MARYLAND
COMBINED HEAT AND POWER
MARKET ASSESSMENT

Prepared by:

US DOE Mid-Atlantic Clean Energy Application Center

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Policy Report

U.S. Department of Energy
Mid-Atlantic Clean Energy Application Center
Promoting CHP, District Energy, and Waste Heat Recovery

NOTICES AND ACKNOWLEDGEMENTS

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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 Maryland. It also assesses the impact of state incentives and rules changes on CHP and CCHP adoption rates, economic, environmental and employment impacts.

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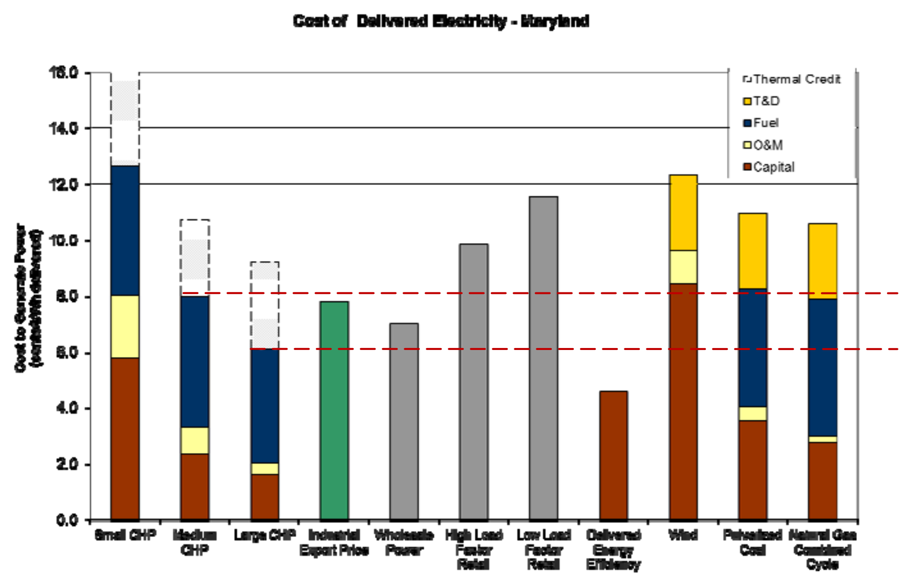
EXECUTIVE SUMMARY

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 Maryland.

CHP systems save energy by recovering heat during the power generation process and using it, on site, for heating, drying, cooling, refrigeration 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%[1] for several decades. CHP can achieve fuel use efficiency[2] 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 Maryland's competitiveness.

Energy Cost

The principle reason to consider providing policies and incentives supporting CHP in Maryland is that it is the lowest cost means of providing additional power generation, as demonstrated in Figure 1. Medium and large scale CHP[3] including the thermal credit[4] provides power at close to the wholesale power price from the grid, lower than new coal or natural gas central station power plants and lower than onshore wind and solar photovoltaic (PV) systems[5]. The conclusion from Figure 1 is that medium and large CHP is the least cost electricity supply side option for retail ratepayers in Maryland today.



Source: ICF for DOE

FIGURE 1: COST FOR ELECTRIC POWER PRODUCTION, SOURCE: ICF FOR DOE

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[1] Includes all extraction, conversion and delivery losses and is measures in Higher Heating Value.

[2] 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)

[3] CHP in large and medium sizes ≥ 1MW in capacity with HHV efficiency of 36% and 37% respectively and using natural gas priced at $7.40 per million Btu's.

[4] 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.

[5] Onshore wind has a production cost of 12.32¢/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.

Furthermore, the optimum loading order for marginal electricity production in Maryland, based on economic dispatch and without accounting for societal benefits, should be:

1. Energy efficiency first and foremost
2. Large CHP[6]
3. Grid existing wholesale electricity (not accessible for most consumers)
4. Large CHP Export[7]
5. Medium CHP[8]
6. Grid based power

From the above energy cost data, CHP would appear to be an important economic means of delivering electricity in Maryland. The additional societal benefits of lower emissions, grid stability and reduced transmission requirements offered by CHP provide further reasons to more fully exploit CHP as an in-state power supply resource.

The first question to understand is the current status of CHP in Maryland and then what are the societal economic, energy and environmental benefits that CHP could deliver to the citizens of Maryland.

Current Status of CHP in Maryland

If CHP is cost effective, then why is it not being widely exploited today in Maryland? The answer lies in studying Maryland energy history. Maryland's entire CHP installed base consists of only 20 sites totaling 828 MW. 697 MW are installed in five sites covering chemicals, pulp and paper, primary metals and solid waste-to-power facilities. Of the 828 MW installed, 557 MW of CHP was installed prior to 2000. This leaves only 272 MW of CHP installed in the past decade, with the last being installed in 2008.

The state of Maryland historically is viewed as a state that is disinterested in implementing CHP as an electricity supply option. The one positive regulation is the instituted PSC-approved standard interconnection rule for systems up to 10 MW in size. Baltimore Gas and Electric and Allegheny Power have implemented standby rates that are considered neutral to CHP.

The Maryland Energy Administration, in January of 2010, published Maryland's Energy Outlook (EO), which presents the state's current assessment of potential energy future strategies. The document presents CHP as energy technology that should be pursued in the following:

> *"State agencies should consider coordinated actions to enhance the economic viability of combined heat and power (CHP) systems. Such regulatory actions may include increasing the size range of generators that are covered by existing interconnection rules and instituting output-based emissions regulations to encourage clean distributed generation (DG) and CHP technologies.[9]"*

The EO further suggests two specific approaches to incentivize CHP focusing on either a capital cost reduction of some form of portfolio standard revision, as follows:

> *"Furthermore, the Governor and General Assembly could strive to revise Maryland's RPS to include CHP as an eligible technology."*

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[6] 40 MW was modeled

[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.

[8] 3 MW was modeled

[9] Maryland Energy Outlook, Maryland Energy Administration page 41, January 2010

"Maryland already has financial incentives for distributed renewable generation. The State should consider establishing new *financial incentives specifically for CHP deployment. New Jersey's CHP grants could be used as a model by providing a rebate for each kW of capacity installed in CHP facilities.*[10]*"*

Finally, the EO concludes CHP is important because of significant societal benefits and recommends further barrier removal. However, because CHP is dependent on the cost of natural gas and electricity, the EO concludes that financial assistance is not justifiable at this time. (see below)

"MEA, in conjunction with other relevant State agencies, should consider presenting a case to the PSC regarding further regulatory actions to enhance the economic viability of combined heat and power (CHP) systems. However, MEA does not believe that devoting significant financial resources to support such installations, such as grants or other financial assistance is justifiable at this time.

Rationale: CHP applications are integrated systems that generate both electricity and thermal energy. These systems are significantly more efficient than separate systems for electricity and thermal energy generation and promise significant benefits in the form of energy efficiency and lower GHG emissions.

The State's regulatory agencies should pursue further actions to remove barriers for CHP technology implementation. Potential options include increasing the size range of generators that are covered by existing interconnection rules and instituting output-based emissions regulations to encourage clean distributed generation technologies. However, the economic viability of CHP projects is mainly dictated by the relative cost of natural gas and electricity. As a result, MEA does not believe that devoting significant resources in support of such installations in the form of grants or other financial assistance is justifiable at this time.[11]*"*

Benefits to the State of Maryland for Supporting CHP

Figure 1 provides a strong macroeconomic reason to support CHP as a means to lower the marginal cost[12] of power to the direct user and also the grid at large by reducing the need to add new electric generation capacity or purchase high cost peak power. Successfully encouraging the in-state development of CHP can permanently forego the need to build new power plants and transmission and distribution infrastructure. This will lead to a more business friendly atmosphere while also reducing emissions and creating or retaining jobs.

Table 1 shows the CHP installations that would result from implementation of a series of supportive measures described in this report, the cost to the state and the private funds leveraged. Table 1 also provides the consequential potential primary energy savings of 5.1 – 13.5 Trillion Btu/year, CO_2 reductions of 13.3– 31 million short tons over 20 years and the direct creation of 148 – 285 construction jobs. This does not take into account the potential retention of 1,000s of jobs by lowering energy prices.

[10] Maryland Energy Outlook, Maryland Energy Administration page 41, January 2010
[11] Maryland Energy Outlook, Maryland Energy Administration page 43, January 2010
[12] 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.

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
Scenario #1 $450/kW Capital incentive[13]						
10 Year Summary no Export[14]	309	3.6	$197	$105	3.7	97
10 Year Summary with Export	508	6.5	$306	$183	7.4	109
20 Year Summary no Export	459	5.1	$307	$151	13.3	148
20 Year Summary with Export	693	8.4	$426	$238	24.1	214
Scenario #2 Multiple Measures 1: consisting of a $450/kW Capital incentive, 0% economic development loan and permit by rule regulation[15]						
10 Year Summary no Export	426	6	$245	$169	5	134
10 Year Summary with Export	674	10.7	$364	$281	9.6	208
20 Year Summary no Export	631	8.4	$386	$246	17.8	204
20 Year Summary with Export	903	13.5	$515	$369	31.4	285
Scenario #3 $10/MW/hr AEC[16]						
10 Year Summary no Export	262	2.5	$265	$0	3.2	86
10 Year Summary with Export	426	4.3	$421	$0	6.2	135
20 Year Summary no Export	386	3.5	$496	$0	11.2	131
20 Year Summary with Export	572	5.4	$576	$0	20.6	186
Scenario #4 Multiple Measures 2: consisting of a $10/MW/hr AEC[17], 0% economic development loan and permit by rule regulation						
10 Year Summary no Export	358	4.3	$338	$5	4.1	115
10 Year Summary with Export	556	7.3	$512	$9	7.8	174
20 Year Summary no Export	504	6	$518	$8	14.7	175
20 Year Summary with Export	728	9.2	$708	$12	25.6	240

Conclusion

While we agree on the benefits to Maryland of implementing CHP, the Mid-Atlantic Clean Energy Application Center, based on its work in the region and its in-depth understanding of CHP efforts in other states, does lead to different conclusions with respect to the current economic viability of CHP from those derived by the Maryland Energy Outlook. With poor performance over the last decade and no CHP installations in the past two years despite relatively low natural gas prices, it is clear that there are not sufficient market signals to develop CHP and as a result, there are few CHP project developers in the state[18]. In order to fully exploit the advantages offered by CHP, a more proactive approach needs to be taken that recognizes the societal benefits provided by CHP. In addition, continued electric power demand growth (expected to continue as we pull out of recession) and impending coal plant retirements will force Maryland

[13] See Results section for details
[14] 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.
[15] See Results section for details
[16] See Results section for details
[17] See Results section for details
[18] Utility based ESCOs appear to be successful with federal agencies trying to meet energy efficiency and GHG goals dictated by Congress and the Center is aware of one large (140 MW) solid waste to energy plant proposed for Baltimore

to rely on more expensive methods of power generation and delivery or curtail usage if it cannot stimulate significant CHP development.

Positive and sustained signals from the Maryland government are required to move the industry forward and overcome a decade of poor market performance by removing remaining regulatory barriers, properly incentivizing CHP and stabilizing the policy environment. The government needs to account for the economic, environmental and job benefits offered by CHP and share these with CHP developers.

CHP addresses energy issues important to Maryland by lowering consumer power costs, increasing power reliability, creating jobs and stimulating 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. This report identifies that implementation of state level programs and policies to incentivize CHP and removal of existing barriers to the implementation of CHP will result in a significant increase in the development of CHP plants within the state. This 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 Maryland 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 resulting ultimately in significantly higher energy costs for consumers.

Table 1 provides four possible scenarios supporting CHP in Maryland to create a more robust market that would allow the state obtain the energy, GHG and other societal benefits delineated in the table. The first two scenarios are largely centered on a capital cost reduction incentive combined with other non-grant supportive policies designed to jump start the industry. The latter two scenarios focus on the creation of a CHP Alternative Energy Credit (AEC) patterned after the Solar Renewable Energy Credit (SREC) concept.

The fundamental difference between these two approaches deals with the source of incentive support. The capital reduction approach requires state budgeting while the AEC approach uses the same auction mechanism as SRECs. While the capital reduction program requires state funds which would normally be derived from a rate or tax based fund, it is expected to result in significantly faster market development. The AEC program which is coupled with a utility paid alternative compliance payment of $10/MWh does not rely on a 'grant fund'. The AEC cost would ultimately be borne by the rate payer. The burden to the rate payer is lower per year but over a longer period. However, the cost of the AEC would potentially be offset by the impact CHP would have on lowering the grid based rate for all rate payers served by the grid due to a reduction in demand.

Figure 2 shows the Historic Auction prices for Solar Renewable Energy Credits (SRECs). In Maryland, SRECs are currently traded at $325/MWh. Solar generators located in Maryland registered with SRECTrade as of May 31st, 2010 amount to 6.25 MW.

Maryland should and must aggressively pursue all forms clean renewable energy including solar photovoltaic, solar thermal, wind and biomass as part of a solid energy plan for the future. This future should also include a focus on energy efficiency and also clean CHP. In this context, the proposed CHP AEC at $10/MWh is under 3% of the SREC incentive and would add between 262 to 426[19] MW in new capacity over 10 years should find its place in the energy portfolio.

[19] 262 MW is without export and 426 is with export

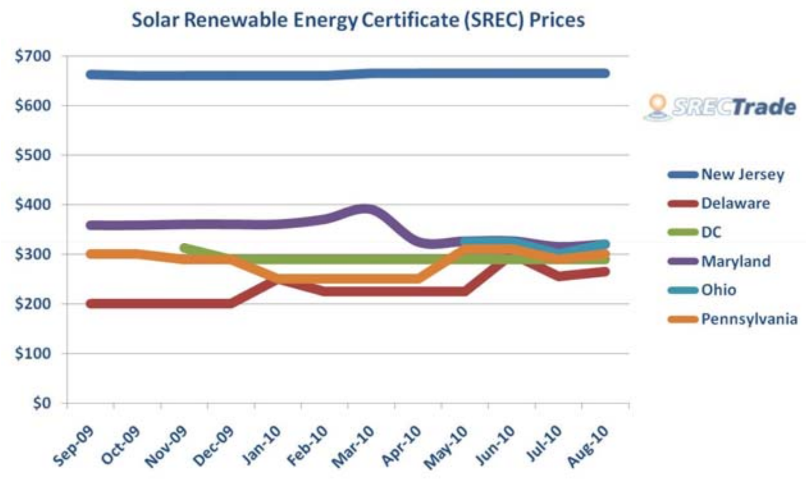


FIGURE 2 SRECTRADE'S HISTORICAL AUCTION PROCES

In order to meet short term power demand needs due to growing consumer demand coupled with coal plant retirements, a mixture of capital reduction program and AEC are suggested. As the industry gains traction, the capital reduction program can be slowly removed as the AEC gains traction. The state PSC will have the authority to increase the AEC portfolio to increase or decrease its stimulating effects.

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[20]) emissions in support of the Maryland 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 Maryland
- Estimate of technical potential for CHP in Maryland
- Base case market analysis
- 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.

[20] 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%.

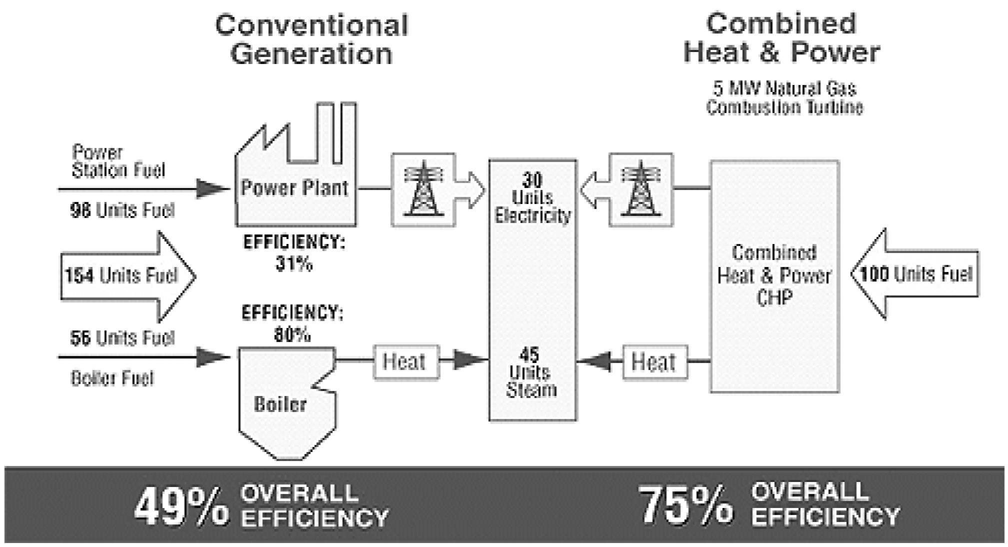


FIGURE 3: SEPARATE HEAT AND POWER VERSUS CHP – PRIMARY ENERGY [21]

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 3 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 4 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 4 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 fuel-fired power plant (emissions based on the U.S. fossil mix) and a natural gas-fired boiler; and (2) a 5

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

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.

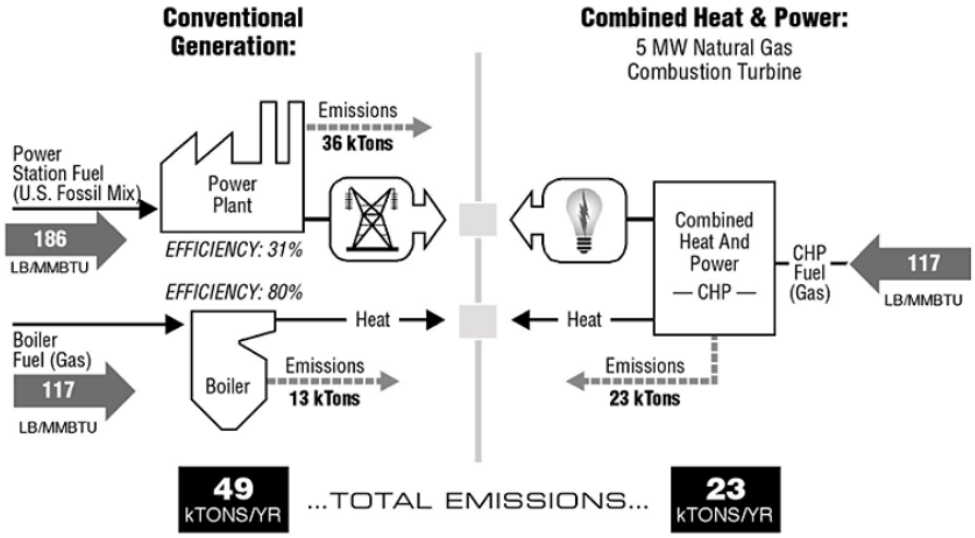
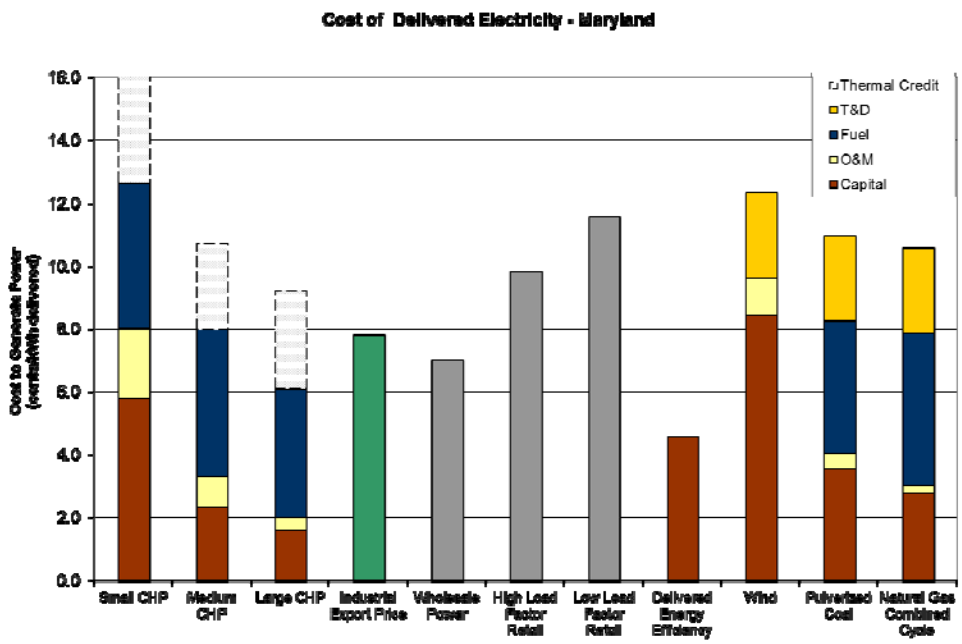


FIGURE 4: SEPARATE HEAT AND POWER VERSUS CHP – CO_2 EMISSIONS [22]

[22] 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[23] 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 5: COST FOR ELECTRIC POWER PRODUCTION

Figure 5[24] 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 6.1¢ to 7.9¢/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.[25]

Figure 5 provides a compelling direct financial reason to promote CHP in Maryland 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 pricing by

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

[24] 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 and DOE.. 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.

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

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

Efficiently lowering the cost of electricity for all Maryland 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[26] of capital investment. Investing in CHP could yield between 115 and 285 new construction/operations jobs that would last over the course of the program. Furthermore, Maryland's industrial base is at risk due to high energy prices and global competition. CHP's power to reduce energy cost and future risk could literally save 1,000s important manufacture jobs in the state.

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

[26] 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

DR. CARL SAGAN REMINDS US THAT "YOU HAVE TO KNOW THE PAST TO UNDERSTAND THE PRESENT." TO UNDERSTAND THE CURRENT SITUATION WITH CHP IN MARYLAND, IT IS IMPORTANT TO UNDERSTAND THE HISTORY OF CHP IN MARYLAND. THE HISTORICAL INSTALLED BASE FOR CHP AND CCHP SYSTEMS IN MARYLAND IS PRESENTED IN

Table 1 of Figure 6. The installed base (Table 2) consists of only 20 sites totaling 828 MW.[27] In fact, Sweetheart Cup's production in Maryland has closed removing 15 MW of capacity from current production.

TABLE 2 MARYLAND INSTALLED CHP DATABASE

Facility Name	Application	Prime Mover	Capacity (MW)	Fuel Type
Pennwood Power Station	Primary Metals	B/ST	152	Waste
U.S. Navy Surface Warefare Center	Military/National Security	B/ST	10	Coal
American Sugar Div. Of Amstar Corp.	Food Processing	B/ST	18	NG
Westvaco Luke Mill	Pulp and Paper	B/ST	60	Coal
Pennwood Power Station	Primary Metals	B/ST	3	Other
Southwest Resource Recovery Facility	Solid Waste Facilities	B/ST	65	WAST
Waste Energy Partners LP	Military/National Security	B/ST	1	Waste
Brown Station Rd / County	Justice/ Public Order	ERENG	4	Biomass
Eastern Correctional Institute	Justice/ Public Order	B/ST	4	Wood
Brandywine Commerce Center	Chemicals	B/ST	240	NG
Millennium Inorganic Chemicals	Chemicals	CC	11	NG
Warrior Run CO_2 Production Project	Chemicals	B/ST	180	Coal
Sweetheart Cup	Pulp and Paper	CC	15	NG
University of Maryland	Colleges/Univ.	CT	27	NG
Aberdeen Proving Ground	Military/National Security	B/ST	1	Oil
Trigen Inner Harbor East	Wholesale Trade	ERENG	2	NG
National Institute of Health Central Utility Plant	General Gov't	CT	23	NG
FDA White Oak Facility	General Gov't	ERENG	6	NG
Back River Wastewater Treatment Plant	Wastewater Treatment	ERENG	3	Biomass
White Oaks	General Gov't	CT	4	NG

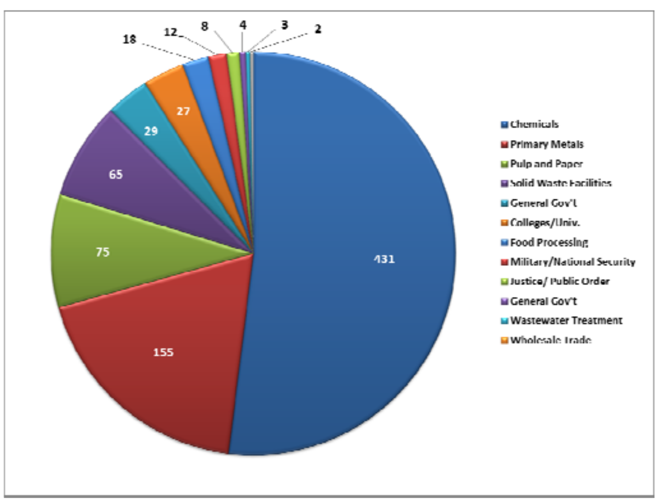

FIGURE 6: CURRENT MARYLAND INSTALLED CHP BASE IN MW BY APPLICATION

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

Figure 6 shows the installed CHP capacity by application with the following major areas:

- Chemicals 431 MW
- Primary Metals, 155 MW
- Pulp and Paper 75 MW (less 15 MW Sweetheart Cup currently offline yields 60 MW)
- Solid Waste Facilities 65 MW
- General Government 29 MW and
- Colleges/Universities 27 MW.

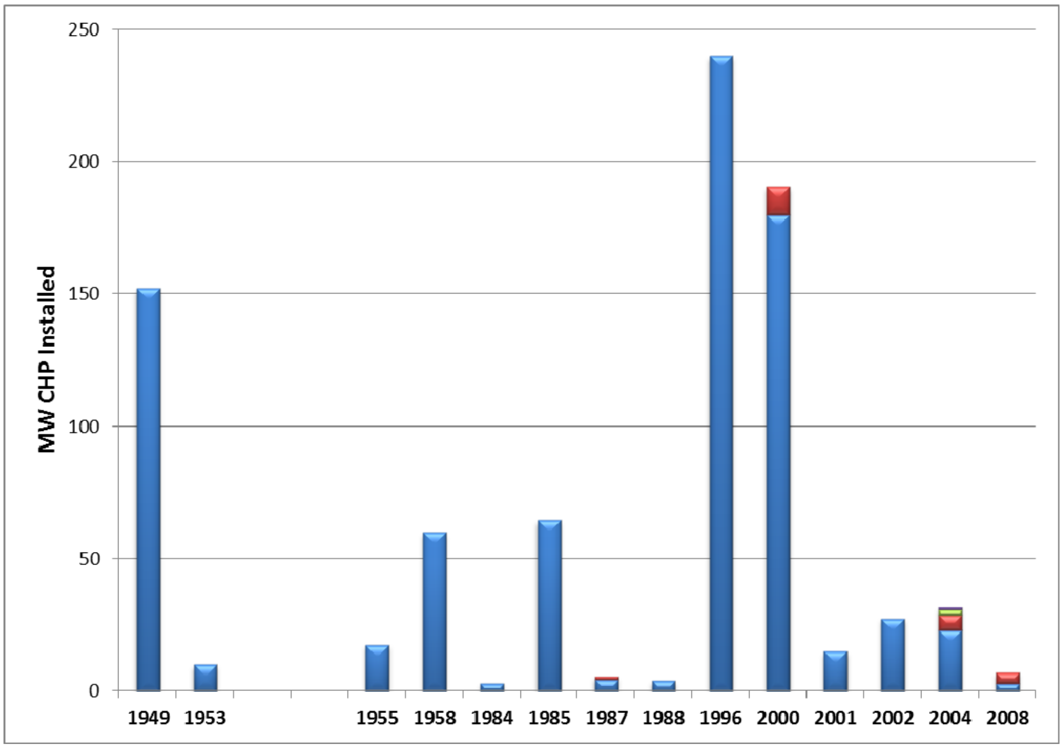

FIGURE 7 CURRENT MARYLAND INSTALLED CHP BASE IN MW BY YEAR

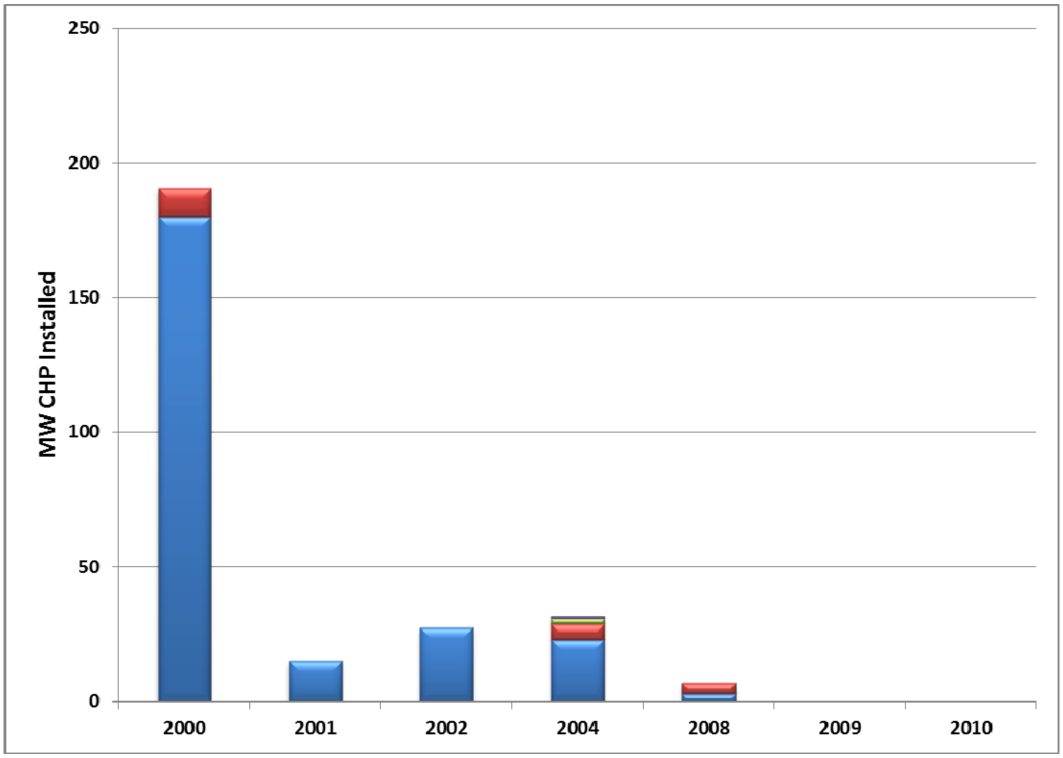

FIGURE 8 CURRENT MARYLAND INSTALLED CHP BASE IN MW BY YEAR 2000 AND LATER

Finally, examining Figure 7 and 8 in combination with the rest of the installation information, shows there are several significant conclusions that can be reached:

1. Prior to 2000, 557 MW of CHP was installed
2. PURPA[28] seems to have little or no effect on CHP in Maryland leading to the conclusion that other factors were dominant
3. Since 2000, 272 MW of CHP was installed
4. Since 2000, 180 MW of this capacity was for a coal fired CO_2 production chemical plant
5. Since 2000, 33 MW was installed in federal facilities influenced by legislation regarding energy efficiency and GHG emissions reductions
6. Since 2000, 27 MW was for the University of Maryland's CHP plant
7. Since 2000, 15 MW was for Sweetheart Cup which is offline
8. No CHP has been installed in Maryland in 2009 or 2010

[28] 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 . 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.

CHP installations in Maryland in the past decade were not influenced by energy price (spark spread) but by external factors. The largest CHP site was installed to produce CO_2 for chemical purposes and the fuel used was coal because it is a large source of CO_2 and CHP was chosen to improve operating economics. The second largest application area was the federal government where facilities are required to economically improve energy efficiency and reduce GHGs. The third largest site was the University of Maryland, College Park campus with the desire to economically improve energy efficiency and reduce GHGs. The single largest manufacturing facility , Sweetheart Cup at 15 MW, ultimately could not compete in today's market.

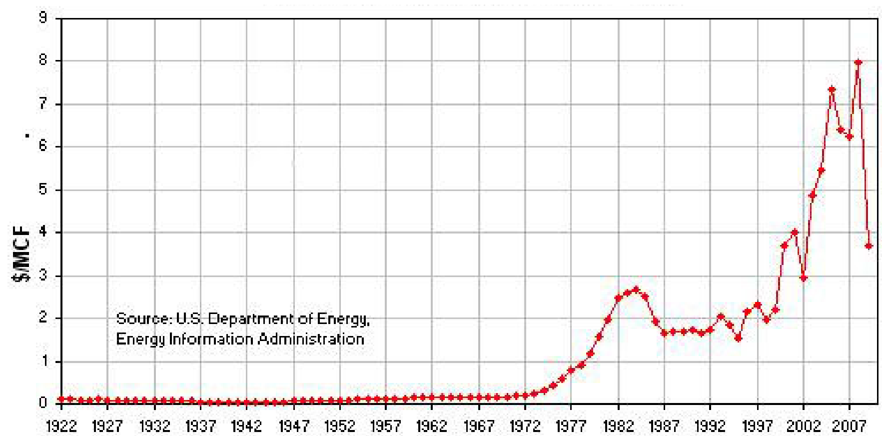

FIGURE 9: WELLHEAD NATURAL GAS PRICE SINCE 1922

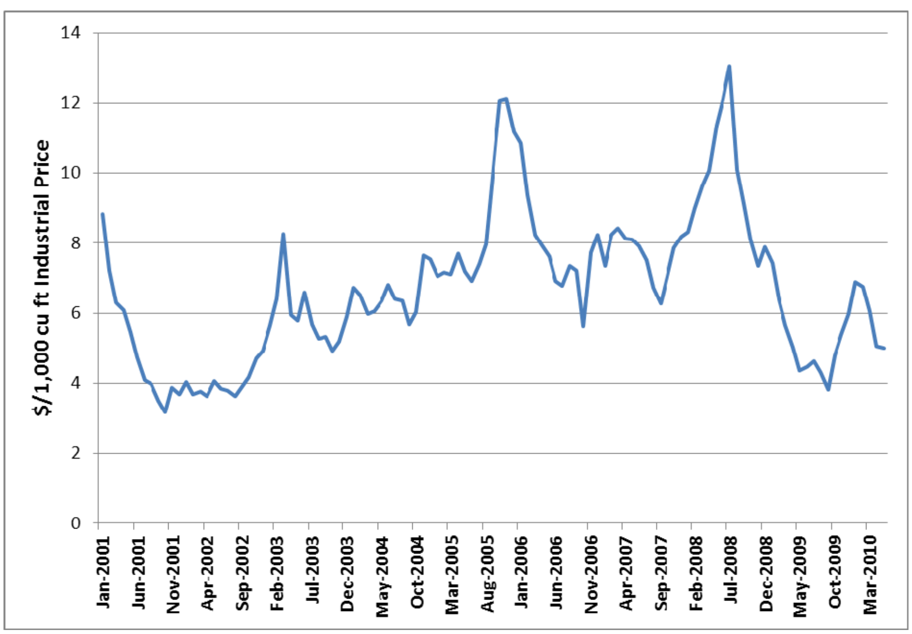

FIGURE 10: INDUSTRIAL NATURAL GAS PRICING (EIA)

The current market situation is that the Maryland Public Service Commission (PSC) provides no financial incentives for CHP. No utility programs are offered for CHP. As shown in Figures 9 and 10, except for two hurricane related spikes, 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 PSC is seeking input for the second phase of EMPOWER Maryland.

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, Maryland 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[29] 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 3. A breakout of assumptions and a more detailed review of the input data and results are provided in the following sections.

TABLE 3: ICF CHP MARKET MODEL

Forecast Periods	**2014, 2019, 2024, 2029**
Market Segmentation: Policies	$225, $450 & $900 / kW Capital Cost Rebate
	$10/MWh AEC
	0% Interest Loan
	Permit by Rule
	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

[29] 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 MWs of CHP installed as a result of implementing these measures. Figure 11 provides an overarching assessment of the 10-year potential to stimulate adoption of CHP systems in Maryland through the various measures as well as the theoretical base case for the period. Figure 12 provides an overarching assessment of the 20-year potential to stimulate adoption of CHP systems in MARYLAND through implementation of these same measures as well as the theoretical base case for the period.

The maximum penetration for any single initiative is through a $900/kW capital cost reduction which would add 1,449 MW over 20 years (with export). The 'Multiple Measures 1' scenario examines the impact of a $450/kW capital investment incentive, 0% interest economic development loan and permit by rule combined scenario over 20 years (with export and avoided cooling). The Multiple Measures scenario would result in:

1. 903 MW of CHP being implemented in Maryland
2. Annual Primary Energy Savings of 51,700 billion Btu/year
3. Total investment to public investment leveraging of incentive funds by about 2.4 to 1
4. Annually reducing CO_2 emissions by 2,330,000 MT at a 20 year cumulative cost to the state of $12/MT
5. Increasing employment in the state by 285 construction/operations jobs and 1,000s of industrial jobs.

The maximum penetration for any single initiative is through a $900/kW capital cost reduction which would add 1,449 MW over 20 years (with export). The 'Multiple Measures 2 ' scenario examines the impact of a $10/MW/hr Alternative Energy Credit incentive, 0% interest economic development loan and permit by rule combined scenario over 20 years (with export and avoided cooling). The Multiple Measures scenario would result in:

1. 728 MW of CHP being implemented in Maryland
2. Annual Primary Energy Savings of 42,689 billion Btu/year
3. Total investment to public investment leveraging of incentive funds by about 20.6 to 1[30]
4. Annually reducing CO_2 emissions by 2,330,000 MT at a 20 year cumulative cost to the state of $1/MT
5. Increasing employment in the state by 239 construction/operations jobs and 1,000s of industrial jobs.

[30] The market penetration assumes 7 years of AEC payments. The first year of payments is included in the state investment and the remaining years are assumed to be balanced by the reduction in local marginal electric prices.

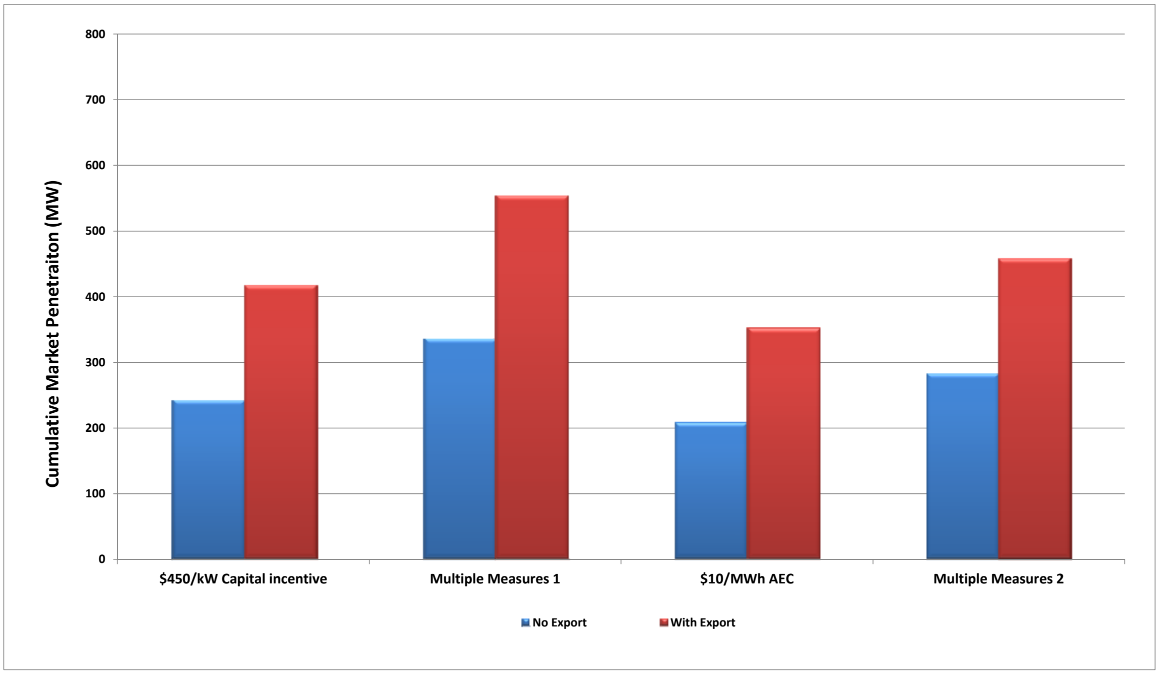

FIGURE 11: MW INSTALLED; 10-YEAR PROJECTION SCENARIOS FOR CHP

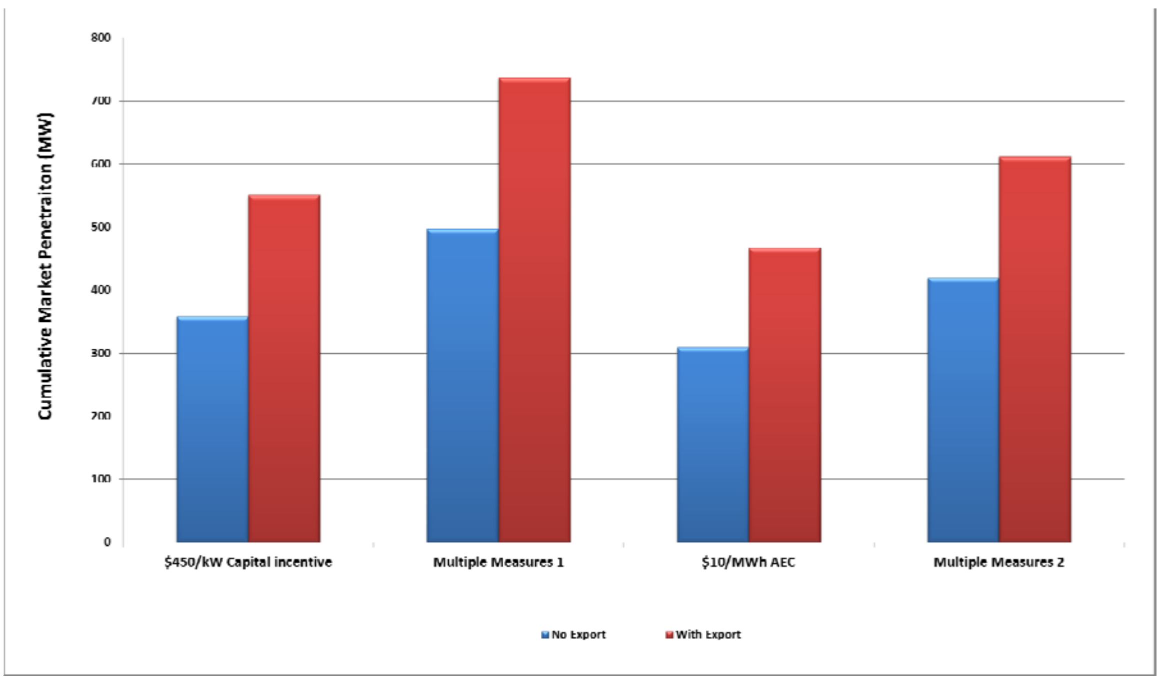

FIGURE 12: MW INSTALLED; 20-YEAR PROJECTION SCENARIOS FOR CHP

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 4: 10-YEAR CHP MARKET PENETRATION SCENARIOS WITH NO EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	$10/MWh AEC	0% Loan	PBR	Multiple Measures 1	Multiple Measures 2
Economic Potential, MW	138	203	309	659	262	178	157	426	358
Cumulative Market Penetraiton (MW)									
Industrial	84	114	155	323	130	101	89	200	162
Commercial/Institutional	25	44	77	176	68	37	32	121	105
Total	109	158	232	499	198	138	121	320	268
Avoided Cooling	3	5	10	23	9	5	4	16	15
Scenario Grand Total	112	163	242	522	208	143	125	336	283
Delta CHP power		49	123	390	89	30	12	211	159
Delta with avoided cooling		51	130	411	96	31	13	224	171
Annual Electric Energy (Million kWh)									
Industrial	647	876	1,188	2,473	992	777	680	1,520	1235
Commercial/Institutional	161	278	473	1,058	425	239	206	726	644
Total	808	1154	1,661	3,531	1417	1,015	886	2,246	1879
Avoided Cooling	8	15	27	62	26	13	11	43	41
Scenario Grand Total	817	1170	1,688	3,593	1443	1,028	898	2,289	1920
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	8,113	11,589	16,670	35,444	14,225	10,192	8,899	22,544	18,862
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	8,197	11,741	16,941	36,066	14,488	10,323	9,010	22,974	19,278
Incremental Onsite Fuel (billion Btu/year)									
Industrial	3,456	4689	6,361	13,145	5357	4,163	3,649	8,160	6692
Commercial/Institutional	1,109	1933	3,315	7,450	3044	1,659	1,429	5,134	4666
Total	4,565	6,622	9,676	20,595	8,401	5,822	5,078	13,294	11,359
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	3,547	4,967	6,994	14,848	5,824	4,370	3,821	9,250	7,503
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	3,632	5,119	7,265	15,471	6,087	4,501	3,932	9,681	7,919
Delta Annual Primary Savings (billion Btu/year) - CHP Power		1,420	3,447	11,301	2,277	823	274	5,703	3,956
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		1,487	3,633	11,839	2,455	869	300	6,049	4,287
Financial Impact									
Cumulative Investment (million 2010 $)	$134	$162	$197	$211	$265	$160	$150	$245	$338
Cumulative Capital Incentives (Million 2010 $)	$0	$36	$105	$449	$0	$5	$0	$169	$18
Annual Operating Incentives (Million 2010 $)	$0.0	$0.0	$0.0	$0.0	$14.2	$0.0	$0.0	$0.0	$18.8
Cumulative Operating Incentives (Million 2010$)	$0.0	$0.0	$0.0	$0.0	$99.2	$0.0	$0.0	$0.0	$131.5
State Incentive Leverage		5.6	2.9	1.5		32		2.4	19.8
Annual Electric Energy (Million 2010 $)									
Industrial	56	77	104	217	87	68	60	134	109
Commercial/Institutional	15	26	45	101	40	22	19	69	61
Total	71	103	149	318	127	90	79	203	170
Avoided Cooling	1	2	3	7	3	1	1	5	5
Scenario Grand Total	72	104	152	325	130	92	80	208	175
Incremental Onsite Fuel (million 2010 $)									
Industrial	28	38	52	108	44	34	30	67	55
Commercial/Institutional	9	16	27	61	25	14	12	42	38
Total	37	54	79	169	69	48	42	109	93
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,225.91	$1,027.92	$846.36	$422.46	$1,337.82	$1,157.82	$1,238.04	$765.11	$1,261.23
Average Incentive Rate $/kW	$0.00	$225.00	$450.00	$900.00	$500.10	$37.76	$0.00	$527.87	$558.13
Equivalent Operating Incentive, $/kWh	$0.0000	$0.0040	$0.0081	$0.0164	$0.0090	$0.0007	$0.0000	$0.0097	$0.0102
Average Electric Cost Saved ($/kW)	$0.0886	$0.0893	$0.0901	$0.0904	$0.0902	$0.0892	$0.0893	$0.0908	$0.0910
Average Incremental Gas Cost ($/MMBtu)	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19
Average Incremental Heat Rate (Btu/kWh HHV)	5,591	5,661	5,733	5,732	5,821	5,661	5,658	5,808	5,915
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	1.9	3.5	5.7	20.1	5.7	3.1	2.8	9.9	11.6
500kW-1,000kW	2.7	6.1	17.9	46.2	17.8	5.4	4.8	34.3	31.4
1-5 MW	28.7	48.0	75.4	153.5	63.9	41.4	37.7	111.4	91.0
5-20 MW	24.6	34.3	47.0	91.5	40.7	29.8	24.6	58.3	49.1
>20 MW	51.0	66.0	86.2	187.8	70.3	58.8	51.0	106.3	84.7
Total Market	108.9	157.8	232.4	499.0	198.4	138.5	121.0	320.1	267.8
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	373	530	759	1,615	642	466	407	1,020	845
Cumulative Avoided CO2 Emissions, thousand MT	1,888	2,646	3,725	8,007	3,160	2,328	2,026	4,988	4,129
Cum Incentive Cost for Cum MT CO2 Reduced		$13	$28	$56	$0	$2	$0	$34	$4
Average unit Emissions savings, lb/MWh	1007.8	999.6	991.1	991.3	980.9	999.6	1000.0	982.3	969.9

TABLE 5: 10-YEAR CHP MARKET PENETRATION SCENARIOS WITH EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	$10/MWh AEC	0% Loan	PBR	Multiple Measures 1	Multiple Measures 2
Economic Potential, MW	249	352	508	1118	426	309	269	674	556
Cumulative Market Penetraiton (MW)									
Industrial	181	244	330	738	274	214	186	418	337
Commercial/Institutional	25	44	77	176	68	37	32	121	105
Total	206	288	407	914	342	252	218	538	443
Avoided Cooling	3	5	10	23	9	5	4	16	15
Scenario Grand Total	209	293	417	938	352	256	222	554	458
Delta CHP power		82	201	708	137	46	12	332	237
Delta with avoided cooling		84	208	729	143	48	13	345	249
Annual Electric Energy (Million kWh)									
Industrial	1,622	2190	2,968	6,618	2454	1,927	1,674	3,748	3018
Commercial/Institutional	161	278	473	1,058	425	239	206	726	644
Total	1,584	2193	3,059	6,852	2568	1,922	1,664	3,988	3276
Avoided Cooling	8	15	27	62	26	13	11	43	41
Scenario Grand Total	1,592	2208	3,086	6,914	2594	1,935	1,675	4,031	3318
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	15,898	22,011	30,704	68,785	25,778	19,290	16,701	40,037	32,886
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	15,983	22,163	30,975	69,408	26,040	19,421	16,812	40,468	33,302
Incremental Onsite Fuel (billion Btu/year)									
Industrial	7,478	10076	13,617	30,364	11342	8,864	7,680	17,208	13960
Commercial/Institutional	1,109	1933	3,315	7,450	3044	1,659	1,429	5,134	4666
Total	8,588	12,009	16,932	37,814	14,386	10,524	9,109	22,341	18,627
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	7,311	10,002	13,772	30,971	11,392	8,766	7,592	17,696	14,259
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided coolin	7,395	10,154	14,043	31,593	11,654	8,897	7,703	18,126	14,675
Delta Annual Primary Savings (billion Btu/year) - CHP Power		2,692	6,462	23,660	4,081	1,455	281	10,385	6,949
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		2,759	6,648	24,198	4,259	1,502	307	10,731	7,280
Financial Impact									
Cumulative Investment (million 2010 $)	$237	$272	$306	$283	$421	$273	$254	$364	$512
Cumulative Capital Incentives (Million 2010 $)	$0	$65	$183	$823	$0	$9	$0	$281	$26
Annual Operating Incentives (Million 2010 $)	$0.0	$0.0	$0.0	$0.0	$25.7	$0.0	$0.0	$0.0	$32.8
Cumulative Operating Incentives (Million 2010$)	$0.0	$0.0	$0.0	$0.0	$179.8	$0.0	$0.0	$0.0	$229.3
State Incentive Leverage		5.2	2.7	1.3		32		2.3	20.4
Annual Electric Energy (Million 2010 $)									
Industrial	119	160	217	484	180	141	122	274	221
Commercial/Institutional	15	26	45	101	40	22	19	69	61
Total	134	186	262	585	220	163	141	343	283
Avoided Cooling	1	2	3	7	3	1	1	5	5
Scenario Grand Total	135	188	265	592	223	165	143	348	287
Incremental Onsite Fuel (million 2010 $)									
Industrial	61	83	112	249	93	73	63	141	114
Commercial/Institutional	9	16	27	61	25	14	12	42	38
Total	70	98	139	310	118	86	75	183	153
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,154.14	$947.59	$751.68	$309.33	$1,228.85	$1,083.89	$1,164.76	$675.86	$1,156.99
Average Incentive Rate $/kW	$0.00	$225.00	$450.00	$900.00	$525.00	$35.34	$0.00	$521.93	$577.72
Equivalent Operating Incentive, $/kWh	$0.0000	$0.0039	$0.0078	$0.0156	$0.0091	$0.0006	$0.0000	$0.0092	$0.0101
Average Electric Cost Saved ($/kW)	$0.0847	$0.0852	$0.0858	$0.0857	$0.0859	$0.0852	$0.0852	$0.0864	$0.0866
Average Incremental Gas Cost ($/MMBtu)	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19	$8.19
Average Incremental Heat Rate (Btu/kWh HHV)	5,393	5,439	5,487	5,469	5,546	5,440	5,439	5,542	5,615
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	1.9	3.5	5.7	20.1	5.7	3.1	2.8	9.9	11.6
500kW-1,000kW	2.7	6.1	17.9	46.2	17.8	5.4	4.8	34.3	31.4
1-5 MW	29.4	49.7	78.5	161.2	66.7	42.6	38.7	116.1	95.0
5-20 MW	31.1	43.7	60.3	118.9	52.3	37.7	31.1	74.8	63.0
>20 MW	140.6	184.7	244.8	567.9	200.0	162.9	140.6	303.2	241.6
Total Market	205.7	287.6	407.2	914.2	342.4	251.7	218.1	538.2	442.7
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	745	1,027	1,428	3,206	1,192	900	779	1,853	1,512
Cumulative Avoided CO2 Emissions, thousand MT	3,916	5,364	7,387	16,843	6,177	4,699	4,057	9,556	7,793
Cum Incentive Cost for Cum MT CO2 Reduced		$12	$25	$49	$0	$2	$0	$29	$3
Average unit Emissions savings, lb/MWh	1030.9	1025.6	1020.0	1022.1	1013.1	1025.5	1025.6	1013.5	1005.0

TABLE 6: 20-YEAR CHP MARKET PENETRATION SCENARIOS WITH NO EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	$10/MWh AEC	0% Loan	PBR	Multiple Measures 1	Multiple Measures 2
Economic Potential, MW	213	309	459	955	386	274	240	613	504
Cumulative Market Penetraiton (MW)									
Industrial	101	138	189	395	157	122	108	243	197
Commercial/Institutional	51	86	148	322	131	74	64	221	192
Total	152	224	336	717	288	197	172	464	389
Avoided Cooling	7	12	22	47	20	11	9	33	31
Scenario Grand Total	159	236	358	763	309	207	181	497	419
Delta CHP power		72	184	564	136	45	20	312	237
Delta with avoided cooling		76	199	604	149	48	22	338	260
Annual Electric Energy (Million kWh)									
Industrial	769	1049	1,430	2,994	1192	931	819	1,832	1487
Commercial/Institutional	326	536	897	1,921	802	466	404	1,323	1160
Total	1,095	1585	2,327	4,915	1994	1,397	1,222	3,155	2647
Avoided Cooling	18	30	53	112	50	27	23	79	75
Scenario Grand Total	1,113	1615	2,380	5,027	2044	1,424	1,245	3,234	2721
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	10,988	15,910	23,358	49,341	20,012	14,024	12,271	31,669	26,567
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	11,171	16,215	23,888	50,463	20,516	14,291	12,499	32,466	27,316
Incremental Onsite Fuel (billion Btu/year)									
Industrial	4,129	5643	7,694	15,936	6481	5,017	4,417	9,878	8112
Commercial/Institutional	2,268	3750	6,347	13,558	5798	3,268	2,823	9,441	8471
Total	6,396	9,393	14,041	29,494	12,279	8,286	7,240	19,319	16,583
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	4,592	6,517	9,317	19,848	7,732	5,738	5,032	12,350	9,984
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided cooling	4,775	6,822	9,847	20,969	8,237	6,005	5,259	13,148	10,733
Delta Annual Primary Savings (billion Btu/year) - CHP Power		1,926	4,726	15,256	3,141	1,147	440	7,759	5,392
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		2,047	5,072	16,194	3,462	1,230	484	8,373	5,958
Financial Impact									
Cumulative Investment (million 2010 $)	$195	$242	$307	$341	$406	$238	$223	$386	$518
Cumulative Capital Incentives (Million 2010 $)	$0	$50	$151	$645	$0	$8	$0	$246	$27
Annual Operating Incentives (Million 2010 $)	$0.0	$0.0	$0.0	$0.0	$19.9	$0.0	$0.0	$0.0	$26.5
Cumulative Operating Incentives (Million 2010$)	$0.0	$0.0	$0.0	$0.0	$139.5	$0.0	$0.0	$0.0	$185.3
State Incentive Leverage		5.8	3.0	1.5		32		2.6	20.3
Annual Electric Energy (Million 2010 $)									
Industrial	74	101	138	289	115	90	79	177	144
Commercial/Institutional	33	55	93	201	83	48	42	139	121
Total	107	156	231	490	198	138	120	316	265
Avoided Cooling	2	4	7	14	6	3	3	10	9
Scenario Grand Total	109	160	238	504	205	141	123	326	274
Incremental Onsite Fuel (million 2010 $)									
Industrial	38	52	70	146	59	46	40	90	74
Commercial/Institutional	21	34	58	124	53	30	26	86	77
Total	58	86	128	269	112	76	66	177	152
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,281.11	$1,081.56	$911.58	$476.19	$1,409.89	$1,211.39	$1,297.18	$831.85	$1,331.20
Average Incentive Rate $/kW	$0.00	$225.00	$450.00	$900.00	$484.30	$39.50	$0.00	$530.09	$545.49
Equivalent Operating Incentive, $/kWh	$0.0000	$0.0041	$0.0084	$0.0169	$0.0090	$0.0007	$0.0000	$0.0100	$0.0102
Average Electric Cost Saved ($/kW)	$0.0983	$0.0990	$0.1000	$0.1002	$0.1001	$0.0990	$0.0990	$0.1007	$0.1009
Average Incremental Gas Cost ($/MMBtu)	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14
Average Incremental Heat Rate (Btu/kWh HHV)	5,748	5,815	5,900	5,867	6,008	5,820	5,815	5,973	6,094
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	4.4	7.6	19.3	53.4	19.4	6.8	6.1	33.3	33.7
500kW-1,000kW	12.2	22.3	43.3	94.7	39.8	19.6	16.7	68.4	60.4
1-5 MW	47.6	77.2	118.8	244.8	100.0	67.3	61.3	171.0	139.5
5-20 MW	32.3	44.6	60.9	121.1	52.5	38.9	32.3	75.2	63.1
>20 MW	55.7	72.0	94.1	202.5	76.5	64.1	55.7	115.9	92.1
Total Market	152.0	223.6	336.4	716.5	288.1	196.7	172.0	463.8	388.8
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	499	719	1,049	2,224	889	633	554	1,413	1,171
Cumulative Avoided CO2 Emissions, thousand MT	6,473	9,219	13,254	28,256	11,226	8,115	7,087	17,809	14,744
Cum Incentive Cost for Cum MT CO2 Reduced		$5	$11	$23	$0	$1	$0	$14	$2
Average unit Emissions savings, lb/MWh	989.5	981.6	971.6	975.5	959.0	981.0	981.6	963.1	948.9

TABLE 7: 20-YEAR CHP MARKET PENETRATION SCENARIOS WITH EXPORT

CHP Measurement	Base	$225/kW Capital incentive	$450/kW Capital incentive	$900/kW Capital incentive	$10/MWh AEC	0% Loan	PBR	Multiple Measures 1	Multiple Measures 2
Economic Potential, MW	346	484	693	1449	572	427	373	903	728
Cumulative Market Penetraiton (MW)									
Industrial	207	281	381	848	316	247	215	483	389
Commercial/Institutional	51	86	148	322	131	74	64	221	192
Total	259	366	529	1,170	446	321	279	704	581
Avoided Cooling	7	12	22	47	20	11	9	33	31
Scenario Grand Total	266	378	550	1,217	467	332	288	737	611
Delta CHP power		108	270	911	188	63	20	445	322
Delta with avoided cooling		113	285	951	201	66	22	471	346
Annual Electric Energy (Million kWh)									
Industrial	1,622	2190	2,968	6,618	2454	1,927	1,674	3,748	3018
Commercial/Institutional	326	536	897	1,921	802	466	404	1,323	1160
Total	1,948	2726	3,864	8,539	3255	2,393	2,078	5,071	4178
Avoided Cooling	18	30	53	112	50	27	23	79	75
Scenario Grand Total	1,966	2757	3,917	8,651	3306	2,420	2,100	5,150	4253
Annual Primary Electric Energy Use (billion Btu/year) - CHP Power	19,550	27,368	38,792	85,715	32,679	24,025	20,856	50,902	41,940
Annual Primary Electric Energy Use(billion Btu/year) - w avoided cooling	19,733	27,672	39,321	86,836	33,184	24,291	21,083	51,700	42,689
Incremental Onsite Fuel (billion Btu/year)									
Industrial	8,542	11553	15,657	34,673	13032	10,175	8,843	19,804	16064
Commercial/Institutional	2,268	3750	6,347	13,558	5798	3,268	2,823	9,441	8471
Total	10,810	15,303	22,004	48,231	18,830	13,443	11,666	29,245	24,536
Annual Primary Electric Energy Reduction (billion Btu/year) - CHP Power	8,740	12,065	16,788	37,484	13,850	10,581	9,190	21,657	17,405
Annual Primary Electric Energy Reduction (billion Btu/year) - w avoided coolin	8,923	12,369	17,318	38,605	14,355	10,848	9,417	22,454	18,153
Delta Annual Primary Savings (billion Btu/year) - CHP Power		3,325	8,049	28,745	5,110	1,842	450	12,917	8,665
Delta Annual Primary Savings (billion Btu/year) - w avoided cooling		3,446	8,395	29,683	5,432	1,925	494	13,532	9,231
Financial Impact									
Cumulative Investment (million 2010 $)	$308	$362	$426	$417	$576	$361	$337	$515	$708
Cumulative Capital Incentives (Million 2010 $)	$0	$82	$238	$1,053	$0	$12	$0	$369	$36
Annual Operating Incentives (Million 2010 $)	$0.0	$0.0	$0.0	$0.0	$32.6	$0.0	$0.0	$0.0	$41.8
Cumulative Operating Incentives (Million 2010$)	$0.0	$0.0	$0.0	$0.0	$227.9	$0.0	$0.0	$0.0	$292.5
State Incentive Leverage		5.4	2.8	1.4		32		2.4	20.6
Annual Electric Energy (Million 2010 $)									
Industrial	148	200	272	604	225	176	153	344	277
Commercial/Institutional	33	55	93	201	83	48	42	139	121
Total	181	256	365	806	308	224	195	483	399
Avoided Cooling	2	4	7	14	6	3	3	10	9
Scenario Grand Total	184	259	372	820	315	228	198	493	408
Incremental Onsite Fuel (million 2010 $)									
Industrial	78	106	143	317	119	93	81	181	147
Commercial/Institutional	21	34	58	124	53	30	26	86	77
Total	99	140	201	441	172	123	107	267	224
Calculated Averages (2010 $)									
Average Capital Cost $/kW	$1,192.46	$988.46	$804.97	$356.31	$1,290.17	$1,124.26	$1,208.62	$731.71	$1,218.83
Average Incentive Rate $/kW	$0.00	$225.00	$450.00	$900.00	$510.71	$36.66	$0.00	$524.25	$565.83
Equivalent Operating Incentive, $/kWh	$0.0000	$0.0039	$0.0080	$0.0160	$0.0091	$0.0006	$0.0000	$0.0094	$0.0102
Average Electric Cost Saved ($/kW)	$0.0934	$0.0941	$0.0949	$0.0947	$0.0952	$0.0941	$0.0942	$0.0957	$0.0959
Average Incremental Gas Cost ($/MMBtu)	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14	$9.14
Average Incremental Heat Rate (Btu/kWh HHV)	5,499	5,551	5,617	5,575	5,696	5,555	5,554	5,678	5,770
Cumulative Market Penetration by Size and Year, MW									
50-500 kW	4.4	7.6	19.3	53.4	19.4	6.8	6.1	33.3	33.7
500kW-1,000kW	12.2	22.3	43.3	94.7	39.8	19.6	16.7	68.4	60.4
1-5 MW	48.7	79.5	122.8	254.7	103.5	69.0	62.8	177.0	144.6
5-20 MW	39.9	55.6	76.3	154.7	65.8	48.2	39.9	94.4	79.2
>20 MW	153.4	201.4	267.1	612.5	217.6	177.7	153.4	330.7	262.8
Total Market	258.6	366.4	528.8	1170.0	446.2	321.3	278.9	703.7	580.7
CO2 Impact									
Avoided CO2 Emissions, Annual basis, thousand MT	908	1,266	1,785	3,962	1,493	1,111	964	2,330	1,904
Cumulative Avoided CO2 Emissions, thousand MT	12,502	17,290	24,124	54,126	20,156	15,158	13,128	31,358	25,584
Cum Incentive Cost for Cum MT CO2 Reduced		$5	$10	$19	$0	$1	$0	$12	$1
Average unit Emissions savings, lb/MWh	1018.6	1012.4	1004.7	1009.6	995.5	1012.0	1012.1	997.6	986.9

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 13 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.

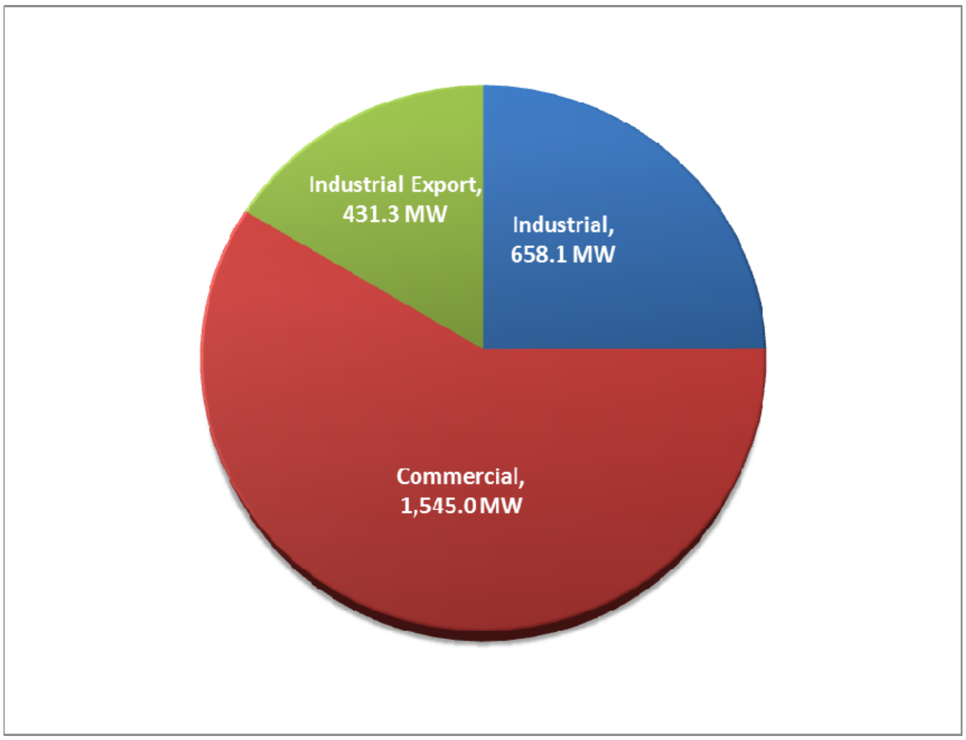

FIGURE 13: TECHNICAL MARYLAND CHP MARKET POTENTIAL IN MW BY APPLICATION

The technical potential derived by ICF is based on EIA data updated with Hoover's data together with input from the MARYLAND 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 8: TECHNICAL MARKET POTENTIAL FOR COMMERCIAL 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
43	Post Offices	6	0.9	1	1.0	0	0.0	0	0.0	0	0.0	7	1.9
52	Retail	358	53.9	12	8.0	4	5.4	0	0.0	0	0.0	374	67.3
4222	Refridgerated Warehouses	12	1.6	0	0.0	0	0.0	0	0.0	0	0.0	12	1.6
4581	Airports	1	0.1	0	0.0	0	0.0	1	12.3	0	0.0	2	12.3
4952	Water Treatment	12	1.4	0	0.0	1	2.8	0	0.0	0	0.0	13	4.2
5411	Food Stores	415	57.6	4	2.9	0	0.0	0	0.0	0	0.0	419	60.4
5812	Restaurants	637	73.7	5	3.1	1	1.1	0	0.0	0	0.0	643	77.9
6512	Commercial Buildings	1,063	212.6	425	318.8	106	159.0	0	0.0	0	0.0	1,594	690.4
6513	Multifamily Buildings	253	50.6	92	69.0	14	21.0	0	0.0	0	0.0	359	140.6
7011	Hotels	297	38.8	21	13.3	13	26.4	1	9.0	0	0.0	332	87.5
7211	Laundries	9	1.5	3	1.7	0	0.0	0	0.0	0	0.0	12	3.2
7374	Data Centers	52	9.6	3	2.1	4	9.6	0	0.0	0	0.0	59	21.3
7542	Car Washes	28	2.1	0	0.0	0	0.0	0	0.0	0	0.0	28	2.1
7832	Movie Theaters	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7991	Health Clubs	80	9.5	5	3.4	0	0.0	0	0.0	0	0.0	85	12.9
7997	Golf/Country Clubs	79	10.3	1	0.7	2	2.4	0	0.0	0	0.0	82	13.4
8051	Nursing Homes	187	33.7	5	2.9	4	7.3	0	0.0	0	0.0	196	43.9
8062	Hospitals	30	4.4	9	6.0	40	86.1	4	27.7	0	0.0	83	124.2
8211	Schools	478	39.6	1	0.7	0	0.0	0	0.0	0	0.0	479	40.3
8221	College/Univ	36	7.4	7	4.3	9	15.2	2	17.2	0	0.0	54	44.0
8412	Museums	17	2.2	0	0.0	1	1.9	0	0.0	0	0.0	18	4.0
9100	Government Buildings	94	15.4	5	3.5	5	11.3	0	0.0	0	0.0	104	30.2
9223	Prisons	29	5.9	10	7.8	14	34.3	2	13.3	0	0.0	55	61.3
Total		**4,173**	**632.8**	**609**	**448.9**	**218**	**383.9**	**10**	**79.4**	**0**	**0.0**	**5,010**	**1,545.0**

TABLE 9: 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	146	21.4	26	17.8	16	31.8	0	0.0	0	0.0	188	71.1
22	Textiles	25	3.8	0	0.0	2	4.7	0	0.0	0	0.0	27	8.5
24	Lumber and Wood	72	9.2	4	2.3	3	6.4	0	0.0	0	0.0	79	17.9
25	Furniture	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	4	0.3
26	Paper	19	5.4	6	4.8	6	15.3	4	44.3	1	56.3	36	126.1
27	Printing	10	1.4	1	0.5	0	0.0	0	0.0	0	0.0	11	1.9
28	Chemicals	100	19.0	17	11.4	22	52.1	10	99.2	4	105.1	153	286.9
29	Petroleum Refining	20	3.4	6	4.6	3	6.3	0	0.0	0	0.0	29	14.3
30	Rubber/Misc Plastics	31	4.7	3	2.1	1	2.5	0	0.0	0	0.0	35	9.3
32	Stone/Clay/Glass	2	0.4	1	0.5	2	2.4	0	0.0	0	0.0	5	3.4
33	Primary Metals	6	1.2	3	2.3	3	5.4	0	0.0	1	91.8	13	100.7
34	Fabricated Metals	12	1.4	0	0.0	0	0.0	0	0.0	0	0.0	12	1.4
35	Machinery/Computer Equip	1	0.1	1	0.8	0	0.0	0	0.0	0	0.0	2	0.9
37	Trasportation Equip.	15	2.8	4	3.1	4	8.7	0	0.0	0	0.0	23	14.6
38	Instruments	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1
39	Misc. Manufacturing	6	0.8	0	0.0	0	0.0	0	0.0	0	0.0	6	0.8
	Total	**470**	**75.4**	**72**	**50.3**	**62**	**135.6**	**14**	**143.5**	**6**	**253.2**	**624**	**658.1**

TABLE 10: 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	146	21.4	26	17.8	15	30.0	1	5.0	0	0.0	188	74.3
22	Textiles	25	3.8	0	0.0	2	4.7	0	0.0	0	0.0	27	8.5
24	Lumber and Wood	72	9.2	4	2.3	2	5.8	1	11.5	0	0.0	79	28.8
25	Furniture	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	4	0.3
26	Paper	19	5.4	6	4.8	3	8.5	3	27.8	5	332.1	36	378.6
27	Printing	10	1.4	1	0.5	0	0.0	0	0.0	0	0.0	11	1.9
28	Chemicals	100	19.0	17	11.4	20	55.9	7	84.6	9	363.0	153	533.9
29	Petroleum Refining	20	3.4	6	4.6	2	5.8	1	10.0	0	0.0	29	23.9
30	Rubber/Misc Plastics	31	4.7	3	2.1	1	2.5	0	0.0	0	0.0	35	9.3
32	Stone/Clay/Glass	2	0.4	1	0.5	2	2.4	0	0.0	0	0.0	5	3.4
33	Primary Metals	6	1.2	3	2.3	3	5.4	0	0.0	0	0.0	12	8.9
34	Fabricated Metals	12	1.4	0	0.0	0	0.0	0	0.0	0	0.0	12	1.4
35	Machinery/Computer Equip	1	0.1	1	0.8	0	0.0	0	0.0	0	0.0	2	0.9
37	Trasportation Equip.	15	2.8	4	3.1	4	8.7	0	0.0	0	0.0	23	14.6
38	Instruments	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1
39	Misc. Manufacturing	6	0.8	0	0.0	0	0.0	0	0.0	0	0.0	6	0.8
	Total	**470**	**75.4**	**72**	**50.3**	**54**	**129.7**	**13**	**138.9**	**14**	**695.1**	**623**	**1,089.5**

8. MARKET ANALYSIS UNDER ALTERNATIVE SCENARIOS

Figure 1 shows the theoretical cumulative market penetration over the 10-year review period. In order to achieve the benefits of CHP it will be necessary for the state to support CHP implementation as well as address existing barriers. This will not only improve the adoption of CHP over the base case but also allow realization of the base case itself. The study assessed seven state-based CHP incentive and/or regulatory changes that would significantly increase CHP installations in the State of Maryland. These 10 year cumulative changes are summarized as follows:

- **Capital Grant Program:** Maryland has not supported a capital grant program in support of CHP systems. This type of program has been successful in establishing and grouping a CHP industry in other states like: New York, New Jersey, Connecticut and Massachusetts). These 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. The model assumed a $5 million cap on the capital reduction incentive and no limitation on installed capacity. The $450/kW case produces a 242 MW[31] (417 MW[32]) increase in total market penetration in the first 10 years.
- **Alternative Energy Credit Program:** This program would add a Tier III to the current Maryland Renewables Portfolio Standard covering high efficient clean power including CHP and waste heat-to-power that meet local air emissions regulations and meet a minimum annual efficiency requirement of 65%. The model assumed a $10/MW/hr credit paid over a seven year period.
- **0% Loan:** In Maryland, 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 a 143 MW[31] (256 MW[32]) increase in total market penetration in the first 10 years.
- **Permit-by-Rule regulation:** Currently, CHP plants in MARYLAND must undergo new source review. A long-term goal would be to create a MARYLAND DEP "Permit by Rule" regulation that would apply to all CHP systems meeting the requisite EPA/DEP emissions requirements resulting in substantial time and applications cost savings.
- **The "Multi-Incentive 1" 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 336[31] MW (554 MW[32]) in the first 10 years.
- **The "Multi-Incentive 2" Case:** This scenario is based on combining the $10/MW/hr AEC program, 0% interest loan program and permit-by-rule measures. This scenario adds 283[31] MW (443 MW[32]) over the Base Case in the first 10 years. Combining these measures provides an additional 8 to 11% increase over the three individual measures amounting to 45 MW[31] (42 MW[32]).
- **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.

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

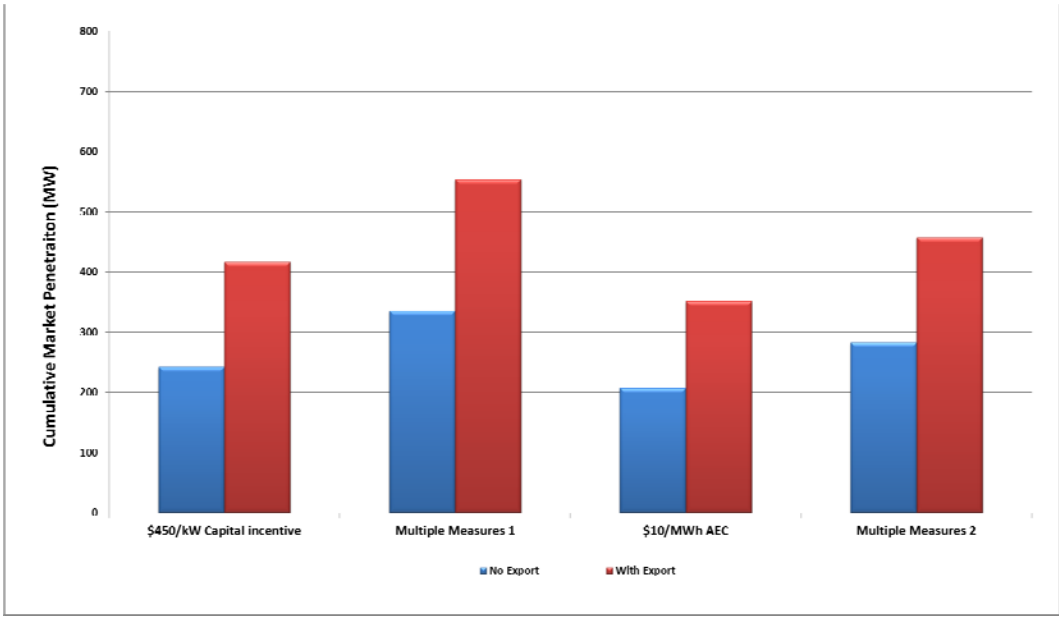

FIGURE 14: MW INSTALLED; 10-YEAR PROJECTION SCENARIOS FOR CHP

Figure 15 presents the time phased view of individual scenarios and Figure 16 focuses on the multiple measure cases consisting.

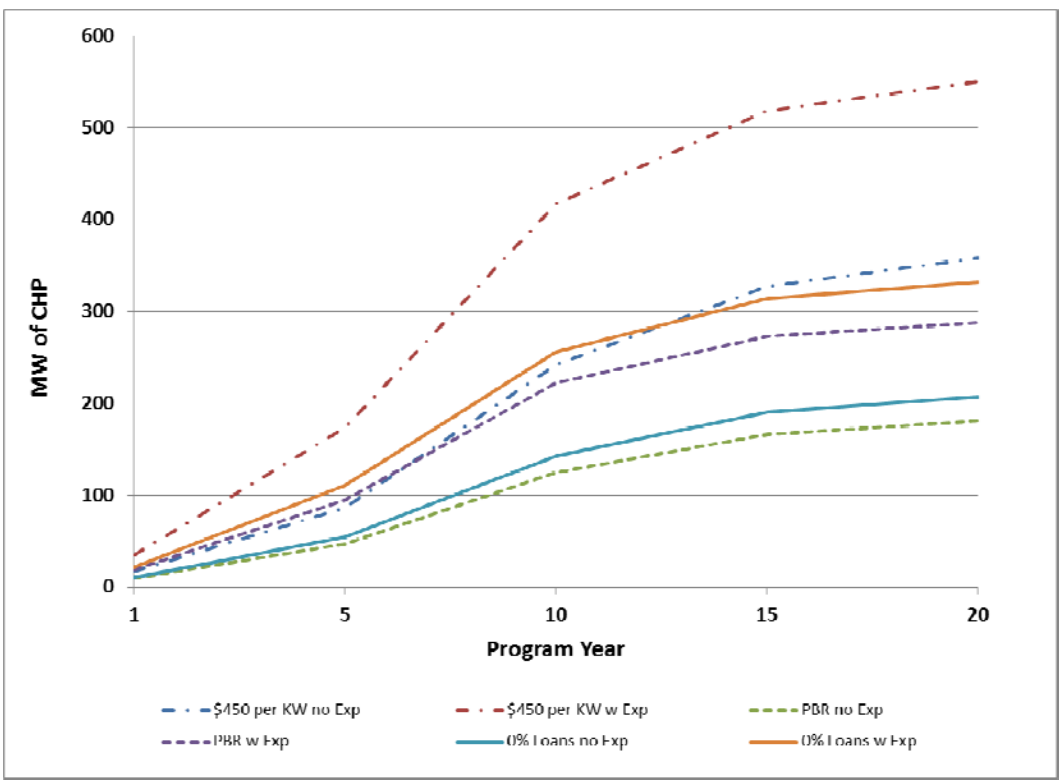

FIGURE 15: INDIVIDUAL INCENTIVE CASES CUMULATIVE MARKET PENETRATION RESULTS
Source: ICF CHP Market Model

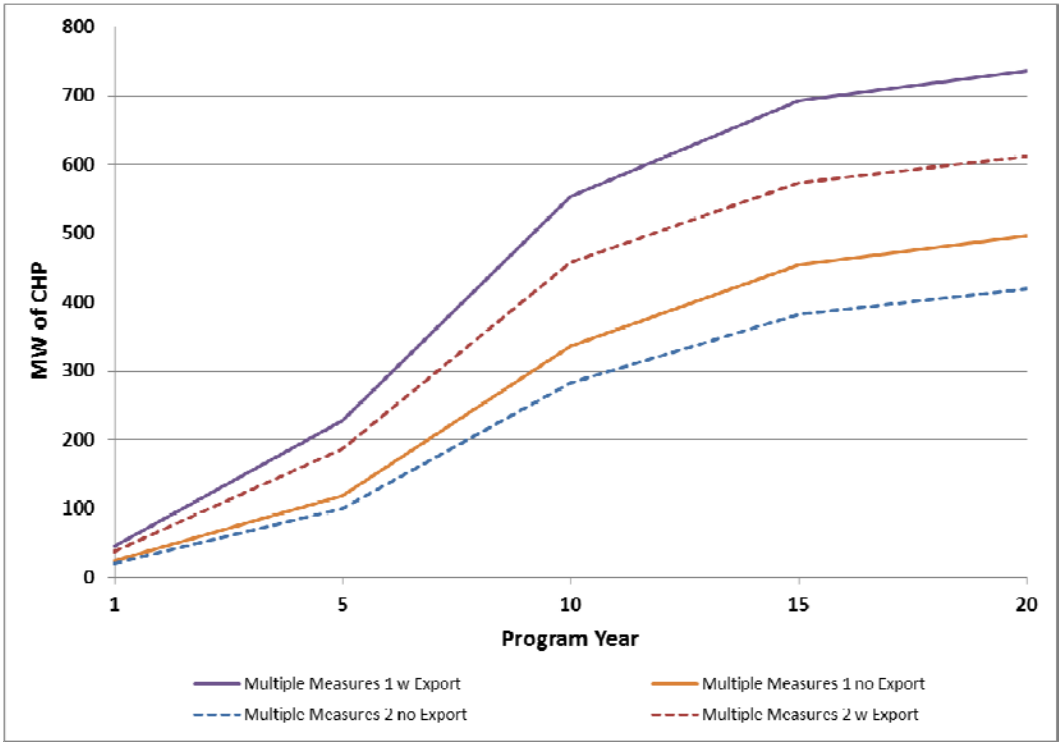

FIGURE 16: MULTIPLE INCENTIVE CASES CUMULATIVE MARKET PENETRATION RESULTS
Source: ICF CHP Market Model

9. CONCLUSIONS

The principle reason to consider providing policies and incentives supporting CHP in Maryland is that it is the lowest cost means of providing additional power generation. Maryland's entire CHP installed base consists of only 20 sites totaling 828 MW. Only 81 MW of the CHP systems were installed since 2001 all at government facilities except 15 MW which has since shut down because the factory was no longer competitive. The last CHP system was installed in 2008.

The state of Maryland historically is viewed as disinterested in implementing CHP as an electricity supply option which has naturally led to declining market and ultimately the current non-existent market for CHP[33]. While natural gas prices have dropped and are expected to remain low for the next 10 to 20 years[34], Maryland has not developed the regulatory, policy or incentive environment to attract CHP investors and developers.

Several no-cost and low-cost state investment strategies have been explored in this report. Both capital reduction and alternative energy credit methods appear to be important factors in reducing investment risk to the point that will assure significant CHP investment is made by the private sector.

The societal benefits of CHP combined with the relatively low cost of power production should lead Maryland policy makers to reconsider CHP as a natural clean energy complement to their solar and wind efforts.

[33] except for certain federal facilities seeking to meet federal mandates for energy efficiency or GHG targets or to provide site energy security
[34] based on recent shale gas projections in the region

APPENDIX A: BACKGROUND DATA FOR FIGURE 1

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	$7.81
Displaced Boiler Fuel Cost, $/MMBtu	$7.81
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.0938
Thermal Credit, $/kWh	($0.0476)
Incremental O&M, $/kWh	$0.0220
Operating Costs to Generate Power, $/kWh	***$0.0682***
Capital Cost	
Installed CHP System Cost, $/kW	$2,431
Operating Hours	5,500
Equipment Life, Yrs	15
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0581
Total Costs to Generate Power, $/kWh	***$0.1264***

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	$7.81
Displaced Boiler Fuel Cost, $/MMBtu	$7.81
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.0740
Thermal Credit, $/kWh	($0.0275)
Incremental O&M, $/kWh	$0.0100
Operating Costs to Generate Power, $/kWh	***$0.0565***
Capital Cost	
Installed CHP System Cost, $/kW	$1,243
Operating Hours	7,000
Equipment Life, Yrs	15
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0233
Total Costs to Generate Power, $/kWh	***$0.0799***

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	$7.81
Displaced Boiler Fuel Cost, $/MMBtu	$7.81
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.0720
Thermal Credit, $/kWh	($0.0311)
Incremental O&M, $/kWh	$0.0040
Operating Costs to Generate Power, $/kWh	***$0.0449***
Capital Cost	
Installed CHP System Cost, $/kW	$1,100
Operating Hours	8,000
Equipment Life, Yrs	20
Cost of Capital, %	10.0%
Capital Charge, $/kWh	$0.0162
Total Costs to Generate Power, $/kWh	***$0.0610***

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	$6.21
Operating Cost to Generate	
Fuel Costs, $/kWh	$0.0451
Variable O&M Costs, $/kWh	$0.0021
Fixed O&M, $/kWh	$0.0036
Operating Costs to Generate Power, $/kWh	***$0.0508***
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	***$0.0764***

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***

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***