CHP Market Assessment

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Combined Heat and Power Workshop
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Topics

- Background
- CHP Market Model
- Existing CHP in California
- Target CHP Markets – CHP Technical Potential
- Energy Prices
- CHP Technology
- Base Case Market Forecast
- Alternative Market Cases
- GHG Impacts
- Observations and Conclusions
- Reference Slides – with Glossary

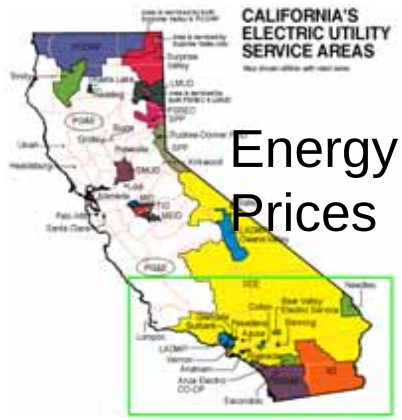
Background – The Current Landscape

- AB-32 is driving current energy policy – ARB *Climate Change Scoping Plan* (12/08) targets 4,000 MW, 30,000 GWh, and 6.7 million metric tons of CO2 emissions reduction from CHP by 2020
- While new growth in CHP is targeted, the future of existing QF contracts for CHP power (representing about 6,000 MW) is in question
- Implementation of AB-1613 is designed to create an economic mechanism for CHP to export power similar to AB-1969 (renewable energy)
- SGIP program canceled for non-fuel cell CHP technology but may be restored by SB-412 Kehoe
- Recession has altered the economic landscape – gas prices are low, economic growth estimates are reduced

ICF CHP Market Model

Applications Databases

Output: Technical Market Potential by Size, Application and State



Energy Prices

Microturbine

Turbine

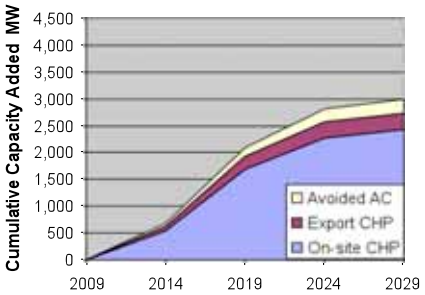
Technology Competition Analysis

Recip. Engine

Fuel Cell

Output: Technology Competition by application, net power costs, emissions profiles

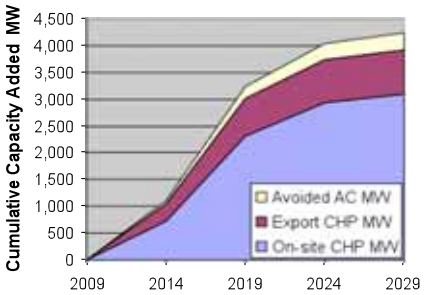
CHP Market Penetration



Base Case

Alternative Scenarios

Analysis of CHP Incentives

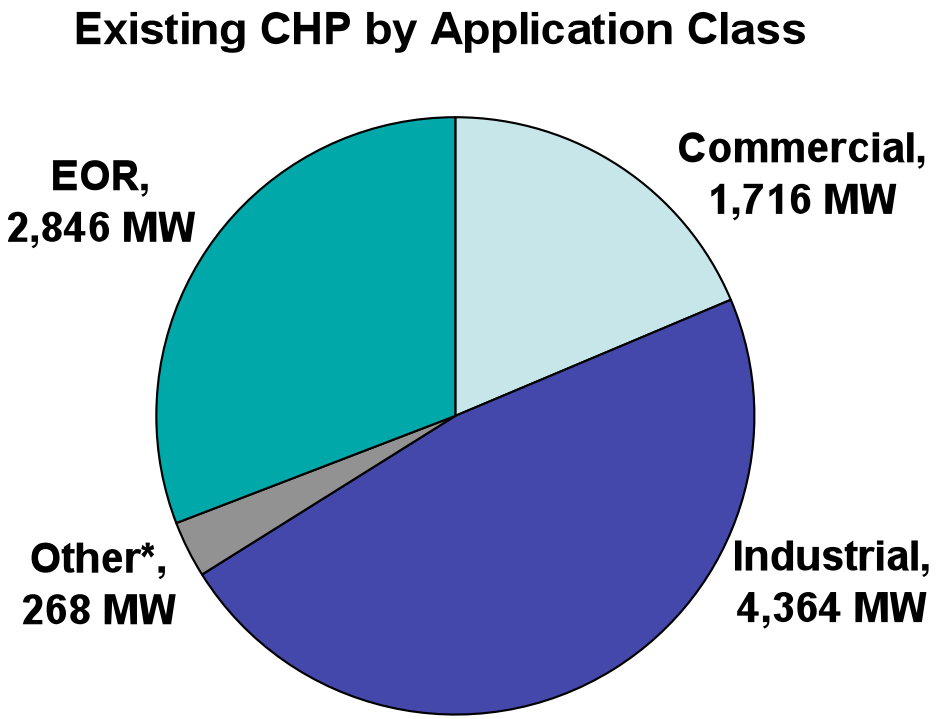


CHP Market Model

- Preliminary Analysis and Input Data
  - Existing CHP
  - Technical Market Potential by size and application from existing facilities and estimated growth over the forecast period (20 years)
  - Electric and gas prices today and over the forecast period
  - CHP technology cost and performance today and over the forecast period
- CHP Model Calculations
  - CHP payback analysis by technology, size, and application
  - Market acceptance as a function of payback
  - Market penetration over time
  - Summary of outputs

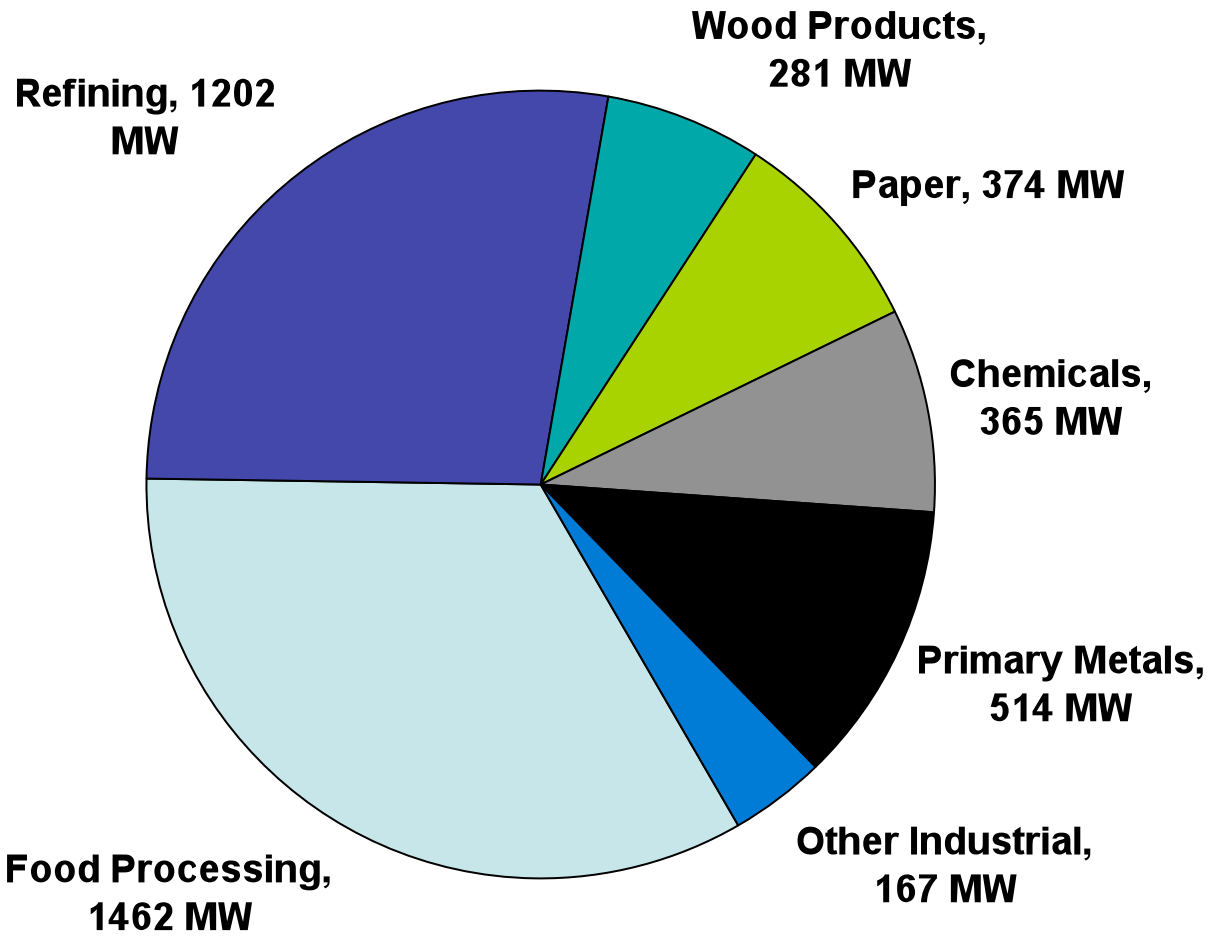
Existing CHP in California

- 1,186 Sites
- 9,194 MW

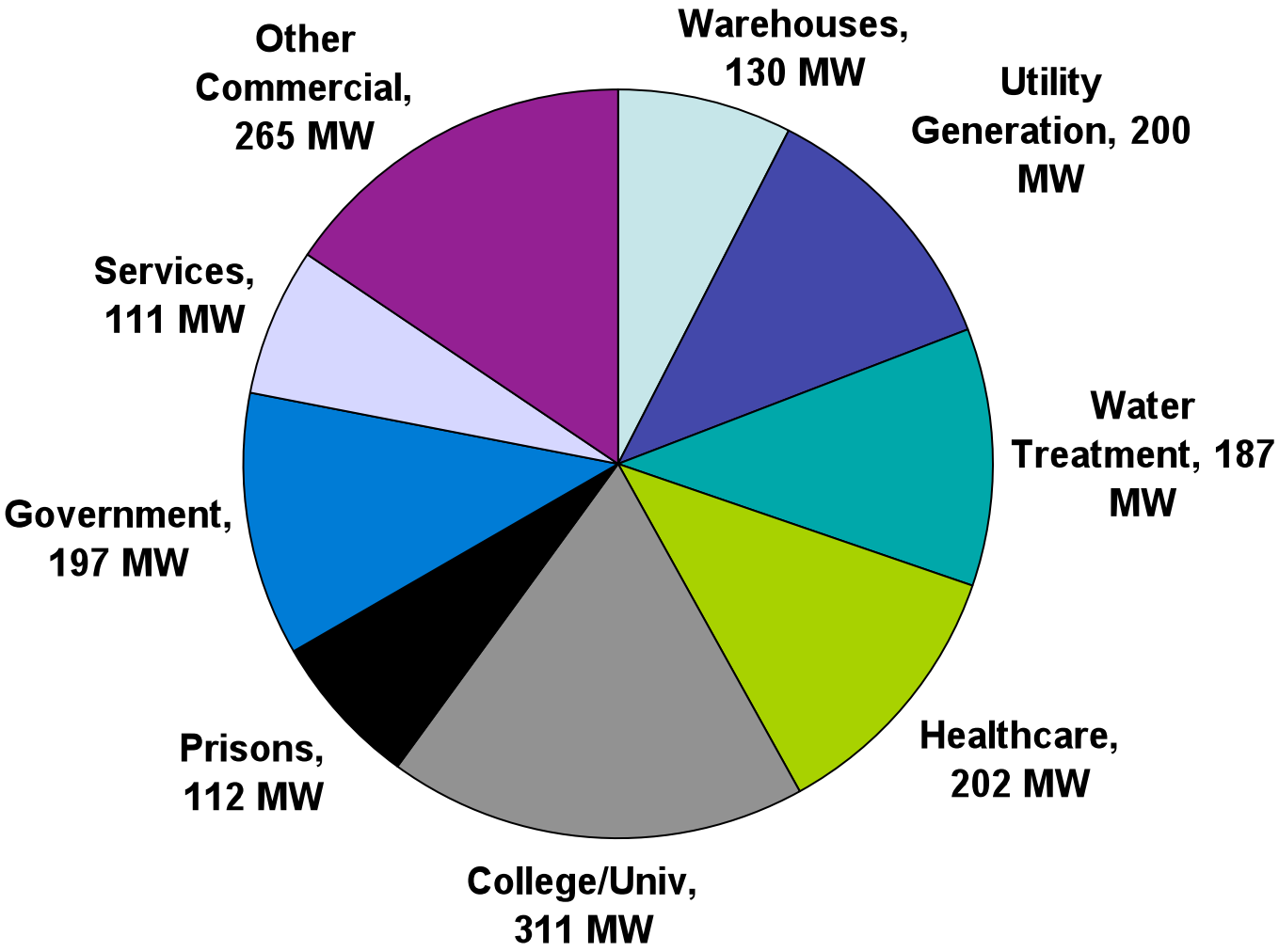


*Other = Agricultural and minerals,

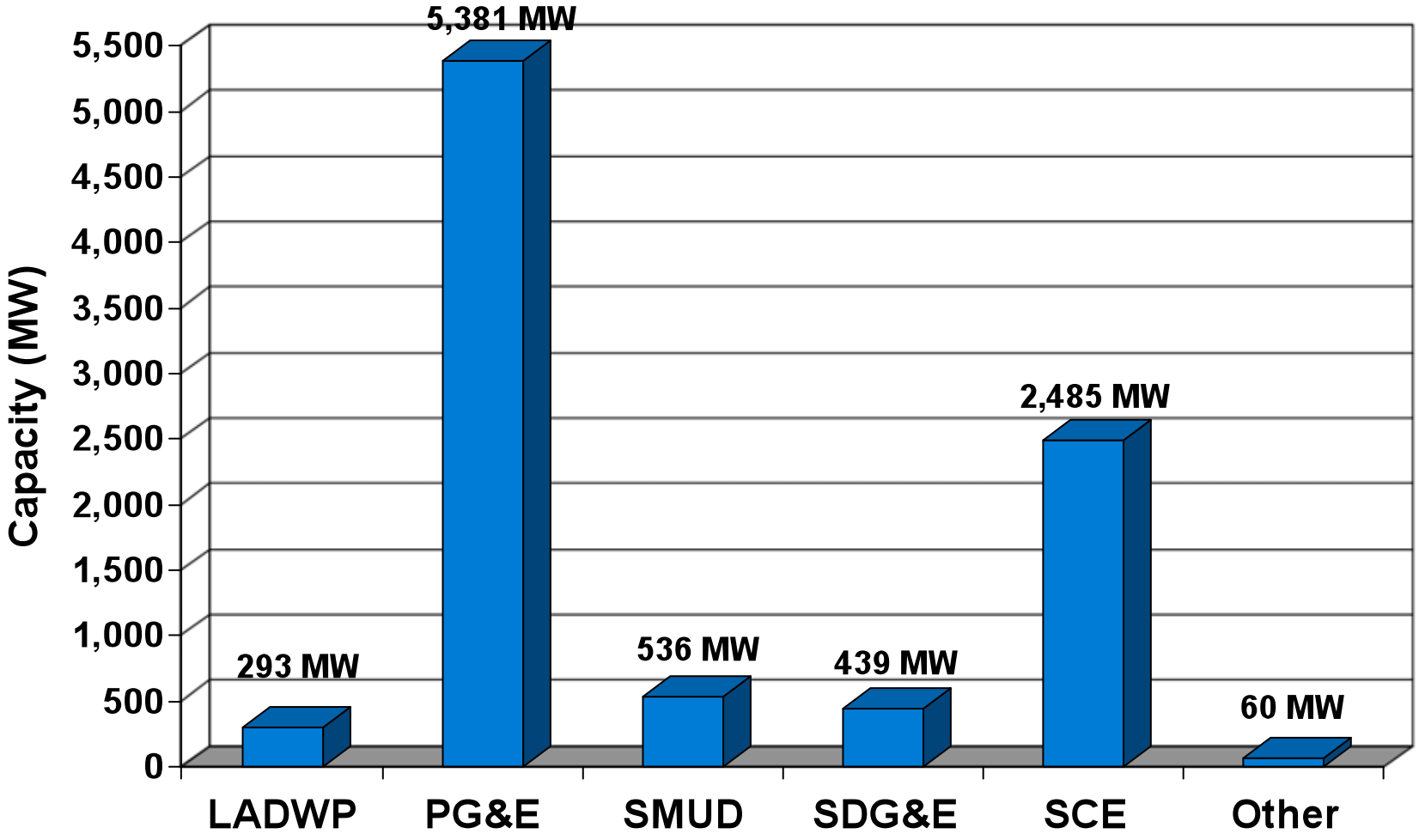
Existing Industrial CHP by Application



Existing Commercial CHP by Application



Existing CHP by Utility Region



QF Power – Significant Share of Power Generation in California

Investor Owned Utility	Fossil Fuel CHP MW	Biomass and Waste MW	CHP QF MW Electric
PG&E	2,457	613	3,070
SCE	2,046	182	2,228
SDG&E	331	6	337
Big 3 IOU Total	4,834	801	**5,635**

Source: Semi-annual utility QF Status Reports to CPUC 2008-1009

- Over 5,600 MW electric of fossil and biomass fueled CHP are under contract with the 3 IOUs
- QF power is 33% of PG&E generation cost, 28% of SCE generation cost

Analysis of CHP Target Markets – CHP Technical Potential

- Identification of target markets
- Evaluation of electric and thermal energy usage patterns
- CHP system configuration and size matching to site thermal energy usage
- Tabulation of CHP electrical generation capacity by application, market and size

Details of Approach and Results in Reference Section at the end

CHP Technical Potential Summary: Total Electrical Generating Potential

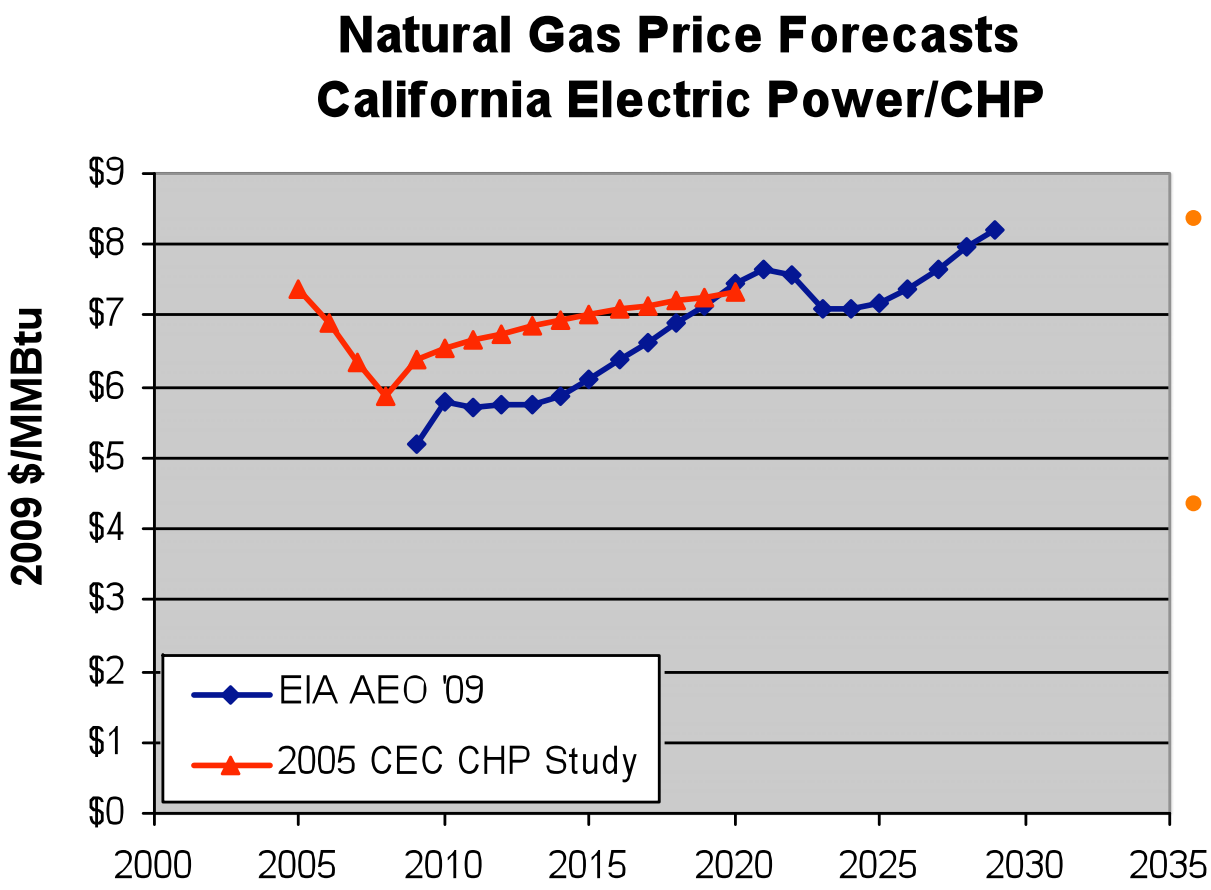
Market Segment	In Existing Facilities MW	In New Facilities MW	Total Technical Potential MW
Industrial On-site	4,157	438	4,595
Commercial On-site	7,371	1,611	8,981
Export < 20 MW (AB-1613)	1,014	122	1,135
Export > 20 MW	3,530	175	3,705
Total Technical Potential	16,071	2,346	18,417

- Existing facilities represent businesses that exist today that have unmet CHP potential – either through new or expanded CHP
- New facilities represent an estimate of economic growth in the target market segments over the next 20 years
- Electric capacity from generators shown – avoided air conditioning electricity and boiler fuel saved, not shown on this table

Base Case Energy Price Assumptions

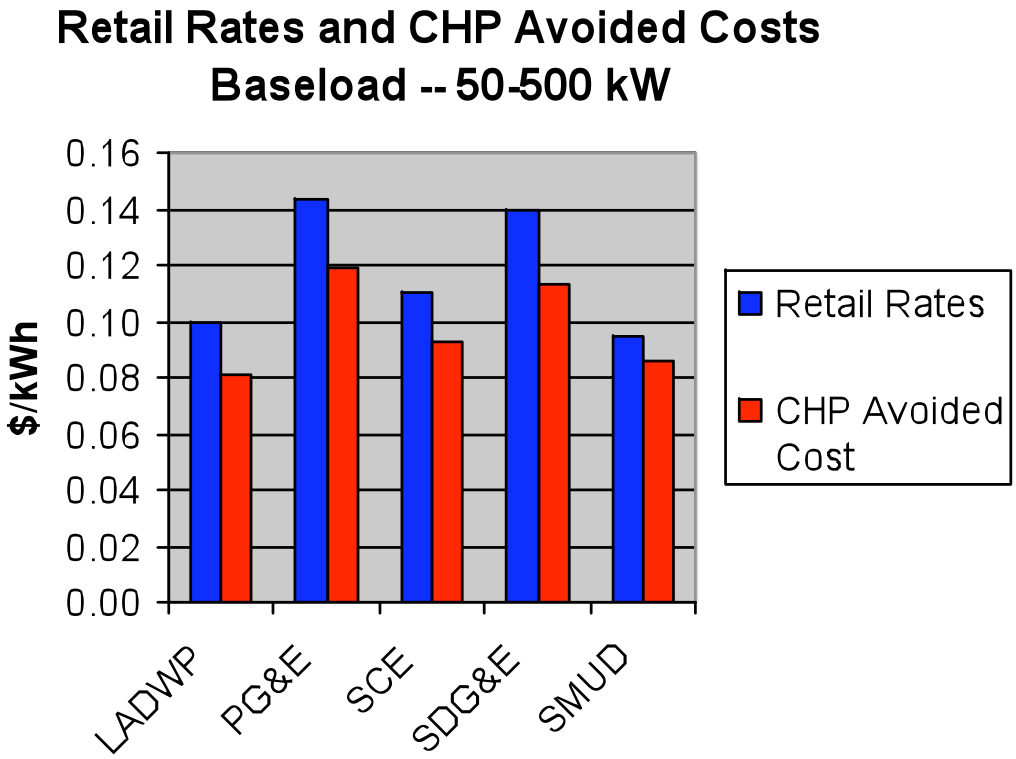
- EIA AEO 2009 Stimulus Case (April 2009) California –WECC gas prices to electric utilities used for EPG/CHP gas price
- Gas delivery markup differentials for CHP and boiler use
- Electric prices evaluated for current tariffs
  - Full Load slice – average unit electric cost savings for high load factor CHP
  - 4500 hour, peak weighted – average unit electric cost savings for intermediate load factor CHP
  - ~2000 hour, on peak – avoided retail power cost for CHP provided air conditioning
- Electric price escalation
  - T&D component assumed constant in real dollars
  - Generation component based on marginal cost of electricity from combined cycle power plant using EIA Cal-WECC EPG price track

Natural Gas Price Forecast



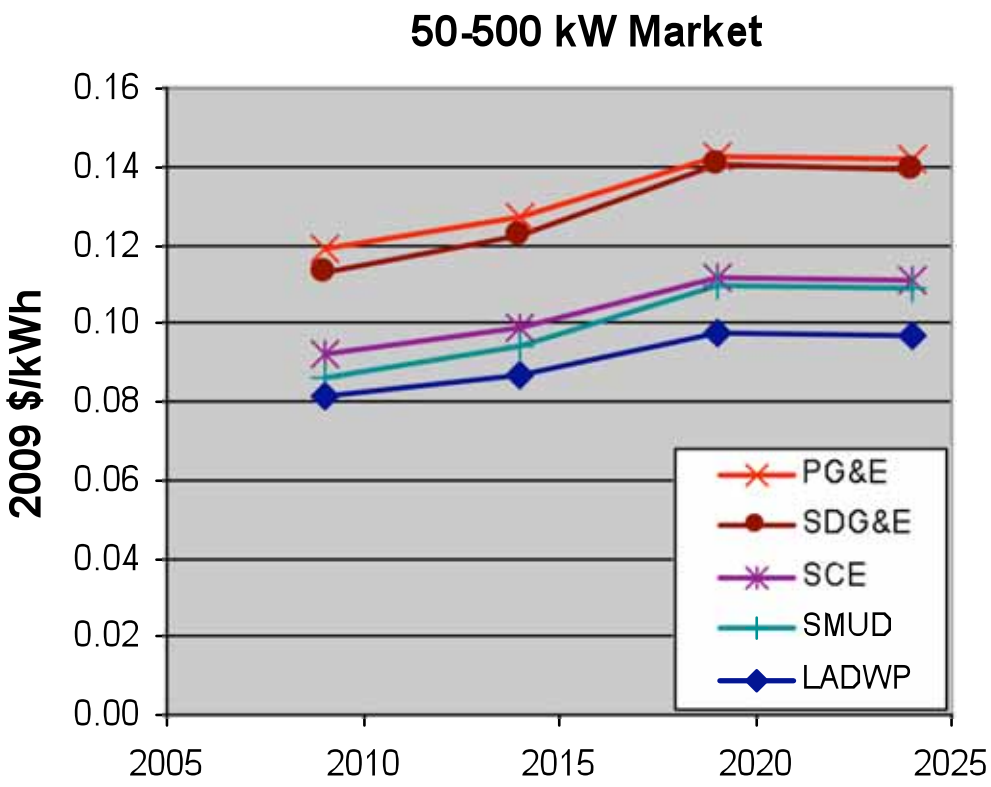
- EIA California EPG price is used for the base case 2009 CHP study
- Gas prices are lower than those used for the 2005 CHP market study
- Boiler fuel forecast assumed to be $1.20/MMBtu higher than EPG price (per analysis of PG&E tariff)

Retail Electric Price Analysis



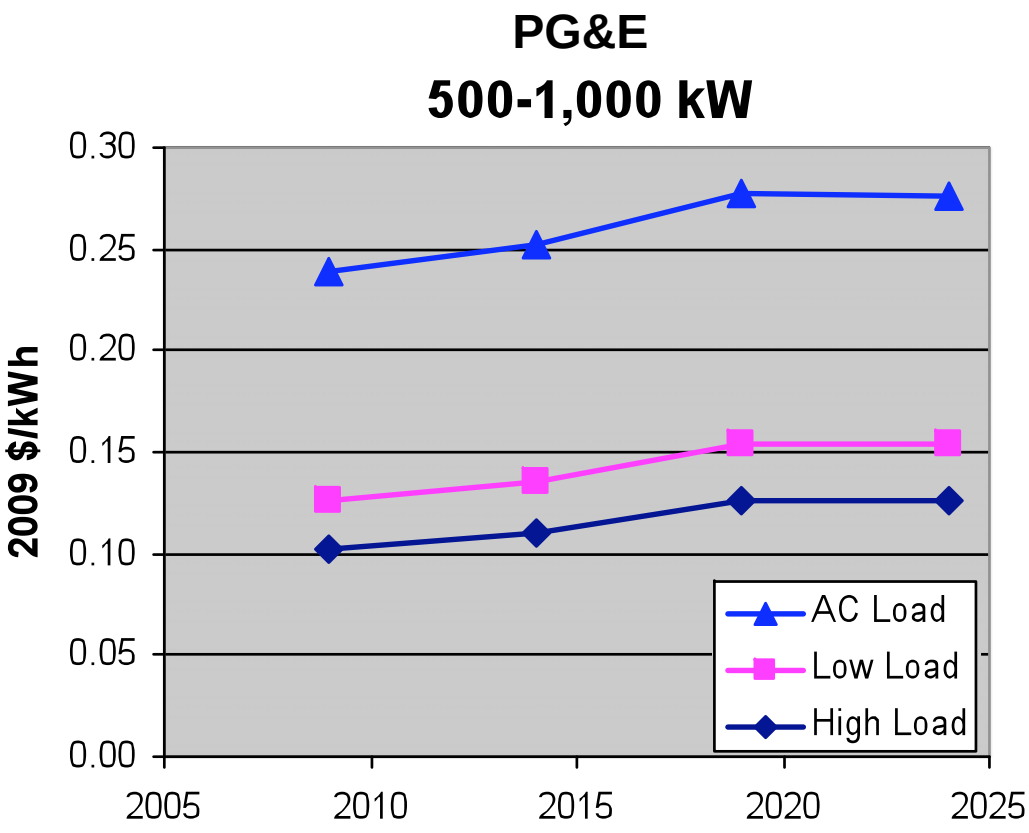
- Analyzed current tariffs for 5 major electric utilities
- Compared retail rates to without CHP to retail rates with CHP to derive avoided CHP costs or "average electricity cost savings"

Average Electricity Cost Savings High Load Factor CHP – 50-500 kW



- Analysis of current tariffs with and without CHP
- Average savings based on CHP availability of 95% with 3 on-peak outages
- Escalation assumptions
  - T&D costs assumed fixed in real dollars
  - Generation portion based on the marginal cost of power from natural gas combined cycle power plant

Average Electricity Cost Savings
Effect of Load Factor on 500 kW to 5 MW Size



- AC savings based on retail rates for ~2000 hour on peak operation
- Low load based on peak weighted 4500 hours/year CHP operation
- High Load assumes constant CHP operation at 95% availability

Export Pricing (Feed-In-Tariff) Assumptions

- Prices are not established yet for CHP except for SMUD Feed-in Tariff (FIT)
- Other municipal FITs assumed to be the same as SMUD
- IOUs assumed to be 95% of 15-year market price referrent for renewable tariff
- Constant flat delivery of power to the utility during all time periods is assumed

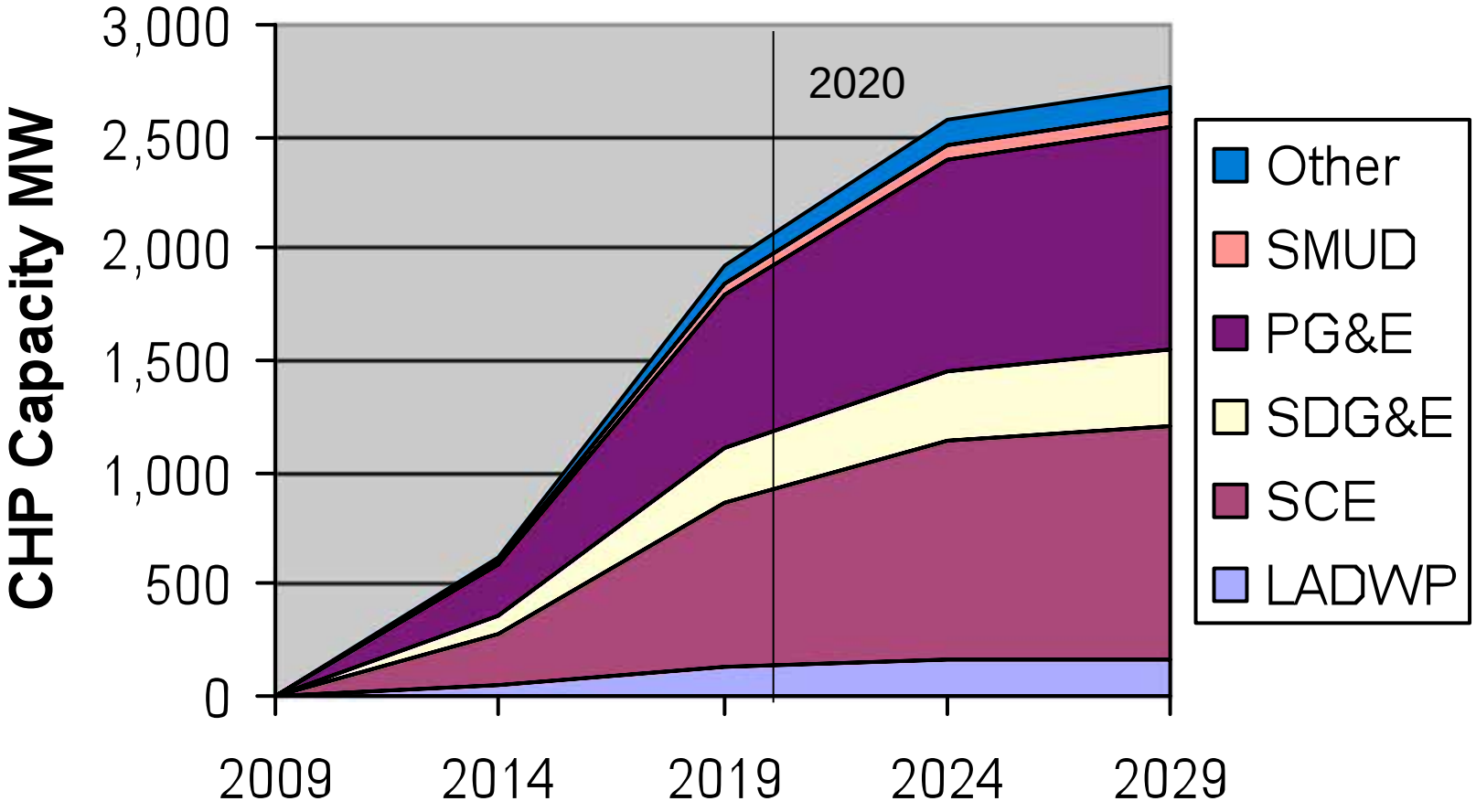
CHP Technology Cost and Performance

- Based on 2003 NREL report "Gas-Fired Distributed Energy Resource Technology Characterizations" with updated cost, performance and emissions data
  - Reciprocating engines: $2,475 - $1,250/kW
  - Microturbines: $3,000 - $2,900/kW
  - Fuel Cells: $7,000 - $5,800/kW
  - Gas Turbines: $1,900 - $1,080/kW
- All systems must meet NOx emissions of 0.07 lb/MWh
  - Recip engines meet with Three Way Catalyst (small) and SCR (medium to large) with thermal credit
- Improvements over time in cost and performance based on ongoing CEC, DOE and manufacturers programs

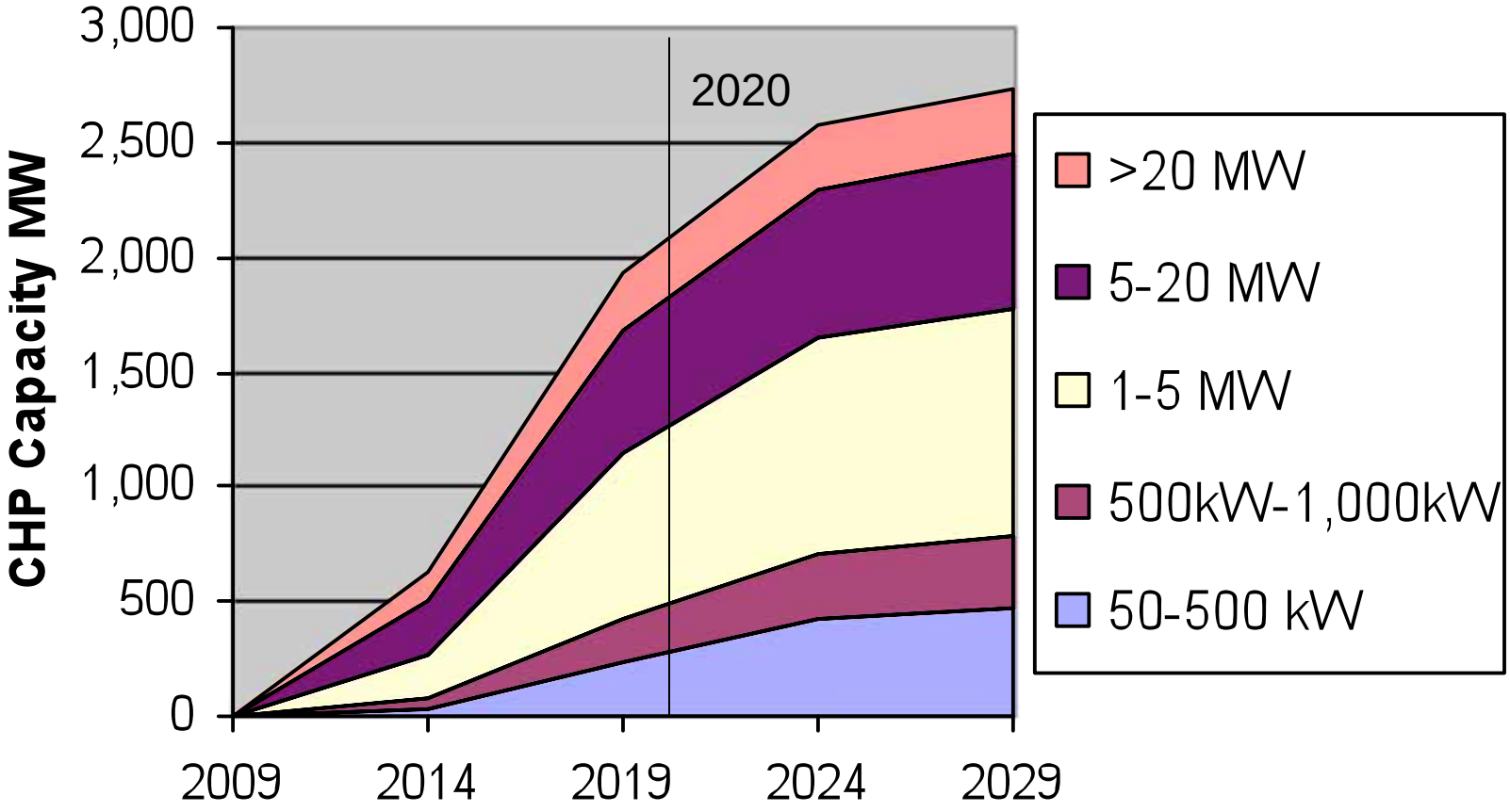
Scenario Definitions

- Base Case
  - Existing SGIP (fuel cells only)
  - Prices as shown
  - Export tariff for projects less than 20 MW
  - No export tariff or new contracts for CHP > 20 MW
- Restore SGIP
  - Base Case assumptions plus SGIP as previously implemented for 10 years
- Expanded Export
  - Tariff development for >20 MW systems based on marginal baseload electric price – natural gas combined cycle cost
- Avoided CO2 Payments for CHP
  - Payments for CHP based on savings compared to appropriate avoided generation mix (methodology discussed later)
  - Payments applied to on-site use, already included in FIT for renewable power and assumed in this study to apply to CHP power

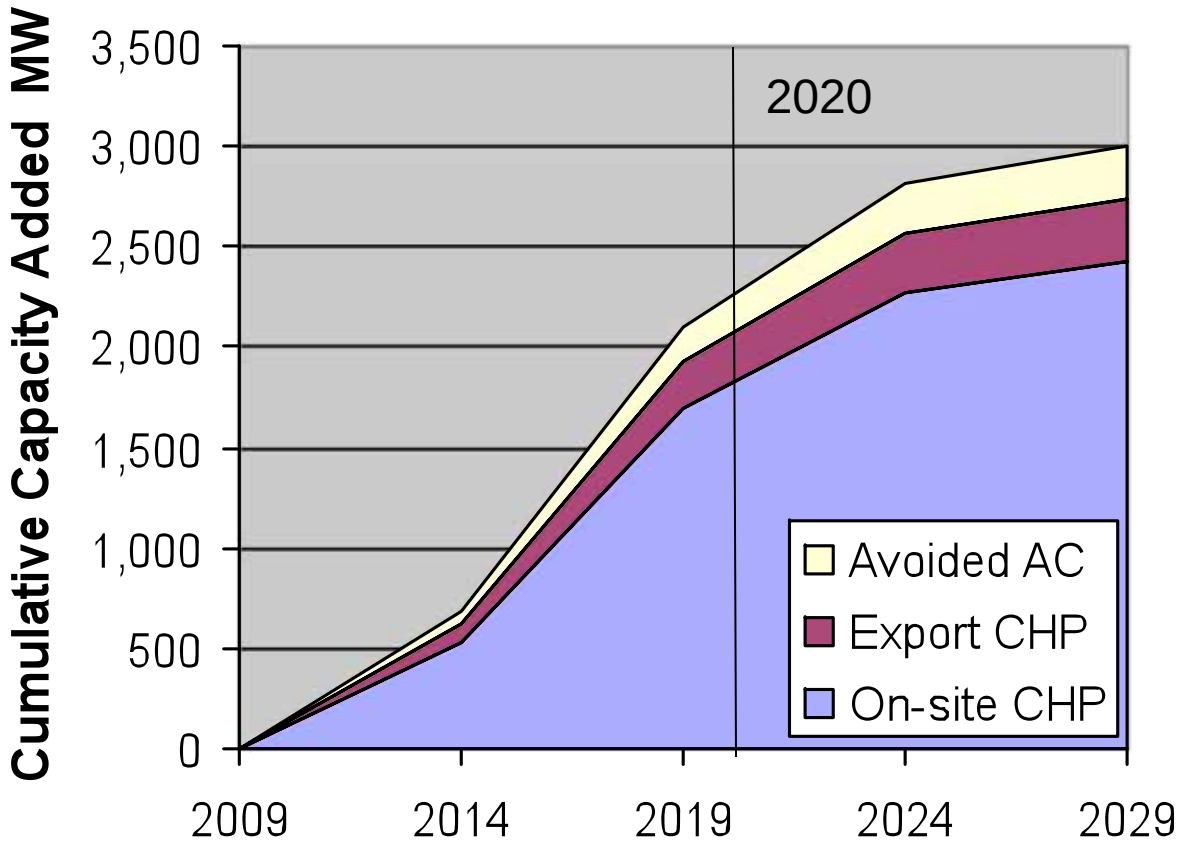
Base Case – Cumulative CHP Market Penetration by Utility



Base Case – Cumulative CHP Market Penetration by Size

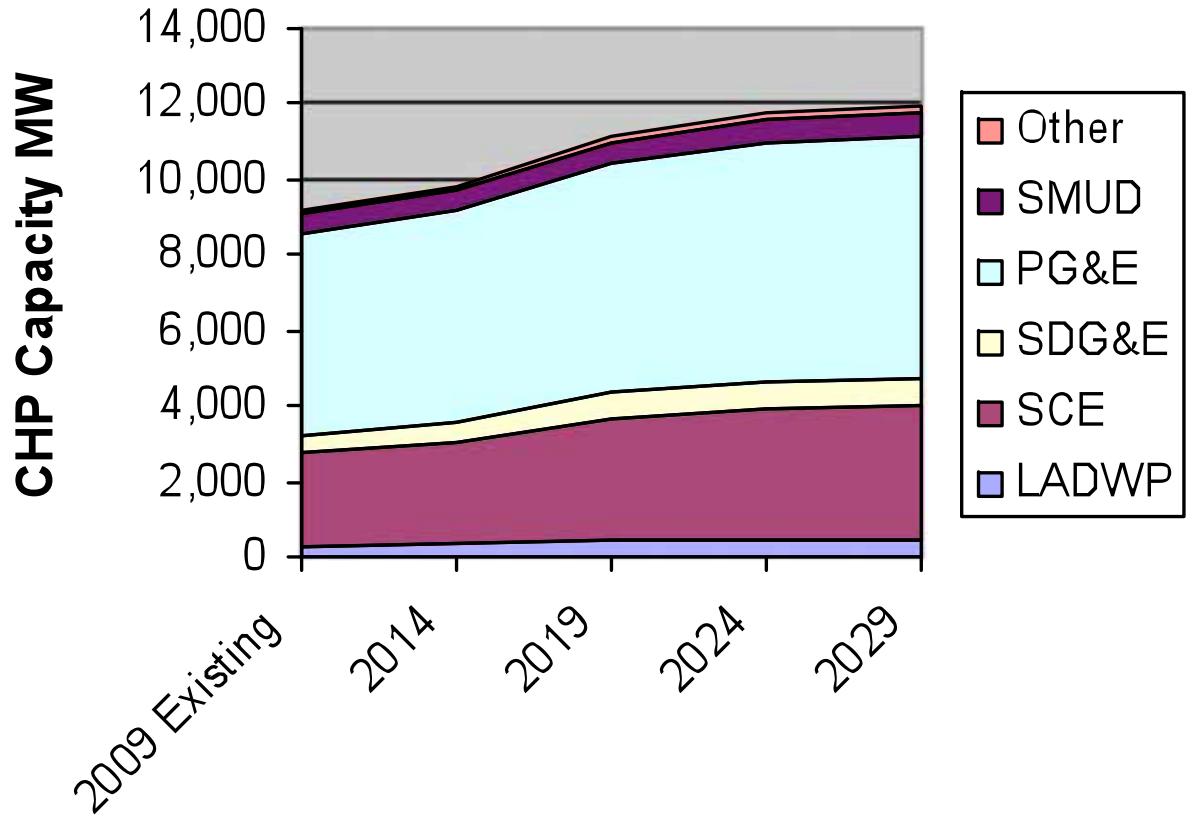


Base Case – Cumulative CHP Market Penetration by Type



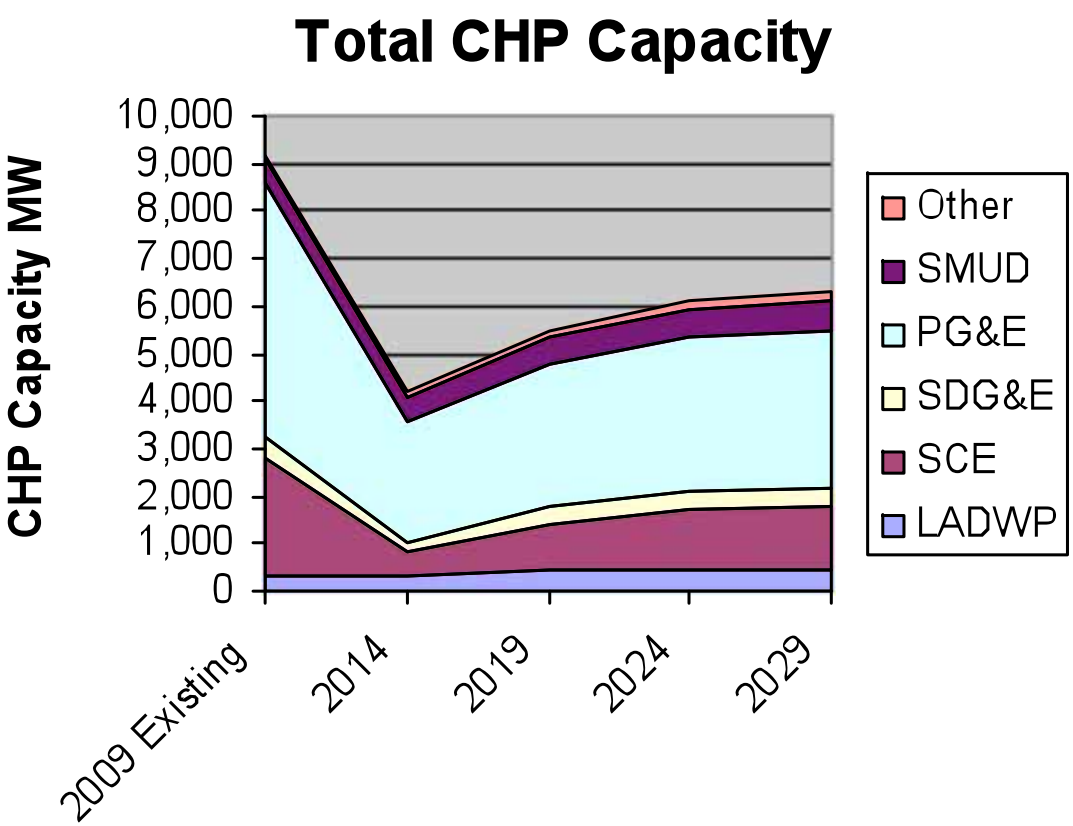
- Includes avoided electric AC capacity met by CHP thermal output (279 MW)
- AB-1613 capacity equals 304 MW

Base Case Market Penetration with Existing CHP Included



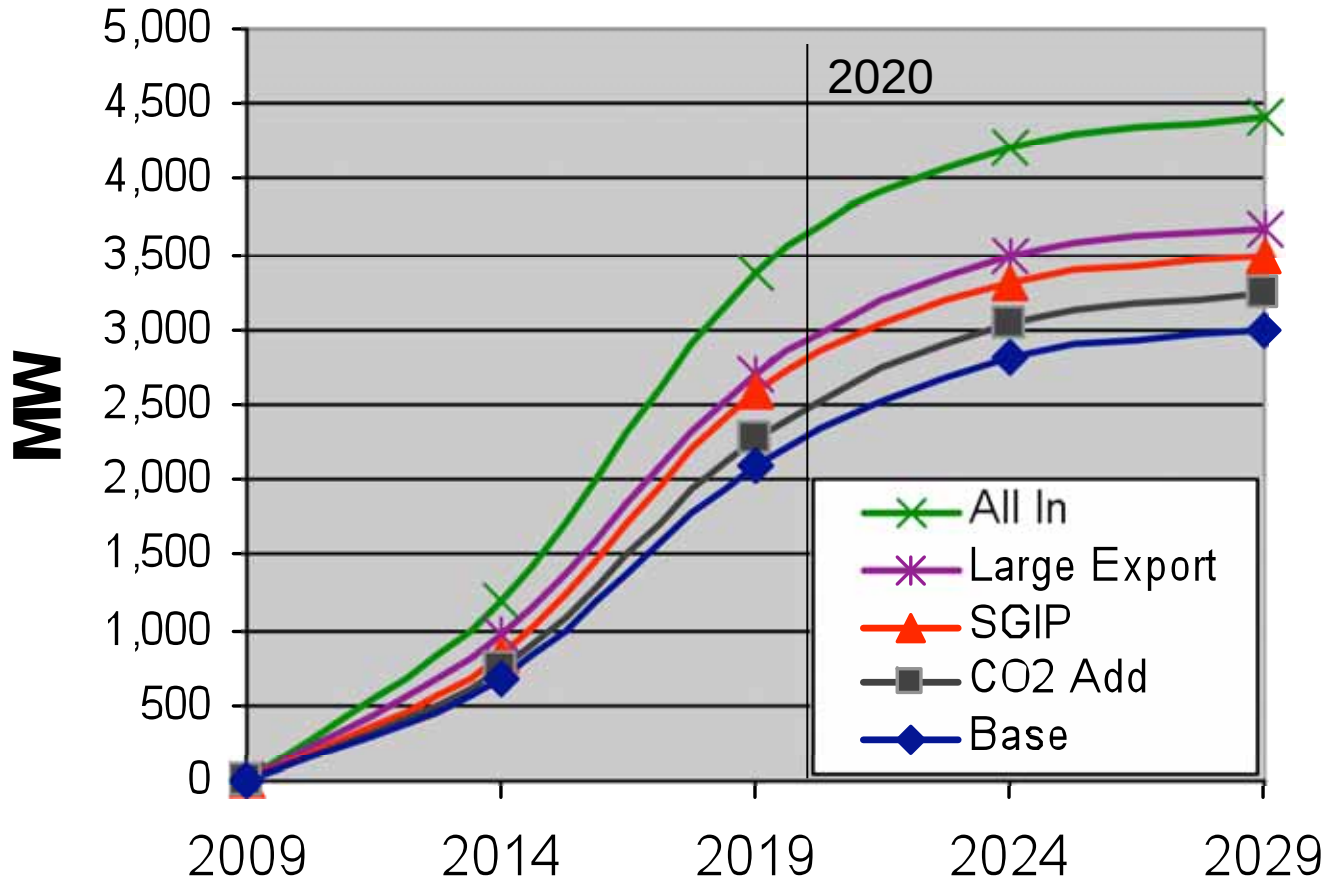
- 9,194 MW of existing CHP in California today
- Assume no reduction in existing CHP
- New CHP forecast shown on top of existing CHP

Base Case with Erosion of Existing CHP – Illustrative Case



- Base case forecast shown on top of modified existing CHP
- Large existing export CHP dropped out of existing QF market
- New CHP market penetration cannot offset loss of existing CHP

Cumulative CHP Market Penetration 2009-2029 by Scenario



Other Scenario Results

- Restore SGIP
  - Base Case assumptions plus SGIP as previously implemented for 10 years
  - 497 MW increase in cumulative market penetration in first 10 years
  - Impact is on small CHP up to 5 MW
- CO2 Payments
  - Payments for CHP based on savings compared to avoided CO2 emissions
  - $50/ton of avoided CO2 emissions payment assumed
  - 244 MW cumulative increase in CHP market penetration
- Large Export
  - Tariff development for >20 MW systems based on marginal baseload electric price – natural gas combined cycle cost
  - 671 MW cumulative increase in CHP market penetration
  - All increase is for systems larger than 20 MW based on
- All In Scenario
  - Includes all measures above
  - Nearly additive increase of 1,408 MW of cumulative market penetration compared to the individual increases by scenario

Export Market Sensitivity

Two sensitivity cases were run on CHP with power for the export market

AB-1613 – Reduced Tariff Assumption

- Feed In Tariff assumptions were lowered for the IOUs by 1.5 cents/kWh – based on renewable and CHP FIT relationships in SMUD existing tariff
- 2029 export market penetration reduced from 304 MW to 247 MW
- If CO2 payments were made to CHP facilities with this pricing the lost penetration would be restored

Large Export – Power Maximization

- Export technical potential was re-evaluated assuming combined cycle power generation with steam extraction (except for EOR which was unchanged)
- Technical potential increased from 3,530 MW to 6,037 MW (> 20 MW size)
- 2029 cumulative market penetration increased from 671 MW to 984 MW

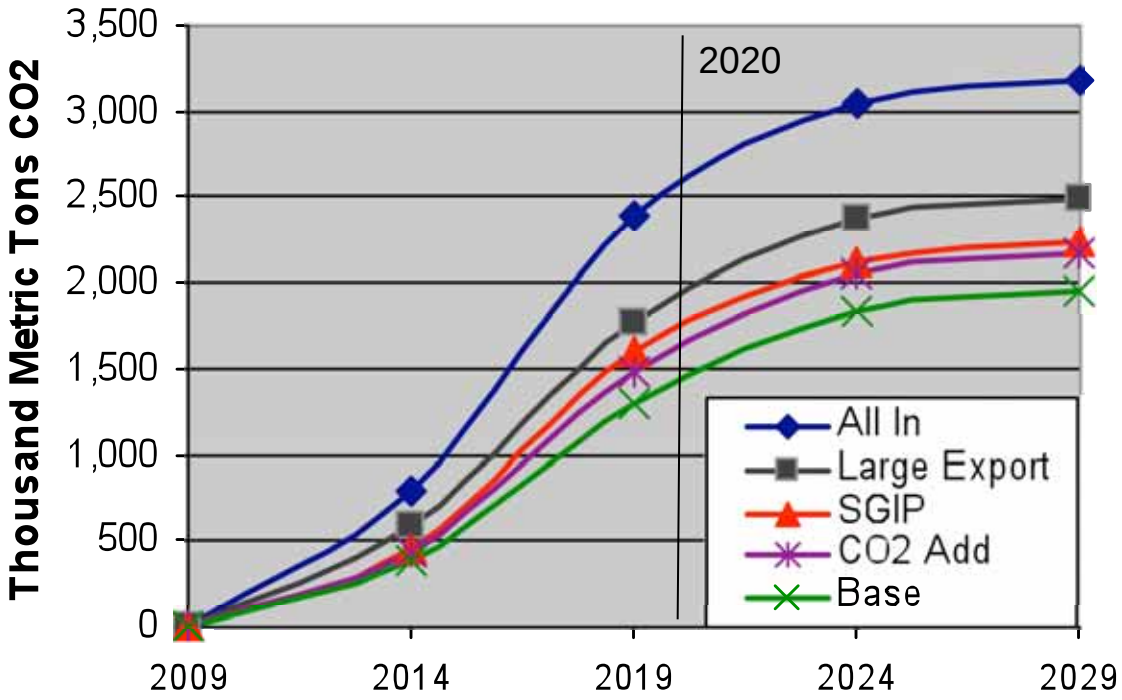
GHG Emissions Savings – Avoided Emissions

CHP System Load Factor	Avg Heat Rate at Generator Btu/kWh HHV	T&D Losses	Avg Heat Rate Delivered Btu/kWh HHV	Avoided CO2 Emissions lb/MWh
Baseload	7,460	5%	7,833	917
Intermediate Load	8,707	8%	9,403	1100
Avoided Electric Air Conditioning	10,487	13%	11,851	1387
Export Baseload	7,460	0%	7,460	873

Natural Gas Emissions Rate = 117 lb/MMBtu

- Avoided power emissions vary by the load factor representing a mixture of new and existing baseload and peaking power generation
- CHP for on-site use also avoids line losses through the T&D system
- Additional details in reference section

Annual CO2 Emissions Savings by Scenario



- 2 to 3.2 million metric tons of avoided CO2 emissions per year by 2029 depending on scenario
- Large export case has the highest CO2 reduction per added CHP MW
- CO2 Payment case has the second highest CO2 reduction per added CHP MW

Summary Results

- New market penetration in the base case (status quo) of just under 3,000 MW in 20 years
  - Includes 304 MW of AB-1613 export and 281 MW of avoided AC
- Policy Cases
  - Restore SGIP (SB-412) – add 497 MW
  - $50/ton avoided CO2 payments – add 244 MW
  - Large export at avoided system marginal generation costs – add 500 MW
  - Sum of all measures – add 1,241 MW
- GHG Impacts – 2-3.2 million metric tons annual avoided CO2 emissions by 2029 (20 years)
  - Large export scenario has highest per MW impact

Comparison to ARB Scoping Plan Goal

Scenario	Capacity MW	Output GWh/year	Avoided CO2 MMT/year	CO2 Savings Rate lb/MWh
ARB 2020 Goal	4,000	30,000	6.70	492
Base Case 2020	2,240	14,486	1.41	215
Base Case 2029	2,998	18,991	1.95	226
All In Case 2020	3,551	23,627	2.52	235
All In Case 2029	4,406	28,806	3.18	243

- Scoping Goal is optimistic both in terms of level of penetration and in expected GHG emissions savings
- Under current policies, CHP will fall well short of these goals
- With aggressive CHP stimulation (all in case) the market penetration goals can be met a a few years beyond 2020
- CO2 savings in the All In case market results are about half of the Scoping Plan Goal

Large versus Small CHP: Market Penetration and Issues

CHP Markets and Measures	Large CHP MW	Small CHP MW
Existing QF Contracts	6,000	
Other Existing CHP	1,900	1,200
Total Existing	7,900	1,200
New On-site Market Penetration Status Quo	278	2,416
Added New from AB 1613 Export		304
Added New from Restoring SGIP		497
Added New from CO2 Payments for on-site CHP	23	208
Large Export -- business focus	671	
Large Export -- Maximize power outputs (add)	223	
Total New	1,195	3,425

- Existing market is 87% “big stuff”, new growth will be 75% “small stuff”
- Large CHP and small CHP face different market issues and react to different market stimuli
  - Small CHP stimulus – Economic feed in tariff, SGIP incentives, RD&D
  - Large CHP stimulus – Preservation of existing contracts, Facilitation of large system contracting for new projects

Observations and Conclusions

- Greatest market and GHG benefit comes from preserving existing large CHP and pursuing remaining large CHP technical potential
- Small CHP is the largest emerging market in the Base Case with 90% of the market penetration in sizes below 20 MW
- Small CHP has additional benefits for California that were not modeled
  - Reduction in the need for T&D investments
  - Increased system and customer reliability
  - Technical innovation and development of economic business opportunities

Recommendations

- Meeting ARB CHP Goals
  - Market forces appear to be inadequate – aggressive polices are needed to reduce barriers and increase economic value to the customer
  - Technical potential exists in both large industrial and smaller industrial and commercial markets to meet the goals, and reasonable economic value can be achieved, but perceived risks need to be addressed to stimulate market response
  - Maximum thermal utilization needs to be encouraged in the commercial markets and more efficient thermally activated cooling systems need to be developed and demonstrated
- Removing Barriers
  - Address lack of information or awareness
    - Demonstration of innovative technologies and applications
    - Education, information, training resources
  - Reduce project risk
    - Establish long term contracting approaches
    - Innovative natural gas contracting to remove effects of volatility
  - Improve project economics especially for small CHP
    - Reduce the degree of nonbypassable charges that CHP must pay and encourage economic treatment for CHP
    - Reduce equipment costs and increase performance
    - Verify small CHP cost and performance through development and demonstration
  - Provide direct value for CO2 emissions reduction – CO2 payments for CHP
  - Provide incentives to internalize other CHP benefits – T&D support, peak capacity, system reliability

CHP Market Assessment

Reference Slides

July 23, 2009

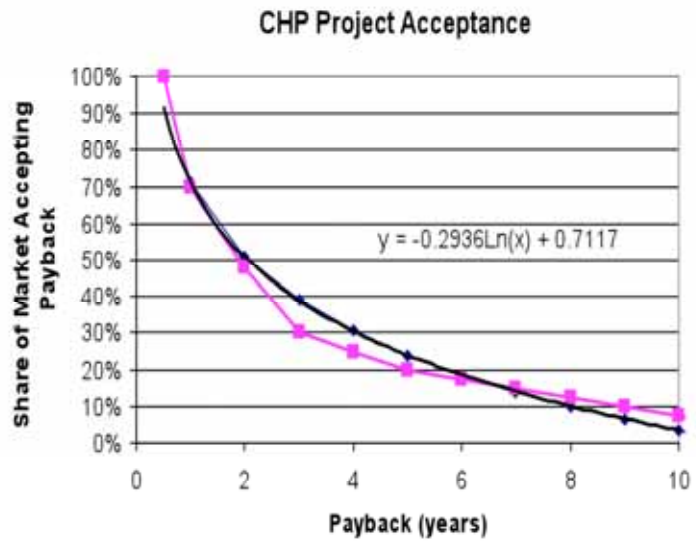
CHP Market Presentation -- Glossary

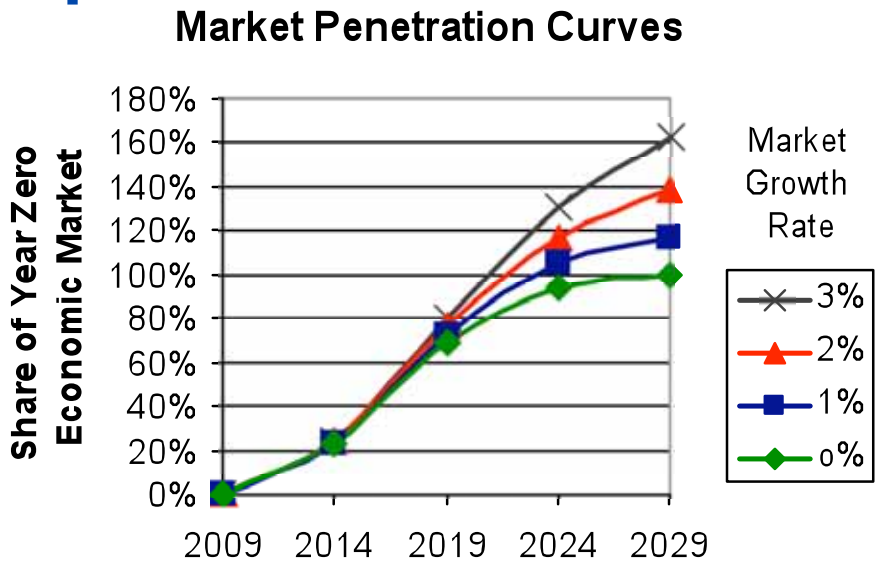
AB-1613 -- Waste Heat and Carbon Emissions Reduction Act
AB-1969 -- Renewable electric generation facilities: feed-in tariffs (actually AB-1807)
AB-32 -- California Global Warming Solutions Act 2006
AC -- Air conditioning
AEO -- Annual Energy Outlook, long range forecast publication of EIA
ARB -- California Air Resources Board
CBECS -- Commercial Buildings Energy Consumption Survey, publication of EIA
CEPD -- Commercial Energy Plant Database
CEUS -- California Energy Utilization Survey
CHP -- Combined heat and power
CO2 -- Carbon dioxide
CPUC -- California Public Utilities Commission
D&B -- Dun & Bradstreet
DER -- Distributed energy resources
DOE -- U.S. Department of Energy
EIA -- U.S. Energy Information Administration
EOR -- Enhanced oil recovery
EPG -- Electric Power Generation
FIT -- Feed-in tariff
GHG -- Greenhouse gas
GT -- Gas turbine
GT-CC -- Gas turbine combined cycle
HHV -- Higher heating value
IOU -- Investor owned utility
LADWP -- Los Angeles Division of Water and Power
LBNL -- Lawrence Berkeley National Laboratory
LHV -- Lower heating value
MECS -- Manufacturers Energy Consumption Survey, publication of EIA
MIPD -- Major Industrial Plant Database
NOx -- Nitrogen oxides
NREL -- National Renewable Energy Laboratory
PG&E -- Pacific Gas and Electric Company
PURPA -- Public Utility Regulatory Policies Act of 1978
QF -- Qualifying Facility, legal designation of CHP under PURPA
SB-412 -- Requires CPUC to continue SGIP
SCE -- Southern California Edison Company
SCR -- Selective catalytic reduction
SDG&E -- San Diego Gas and Electric Company
SGIP -- Self Generation Incentive Program
SMUD -- Sacramento Municipa Utility District
T&D -- Transmission and distribution
WECC -- Western Electric Coordinating Council

CHP Market Model – Economic Competitiveness

- Site Characteristics
  - 5 application size bins
  - 5 electric and thermal load shapes
- CHP Technology
  - 12 CHP technologies detailed cost and performance characteristics
  - Absorption chiller cost and performance as a function of size and CHP heat temperature
- Energy Prices
  - 5 utility rate analyses
  - Statewide natural gas cost analysis
  - 4 time periods representing 20 year forecast
- Payback Analysis
  - 240 payback calculations per scenario

CHP Market Model – Estimating Market Acceptance





- Market acceptance or economic market is a function of payback – based on Primen survey conducted in 2004
- Market penetration is a function that apportions the market acceptance over time – all economic projects do not enter the market at once

California CHP Technical Potential

- *Definition of CHP Technical Potential -*

  The total electric generating capacity potential from existing and new facilities that are likely to have the appropriate physical electric and thermal load characteristics that would support a CHP system with high levels of thermal utilization.

  The technical potential does not address the economic viability of the CHP system.

CHP Technical Potential – Approach

- Site Identification
  - Targeted applications with electric and thermal load profiles conducive to CHP
  - Dun & Bradstreet (D&B) *Selectory* database
  - Major Industrial Plant Database (MIPD)
  - Two new applications added for 2009 – data centers and government buildings
- Power Consumption Estimation
  - D&B – estimated on a per employee basis by NAICS/SIC compared to California ECDMS
  - MIPD – direct data output

CHP Technical Potential – Approach

- Thermal Load Estimation
  - Industrial – MIPD and MECS data analysis and extrapolation to industry sites in D&B
  - Commercial – Analysis of CEUS data, work by LBNL, analysis of CBECS
  - Greater focus on cooling applications
- CHP Sizing
  - Objective of high electric load factor and high thermal utilization
  - Commercial: Assume meeting 80% of space heating/hot water load and/or 60% of air conditioning load converted to thermal energy input
  - Industrial sized to process steam loads
- Future Growth of New Facilities – based on EIA industry and business sector growth rates in AEO 2009

CHP Technical Potential: Industrial On-site (Existing Facilities)

SICs	Application	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
20	Food	256.4	140.7	335.8	105.0	56.3	894.1
22	Textiles	51.8	16.6	42.3	16.4	0.0	127.0
24	Lumber and Wood	64.0	16.1	57.0	8.4	0.0	145.6
25	Furniture	4.6	0.8	0.0	0.0	0.0	5.4
26	Paper	87.4	57.9	161.9	199.9	29.3	536.4
27	Printing	11.3	7.9	4.5	5.4	0.0	29.1
28	Chemicals	200.0	158.4	545.7	484.7	0.0	1,388.8
29	Petroleum Refining	11.3	10.4	85.1	63.4	122.9	293.1
30	Rubber/Misc Plastics	71.5	22.1	28.9	0.0	0.0	122.5
32	Stone/Clay/Glass	7.3	5.5	21.7	26.8	0.0	61.3
33	Primary Metals	38.5	17.9	41.9	44.0	0.0	142.2
34	Fabricated Metals	49.2	13.3	15.4	0.0	0.0	77.9
35	Machinery/Computer Equip	29.2	3.2	19.7	0.0	0.0	52.1
37	Trasportation Equip.	40.0	18.6	28.6	82.8	36.5	206.5
38	Instruments	33.4	9.2	14.9	5.1	0.0	62.6
39	Misc Manufacturing	10.3	1.9	0.0	0.0	0.0	12.3
	Total	966.1	500.6	1,403.3	1,041.8	244.9	4,156.8

CHP Technical Potential: Commercial Heating/Hot Water CHP (Existing Facilities)

SICs	Application	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
4941	Water Treatment/Sanitary	24.5	7.5	7.5	0.0	0.0	39.5
6513	Apartments	149.6	108.2	68.1	0.0	0.0	325.8
7211	Laundries*	28.7	6.5	2.5	0.0	0.0	37.7
7542	Carwashes*	12.7	0.8	0.0	0.0	0.0	13.5
7991	Health Clubs*	2.7	0.6	1.1	0.0	0.0	4.4
7992	Golf/Country Clubs*	57.3	0.7	1.7	14.7	0.0	74.3
8412	Museums*	9.9	1.1	0.0	0.0	0.0	11.0
9223	Prisons	12.1	7.4	42.7	0.0	0.0	62.2
	Total	297.4	132.7	123.6	14.7	0.0	568.4

- Thermal energy used to replace boiler fuel (heating, hot water)

CHP Technical Potential: Commercial Heating/Hot Water and Cooling (Existing Facilities)

Low Load Factor Applications

SICs	Application	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
43	Post Offices	7.3	1.9	0.0	0.0	0.0	9.3
52	Big Box Retail	322.2	31.8	15.6	0.0	0.0	369.7
4581	Airports	3.5	0.9	0.0	15.5	0.0	19.8
5411	Food Sales	256.0	7.8	3.8	9.7	0.0	277.3
5812	Restaurants	453.1	14.2	8.8	8.9	0.0	485.0
6512	Commercial Buildings*	487.6	362.7	491.3	0.0	0.0	1,341.5
7832	Movie Theaters	1.7	0.0	1.4	0.0	0.0	3.1
8211	Schools	525.8	14.7	34.4	11.3	0.0	586.1
9100	Government Buildings	213.3	57.7	190.8	148.4	41.3	651.5
	Total	2,270.4	491.7	746.0	193.8	41.3	3,743.3

High Load Factor Applications

SICs	Application	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
4222	Warehouses	15.9	3.2	0.0	0.0	0.0	19.1
7011	Hotels	219.0	78.3	175.5	39.4	0.0	512.3
7374	Data Centers	23.0	9.2	9.5	0.0	0.0	41.7
8051	Nursing Homes	123.1	3.5	7.5	5.9	0.0	140.0
8062	Hospitals	70.4	70.2	303.2	37.9	0.0	481.7
8221	Colleges/Universities	139.9	104.1	426.6	630.4	563.0	1,864.1
	Total	591.4	268.6	922.3	713.6	563.0	3,058.9

Incremental CHP Technical Potential at Existing Facilities when Electricity Export is Allowed

SICs	Application	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
13	Enhanced Oil Recovery	0.0	0.0	0.0	0.0	1070.0	1,070.0
20	Food	8.7	16.3	35.6	3.6	282.2	346.5
22	Textiles	0.0	0.0	0.0	3.0	0.0	3.0
24	Lumber and Wood	48.5	20.6	61.3	93.8	67.8	292.0
25	Furniture	0.0	0.0	0.0	0.0	0.0	0.0
26	Paper	5.8	22.3	66.7	133.6	699.3	927.6
27	Printing	0.0	0.0	0.0	0.0	0.0	0.0
28	Chemicals	3.5	39.2	83.0	168.0	456.3	749.9
29	Petroleum Refining	0.8	6.3	1.7	150.1	934.0	1,092.9
30	Rubber/Misc Plastics	0.0	0.0	0.0	0.0	0.0	0.0
32	Stone/Clay/Glass	0.6	2.3	12.9	18.6	20.5	54.8
33	Primary Metals	0.0	0.0	0.0	0.0	0.0	0.0
34	Fabricated Metals	0.0	0.0	0.0	0.0	0.0	0.0
35	Machinery/Computer Equip	0.0	0.0	0.0	0.0	0.0	0.0
37	Trasportation Equip.	0.0	0.0	0.0	0.0	0.0	0.0
38	Instruments	0.0	0.0	0.0	0.0	0.0	0.0
39	Misc Manufacturing	3.5	3.5	0.0	0.0	0.0	7.0
	Total	71.4	110.5	261.2	570.6	3,530.1	4,543.7

AB-1613 eligible capacity up to 20 MW (blue shaded columns)

Reciprocating Engine Technology Assumptions

CHP System	Characteristic/Year Available	2009	2014	2019
100 kW - Rich Burn with 3 way catalyst	Installed Costs, $/kW	$2,210	$1,925	$1,568
	CA Installed Costs	$2,475	$2,137	$1,741
	Heat Rate, Btu/kWh	12,000	10,830	10,500
	Electric Efficiency, %	28.4%	31.5%	32.5%
	Thermal Output, Btu/kWh	6100	5093	4874
	Overall Efficiency, %	79.3%	78.5%	78.9%
	Power to Heat	0.56	0.67	0.70
	O&M Costs, $/kWh	0.02	0.016	0.012
	NOx Emissions, lbs/MWh (w/ AT)	0.15	0.15	0.15
	NOx Emissions, lbs/MWh (w/AT) CHP Credit	0.05	0.06	0.06
	After-treatment Cost, $/kW	incl.	incl.	incl.
800 kW - Lean Burn	Installed Costs, $/kW	$1,640	$1,443	$1,246
	CA Installed Costs	$1,820	$1,602	$1,384
	Heat Rate, Btu/kWh	9,760	9,750	9,225
	Electric Efficiency, %	35.0%	35.0%	37.0%
	Thermal Output, Btu/kWh	4299	4300	3800
	Overall Efficiency, %	79.0%	79.1%	78.2%
	Power to Heat	0.79	0.79	0.90
	O&M Costs, $/kWh	0.016	0.013	0.011
	NOx Emissions, gm/bhp (w/o AT)	0.7	0.4	0.25
	NOx Emissions, lbs/MWh (w/o AT)	2.17	1.24	0.775
	NOx Emissions, lbs/MWh (w/AT)	0.11	0.12	0.08
	NOx Emissions, lbs/MWh (w/AT) CHP Credit	0.05	0.05	0.04
	After-treatment Cost, $/kW	300	190	140

CHP System	Characteristic/Year Available	2009	2014	2019
3000 kW - Lean Burn	Installed Costs, $/kW	$1,130	$1,100	$1,041
	CA Installed Costs	$1,254	$1,221	$1,155
	Heat Rate, Btu/kWh	9,492	8,750	8,325
	Electric Efficiency, %	35.9%	39.0%	41.0%
	Thermal Output, Btu/kWh	3510	3189	2900
	Overall Efficiency, %	72.9%	75.4%	75.8%
	Power to Heat	0.97	1.07	1.18
	O&M Costs, $/kWh	0.014	0.012	0.01
	NOx Emissions, gm/bhp (w/o AT)	0.7	0.4	0.25
	NOx Emissions, lbs/MWh (w/o AT)	2.17	1.24	0.775
	NOx Emissions, lbs/MWh (w/AT)	0.11	0.12	0.08
	NOx Emissions, lbs/MWh (w/AT) CHP Credit	0.05	0.06	0.04
	After-treatment Cost, $/kW	200	130	100
5000 kW - Lean Burn	Installed Costs, $/kW	$1,130	$1,099	$1,038
	CA Installed Costs	$1,254	$1,220	$1,153
	Heat Rate, Btu/kWh	8,758	8,325	7,935
	Electric Efficiency, %	39.0%	41.0%	43.0%
	Thermal Output, Btu/kWh	3046	2797	2605
	Overall Efficiency, %	73.7%	74.6%	75.8%
	Power to Heat	1.12	1.22	1.31
	O&M Costs, $/kWh	0.011	0.01	0.009
	NOx Emissions, gm/bhp (w/o AT)	0.5	0.4	0.25
	NOx Emissions, lbs/MWh (w/o AT)	1.55	1.24	0.775
	NOx Emissions, lbs/MWh (w/AT)	0.11	0.12	0.08
	NOx Emissions, lbs/MWh (w/AT) CHP Credit	0.06	0.07	0.04
	After-treatment Cost, $/kW	150	115	80

Microturbine Technology Assumptions

CHP System	Characteristic/Year Available	2009	2014	2019
65 kW	Installed Costs, $/kW	$2,739	$2,037	$1,743
	CA Installed Costs	$3,040	$2,261	$1,935
	Heat Rate, Btu/kWh	13,542	12,500	11,375
	Electric Efficiency, %	25.2%	27.3%	30.0%
	Thermal Output, Btu/kWh	6277	5350	4500
	Overall Efficiency, %	71.5%	70.1%	69.6%
	Power to Heat	0.54	0.64	0.76
	O&M Costs, $/kWh	0.022	0.016	0.012
	NOx Emissions, lbs/MWh (w/o AT)	0.17	0.14	0.13
	NOx Emissions, lbs/MWh (w/o AT) CHP Credit	0.06	0.05	0.06
250 KW - use multiple units	Installed Costs, $/kW	$2,684	$2,147	$1,610
	CA Installed Costs	$2,979	$2,383	$1,788
	Heat Rate, Btu/kWh	12,290	11,750	10,825
	Electric Efficiency, %	27.8%	29.0%	31.5%
	Thermal Output, Btu/kWh	4800	4300	3700
	Overall Efficiency, %	66.8%	65.6%	65.7%
	Power to Heat	0.71	0.79	0.92
	O&M Costs, $/kWh	0.015	0.013	0.012
	NOx Emissions, lbs/MWh (w/o AT)	0.14	0.13	0.13
	NOx Emissions, lbs/MWh (w/o AT) CHP Credit	0.06	0.06	0.06

Fuel Cell Technology Assumptions

CHP System	Characteristic/Year Available	2009	2014	2019
200/400 kW PAFC (assumes all high grade and 50% low grade thermal utilized)	Installed Costs, $/kW	$6,310	$4,782	$3,587
	CA Installed Costs	$7,004	$5,308	$3,981
	Heat Rate, Btu/kWh	9,475	9,475	9,000
	Electric Efficiency, %	36.0%	36.0%	37.9%
	Thermal Output, Btu/kWh	2923	2923	2800
	Overall Efficiency, %	66.9%	66.9%	69.0%
	Power to Heat	1.17	1.17	1.22
	O&M Costs, $/kWh	0.038	0.017	0.015
	NOx Emissions, lbs/MWh (w/o AT)	0.04	0.035	0.035
300 kW MCFC	Installed Costs, $/kW	$5,580	$4,699	$3,671
	CA Installed Costs	$6,194	$5,216	$4,075
	Heat Rate, Btu/kWh	8,022	7,700	7,300
	Electric Efficiency, %	42.5%	44.3%	46.7%
	Thermal Output, Btu/kWh	1600	1500	1300
	Overall Efficiency, %	62.5%	63.8%	64.5%
	Power to Heat	2.13	2.27	2.62
	O&M Costs, $/kWh	0.035	0.02	0.015
	NOx Emissions, lbs/MWh (w/o AT)	0.01	0.01	0.01
1500 kW MCFC	Installed Costs, $/kW	$5,250	$4,523	$3,554
	CA Installed Costs	$5,828	$5,021	$3,945
	Heat Rate, Btu/kWh	8,022	7,500	6,820
	Electric Efficiency, %	42.5%	45.5%	50.0%
	Thermal Output, Btu/kWh	1583	1400	1100
	Overall Efficiency, %	62.3%	64.2%	66.2%
	Power to Heat	2.15	2.44	3.10
	O&M Costs, $/kWh	0.032	0.019	0.015
	NOx Emissions, lbs/MWh (w/o AT)	0.01	0.01	0.01

Gas Turbine Technology Assumptions

CHP System	Characteristic/Year Available	2009	2014	2020
3000 KW GT	Installed Costs, $/kW	$1,690	$1,560	$1,300
	CA Installed Costs	$1,876	$1,732	$1,443
	Heat Rate, Btu/kWh	13,100	12,650	11,500
	Electric Efficiency, %	26.0%	27.0%	29.7%
	Thermal Output, Btu/kWh	5018	4750	4062
	Overall Efficiency, %	64.4%	64.5%	65.0%
	Power to Heat	0.68	0.72	0.84
	O&M Costs, $/kWh	0.0074	0.0065	0.006
	NOx Emissions, ppm (w/o AT)	15	9	5
	NOx Emissions, lbs/MWh (w/o AT)	0.68	0.38	0.2
	NOx Emission, lb/MWh (w/AT)	0.07	0.07	0.07
	After-treatment Cost, $/kW	210	175	150
10 MW GT	Installed Costs, $/kW	$1,298	$1,278	$1,200
	CA Installed Costs	$1,441	$1,419	$1,333
	Heat Rate, Btu/kWh	11,765	10,800	9,950
	Electric Efficiency, %	29.0%	31.6%	34.3%
	Thermal Output, Btu/kWh	4674	4062	3630
	Overall Efficiency, %	68.7%	69.2%	70.8%
	Power to Heat	0.73	0.84	0.94
	O&M Costs, $/kWh	0.007	0.006	0.005
	NOx Emissions, ppm (w/o AT)	15	9	5
	NOx Emissions, lbs/MWh (w/o AT)	0.68	0.38	0.2
	NOx Emission, lb/MWh (w/AT)	0.07	0.07	0.07
	After-treatment Cost, $/kW	140	125	100
40 MW GT	Installed Costs, $/kW	$972	$944	$916
	CA Installed Costs	$1,079	$1,048	$1,017
	Heat Rate, Btu/kWh	9,220	8,865	8,595
	Electric Efficiency, %	37.0%	38.5%	39.7%
	Thermal Output, Btu/kWh	3189	3019	2892
	Overall Efficiency, %	71.6%	72.5%	73.3%
	Power to Heat	1.07	1.13	1.18
	O&M Costs, $/kWh	0.004	0.004	0.004
	NOx Emissions, ppm (w/o AT)	15	5	3
	NOx Emissions, lbs/MWh (w/o AT)	0.55	0.2	0.1
	NOx Emission, lb/MWh (w/AT)	0.06	0.06	0.06
	After-treatment Cost, $/kW	90	75	40

Average Electric Cost Savings from Baseload CHP – 50-500 kW

Utility	2009 $/kWh	2014 $/kWh	2019 $/kWh	2024 $/kWh
LADWP	$0.0814	$0.0868	$0.0975	$0.0969
Other North	$0.0877	$0.0948	$0.1087	$0.1080
Other South	$0.0877	$0.0948	$0.1087	$0.1080
PG&E	$0.1189	$0.1270	$0.1428	$0.1420
SCE	$0.0922	$0.0988	$0.1115	$0.1109
SDG&E	$0.1130	$0.1222	$0.1402	$0.1393
SMUD	$0.0857	$0.0938	$0.1095	$0.1087

LADWP – General Service A2-b

PG&E – A10 TOU

SCE – TOU-GS-3

SDG&E – AL-TOU

SMUD – GS-TOU3

Other North – 105% of SMUD and LADWP average

Other South – 110% of LADWP, SMUD average

All assume secondary voltage delivery

Average Electric Cost Savings from Baseload CHP – 500 kW to 5 MW

Utility	2009 $/kWh	2014 $/kWh	2019 $/kWh	2024 $/kWh
LADWP	$0.0877	$0.0936	$0.1051	$0.1045
Other North	$0.0897	$0.0970	$0.1110	$0.1103
Other South	$0.0897	$0.0970	$0.1110	$0.1103
PG&E	$0.0946	$0.1027	$0.1184	$0.1177
SCE	$0.0941	$0.1008	$0.1140	$0.1133
SDG&E	$0.1187	$0.1279	$0.1458	$0.1449
SMUD	$0.0832	$0.0911	$0.1063	$0.1056

LADWP – General Service A3-c

PG&E – A19-TOU, E20

SCE – TOU-GS-8

SDG&E – AL-TOU

SMUD – GS-TOU1

Other South and North – 105% of SMUD and LADWP average

Secondary voltage delivery

Average Electric Cost Savings from Baseload CHP– 5-20 MW

Utility	2009 $/kWh	2014 $/kWh	2019 $/kWh	2024 $/kWh
LADWP	$0.0846	$0.0902	$0.1013	$0.1007
Other North	$0.0854	$0.0922	$0.1055	$0.1049
Other South	$0.0854	$0.0922	$0.1055	$0.1049
PG&E	$0.0930	$0.1008	$0.1161	$0.1154
SCE	$0.0695	$0.0748	$0.0849	$0.0844
SDG&E	$0.1164	$0.1255	$0.1431	$0.1422
SMUD	$0.0781	$0.0855	$0.0998	$0.0990

LADWP – General Service A3-c

PG&E – A19-TOU, E20

SCE – TOU-GS-8

SDG&E – AL-TOU

SMUD – GS-TOU1

Other South and North – 105% of SMUD and LADWP average

Assume primary voltage delivery

Average Electric Cost Savings from Baseload CHP– > 20 MW

Utility	2009 $/kWh	2014 $/kWh	2019 $/kWh	2024 $/kWh
LADWP	$0.0846	$0.0902	$0.1013	$0.1007
Other North	$0.0856	$0.0925	$0.1058	$0.1051
Other South	$0.0856	$0.0925	$0.1058	$0.1051
PG&E	$0.0796	$0.0873	$0.1023	$0.1016
SCE	$0.0695	$0.0748	$0.0849	$0.0844
SDG&E	$0.1064	$0.1155	$0.1332	$0.1323
SMUD	$0.0785	$0.0859	$0.1003	$0.0995

LADWP – General Service A3-c

PG&E – A19-TOU, E20

SCE – TOU-GS-8

SDG&E – AL-TOU

SMUD – GS-TOU1

Other South and North – 105% of SMUD and LADWP average

All assume transmission or sub-transmission voltage delivery

Base Case Market Forecast (MW)

Utility	2009	2014	2019	2024	2029
LADWP	0	50	125	156	164
SCE	0	233	743	990	1,047
SDG&E	0	83	241	313	331
PG&E	0	217	692	939	1,007
SMUD	0	15	42	56	60
Other	0	25	83	114	122
Combined Total	0	623	1,926	2,569	2,731

- New CHP cumulative market penetration by utility
- Includes CHP with power used on-site plus export for systems smaller than 20 MW
- No Export assumed for systems >20 MW

Base Case with Existing CHP Included (MW)

Utility	2009 Existing	2014	2019	2024	2029
LADWP	293	343	418	449	457
SCE	2,484	2,718	3,227	3,474	3,531
SDG&E	439	522	680	752	770
PG&E	5,376	5,593	6,068	6,315	6,383
SMUD	536	551	578	593	596
Other	66	91	148	179	187
California Total	9,194	9,817	11,120	11,763	11,925

- CHP market increases by 33%
- No loss in existing CHP assumed

CO2 Payments Case – Cumulative Market Penetration by Utility (MW)

Utility	2009	2014	2019	2024	2029
LADWP	0	54	137	171	180
SCE	0	267	828	1,092	1,153
SDG&E	0	86	250	324	343
PG&E	0	239	750	1,011	1,082
SMUD	0	17	49	65	69
Other	0	28	92	126	135
Combined Total	0	692	2,106	2,789	2,961

- $50/ton of avoided CO2 payment for on-site CHP
- 8% increase in new CHP market penetration

CO2 Payments Case – Cumulative Market Penetration by Type (MW)

Year	On-site CHP MW	Export CHP MW	Avoided AC MW	Total MW
2009	0	0	0	0
2014	605	87	61	753
2019	1,870	236	178	2,284
2024	2,496	292	259	3,048
2029	2,658	304	281	3,242

SGIP Case – Cumulative Market Penetration by Utility (MW)

Utility	2009	2014	2019	2024	2029
LADWP	0	56	148	179	187
SCE	0	290	940	1,187	1,244
SDG&E	0	93	279	351	369
PG&E	0	266	851	1,098	1,166
SMUD	0	17	52	67	70
Other	0	31	107	138	146
Combined Total	0	752	2,377	3,020	3,182

- Restoration of SGIP incentives for 10 years
- 17% increase in new CHP market penetration

SGIP Payments Case – Cumulative Market Penetration by Type (MW)

Year	On-site CHP MW	Export CHP MW	Avoided AC MW	Total MW
2009	0	0	0	0
2014	662	90	70	823
2019	2,129	248	217	2,594
2024	2,715	304	293	3,313
2029	2,866	316	314	3,496

All In Scenario – Cumulative Market Penetration by Utility (MW)

Utility	2009	2014	2019	2024	2029
LADWP	0	91	224	264	273
SCE	0	392	1,169	1,447	1,509
SDG&E	0	96	288	362	381
PG&E	0	470	1,285	1,580	1,654
SMUD	0	20	60	76	80
Other	0	44	138	175	185
Combined Total	0	1,113	3,164	3,904	4,082

- CO2 payments, restored SGIP, and large facility export
- 41% increase in new CHP market penetration

All In Scenario – Cumulative Market Penetration by Type (MW)

Year	On-site CHP MW	Export CHP MW	Avoided AC MW	Total MW
2009	0	0	0	0
2014	725	388	73	1,186
2019	2,306	857	223	3,387
2024	2,933	971	304	4,207
2029	3,095	987	325	4,406

GHG Impact – Avoided Power GHG Emissions

Generator Heat Rates	GT-CC Existing Btu/kWh	GT-CC New Btu/kWh	GT
Heat Rate, LHV 59 F	6,369	5,950	8,900
Heat Rate, LHV 88 F			9,474
Heat Rate HHV as used	7,050	6,802	10,487

CHP System Load Factor	GT-CC Existing Share	GT-CC New Share	GT Share	Avg Heat Rate at Generator Btu/kWh HHV	T&D Losses	Avg Heat Rate Delivered	Avoided CO2 Emissions lb/MWh
Baseload	42.5%	42.5%	15.0%	7,460	5%	7,833	917
Intermediate Load	25.0%	25.0%	50.0%	8,707	8%	9,403	1100
Avoided AC	0.0%	0.0%	100.0%	10,487	13%	11,851	1387
Export Baseload	42.5%	42.5%	15.0%	7,460	0%	7,460	873

- 50/50 split between new and existing power assumed for baseload power generation
- Peaking power efficiency corrected for avg. temp., load factor, and SCR losses