access to a long term competitive power generation market.

Figure 14 presents the time phased view of all scenarios and Figure 15 focuses on the multiple program case consisting of a $450 capital incentive capped at $5,000,000 per project and/or site, plus a 0% interest loan program and creating a permit-by-rule siting program.

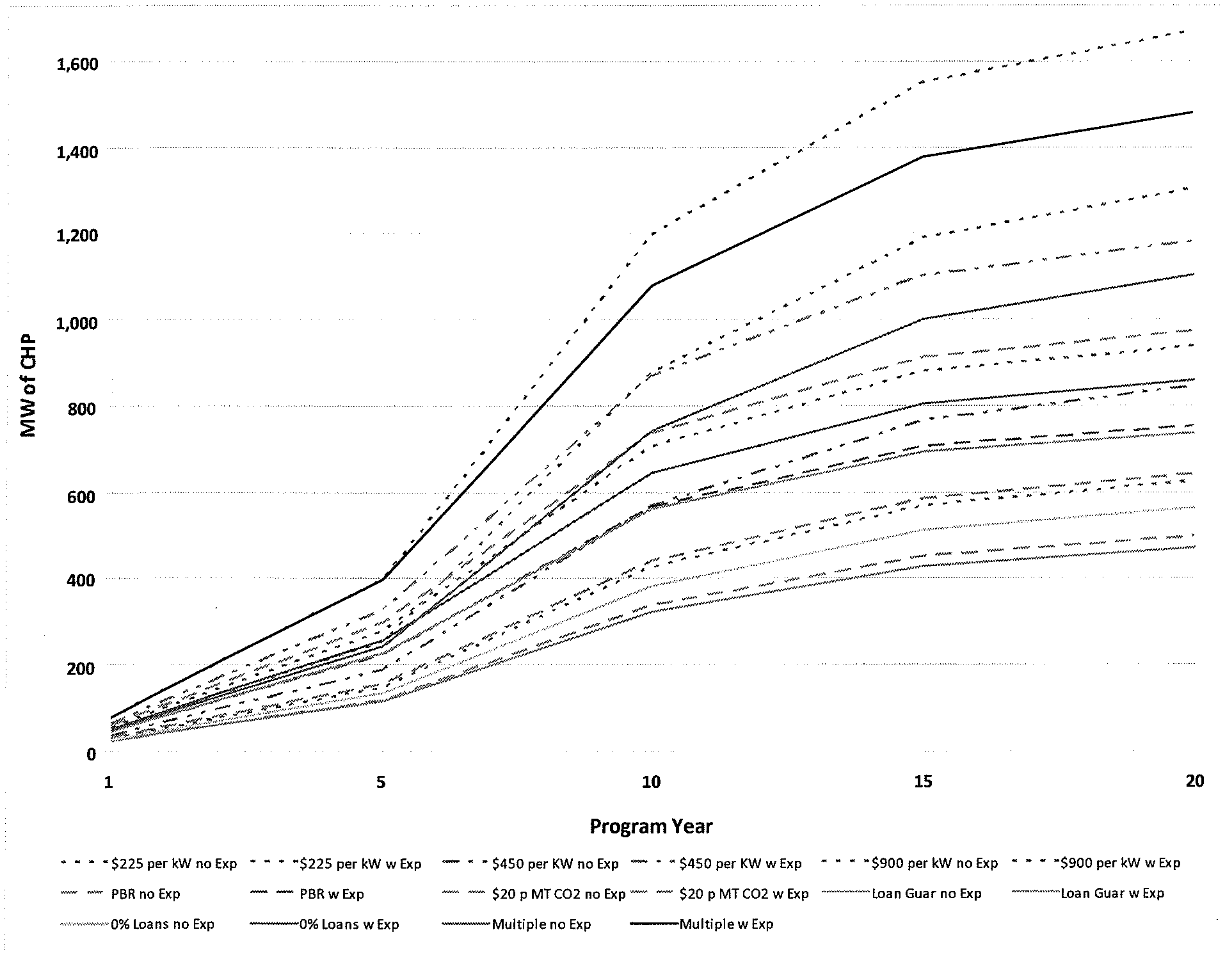

FIGURE 14: INCENTIVE CASES CUMULATIVE MARKET PENETRATION RESULTS
Source: ICF CHP Market Model

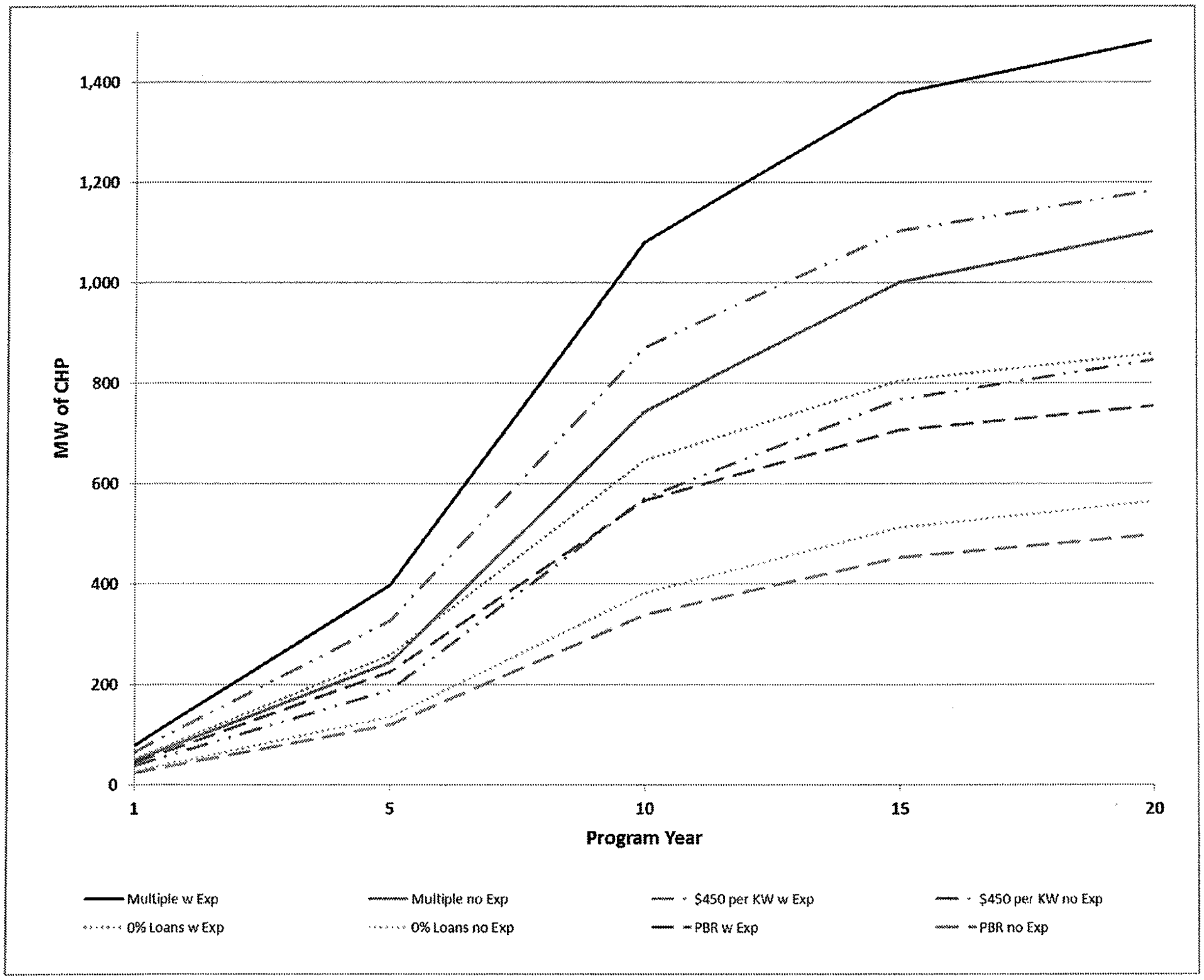

FIGURE 15: MULTIPLE INCENTIVE CASES CUMULATIVE MARKET PENETRATION RESULTS
Source: ICF CHP Market Model

9A. CHP Portfolio Standard with Alternative Compliance Payment

Subsequent to the initial publication of this report an alternative approach to stimulating the long term development of CHP was considered and is presented in this section. This market based approach considers the implementation of a CHP Portfolio Standard with an associated Alternative Energy Credit (AEC). The AEC is configured in two ways; a $20 credit per MWh for the first 12 years of system operation or a $40 credit per MWh for the first 7 years of operation. The credits would be bought or generated by the NJ utilities in the same method as that now used to trade Solar REC's and the cost would be offset by negating transmission and distribution costs as well as reducing power demand at the pricing node. After the credit period is ended no further payments would be made as the total value of the credits throughout the payment period is considered to provide sufficient income to the developer to cover the percentage of capital cost reduction necessary to stimulate the project's development.

Figure 16 shows the estimated market penetration due to the two levels of AEC for both non-export and export scenarios over the 20 year model period. The figures incorporate the avoided central station electric capacity that would have otherwise been needed to supply the air conditioning now provided by the CHP thermal recovery systems (this amounts to 96 MW for the $40 AEC with export over the 20 year period).The model demonstrates that over a 10-year period the $40 AEC case with export and cooling would amount to 1,305 MW. Combining the Portfolio Standard with AEC approach with other non-grant measures would work synergistically to encourage even higher CHP adoption rates.

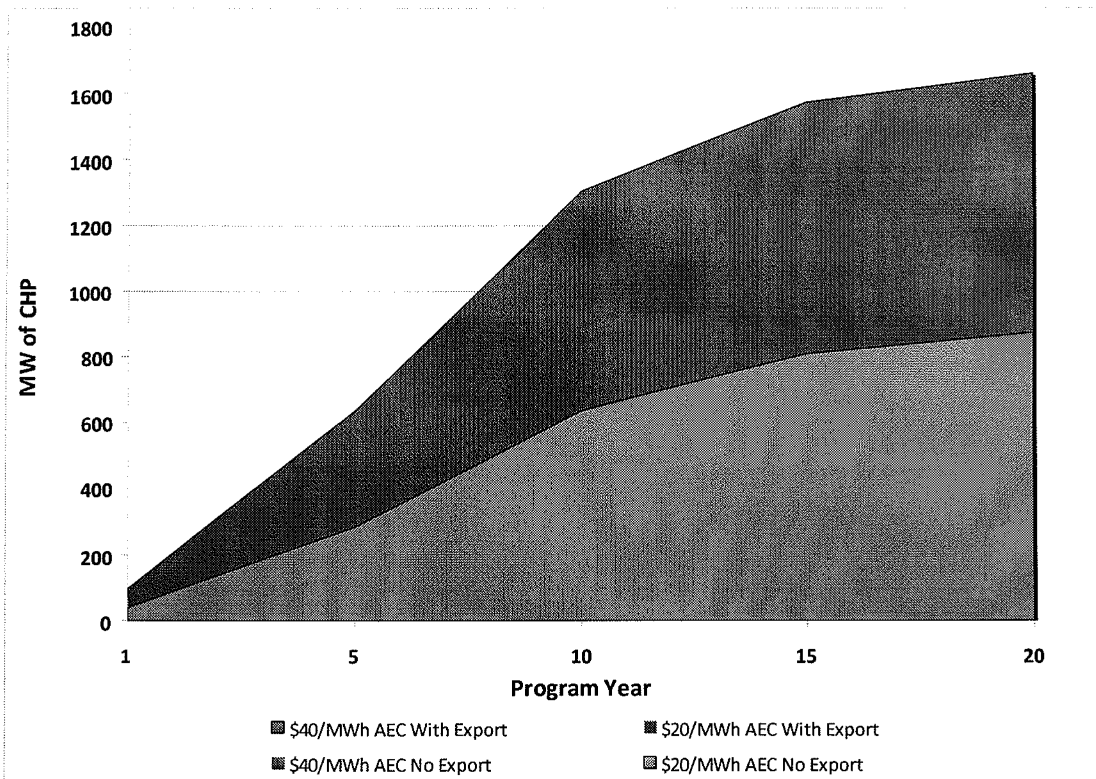

FIGURE 16: PORTFOLIO CASE CUMULATIVE MARKET PENETRATION BY AEC TYPE
Source: ICF CHP Market Model

10. AREAS UNDER REVIEW

It should be noted that the average system installation cost or 'Total Capital Cost' (Table 10) of the model penetration results is heavily weighted toward larger installations because this is where the bulk of the capacity additions are, so this drives down the overall average costs. This may also be distorting the numbers a bit in comparison to expected values.

TABLE 10: 2010-2014 PERIOD CAPITAL COSTS ($ PER KW)

Modeled Size	40 MW Turbine	5 MW IC	10 MW Turbine	IC 3 MW	IC 800 kW	IC 100 kW
Size Range	>20 MW	5-20 MW	5-20 MW	1-5 MW	0.5 – 1 MW	50 - 500 kW
Base Technology Cost	$972	$1,130	$1,298	$1,200	$1,640	$2,210
Early Market Multiplier	5%	5%	5%	10%	20%	20%
Early Market Cost	$1,021	$1,187	$1,363	$1,320	$1,968	$2,652
Federal Tax Credit	$38	$119	$136	$132	$197	$265
After Treatment	$90	$150	$140	$200	$300	$0[23]
Regional Multiplier	10%	10%	10%	10%	10%	10%
Total Capital	$1,222	$1,470	$1,653	$1,672	$2,495	$2,917
Capital - Fed ITC	$1,180	$1,340	$1,503	$1,527	$2,278	$2,625

The values shown in Table 10 generally represent installed costs for installations where space is readily available and utility interconnections (thermal and electrical) are at the CHP plant location. Some compensation was made in the model to the gross market acceptance curve to adjust penetration to reflect less than ideal installation applications (likely to lead to increased capital costs). While ICF believes their CHP costs are within reason for NJ, a future review of installation costs will be undertaken and is anticipated to result in a somewhat higher number than those reflected in this study.

The cost reductions in the out years as reflected in Table 4 are a combination of comparison technology improvements based on ongoing research and development activities (ARES[24], etc.) and the eventual elimination of the 10 to 20 % early market multiplier (the percentage varies by technology and size). These ICF assumptions are considered to be aggressive with respect to cost reduction, particularly given that technology improvements such as ARES have already been fully developed and future expectations for similar cost/efficiency improvements are unlikely. The 10% Federal Investment Tax Credit will have expired by 2025 and is not included.

Figure 17 shows the ICF capital cost curves (orange squares) falling within a reasonable range of similar data from DOE's Energy Information Agency (EIA) (orange Xs) and a CHP expert's low capital cost installations (JAC blue line) and high capital cost installations (JAC pink line) assessments. The difference between the low and high capital cost lines are principally the difference between a simple installation and a complex installation.

[23] It is assumed that a 3-way catalyst is already included in the base technology cost.
[24] ARES is the Department of Energy's Advanced Reciprocating Engine System program.

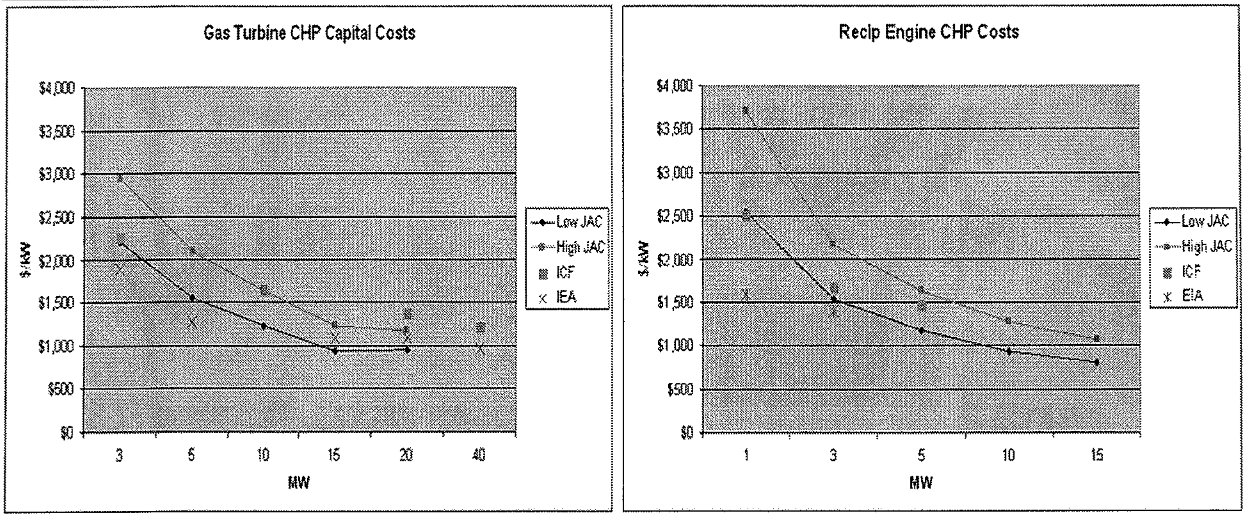

FIGURE 17: ICF PROFFERED CHP COST CURVES

TABLE 11: 2025-2029 PERIOD CAPITAL COSTS ($ PER KW)

Modeled Size	40 MW Turbine	5 MW IC	10 MW Turbine	IC 3 MW	IC 800 kW	IC 100 kW
Size Range	>20 MW	5-20 MW	5-20 MW	1-5 MW	0.5 – 1 MW	50 - 500 kW
Base Technology Cost	$916	$1,038	$1,143	$1,041	$1,246	$1,568
Early Market Multiplier	0%	0%	0%	0%	0%	0%
Early Market Cost	$916	$1,038	$1,143	$1,041	$1,246	$1,568
After Treatment	40	80	100	100	140	0
Regional Multiplier	10%	10%	10%	10%	10%	10%
Total Capital	$1,052	$1,230	$1,368	$1,255	$1,525	$1,725

While the values used in the model are regarded to be low, they are within an acceptable uncertainty range for New Jersey at this stage of the analysis. As mentioned above, ICF is in the process of reviewing and updating system cost and performance data.

The second area in need of review is NJ's initial desire not to restrict the capital cost reduction incentive by MW capacity or absolute value. Incentivizing large CHP projects based on providing a stipulated dollar rebate per kW for the entire project may not be the best use of state funds. Implementing a limit such as incentivizing only the first 5 MW of capacity would increase leveraging of state/public benefit funds. This approach has been adopted in the rebate policy program tested by the model.

It should be noted that large CHP systems ≥ 25 MW are subject to RGGI[25] and as such have an additional operating cost of carbon emissions allowances. As of January 1, 2009, sources ≥ 25 MW are required to possess CO_2 allowances equal to their CO_2 emissions over a three-year control period. The first three-year control period took effect on January 1, 2009 and extends through December 31, 2011. The June 2010 allowance auction valued a short ton of CO_2 emitted at $1.86. While this 'cost of carbon' has a very slight effect on market adoption of CHP, this may change with a growing economy or implementation of a Federal cap and trade policy.

APPENDIX A: BACKGROUND DATA FOR FIGURE 1

[25] The Regional Greenhouse Gas Initiative (RGGI) is the first mandatory, market-based effort in the United States to reduce greenhouse gas emissions. Ten Northeastern and Mid-Atlantic states have capped and will reduce CO_2 emissions from the power sector 10% by 2018.

Small CHP Cost to Generate Power Estimator

Operating Assumptions	
CHP Electric Efficiency, %	28.4%
CHP Power to Heat Ratio	0.56
CHP Fuel, Btu/kWh	12,014
CHP Thermal Output, Btu/kWh	6,093
CHP Efficiency	79.1%
Displaced Boiler Efficiency	80.0%
CHP Thermal Utilization, %	80.0%
Incremental CHP O&M Costs, $/kWh	$0.0220
CHP Fuel Cost, $/MMBtu	$8.35
Displaced Boiler Fuel Cost, $/MMBtu	$8.93
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.1003
Thermal Credit, $/kWh	($0.0544)
Incremental O&M, $/kWh	$0.0220
Operating Costs to Generate Power, $/kWh	***$0.0679***
Capital Cost	
Installed CHP System Cost, $/kW	$2,500
Operating Hours	5,500
Equipment Life, Yrs	15
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0598
Total Costs to Generate Power, $/kWh	***$0.1276***

Medium CHP Cost to Generate Power Estimator

Operating Assumptions	
CHP Electric Efficiency, %	36.0%
CHP Power to Heat Ratio	0.97
CHP Fuel, Btu/kWh	9,478
CHP Thermal Output, Btu/kWh	3,518
CHP Efficiency	73.1%
Displaced Boiler Efficiency	80.0%
CHP Thermal Utilization, %	80.0%
Incremental CHP O&M Costs, $/kWh	$0.0100
CHP Fuel Cost, $/MMBtu	$8.35
Displaced Boiler Fuel Cost, $/MMBtu	$8.93
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.0791
Thermal Credit, $/kWh	($0.0314)
Incremental O&M, $/kWh	$0.0100
Operating Costs to Generate Power, $/kWh	***$0.0577***
Capital Cost	
Installed CHP System Cost, $/kW	$1,400
Operating Hours	7,000
Equipment Life, Yrs	15
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0263
Total Costs to Generate Power, $/kWh	***$0.0840***

Large CHP Cost to Generate Power Estimator

Operating Assumptions	
CHP Electric Efficiency, %	37.0%
CHP Power to Heat Ratio	1.07
CHP Fuel, Btu/kWh	9,222
CHP Thermal Output, Btu/kWh	3,189
CHP Efficiency	71.6%
Displaced Boiler Efficiency	80.0%
CHP Thermal Utilization, %	100.0%
Incremental CHP O&M Costs, $/kWh	$0.0040
CHP Fuel Cost, $/MMBtu	$8.35
Displaced Boiler Fuel Cost, $/MMBtu	$8.93
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.0770
Thermal Credit, $/kWh	($0.0356)
Incremental O&M, $/kWh	$0.0040
Operating Costs to Generate Power, $/kWh	***$0.0454***
Capital Cost	
Installed CHP System Cost, $/kW	$1,000
Operating Hours	8,000
Equipment Life, Yrs	20
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0147
Total Costs to Generate Power, $/kWh	***$0.0601***

Central Station Cost to Generate Power Estimator - Natural Gas CC

Operating Assumptions	
Electric Efficiency, %	47.0%
Fuel, Btu/kWh	7,260
Variable O&M Costs, $/kWh	$0.0021
Fixed O&M Costs, $/kW	$12.76
Fuel Cost, $/MMBtu	$6.32
Operating Cost to Generate	
Fuel Costs, $/kWh	$0.0459
Variable O&M Costs, $/kWh	$0.0021
Fixed O&M, $/kWh	$0.0036
Operating Costs to Generate Power, $/kWh	***$0.0516***
Capital Cost	
Installed Cost, $/kW	$984
Operating Hours	3,565
Equipment Life, Yrs	30
Cost of Capital, %	8.5%
Capital Charge, $/kWh	$0.0257
Total Costs to Generate Power, $/kWh	***$0.0772***

Central Station Cost to Generate Power Estimator - Coal

Operating Assumptions	
Electric Efficiency, %	37.0%
Fuel, Btu/kWh	9,222
Variable O&M Costs, $/kWh	$0.0047
Fixed O&M Costs, $/kW	$28.15
Fuel Cost, $/MMBtu	$4.21
Operating Cost to Generate	
Fuel Costs, $/kWh	$0.0388
Variable O&M Costs, $/kWh	$0.0047
Fixed O&M, $/kWh	$0.0045
Operating Costs to Generate Power, $/kWh	***$0.0480***
Capital Cost	
Installed Cost, $/kW	$2,231
Operating Hours	6,325
Equipment Life, Yrs	30
Cost of Capital, %	8.5%
Capital Charge, $/kWh	$0.0328
Total Costs to Generate Power, $/kWh	***$0.0808***

On Shore Wind

Operating Assumptions	
Load Factor	28.0%
Fuel, Btu/kWh	
Variable O&M Costs, $/kWh	$0.0110
Fixed O&M Costs, $/kW	
Fuel Cost, $/MMBtu	
Operating Cost to Generate	
Fuel Costs, $/kWh	
Variable O&M Costs, $/kWh	$0.0110
Fixed O&M, $/kWh	$0.0000
Operating Costs to Generate Power, $/kWh	***$0.0110***
Capital Cost	
Installed Cost, $/kW	$2,056
Operating Hours	2,453
Equipment Life, Yrs	30
Cost of Capital, %	8.5%
Capital Charge, $/kWh	$0.0780
Total Costs to Generate Power, $/kWh	***$0.0890***