Energy and Environmental Analysis, Inc.

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CHP Market Potential in the Western States

Task 5 Report

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1. INTRODUCTION

This report summarizes the combined heat and power (CHP) market potential for eight Western States – Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington. This is the final summary report of a series of reports designed to assist the Department of Energy to define the CHP opportunity in the Western United States. The purpose of these reports is to help focus the market outreach activities of the DOE Western Regional Office. The four studies in this series, three of which were conducted by Energy and Environmental Analysis, Inc. (EEA), cover the eight states in the DOE Western Region.:

- The initial study in the series covered CHP market opportunities in the Pacific Northwest covering the states of Idaho, Oregon, Washington, and Alaska.[1]

- The second study, conducted independently by another project team, described the market opportunities in Hawaii.[2] Comments made about this study in this report are based on analysis of a partial draft provided by the Hawaii Department of Business, Economic Development and Tourism and as such may not reflect the opinions and conclusions of the authors or the sponsors.

- The third study concerned CHP market opportunities in California. EEA undertook this study for the Electric Power Research Institute and the California Energy Commission.[3] It was the only study in the series not funded by the Department of Energy.

- The fourth study focused on the CHP market opportunities in Arizona and Nevada.[4]

The remaining sections of the report are organized as follows:

2. **Economic and Energy Situation in the West** – This section identifies economic growth and energy prices by state and describes the interdependence of the Western electrical system.
3. **Existing CHP in the Region** – This section provides a baseline of existing CHP in each state and discussion of incentive programs.
4. **CHP Market Outlook** – This section summarizes the technical and economic market potential for CHP in each of the eight states, identifying applications and markets for CHP by industry category, application, size, and state. Market penetration estimates are provided for each of the states.
5. **Conclusions and Recommendations** – This section summarizes the key conclusions and results of state-by-state assessments.

[1] *Combined Heat and Power in the Pacific Northwest: Market Assessment*, Energy and Environmental Analysis, Inc. for Oak Ridge National Laboratory and the U.S. Department of Energy, August 2004.
[2] *Creating Distributed Energy Opportunities for Hawaii, Global Energy Partners, LLC, for State of Hawaii and the U.S. Department of Energy, June 27, 2003.*
[3] *Assessment of California CHP Market and Policy Options for Increased Penetration*, Electric Power Research Institute with Energy Environmental Analysis, Inc., E3, and Primen for California Energy Commission, April 2005.
[4] *Combined Heat and Power in Arizona and Nevada: Market Assessment*, Energy and Environmental Analysis, Inc. for Oak Ridge National Laboratory and the U.S. Department of Energy, August 2005.

2. ECONOMIC AND ENERGY SITUATION IN THE WEST

2.1 Economic Activity

The economy of the region consists of the interconnected six states that are linked geographically and economically and the isolated economies of Alaska and Hawaii. As shown in **Figure 1**, the region is dominated by California which represented 65% of the total combined economic output in 2004. The next largest state economies are Arizona (11%), Washington (9%), Oregon (6%), and Nevada (4%.) Hawaii, Idaho, and Alaska together comprise only 5% of the economic output of the eight state Western region. Altogether, the eight states make up over 20% of the total U.S. economy.

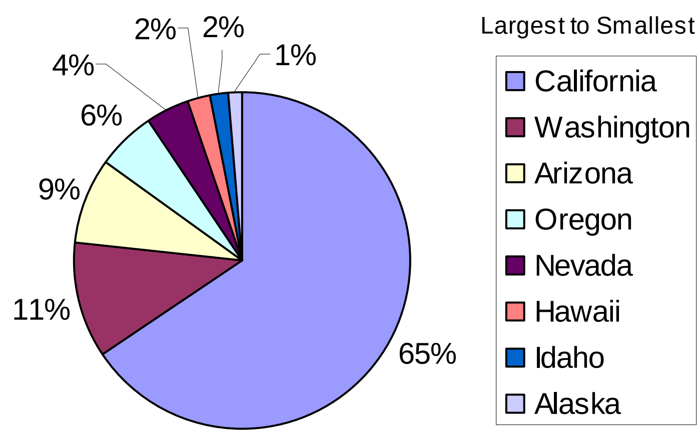

Figure 1 Share of Western 2004 Economic Output by State from Largest to Smallest

The economies of the six Western states in the contiguous lower-48 states are all growing faster than the U.S. as a whole. **Figure 2** shows the 1997-2004 average annual growth rates for the eight states from highest to lowest. Arizona is the most rapidly growing economy, followed closely by Nevada, Idaho, and California. Growth of the two most populous states in the Northwest, Oregon and Washington, is comparatively slower, but still faster than the average growth rate for the U.S. economy as a whole. Alaska and Hawaii, on the other hand, are growing very slowly.

Rapid economic growth creates opportunities for CHP by increasing the rate of development of new facilities. It is generally more economic to design a CHP system for a new facility than to retrofit CHP to an existing building. Installation costs are lower, there are fewer engineering and design problems to solve, and some of the costs of separate heating and cooling equipment can be avoided. Another important factor is the strain on energy infrastructure in a rapidly growing area. CHP as a distributed energy resource can help to reduce or delay the need for costly expansions in electric generation, transmission, and distribution.

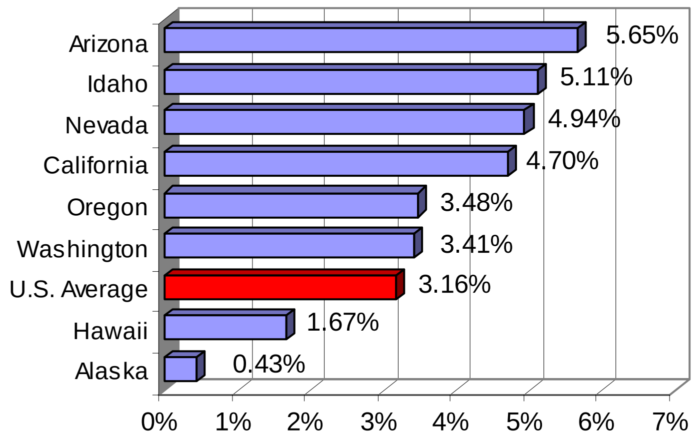

Figure 2 ***1997-2004 Real Growth in Gross State Product by State Compared to U.S. Average Growth***

The composition of economic activity in the individual states differs significantly from each other and from the average U.S. breakdown of gross domestic product, particularly in the smaller states.

California is a very large and diverse economy. Agriculture, forestry and fishing are above national average shares of GSP. Computers, apparel, oil refining represent important manufacturing sectors. The sheer size of the economy makes for large opportunities in CHP target sectors. For example, the real estate market alone is nearly as large as Washington's entire economy. Health care and social service expenditures in California are greater than the entire GSP of Nevada. The output of restaurants and bars is larger than the entire private sector economy of Alaska. The same is true for the motion picture and sound recording industry.

In the Southwestern states of Arizona and Nevada, there is a lower percentage of manufacturing industry output, particularly in the energy and CHP intensive sectors – food, wood products, paper, chemicals, refining. Arizona does have comparatively higher concentrations of mining, electronic, computer, and transportation manufacturing than the rest of the U.S. In Nevada, the hotel, restaurant, and entertainment industries are very important making up over 18% of gross state product – compared to about 4% for Arizona and the U.S. as a whole. Nevada also has nearly double the construction industry output, on a percentage basis, compared to the U.S. figures.

The three Pacific Northwest states of Idaho, Oregon, and Washington have a strong industrial base in CHP friendly process industries such as wood and paper manufacturing, and food processing. Oil refining is important in Washington. For the most part, these energy intensive industries are on the decline as are aluminum smelters in the region. High tech industries in Oregon and Washington are important sources of economic activity, but do not have the steam loads of traditional industries. Washington has a number of military bases.

Alaska and Hawaii are small isolated economies. They both have a high degree of military and civilian federal expenditures. Military bases in particular offer strong opportunities for CHP. Air and water transportation is also comparatively important. Both are lacking in manufacturing activity. Alaska's principal industries are oil and gas extraction, mining, and fishing. Petroleum refining and food (mostly fish) processing are important manufacturing activities. In Hawaii, agriculture and fishing are important, and like Alaska, manufacturing is limited except for refining, apparel, and food. Petroleum refining and food represent good CHP markets. Hawaii also has a strong tourism industry with hotels, restaurants, and entertainment facilities; these sectors also represent potential CHP targets.

2.2 Electricity Supply and Pricing

Table 1 summarizes selected electric power generation and sales statistics for the eight states. There are nearly 23 million electric customers, the majority in California. Altogether, the eight states have a summary generating capability of 130,000 MW. By comparing the generation and retail sales statistics, one can see that Arizona and Washington are net electricity exporters and California and Idaho are net electricity importers. Existing CHP, to be described in more detail in Section 3, is summarized for each state. Hawaii has the highest share of generating capability that is met by CHP at nearly 30% followed by Alaska (19%), Oregon (18%), and California (16%). In Arizona, CHP contributes the lowest share followed by Washington, and then Idaho. Across the eight states, about 11% of electric capacity comes from CHP. Much of this capacity is in the large merchant and independent power plants that provide power to the electric grid and steam to a nearby industrial facility.

Table 1 Selected Electricity Statistics by State, 2002 data (EIA)

Electric Industry	Alaska	Arizona	California	Hawaii	Idaho	Oregon	Nevada	Washington
Thousands of Retail Customers	285	2,352	13,623	435	668	1,715	981	2,838
Generating Capability MW	2,006	19,442	56,663	2,267	3,264	12,485	6,856	27,112
Generation Million MWh	7	94	184	12	10	47	32	103
Retail Sales Million MWh	6	63	235	10	21	45	29	76
Active CHP MW	382	169	9,130	675	175	2,253	551	1,044
CHP Share of Total Capability	19.0%	0.9%	16.1%	29.8%	5.4%	18.0%	8.0%	3.9%

Excluding the isolated systems in Alaska and Hawaii, the six Western states are part of a large interconnected grid known as the Western Interconnection. **Figure 3**, from the Western Governors' Association transmission study[5], shows the summer-installed capacity by generation type within each transmission-constrained area in the Western grid. The width of the blue line between the circles shows the relative transfer capacity between the transmission-constrained areas. Washington, Oregon, and Idaho, along with British Columbia, have very large hydroelectric power resources. Additional power comes from thermal power plants, mostly fired by natural gas, though coal capacity is in Washington.

California generating capacity is mainly natural gas-based with hydroelectric, renewables, and nuclear making up the remaining capacity.

[5] *Conceptual Plans for Electricity Transmission in the West*, Report to the Western Governors' Association, August 2001.

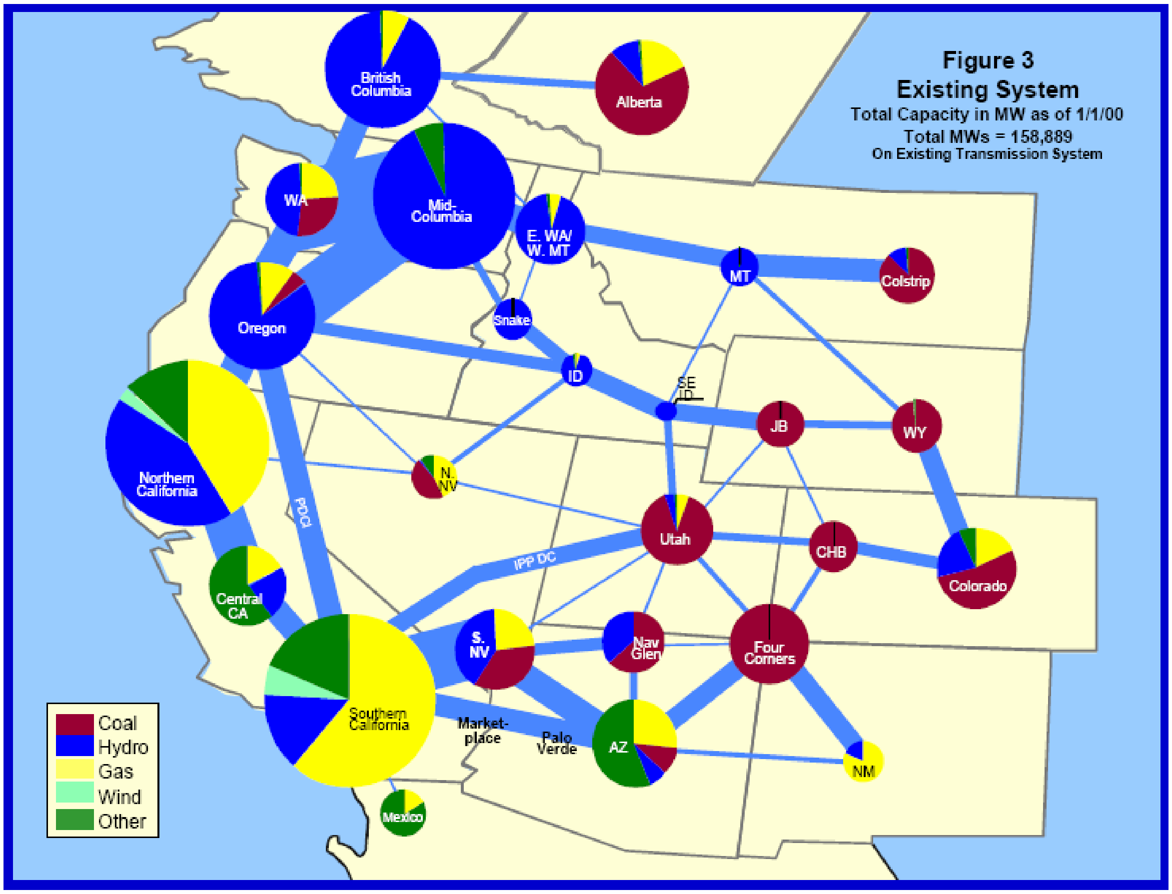

Figure 3 Western Grid Electric Generating and Transmission Capacity

Nevada has hydroelectric resources in the South, though most power comes from natural gas and coal. In Arizona, power comes from gas, coal, and nuclear energy.

Figure 4 indicates the amount of exports and imports between the market centers that might be expected during the peak summer hours under average hydro conditions in the Western System. As the figure shows, California is pulling power in from the Northwest, Canada and the Southwest. A significant amount of transmission on the West Coast links the hydro generation areas of the Northwest with coastal load areas. It facilitates the considerable amount and variation of inexpensive hydro generation that can occur depending on seasonal water conditions. There also is a significant amount of transmission between the Desert Southwest areas and Southern California areas facilitating large amounts of dedicated coal-fired generation, jointly built and owned by California and Southwest utilities.

Because of the long distances between areas in the Rocky Mountain states, transmission is limited in the eastern part of the loop. In this area dominated by coal-fired generation, the existing transmission is generally tailored to fit specific generation and exports. These plants supply power to load centers in the eastern end of the Western Interconnection. They also supply energy through the limited east side transmission system to the West Coast and Southwest areas where hydro and gas peaking capacity is used to shape the energy and follow capacity demand.

CHP development in each of these six states will have an impact on the overall need for power and for power transmission in the region.

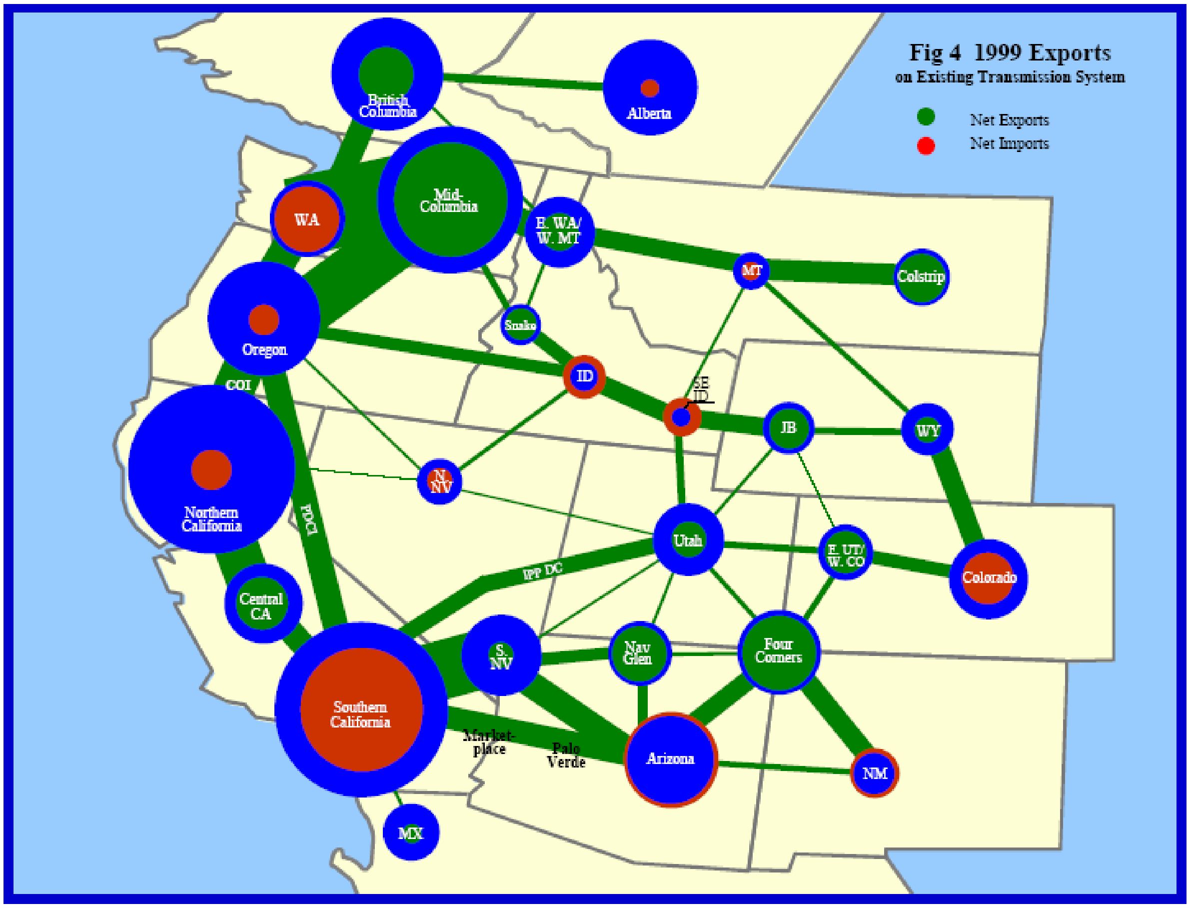

Figure 4 Regional Power Movement – Net Imports and Exports

In Alaska and Hawaii, there are a number of individual power grids separated by either water or relatively uninhabited areas. Power in Alaska comes from coal, oil, and natural gas. Power in Hawaii is produced primarily from oil and coal, though there is a strong push to increase renewable power generation.

Electric prices vary widely in the eight states. **Figures 5 and 6** show the average Industrial and Commercial Electric costs per kilowatt-hour for each state ordered from highest to lowest. The U.S. average is shown on each chart. Hawaii has the highest electric rates in the nation with an average 18 cents/kWh for commercial customers and 15 cents/kWh for industrial customers. Rates in Alaska are also very high. After these two isolated markets, California has the next highest rates in the region. In the Southwest, Arizona rates are around the national average while Nevada rates are higher. Rates are below the national average in all the Northwest states, lowest in Idaho and highest in Oregon. In terms of CHP markets, Hawaii, Alaska, California, and Nevada rates should encourage CHP; rates in Arizona, Oregon, Washington, and Idaho present a more difficult market for CHP.

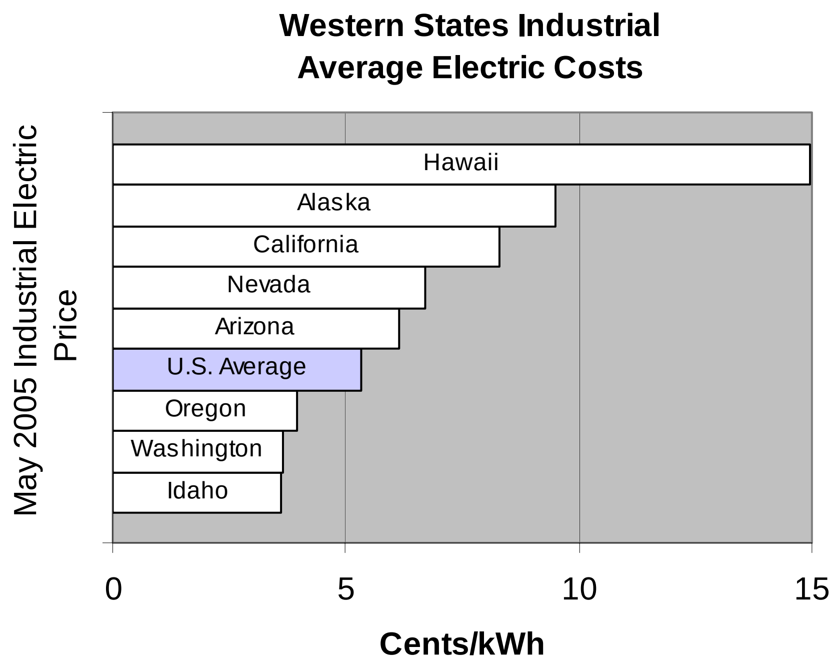

Figure 5 ***May 2005 Average Industrial Electricity Price (EIA)***

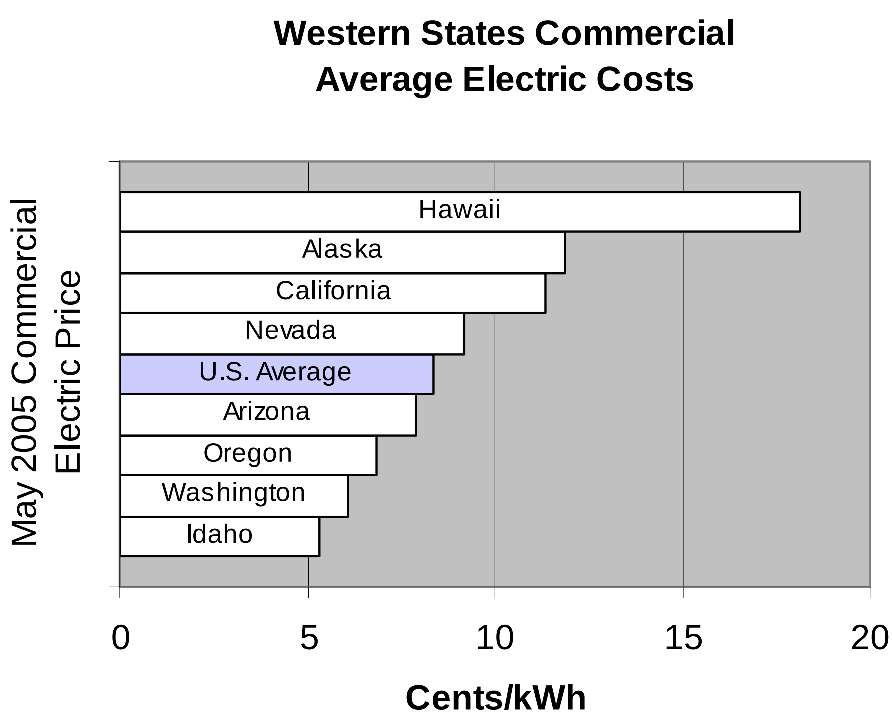

Figure 6 ***May 2005, Average Commercial Electricity Price (EIA)***

3. EXISTING CHP IN THE REGION

There are over 14,000 MW of existing CHP capacity in the eight state Western region. Nearly two-thirds of this capacity is in California; one quarter is in the three Northwestern states (ID, OR, WA); 7% is in Alaska and Hawaii, and only 5% is in Arizona and Nevada. **Figure 7** shows this breakdown. .

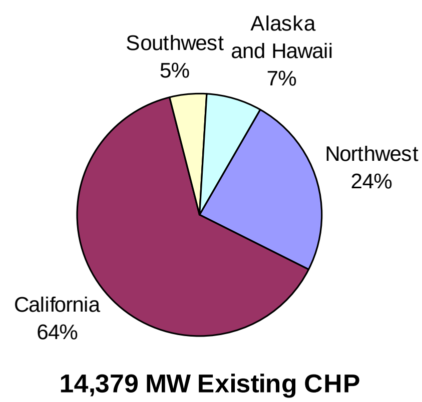

Figure 7 Existing CHP Capacity by Western Region

Figure 8 shows the share of total generating capability in each state made up by CHP. Hawaii has the highest share at nearly 30%. Alaska, Oregon, and California all have CHP that equals over 15% of total generating capacity. The other four states all have much lower CHP shares.

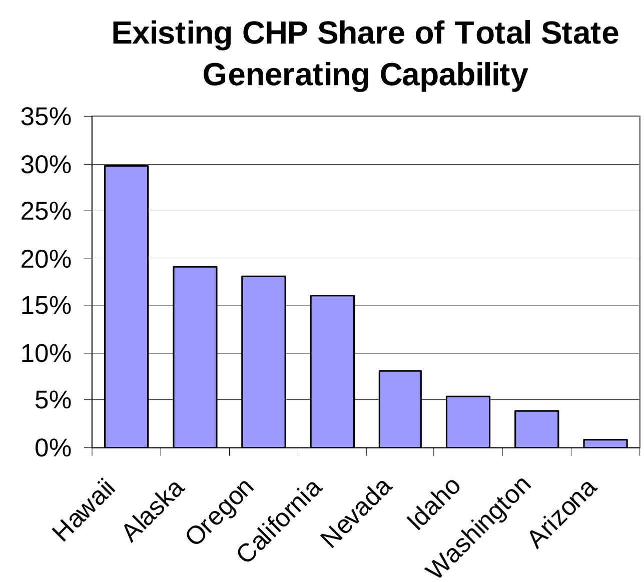

Figure 8 CHP Share of Total State Generating Capability

2.1 Existing CHP in the Northwest

There are 146 active CHP installations with a total capacity of 3,854 megawatts in the PNW region including Alaska. In spite of having overall electric production that is less than half that of Washington, Oregon has over twice the capacity of installed CHP and leads the entire region with 58% of the total regional CHP capacity. Oregon has the highest active CHP capacity in the region due, in large part, to recent large merchant plant installations concentrated close to the California border. Washington has the next largest share (27%), followed by Alaska (10%) and Idaho (5%).

Alaska leads in active installations (82) – the majority of which are remote village diesel power systems with heat recovery for surrounding buildings. Oregon (31), Washington (21), and Idaho (12) trail in site totals.

Figure 9 shows the breakdown of existing CHP capacity by end-use application. Four industries account for a total of 89% of the active CHP capacity. The food industry is the largest, followed by the pulp and paper, oil refining, and wood product industries. Another 3% of the regional CHP capacity is located at “other industrial” sites. The commercial sector accounts for 6% of total capacity; though, it is important to note that this sector, by definition, includes several large projects at military bases in Alaska. Outside of these large military base systems, there is little other commercial sector activity in the region. Finally, 2% of the CHP capacity is made up of Alaskan Village power systems.

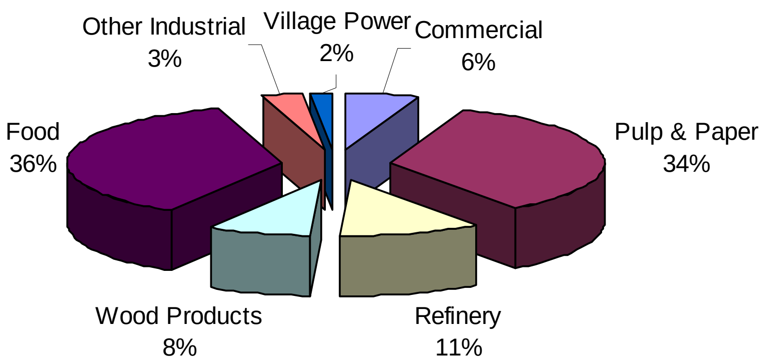

Figure 9 Existing CHP Capacity in the Northwest

Natural gas is the predominant fuel powering CHP in the Northwest region, supplying nearly 80% of installed CHP capacity. Biomass is the next most important fuel source, supplying 12% of installed CHP capacity in the region. The primary sources of biomass-derived fuels are black liquor and wood waste, but biomass also includes digester gas from sewage treatment plants and dairy feedlots. Coal is used as a fuel primarily in the remote Alaskan military bases. Diesel oil is the predominant fuel in the Alaskan Village power systems.

Alaska has the highest spark spread (high power costs / low fuel costs), making for a favorable economic environment for CHP. There are also a large number of remote facilities (villages, military bases, and seafood packing plants) where grid power is unavailable. Natural gas is used where available; oil and coal are used in remote areas. Alaska also has the highest share of CHP as a percentage of total generating capacity of the four states in the region.

Idaho has the lowest power costs in the U.S., which results in a low share of CHP as a percentage of total power generation. There are a small number of food and forest product CHP plants; however, there has not been much recent CHP development activity in the state. The average age of the operating CHP plants in Idaho is 20 years old.

Oregon has the highest total CHP capacity in the region. There have been many combined cycle power plants recently installed near the California border that provide steam to Oregon industrial facilities and power to both the Northwest and California power markets. Oregon has very active state incentive programs that support CHP development on the basis of energy conservation, reduction in green house gas emissions, and economic development. Somewhat offsetting these positive trends, Oregon has the highest retirement rate for CHP projects in the declining pulp and paper and wood products industries.

Washington is similar to Oregon and Idaho in industry make-up with a large share of paper and wood product plants, but refinery installations are also important. Washington is suffering from declining traditional industries as well as slumping high-tech industries. As the largest power producer in the region with the highest level of imbedded hydroelectric capacity, Washington has the lowest share of CHP capacity as a percentage of total power production capacity.

Industrial use dominates the market for CHP in the PNW region, but it is concentrated in older, stable or declining industries – many CHP plants have been shut-down in recent years. Large combined cycle plants are tied more to the economics of the overall Western regional power markets than to the needs of the Pacific Northwest. With the exception of Alaska, there are a very limited number of commercial buildings that have CHP projects outside of large campus power and steam systems. For example, there is one hospital project in Washington, which is the only commercial sector CHP system in the state. Village power systems based on diesel generators with heat recovery are very common in Alaska, although heat recovery is used at only one-third of such systems. The village power plant and heat recovery system for St. Paul Island in Alaska is an advanced system combining diesel generators and wind power turbines. Anaerobic digesters for waste water treatment and dairy manure treatment is an emerging market; most use internal combustion engines to generate power from the digester gas, but a number are using fuel cells and microturbines.

2.2 Existing CHP in the Southwest

There are 29 active CHP installations with a total capacity of 720 megawatts in Arizona and Nevada. **Figure 10** presents the two state capacity breakdown by application.

Arizona has 14 active projects in the commercial sector consisting of three colleges, four medical centers, three hotels, a retirement home, water treatment facility, municipal buildings complex, and an army base. Arizona has six industrial facilities that are spread out in mining (2), refining, electronics manufacturing, paper, and textiles.

Of the nine active projects in Nevada, six are in the industrial sector. These facilities are all in different industries: printing, chlor-alkali, greenhouse, paper manufacturing, gypsum, and an unspecified steam host. The three commercial facilities are in a large casino hotel, an aquatic center, and an apartment building.

The spark spread for CHP has eroded in Arizona in recent years as gas prices have risen. Eleven previously active CHP projects with a combined capacity of 28 MW have been shutdown or in one or two cases converted to peak-shaving duty. Almost all of these shut-down plants were smaller facilities using reciprocating engine prime movers that were installed in the 1980s or early 1990s. There has not been much CHP activity in the last three years, but there is some planned growth. A 16 MW plant is under construction and expected to come on line in May 2006 at Arizona State University and two small projects (under 100 kW) have also been announced.

A couple of older small reciprocating engine sites have also been shut down in Nevada, but there are a number of planned projects.

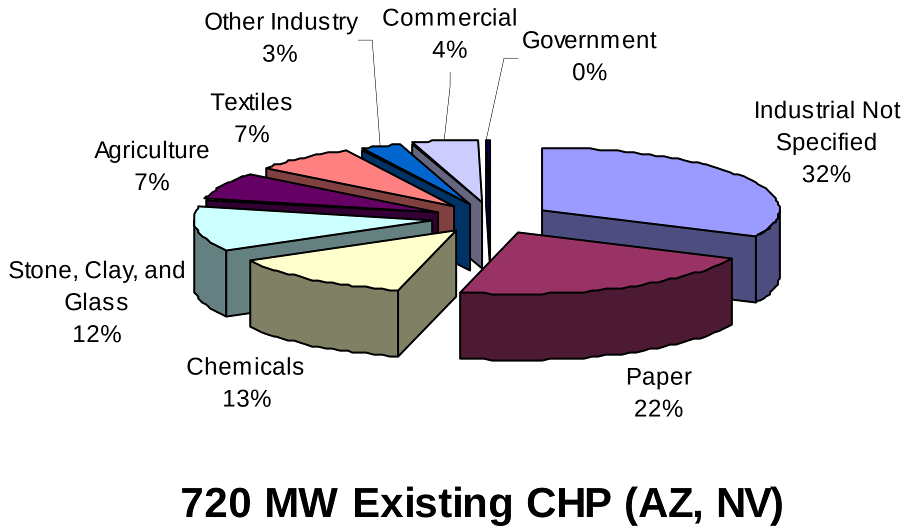

Figure 10 Arizona and Nevada Existing CHP

2.3 Existing CHP in California

There are 9,130 MW of active CHP in California at 776 sites. Nearly 90% of this capacity resides in large systems with site capacities of over 20 MW.

The largest share of active CHP capacity (**Figure 11**) is located in the oil fields to provide steam for enhanced oil recovery (EOR). Half of the total capacity is in the industrial sector and is heavily concentrated in five process industries: food processing, refineries, metals processing, pulp and paper, and chemicals. CHP in all other industrial sectors accounts for 7% of the total. The commercial and institutional sector represents 19% of the total capacity. While this commercial/institutional share is a small part of the California total, this market is comparatively well developed compared to the rest of the country; the commercial/institutional sector represents only 12% of total CHP capacity on a national basis.

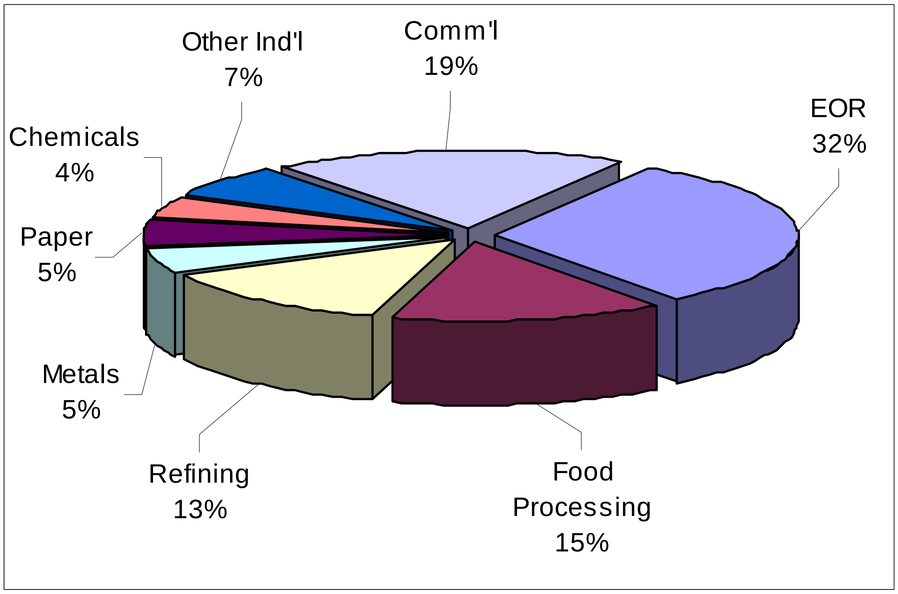

Figure 11 California CHP Capacity by Application

Large installations make up most of the existing capacity. Systems under 5 MW represent only 3.2% of total existing CHP capacity in California. Systems greater than 100 MW represent almost 40% of the total existing capacity. However, as will be shown later, the market saturation of CHP in large facilities is much higher than for smaller sites. Much of the remaining technical market potential is comprised of smaller systems.

By far the most important fuel utilized for CHP is natural gas representing 84% of the total installed capacity. Renewable fuel makes up 4% of the total capacity with the bulk of this capacity in the wood products, paper, and food processing industries and in waste water treatment facilities.

2.4 Existing CHP in Hawaii

There are 22 active CHP projects in Hawaii with a combined capacity of 675 MW. **Figure 12** shows the breakdown of existing CHP capacity in Hawaii. There are five refinery projects totaling 532 MW. The next largest source of existing CHP capacity is in food processing. Most of these plants are sugar mills that burn bagasse, a fibrous waste product of sugar refining. Many of these plants supplement the biomass with fossil fuels. There are two coal-fired CHP plants providing steam to industrial facilities. There are only 3.2 MW of commercial and government capacity, in seven installations – three hotels, three educational institutions, and one government facility

Unlike the mainland U.S., Hawaii CHP capacity is predominantly fueled by oil. About one-third of capacity is fired by coal, 9% by biomass and waste. A small number of projects are reciprocating engines fueled by propane.

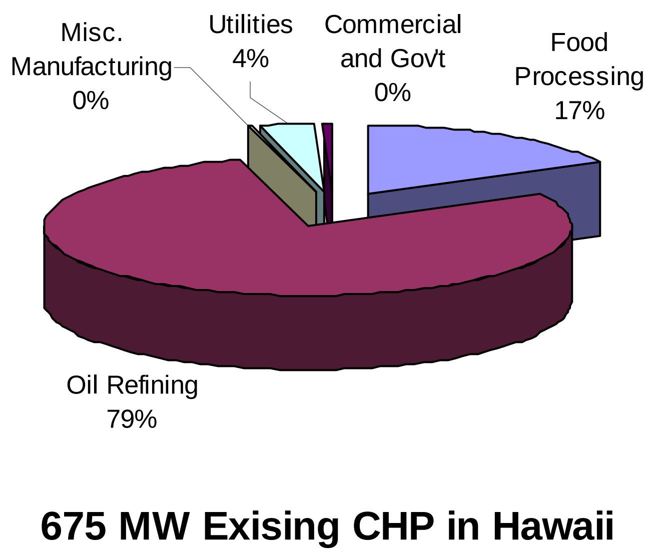

Figure 12 Existing CHP in Hawaii by Application

4. CHP MARKET OUTLOOK

This section compares the market outlook for CHP in the eight states. This comparison looks at technical market potential, CHP technology cost and performance, input fuel prices, incentives for CHP, economic potential, and market penetration. This comparison is made with some caution as the results are from four different studies, done at different times, with different input assumptions, and in some cases for different clients, and by different analysts. **Table 2** summarizes the basic parameters of the four studies.

Table 2 Scope and Design of the CHP Market Studies

CHP Study	Northwest	Southwest	California	Hawaii
States Covered	AK, ID, OR, WA	AZ, NV	CA	HI
Date of Study	2003	2005	2005	2003
Forecast Period	2004-2025	2005-2020	2005-2020	n.a.
Analytical Team	EEA	EEA	EEA	Global Energy Partners
Study Sponsor	DOE/ORNL	DOE/ORNL	CEC/EPRI	Hawaii/ DOE
Market Scenarios Analyzed	2	2	8	1
Scenario Focus	CHP Cost and Performance and Customer Acceptance	CHP Cost and Performance and Customer Acceptance	State CHP Policy and Incentives	Economic Potential of DER

3.1 Technical Market Potential

To effectively utilize CHP, a facility must have coincident electric and thermal energy requirements. For best economic performance, this coincident thermal and electric load should be fairly steady for as many hours per year as possible. A continuous process industry with a nearly constant steam demand and electric load is an excellent target; a hospital with steady electric and hot water demands is a very good target. Facilities with intermittent electric and thermal loads are progressively less attractive as the number of hours of coincident load diminishes. The three studies conducted by EEA used the same approach to identifying target market facilities, though the number of markets evaluated differed somewhat by study. The Hawaii study used a similar approach, namely identifying the types of facilities that would likely have appropriate loads, and then building up the estimate of technical market potential based on the number, sizes, and energy usage characteristics of facilities in each target application.

In the EEA studies, four different types of CHP markets were included, though not all markets were included in each study. The markets included in each study are noted in parentheses:

- Traditional CHP – electric output is produced to meet all or a portion of the base load for a facility and the thermal energy is used to provide steam or hot water. 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 colleges, hospitals, hotels, and prisons. (All Studies)

  - 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, restaurants, schools, and laundries. (Southwest, California)

- CHP with thermally activated cooling (CCHP) – All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round thermal 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 in during the summer months. Two sub-categories were considered:

  - Low load factor applications – These represent markets that otherwise could not support CHP due to a lack of thermal load. (California, Southwest, Hawaii)

  - Incremental high load factor applications – These markets represent round-the-clock commercial/institutional facilities that could support traditional CHP, but with cooling, incremental capacity could be added while maintaining a high level of utilization of the thermal energy from the CHP system. (California, Southwest, Hawaii)

- CHP Export Market – The previous two categories are based on the assumption that all of the thermal and electric energy is utilized on-site. Within large industrial process facilities, there is typically an excess of steam demand that could support larger CHP systems with significant quantities of export electricity to the wholesale power system. The incremental export value of power from these facilities was quantified and evaluated as a separate market. (Northwest, California, Southwest)

- Resource Recovery – The preceding markets focus on applications in which fuel, usually natural gas, is purchased to run the CHP system and displace the site thermal energy requirements. There are applications in which renewable, waste, or opportunity fuels can be utilized in a CHP system. In the industrial sector, there are opportunities in food processing and pulp and paper industries to utilized biomass based fuels. Sewage treatment plants and agricultural operations such as dairy feedlots can utilize digester gas to generate electricity and heat. (Northwest, Southwest, Hawaii.)

The technical potentials by market category are summarized in **Table 3**. The values represent target facilities at both existing sites and for expected growth during the forecast period that could utilize the simultaneous output of heat and power provided by a CHP system.

CHP Markets	AK	ID	OR	WA	CA	AZ	NV	HI
High Load Factor Traditional	708	1,537	3,954	6,491	14,562	1,851	1,447	45
Low Load Factor Traditional	not incl.	not incl.	not incl.	not incl.	5,611	188	109	62
High Load Factor Cooling	not incl.	not incl.	not incl.	not incl.	1,289	109	280	640
Low Load Factor Cooling	not incl.	not incl.	not incl.	not incl.	2,843	2,030	2,724	67
Industrial Export	409	83	753	870	4,089	42	0	not incl.
Resource Recovery	2	23	356	360	not incl.	22	6	21
Total Technical Market Potential	1,119	1,643	5,063	7,721	28,394	4,242	4,566	835

Notable aspects of the potentials in each state are described below:

- Alaska – There are large military facilities in the state. Most already utilize CHP. There are also a large number of isolated village power systems powered by diesel generators that are being converted to CHP.

- Idaho – There are a large number of potato and beet sugar processing facilities in the state that require large amounts of both power and steam.

- Oregon – Pulp and paper and wood products industries are important. The commercial opportunities in the population centers West of the Cascades enjoy a fairly moderate climate – air conditioning loads are small. Combined cooling heating and power was not considered in the Northwest study.

- Washington – Like Oregon, Washington has a significant industrial market in pulp and paper and wood products. In addition, there are several petroleum refineries. Also, like Oregon, the population and economic activity is concentrated West of the Cascade mountains.

- California – There are a large number of petroleum refineries in the state that could support large capacity CHP systems. There are also pulp and paper plants in the North of the state. For commercial applications, air conditioning is important. Furthermore, California is such a large state that opportunities in individual market sectors are often larger than the entire potential in other states.

- Arizona – One of the fastest growing areas in the U.S. there will be a large number of new commercial, multifamily residential, and industrial facilities coming on line in the next 20 years. Arizona lacks the heavy steam using industries of the Northwest and California. This reduces both the industrial on-site CHP potential and also the export opportunities. Air conditioning in commercial applications is a very important market.

- Nevada – Like Arizona, Nevada has a comparatively small industrial base, and the population and economic output are growing extremely rapidly. Perhaps one of the most important sectors in Nevada are applications associated with tourism – hotels, restaurants, entertainment facilities, and casinos.

- Hawaii – The potential is based on analysis of 17 specific application sectors in the state. In the industrial sector, the focus was on petroleum refineries, food processing facilities, and mining activities. In the commercial sector, the focus was on hospitals, office buildings, multifamily, educational facilities, hotels, restaurants, and retail stores. In the public sector, the potential was analyzed for airports, wastewater treatment, and landfills. Like Nevada, applications related to tourism are comparatively important. Like Alaska, there are number of military bases.

These technical potentials are quite large compared to the generating capability in each state, averaging about 50% of total capacity. This identified potential must go through several more tests before a CHP system might actually be installed. First, the customer must be willing to consider CHP; next there must not be site specific factors that could preclude CHP installation; then the facility must produce a positive economic return based on the system costs and prevailing fuel and power rates; finally, the facility operator must be willing to invest based on the expected economic return.

3.2 CHP Technology

All of the seven states analyzed by EEA used generally the same basic technology assumptions with some individual changes to account for local construction costs, emissions control requirements, and early market cost premiums that raise the cost of small CHP systems (less than 5 MW) by 15%-30%. These local changes resulted in technology costs for early market applications being as much as 80% higher than the base technology cost estimates for small engine systems. In this extreme case[6], costs were 15% higher due to escalation of the basic cost estimates during the two years between studies, 23% higher due to the high construction costs (San Francisco), and 28% higher due to the early market premium.

Table 3 shows a cost comparison for a small reciprocating engine CHP system for the four studies. In the Northwest study, there was no adjustment made for local construction costs and no early market premium. In the base case, cost and performance stayed the same throughout the forecast period; technology improvement effects were modeled in the accelerated case. In the California and Southwest studies undertaken two years later, there was a modest upward adjustment to the basic capital costs. In addition, adjustments were made for local construction costs and early market cost premiums. The local cost adjustments raised costs in California, which is 4% to 23% more expensive than national average construction costs. In the Southwest, construction costs are 0% to 15% cheaper than national average costs.

Table 3 Comparison of Cost Estimates for 100-150 kW Reciprocating Engine CHP System

	Northwest	California	Southwest	Hawaii
Cost Estimate Date	2003	2005	2005	2003

[6] The cost multipliers in this numerical example compare the 100 kW reciprocating engine between the estimates used for the Pacific Northwest study developed in 2003 and the estimates used for the San Francisco area of California developed in 2005.

Local Construction Cost Adjustment	No	Yes	Yes	Yes
Early Market Premium	No	Yes	Yes	Yes
Exhaust After-treatment	No	Yes	No	No
Base CHP Estimate $/kW	$1,350	$1,550	$1,550	n.a.
2005 Capital Cost $/kW	$1,350	$2,076-$2441	$1686-$2043	$1531-$1698
2020 Capital Cost $/kW	$1,350	$1265-$1488	$1029-$1246	$1111-$1531

The Hawaiian study was based on diesel and propane engines. There was explicit treatment of differences in local construction costs, which tend to be much higher than on the mainland. There was an improvement over time for these costs, though it wasn't clear whether these changes were due to reductions in the equipment costs or reductions in the costs associated with design, engineering, and installation of CHP systems.

The high costs estimated for California were moderated in the economic analysis due to a $600/kW incentive payment under the Self Generation Incentive Program available for systems under 1 MW in size.

All of the EEA studies modeled the competition of emerging technologies – microturbines and fuel cells versus the major existing technologies, reciprocating engines and gas turbines. In general these emerging technologies were shown to require additional RD&D to be competitive with the existing technologies. **Figure 13** from the Southwest study shows the technologies modeled by size range and the calculated net power costs for each. Net power cost represents the cost of electricity from the CHP system based on fuel and operating costs plus amortized capital expenses minus the fuel savings due to the productive use of the thermal energy. The figure shows that, in general, the net cost of producing on-site power goes down as the size of the system increases.

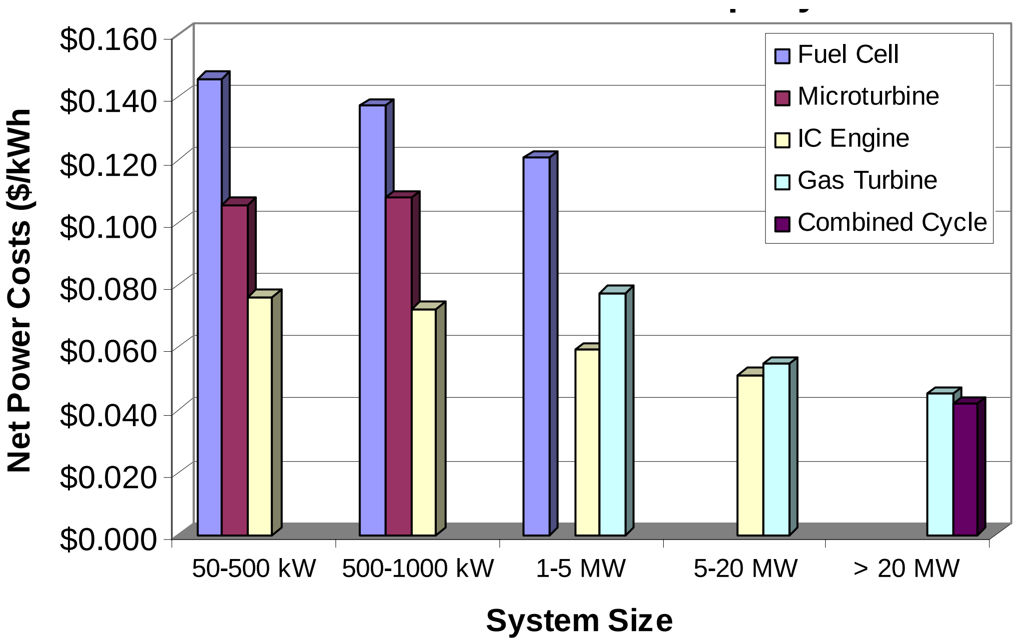

Figure 13 Net Power Costs by System Size and Technology – Southwest Study Base Case Assumptions

3.3 Gas Price Assumptions

One the most critical and volatile aspects of defining the future market potential for CHP is expected future track of natural gas prices. Due to the price swings that have occurred in the last several years, there is a very wide range of viewpoints regarding future natural gas prices. **Figure 14** summarizes the three price tracks used in the Northwest, California, and Southwest studies. The Northwest study undertaken in 2003, was based on the natural gas price forecasts of the Northwest Power and Conservation Council (previously named the Northwest Power Planning Council) forecasts for their 4th Regional Power Plan, the most recent regional forecast available at the time the CHP study was done. This price track represented NPCC's mid-range estimate for gas delivered west of the Cascade Mountains. There was an assumption that the recent gas price increases and volatility would return to a more stable historical track of lower prices.

The California study, undertaken for the California Energy Commission, was based on a combination of Henry Hub gas price futures for the first four years merging into the CEC 2003 natural gas price forecasts developed for their 2003 Integrated Energy Policy Report. The price track shown on the figure is the electric utility price averaged between the Northern and Southern halves of the state. This forecast shows an initial moderation in the current high gas prices followed by a return to real price escalation and a world of basically permanent high gas prices.

For the Southwestern study, the project team selected a third price track that shows the early years of high gas prices falling over time based on the ultimate price stabilization effects of future LNG projects. This forecast was developed and used by the Regional Greenhouse Gas Initiative (RGGI, colloquially known as "Reggie.") The RGGI forecast, utilized EEA's natural gas forecast for the near term and then phasing into the EIA 2004 Annual Energy Outlook , average between the base case and high oil price scenarios. While the RGGI project was focused on impacts in the Northeast, the modeling approach was national in scope, and the assumptions were broadly reviewed.

Given the persistence of high gas prices and price volatility, the NPCC forecast is no longer considered current. In a later section of this summary report, the Northwest market forecast is shown as calculated in 2003 and also with the substitution of the RGGI price forecast used in the Southwest study.

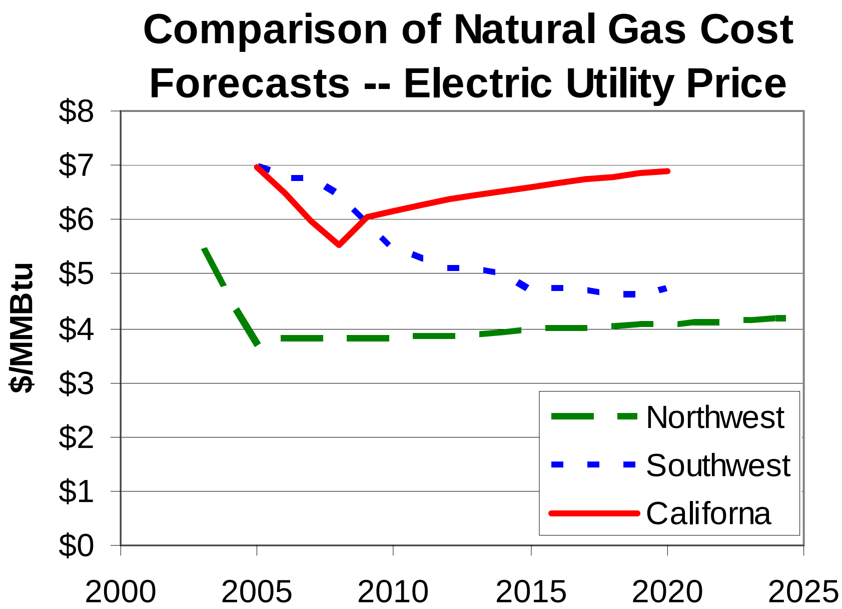

Figure 14 Comparison of Natural Gas Price Forecasts Used in Each Study

3.4 Customer Acceptance of CHP

The economic potential and market penetration estimates in the studies were based on a calculation of the payback associated with CHP compared to the forecast retail electric rates. The behavior of customers to this payback was modeled as a customer acceptance curve – percent of customers that would accept the CHP investment at a given payback. For the first study in the Northwest, it was assumed that all customers would accept a 2-year or less payback and that this acceptance level would decline linearly to zero acceptance at a 10-year payback.

As part of the California study conducted two years later, a separate market research analysis of customer responses and attitudes toward CHP was conducted by Primen. The results of this market research showed that customers were, in general, very risk averse when considering CHP investments. Their acceptance levels were much lower for a given payback. Only 50% of customers said they would accept a 2-year project payback on a CHP investment. Acceptance levels were similarly much lower at higher paybacks. **Figure 15** shows the comparison of the initial curve used in the Northwest study and the curve fitted to the Primen market research that was used in both the California and Southwest studies.

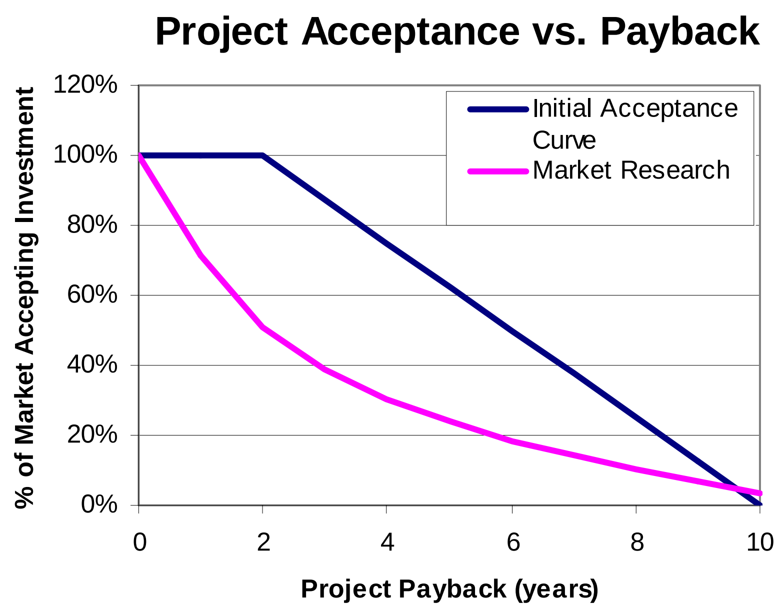

Figure 15 Alternative Assumptions Regarding Customer Acceptance of CHP Project Payback

As in the case of the natural gas price forecasts, the differences in customer acceptance assumed for the Northwest study is significant compared to the other studies. Consequently, the results of that study will be presented as run and then adjusted for gas prices and customer acceptance.

3.5 Economic Potential and Market Penetration

The four studies describe a cumulative market penetration across the eight states of 5,000 MW in the base cases. Adding the high, or accelerated market penetration, cases in each study yields a cumulative market penetration of over 14,000 MW. **Table 4** summarizes the results of the studies as they were presented.

The base cases in each study, for the most part, reflect continuation of the current incentive levels and attitudes toward CHP. The California base case includes the fairly aggressive Self Generation Incentive Program than provides $600 to $2500/kW for small projects – the low end of the range for conventional technology and the high figure for fuel cells. As previously shown, the base case in the Northwest does not include improvements to CHP technology cost and performance. The other studies show evolutionary improvements to technology over time.

Table 4 CHP Market Penetration Comparison for Eight Western States

	AK	ID	OR	WA	CA	AZ	NV	HI
	-- MW --							
Total Technical Market Potential	1,119	1,643	5,063	7,721	28,394	4,242	4,566	835
Market Penetration (Base Case)								
Economic Market Potential (Base Case)	916	76	384	731	n.a.	n.a.	n.a.	809
2010 Cumulative Market Penetration					234	37	66	
2015 Cumulative Market Penetration	383	36	150	298	1,142	104	162	
2020 Cumulative Market Penetration					1,966	197	291	
2025 Cumulative Market Penetration	756	72	297	589				
Market Penetration (High Case)								
Economic Potential (High Case)	1,046	427	1,831	2,847	n.a.	n.a.	n.a.	
2010 Cumulative Market Penetration					1,798	56	92	
2015 Cumulative Market Penetration	756	72	297	589	4,790	170	238	
2020 Cumulative Market Penetration					7,340	300	416	
2025 Cumulative Market Penetration	910	365	1,498	2,386				

The high case shown in Table 4 reflects the most favorable CHP scenario in each study. In the Northwest and Southwest studies, the base and high cases shown reflect the only two scenarios that were analyzed. The high case assumes aggressive improvement to CHP technology, an incentive package equal to 15% of total capital costs, and higher acceptance levels for CHP investment. The Southwest high case includes the aggressive technology improvement and the higher levels of consumer acceptance, but not the incentive package. In the California case, at least eight scenarios were evaluated to test alternative policy assumptions. The high case includes aggressive technological development, higher consumer acceptance levels, CO2 credits of $8/ton and an expanded Small Generation Incentive Program. The Hawaiian study characterized only one case, shown in the table as the base case.

It is difficult to fairly compare the market outlook for CHP in the eight states given the differences in the scenario assumptions. The Northwest study, in particular, conducted two years before the California and Southwest studies shows a more optimistic outlook for CHP in the region than would be expected using the assumptions in the more recent studies. The Northwest cases were rerun using the RGGI natural gas price assumptions employed in the Southwest study and the customer CHP investment acceptance levels that was defined by the market research conducted for the California study by Primen and used in both the California and Southwest studies. The Alaskan analysis was updated using their current natural gas prices which are 50% higher than prices in 2003.

These changes dramatically reduce the expected market penetration for CHP in the Northwest. Base case cumulative market penetration for the region declines from 1,714 MW to 310 MW; the accelerated case declines from 5,138 MW to 519 MW. **Figure 16** shows these changes for the accelerated case by state. Market penetration is reduced by about half in Alaska, but the markets in Idaho, Oregon, and Washington are reduced drastically.

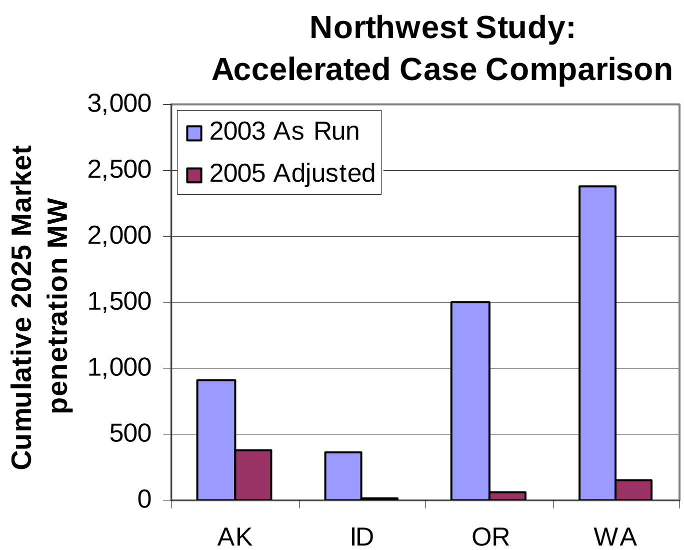

Figure 16 Northwest Accelerated Case Market Penetration Adjusted for Future Gas Prices and Restricted Customer Acceptance Levels

5. CONCLUSIONS

Comparing all eight states using the adjusted Northwest figures, we can rank the outlook for CHP in each state based on the base case cumulative market penetration (or economic potential in the Hawaiian study) to the technical market potential calculated for each state.

- Hawaii and Alaska represent the most attractive targets for CHP deployment due to very high electric prices. Unlike Alaska, Hawaii also has very high fuel prices, but the combination of high electric prices and high fuel prices is not a deterrent to CHP deployment.
- California and Nevada are the next most favorable markets for CHP deployment, based largely on having the highest electric prices in the Western continental U.S.
- Arizona, with its abundant power generating capability, a portion of which is for export to California, has lower prevailing electric rates, and consequently lower market deployment of CHP on a percentage basis.
- The projected base case world of high natural gas prices and customer risk aversion to CHP investments, the market for CHP becomes extremely difficult, particularly in small applications. Very large merchant power plants with CHP serving area steam loads might still be economic based on the overall power needs of the entire Western region.

CHP market penetration benefits the customers that adopt CHP, reduces energy consumption, helps to stimulate the local economy, and reduces environmental emissions of criteria pollutants and greenhouse gases.

California has the most aggressive incentive program, the Small Generation Incentive Program, providing $600/kW payments for conventional CHP systems up to 1 MW and up to $2,500/kW for fuel cell systems. This program has been effective in stimulating the deployment of small CHP systems. Oregon also has an active incentive program, providing tax credits under their Business Energy Tax Credit (BETC or "Betsy") Hawaii, is actively promoting CHP through DOE funded State Energy Programs and through utility integrated resource plan requirements.

Based on its sheer size, California dominates the Western landscape in terms of population, economic activity, electricity needs, and CHP market potential. California also has active and well-funded state energy programs. The two smallest states, in terms of population and economic activity are Alaska and Hawaii. These isolated economies show the strongest reliance on CHP of the Western states. Therefore, the greatest impact on local economies will come from DOE support of CHP development in these states.

Nevada, another small state, has the highest concentration of hotels and casinos of anywhere in the country. There are significant market opportunities for CHP in this sector, and there is a value for DOE to focus sector-specific CHP development programs to assist in the development of applications in this market.

The degradation of the market outlook for CHP in the Northwest due to the changing outlook for natural gas prices shows how critical a factor that natural gas prices are in CHP market development. However, natural gas is becoming increasingly more important in power generation generally. It is important for DOE to evaluate the interactions of natural gas pricing and supply on electricity pricing and supply and in determining how these interdependencies affect the economic development in the region and the potential market for CHP.