Arnold Schwarzenegger
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INDUSTRIAL SECTOR COMBINED HEAT AND POWER EXPORT MARKET POTENTIAL

PIER INTERIM PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
ICF International, Inc.

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

- PIER funding efforts are focused on the following RD&D program areas:
- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Industrial Sector Combined Heat and power Export Market Potential is an interim report for project RD&D Analysis and Targets for Environmentally Preferred Advanced Generation, contract number 500-06-011, work authorization number WA-024, conducted by ICF International, Inc.. The information from this project contributes to PIER's Environmentally Preferred Advanced Generation Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

This report analyzes the potential market penetration of electric power capacity available for sale into the California electric power grid from new or expanded industrial combined heat and power projects. The paper promotes the evaluation of the effect of potential tariffs for combined heat and power export. The analysis is based on the quantification of the steam and power demands of industrial facilities in California. The technical potential for combined heat and power at these facilities was determined based on meeting the on-site steam demand with the recovered heat from an appropriately sized gas turbine power plant. The power generation capability in excess of the facility's on-site power needs is defined as the *export market potential.* This technical market potential was further evaluated using a proprietary market penetration model to estimate the future market penetration of exported power as a function of the electric power tariff.

Keywords: Public Interest Energy Research (PIER) Program, combined heat and power, CHP, industrial market, steam, gas turbine.

Executive Summary

Based on an evaluation of 947 major California industrial facilities, there is a maximum potential for 5,268 megawatts of electricity for export to the California power grid. This potential would come from new or expanded combined heat and power systems at 110 facilities with combined heat and power greater than 5 megawatts per site. About 93 percent of this potential is in facilities larger than 20 megawatts per site.

To determine how much of the maximum potential would export power to the grid at various utility purchase prices, an analysis was conducted using the combined heat and power market penetration model developed by ICF International, Inc. This analysis used three natural gas price scenarios defined in the U.S. Energy Information Administration's *Annual Energy Outlook for 2008*. As the export purchase price paid by the utilities increased, there was less sensitivity to the natural gas price assumptions.

The 5 to 20 megawatt-sized combined heat and power facilities are capable of 245 to 281 megawatts of cumulative export power by 2025 at a utility purchase price of $0.10 per kilowatt-hour. For combined heat and power facilities greater than 20 megawatts, the market response initially begins at about $0.06 per kilowatt-hour when using the Energy Information Administration gas price scenario and at $0.08 per kilowatt-hour when using 2008 California gas prices and approached convergence at a technical market potential of about 4,800 megawatts as the purchase price was increased. At all assumed electric prices, the majority of potential market penetration will come from facilities that are larger 20 megawatts.

Benefits to California

This project benefits California's ratepayers by providing updated information that can be used to clarify state policies that encourage combined heat and power technologies. These technologies have the potential to advance the efficiency of the state's use of natural gas by capturing unused waste heat.

1.0 Introduction

This technical white paper provides estimates of the additional combined heat and power (CHP) potential at existing industrial sites in California if the CHP is sized to the remaining thermal load. Estimates of the resultant technical export potential[1] and the excess electricity selling price required to achieve technical export potential are included.

This paper provides estimates of the export market potential at industrial facilities in California based on the methodology used in the 2005 CHP market assessment[2] with updated assumptions on technology cost and performance and natural gas pricing.

2.0 Limitations of Scope and Study Assumptions

It was assumed in both the 2005 CHP market study and this analysis that the export CHP market potential would be in industrial facilities only and that gas turbines would be the prime mover for these CHP systems. Industrial facilities often have process steam loads that are fairly constant, and CHP systems sized to serve this steam load could easily have power capacities that are well above the facility's on-site electric demand.

In contrast, commercial and institutional facilities typically do not have on-site heating loads that are consistently high enough to provide a power export opportunity. The addition of cooling capability via absorption cooling was not considered as a CHP system option. Absorption cooling, and the capability to provide both heating and cooling simultaneously, would make greater use of waste heat and would improve the technical market potential for CHP.

[1] Export Potential is defined as CHP capacity that is in excess of on-site electric requirements while still meeting on-site thermal load.
[2] *Assessment of California CHP Markets and Policy Options for Increased Penetration*, CEC Report Number CEC-500-2005-060-D, April 2005

3.0 Project Approach

The approach taken in determining the CHP export market potential was as follows:

- Analysis of steam and power loads for 947 California industrial facilities based on information contained in a proprietary industrial facility database.
- Assessment of cost and performance for CHP technology appropriate for the generation of 5 MW of power and greater and the production of 150 pounds-force per square inch gauge (psig) of process steam.
- Development of assumptions regarding future natural gas prices in California, assuming natural gas is the preferred fuel for industrial CHP systems.
- Parametric analysis of CHP export market penetration under a range of potential future electric power price tariffs using ICF's proprietary CHP market penetration model based on the U.S. Energy Information Administration for *2008 Annual Energy Outlook* low, base, and high natural gas pricing scenarios.

3.1. Industrial Market Analysis

The project team used a commercially available industrial facility database to screen California industrial facilities for CHP potential.[3] A total of 947 California industrial facilities were evaluated using this database of steam and power demands for each facility. CHP capacity potential was estimated based on the ability of an appropriate CHP system to meet 100 percent of the facility on-site steam load.

Existing CHP systems at these facilities were subtracted from this calculated CHP potential using ICF's existing CHP database. There were 56 existing CHP systems with an electric capacity of 2,392 MW that the project team compared to the industrial facility database. The remaining export potential was determined by subtracting both existing CHP capacity and on-site electricity load.

The remaining CHP export technical market potential for existing industrial facilities was extrapolated to assumed growth in industry over the forecast period on a proportional basis by industrial classification. The addition of new industrial facilities over the 20 year forecast period was assumed to occur based on an analysis of gross state product trends by industrial classification. Growth of heavy industry in the state is expected to be fairly limited. Therefore, most of the potential will come from existing industrial sites rather than from new industrial facilities that may emerge over the next 20 years.

3.2. Technology Assumptions

The CHP electric capacity estimate is based on the power-to-heat ratio of the prime mover technology. Gas turbines were assumed for the industrial market because they are capable of producing the high quality steam needed for industrial processes. For systems in the 5-20 MW

[3] Major Industrial Plant Database, IHS, Inc.

size range, simple-cycle industrial gas turbines were assumed that are capable of providing up to 4,400 Btu/kWh of thermal energy. For the over-20 MW market, larger gas turbines were assumed to be progressively more efficient with thermal ratios ranging down to 3,100 Btu/kWh. For the very largest facilities, it was assumed that combined-cycle power plants could be economically applied. Combined cycle power plants had a thermal contribution of 1,760 Btu/kWh. Therefore, the larger the facility, the higher the power-to-heat ratio assumed.

Alternative prime movers (such as reciprocating engines) and alternative CHP system configurations were not considered. Alternative configurations include the addition of duct or supplemental firing in the gas turbine exhaust to increase the thermal output.

The economic potential and market penetration depends on both the cost and performance of the CHP technologies. The assumptions used in the 2005 study have been updated to reflect capital cost escalation that has occurred in the last three years. **Table** 1 summarizes the preliminary cost and performance assumptions. These technology assumptions are subject to change pending work under the current project. For the 5-20 MW size, a 10 MW simple cycle gas turbine was chosen as the appropriate technology. For the over 20 MW size, a 200 MW gas turbine combined cycle plant was selected. Not all of the projects in the over 20 MW size bin are large enough to use combined cycle technology, but for the majority of the technical market potential in this size, combined cycle would be technically feasible and economically attractive.

Table 1: Preliminary CHP Technology Assumptions

CHP Technology Assumptions	5-20 MW Market	>20 MW Market
Equipment Type	Gas Turbine	GT -- Combined Cycle
Capacity, MW	10	200
Basic Installed Costs, $/kW	1,300	800
After-treatment Costs (SCR) $/kW	140	65
O&M Costs, $/kWh	0.007	0.004
Heat Rate, Btu/kWh	11,765	7,937
Electric Efficiency, %	29.0	43.0
Thermal Output, Btu/kWh	Up to 4674	3100 to 1706
Power-to-Heat Ratio	0.73	2.00
Emissions	Meets ARB[4] 2007	Meets ARB 2007

Source: (ICF 2007)

3.3. Natural Gas Price Assumptions

The cost of natural gas is a key determinant of the economic competitiveness of CHP systems. This effect is moderated somewhat in that the higher the cost of natural gas, the higher the value of replacing boiler fuel with recovered thermal energy. In general, as natural gas prices

[4] California Air Resources Board

get higher the competitiveness of CHP is reduced because the cost of on-site generation of electricity is increased.

The natural gas prices for CHP systems assumed in the 2005 study ranged from $6.00-7.30/Million British Thermal Units (MMBtu). The historic track of natural gas prices since that study was completed has shown significant volatility (**Figure** 1) with price excursions above this range to levels of greater than $15/MMBtu. Mid-year 2008 natural gas prices were again above $12 but have since (to end of October 2008) dropped back down to levels below $6.00/MMBtu

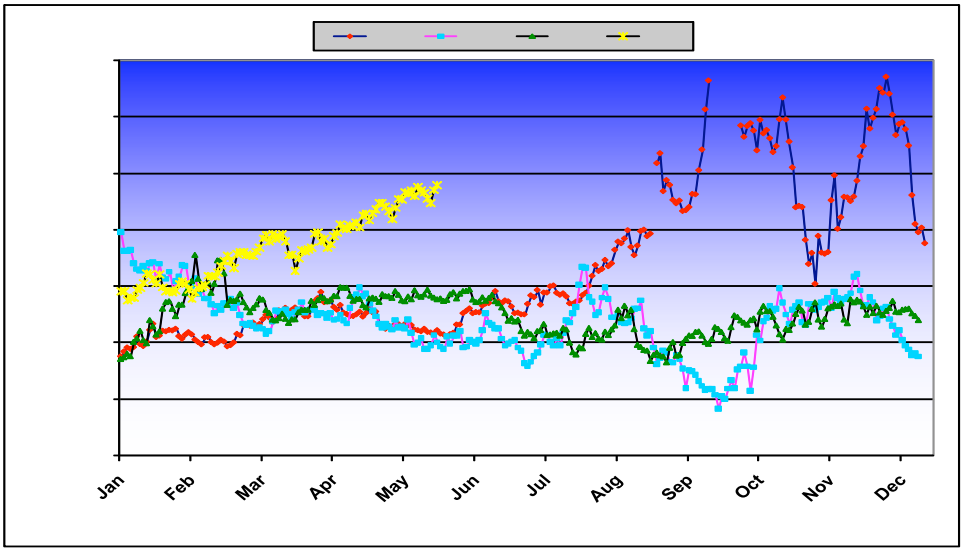

Figure 1. Daily Natural Gas Spot Price at Henry Hub

Source: U.S. EIA reported NGI average of Malin, PG&E Citygate, and Southern California Border Price in 2008

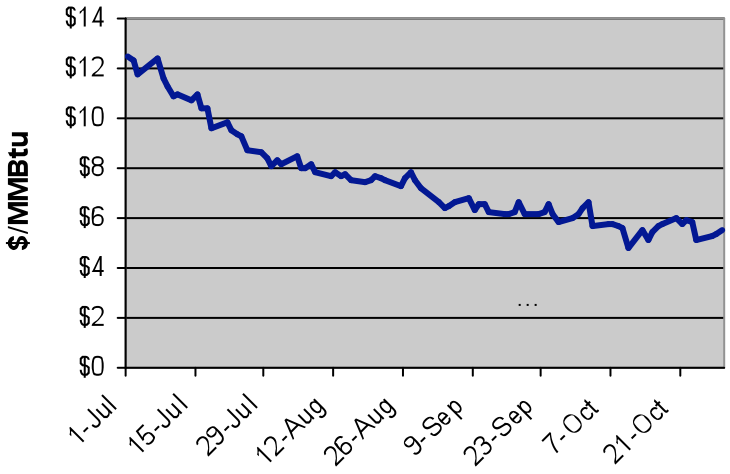

Figure 2. California Composite Daily Natural Gas Spot Price

Source: U.S. EIA reported Natural Gas Intelligence average of Malin, PG&E Citygate, and Southern California Border Price in 2008

The forecast for future natural gas prices that was used for this analysis came from the U.S. Energy Information Administration (EIA) *Annual Energy Outlook for 2008* (AEO 2008). EIA defined a base, high, and low natural gas price track. In 2020, the high and low price tracks are plus and minus 17% compared to the base case prices. Delivered natural gas prices to the industrial and electric utility demand sectors by five-year increments are shown in **Table 2**. Error! Reference source not found. compares the EIA forecast with New York Mercantile Exchange (NYMEX) Henry Hub Settlement prices adjusted to real 2007 dollars using an assumed inflation rate of 2.2% per year. No delivery charge was added to the NYMEX settlement prices in this comparison because the California border price has been averaging $0.50-1.00/MMBtu less than the Henry Hub price shown. The NYMEX price track is very similar to the EIA high gas price case.

Delivered Gas Prices $/MMBtu	2010	2015	2020	2025	2030
Industrial					
Base Case	$7.21	$6.15	$6.21	$6.56	$7.29
Low Price Case	$6.94	$5.38	$5.35	$5.71	$6.22
High Price Case	$7.58	$7.15	$7.29	$7.52	$8.44
Electric Utility					
Base Case	$6.96	$5.93	$5.95	$6.26	$6.93
Low Price Case	$6.71	$5.20	$5.11	$5.42	$5.90
High Price Case	$7.31	$6.89	$6.96	$7.15	$8.06

Source: U.S. Energy Information Administration

Table 2. U.S. EIA Annual Energy Outlook 2008 Gas Price Forecasts

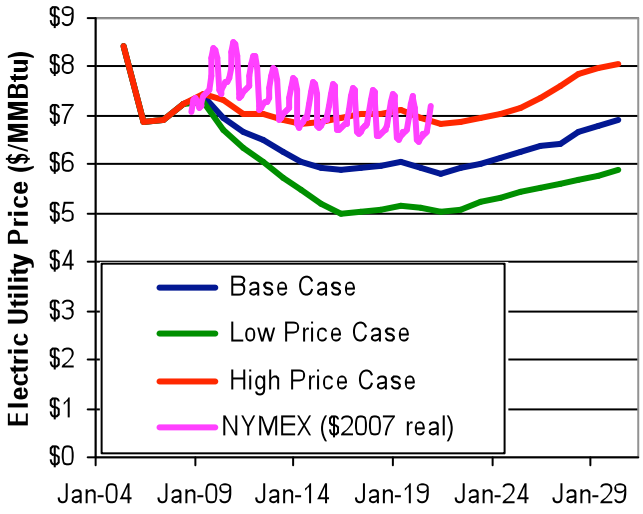

Figure 3. EIA forecase vs NYMEX

Source: U.S. EIA, NYMEX

4.0 Project Results

The results of the analysis include the quantification of technical market potential based on the physical ability of industrial facilities to meet their steam load with combined heat and power systems with excess power capacity after meeting plant needs that can be exported to the California electric grid. This technical potential was then analyzed as a function of electric selling price to the grid in an economic competition and market penetration model to determine the potential cumulative market penetration of CHP generated power for grid export under a range of natural gas price scenarios

4.1. Technical Market Potential

The analysis of the 947 California industrial sites, described in the previous section, yielded a total of 5,268 MW of potential export power from CHP facilities that could be developed to meet on-site industrial steam loads.

Only a limited number of sites had export potential. Of the 947 facilities evaluated, 110 showed export market potential, 40 facilities in the greater than 20 MW size class and 70 facilities in the 5-20 MW size range. While the total potential is quite large, only 7 percent of this potential (392 MW) is below 20 MW. Most of the potential is in very large facilities with more than 100 MW of export. Power export is maximized in these large facilities by using gas turbine combined cycle power plants that increase the power-to-heat ratio compared to smaller industrial turbines.

Export potential was not analyzed for facilities less than 5 MW in the 2005 study. Looking at these 837 smaller facilities, there is an estimated 149 MW of additional export market potential in 142 facilities.

	5- 20 MW		
Utility	Additional MW CHP at Existing Facilities (Consumed Onsite)	MW Available for Export from Existing Facilities	Export from New Industrial Facilities 2007-2025
SCE	87	151	36
LADWP			
SDG&E			
Other (South)		6	1

PG&E	98	179	18
SMUD	5	1	0
Totals	191	337	55

Table 3. California CHP Export Technical Market Potential from Industrial Facilities 5 to 20 MW

Source: (ICF 2007)

Utility	>20 MW		
	Additional MW CHP at Existing Facilities (Consumed Onsite)	MW Available for Export from Existing Facilities	Export from New Industrial Facilities 2007-2025
SCE	174	1,027	212
LADWP	57	738	27
SDG&E	8	14	15
Other (South)		106	10
PG&E	280	2,647	81
SMUD			
Totals	518	4,538	344

Table 4. Export Technical Market Potential from Industrial Facilities Greater Than 20 MW

Source: (ICF 2007)

Existing CHP [5] (5 MW and up)	Additional MW CHP at Existing Facilities (Consumed Onsite)	MW Available for Export from Existing Facilities	Estimated Export in New Industrial Facilities 2007-2025	Additional Export in Existing Facilities < 5 MW [6]

[5] In the 5 to 20 MW size, 947 facilities were evaluated. Of these, 110 showed export market potential. Forty facilities were in the >20 MW size class range and 70 facilities were in the 5-20 MW size range.

[6] The 2005 study did not analyze export potential for facilities less than 5 MW. For the purpose of this paper, 837 facilities in this size were examined. There is an estimated 149 MW of additional export market potential in 142 facilities.

762 MW	5-20 MW	>20 MW	5-20 MW	>20 MW	5-20 MW	>20 MW	149 MW
	191 MW	518 MW	337 MW	4,538 MW	55 MW	344 MW	
			4,875 MW		399 MW		149 MW

Table 5. California CHP Export Technical Market Potential (All Industrial)

Source: (ICF 2007)

4.2. Potential Economic Market Penetration

The cumulative 2025 export market penetration was estimated using the three future natural gas pricing scenarios in the EIA *Annual Energy Outlook for 2008* is shown. **Figure 4 and Figure 5** show cumulative export market penetration as a function of export power price for the greater than 20 MW and the 5-20 MW markets, respectively.

The greatest penetration potential is in the greater than 20 MW market size. Up to 4,000 MW of CHP could penetrate the market by 2025 at an export tariff of $0.10/kWh. At this price level, all of the gas price scenarios produce the same result – maximum market penetration. The threshold electric price, the price that market penetration starts to occur, ranges from $0.05-0.06/kWh.

The 5-20 MW CHP export market for industrial facilities is capable of cumulative 2025 market penetration of 245 to 281 MW of CHP produced power at a purchase rate of $0.10/kWh. The threshold electric price ranges from $0.063/kWh to $0.072/kWh.

If the export tariff is close to the threshold electric price, the level of market penetration is very sensitive to the natural gas price assumed. As the electric tariff increases, there is less sensitivity to the gas price as shown in Error! Reference source not found.. At an export tariff of $0.10/kWh there is very little proportional variation in market penetration resulting from changes in the assumed gas prices. However, at a tariff of $0.08/kWh, the market penetration within the target size varies by a factor of about three to one.

For the >20 MW market for industrial facilities, the initial market response begins at about $0.06/kWh for the EIA gas price scenario and at $0.08/kWh using current California gas prices. Both cases move toward convergence with the technical market potential of about 4,800 MW.

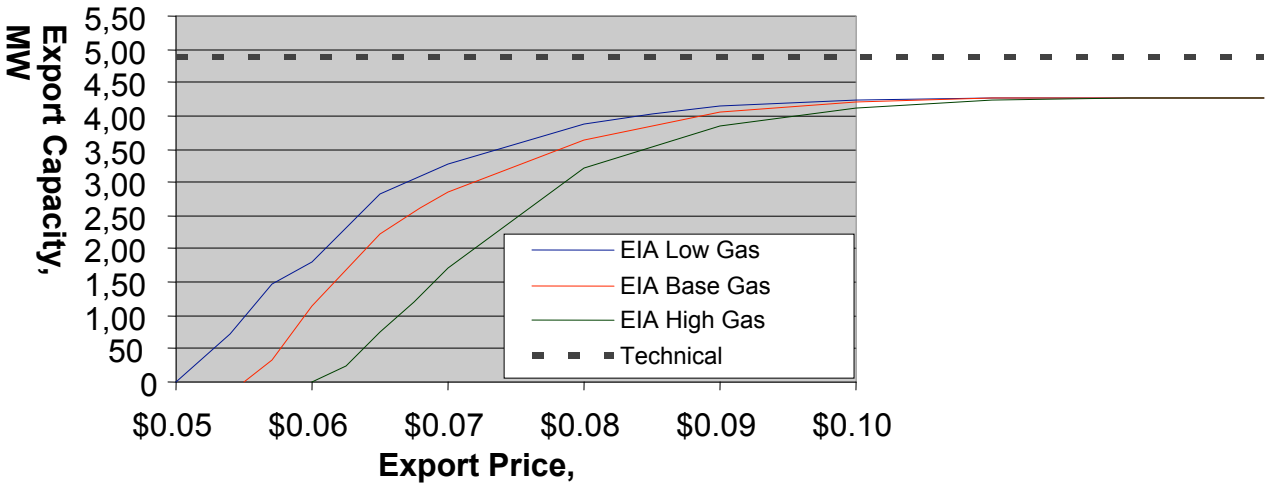

Figure 4. CHP Export Cumulative Market Penetration for Industrial Facilities Greater Than 20 MW

Source: (ICF 2007)

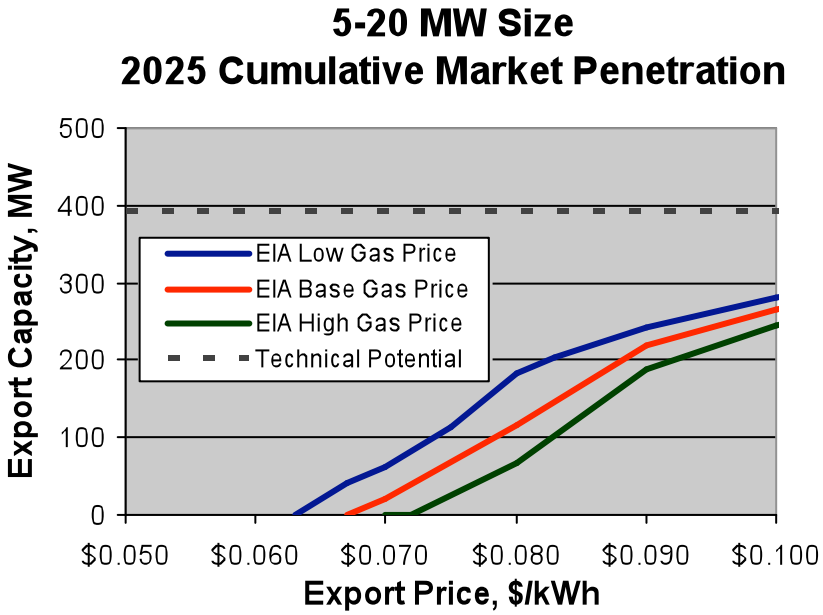

Figure 5. CHP Export Cumulative Market Penetration for Industrial Facilities in the 5-20 MW Size Range source: (ICF 2007)

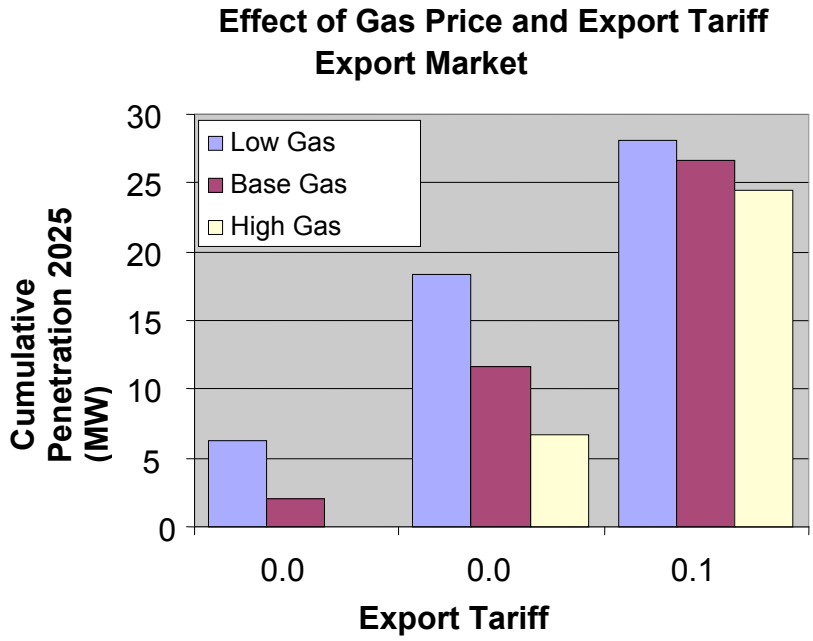

Figure 6. CHP Market Penetration for Selected Electric Tariffs Source: (ICF 2007)

4.3. Conclusions

Most of the technical market potential identified in the industrial facility analysis was larger than 20 MW per site. There were 40 industrial facilities that could install new CHP systems with a total export power potential of 4,532 MW. Estimated growth in the covered markets over the forecast period increases this potential to a total of 4,876 MW.

The technical potential for export CHP in facilities less than 20 MW per site is 541 MW, which includes 392 MW in the 5-20 MW size range and 149 MW in facilities with export capability of less than 5 MW.

The likelihood that this CHP export potential will penetrate the California market depends on future gas prices and on the contract price for export power. As the contract export price increases, the market penetration of CHP systems also increases. A threshold electric price of $0.05-0.06/kWh is required as the minimum stimulus for market penetration for large facilities. A threshold electric price of $0.063-0.072/kWh is required to stimulate export market penetration for facilities in the 5-20 MW size range.

As with the technical market potential, future market penetration at any given contract export price will be predominantly in systems of greater than 20 MW per site. In fact, CHP systems greater than 20 MW can compete at lower contract export prices than can smaller systems due to the economies of scale in CHP technology.

4.4. Recommendations

This analysis looked at the industrial market only. Other markets should be evaluated to determine if there is additional potential.

- Fuel ethanol production – There are several ethanol plants that have been planned for construction in California to meet growing fuel ethanol demand. Ethanol plants have significant steam demand and could make effective use of CHP if they could export a large share of the power produced. A typical ethanol plant could support a 20 MW CHP plant to meet onsite steam loads. Onsite power demands are only about 4 MW.
- Enhanced Oil Recovery – There are 2,900 MW of existing CHP providing steam for enhanced oil recovery in California. A study undertaken in 1999 by Electric Power Research Institute (EPRI) shows that there is additional remaining potential for CHP.[7]
- Repowering of Existing CHP – The potential for expanding existing CHP systems to increase the power output and the export potential should be studied.
- Commercial and Institutional Markets – There is a significant potential for added CHP in commercial and institutional markets. These markets should be evaluated to see if there is additional potential for CHP systems that meet on-site thermal loads and produce excess power for export. This evaluation should include the range of

[7] *Enhanced Oil Recovery Scoping Study*. (TR-113836), EPRI, October 1999.

competitive CHP technologies in these applications (reciprocating engines, fuel cells, microturbines, gas turbines).

- The choices of CHP system configurations used for this paper (simple cycle gas turbine and gas turbine combined cycle plant) result in high electrical power output (as high as 3,100 and 1,760 Btu per kilowatt-hour of electrical energy, respectively). Technical and financial considerations, including tariff structures, could result in the choice of alternative system configurations. Alternative configurations should be considered.

Since the future market penetration of export CHP is so dependent on the relative pricing of natural gas and the contract export price, further study is warranted on the market impacts of such contract mechanisms as locational contract pricing to include distribution values and indexing to natural gas prices. The impact of Self-Generation Incentive Program incentives, "pay as you save" financing of CHP facilities, and future gas and electric pricing are also important and should be considered.

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