CEC Combined Heat and Power Workshop - July 14th, 2014

Evaluating the Greenhouse Gas Performance of Combined Heat and Power
A Summary for California Policymakers

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Synopsis of 2013 CRRI Annual Western Conference paper

Introduction

Objective Evaluate GHG Performance of Conventional CHP

- **Scope of the Paper**
  - Framework for GHG analysis of gas-fired topping-cycle CHP
  - Range of representative Separate Heat and Power (SHP) performance standards
  - Sensitivities around design and operational performance of CHP
- **Topics Not Covered**
  - GHG impact of other forms of CHP, such as bottoming-cycle and renewable
  - Other attributes of CHP: Contribution to system reliability, operational flexibility, and affordability to utility customers

Basis for Evaluation

CHP reduces GHG emissions if the CHP facility produces fewer emissions than separate heat and power for a given amount of electricity and heat

A CHP unit is net GHG reducing if

$$\mathbf{GHG}_{\mathbf{CHP}} < \mathbf{GHG}_{\mathbf{Heat}} + \mathbf{GHG}_{\mathbf{Elec}}$$

Where,

$\mathrm{GHG_{CHP}} =$ Direct GHG Emissions of a CHP unit

$\mathrm{GHG_{Heat}} =$ GHG Emissions from the seperate production of heat(boiler)

$\mathrm{GHG_{Elec}} =$ GHG Emissions from grid supplied electricity

Mathematical Translation to X-Y Dimensional Efficiency Plot

A CHP unit is net GHG reducing if

$$\mathbf{GHG}_{\mathbf{CHP}} < \mathbf{GHG}_{\mathbf{Heat}} + \mathbf{GHG}_{\mathbf{Elec}}$$

$$F_{MMBtu} * G_{CHP,\ tonnes\ CO2e/MMBtu} < H_{MMBtu} * \frac{G_{B,\ tonnes\ CO2e/MMBtu}}{\text{Boiler}_{Eff}} + P_{MWh} * G_{\ Grid,\ tonnes\ CO2e/MWh}$$

$\equiv$

$$G_{CHP,\ tonnes\ CO2e/MMBtu} < \frac{H_{MMBtu}}{F_{MMBtu}} * \frac{G_{B,\ tonnes\ CO2e/MMBtu}}{Boiler_{Eff}} + \frac{P_{MWh}}{F_{MMBtu}} * G_{\ Grid,\ tonnes\ CO2e/MWh}$$

$\equiv$

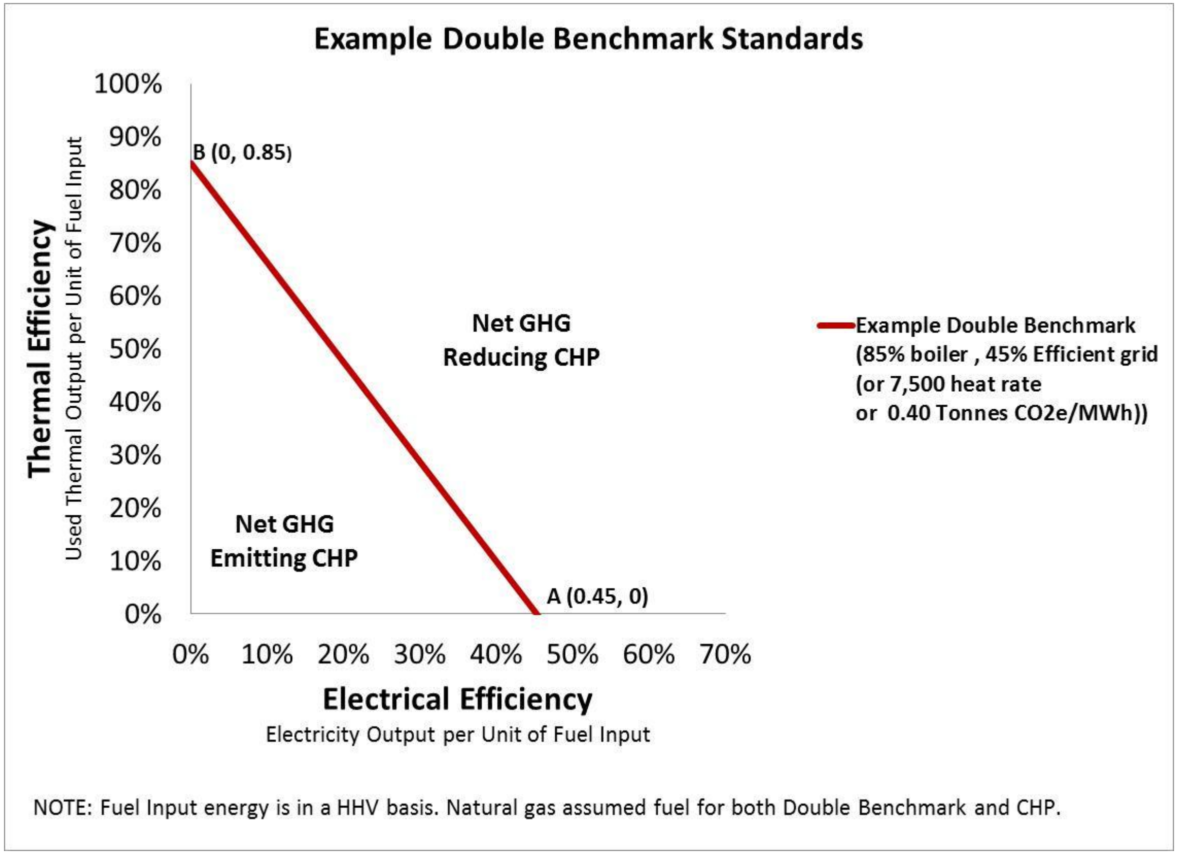
$$1 < \frac{\eta_{CHP-H}}{\text{Boiler}_{Eff}} + \frac{\eta_{CHP-E}}{\text{Grid}_{Eff}}$$ ---- (form of a X + b Y > 1)

This represents an equation of straight line with two variables: η_{CHP-E} *(x- variable),* η_{CHP-H} *(y-variable) and two constants* $Boiler_{Eff}$ *(y-axis intercept),* $Grid_{Eff}$ *(x-axis intercept)*

Where,

- $\text{F}_{\text{MMBtu}} = CHP\ Fuel\ Input\ (HHV)$
- $\text{P}_{\text{MWh}} = Electricity\ Produced\ (both\ onsite\ and\ export)$
- $\text{H}_{\text{MMBtu}} = \text{Used Thermal Output}$
- $\text{G}_0 = \text{GHG Emissions Rate of the fuel}$
- $\eta_{\text{CHP-E}} = \frac{\text{P}_{\text{MWh}} * 3.413}{\text{F}_{\text{MMBtu}}} = \text{CHP Electrical Efficiency}$
- $\eta_{\text{CHP-H}} = \frac{\text{H}_{\text{MMBtu}}}{\text{F}_{\text{MMBtu}}} = \text{CHP Thermal Efficiency}$

GHG Performance - Comparing Gas-fired CHP to Separate Heat and Power



What is the Double Benchmark?

- A greenhouse gas performance metric
- Answers the question: Is the CHP facility reducing GHGs?

Where is it used?

- QF/CHP Settlement, Self-Generation Incentive Program (SGIP)

PG&E Used Representative Public Data Sources for CHP Performance

Key Inputs		Data Sources
CHP Technology Types Analyzed	• Micro-turbine (65 – 925kW), • Fuel Cells (300-1200 kW), • IC Engine (100-5000 kW), • Gas Turbines (3000-40000 kW)	2012 ICF CEC report [1]
CHP Technology Performance	*Scenario 1- Design Performance* Representative CHP units performance in 2016-2020 timeframe	2012 ICF CEC report [1]
	Scenario 2- Operational Performance • Used Thermal Output: 80% thermal utilization factor from the design performance scenario • Electrical Output: 1% annual heat rate degradation from the design performance scenario	CPUC SGIP impact evaluation reports [2] No public data available for larger CHP units. PG&E has limited visibility to ARB Mandatory GHG reports

References:

1. 2012 ICF CEC report : California Energy Commission, 2012, *Combined Heat and Power: 2011-2030 Market Assessment Report,* p. 91-99 ; Online at - http://www.energy.ca.gov/2012publications/CEC-200-2012-002/CEC-200-2012-002.pdf
2. CPUC SGIP reports: Itron, Inc, 2012, *CPUC Self-Generation Incentive Program Eleventh-Year Impact Evaluation*, p.1-9 and Itron, Inc, 2011, *CPUC Self-Generation Incentive Program Cost-Effectiveness of Distributed Generation Technologies* Report, p.3-3; Online at http://www.cpuc.ca.gov/PUC/energy/DistGen/sgip/sgipreports.htm

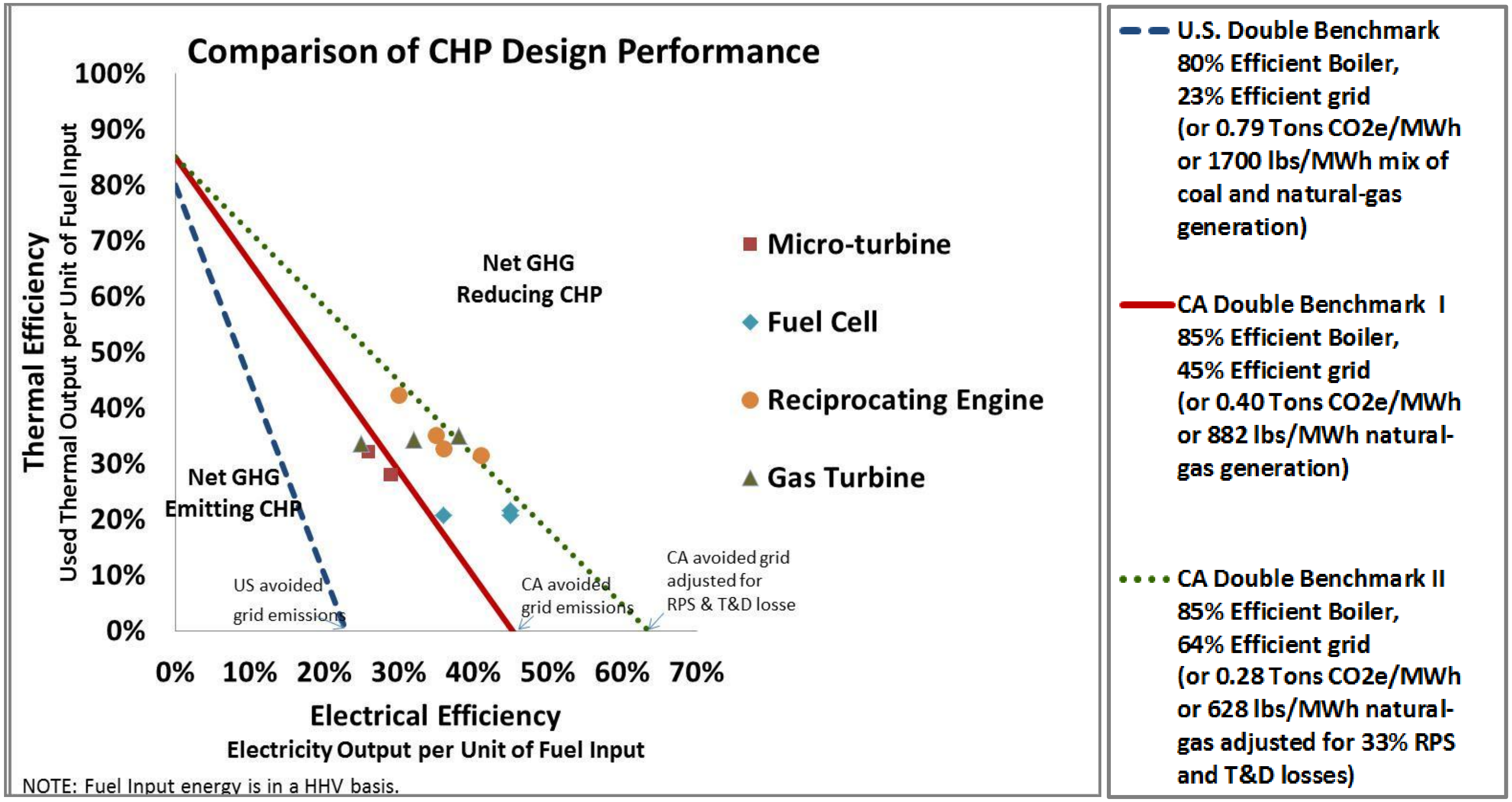
PG&E Used Representative Public Data Sources for SHP Performance

Key Inputs		Data Sources
Avoided Grid Emissions	Three reference avoided grid emissions factors are considered • 2009 U.S. avoided grid emissions • 2020 California (CA) avoided grid emissions • 2020 CA avoided grid emissions adjusted from 33% RPS and 6.9% T&D losses	EPA CHP Calculator[1] CPUC GHG Calculator[2] 33% RPS and CEC study for T&D losses [3]
Avoided Boiler Efficiency	Two separate heat sources efficiency benchmarks are considered 80% and 85%	Representation of CEC appliances database for new boiler installations[4] ARB Cap-and-Trade regulation: 85% is a standard for relatively efficient industrial boiler [5]

References:

1. EPA CHP calculator - US Environmental Protection Agency, 2012, *Combined Heat and Power: A Clean Energy Solution p. 8* Online at - http://www.epa.gov/chp/documents/clean_energy_solution.pdf
2. CPUC GHG Calculator - CPUC, 2010, *GHG Calculator : Greenhouse Gas Modeling of California's Electricity Sector to 2020: Updated Results of the GHG Calculator Version 3b update* - Developed by E3 http://ethree.com/public_projects/cpuc2.php
3. CEC study for T&D losses - California average system losses for transmission and distribution ranged from 5.4 percent to 6.9 percent during 2002 to 2008. See: California Energy Commission, 2011, *A Review of Transmission Losses in Planning Studies*
4. CEC boiler survey installed between 1990 and 2012, with average boilers efficiency of 86% and some new boilers attaining design efficiencies of up to 95% - CEC Appliances Database, Heating Products- Boilers: http://www.appliances.energy.ca.gov/
5. ARB Cap-and-trade regulation Allowance Allocation Appendix J of the Cap and Trade staff report, page J-53 http://www.arb.ca.gov/regact/2010/capandtrade10/capv4appj.pdf

Avoided Regional Grid Emissions Have a Substantial Impact on CHP GHG performance



Performance of example CHP technologies relative to Double Benchmarks	
Relative to US SHP Double Benchmark	Net GHG Reducing
Relative to CA SHP Benchmark I	Mixed
Relative to CA SHP Benchmark II	Net GHG Emitting

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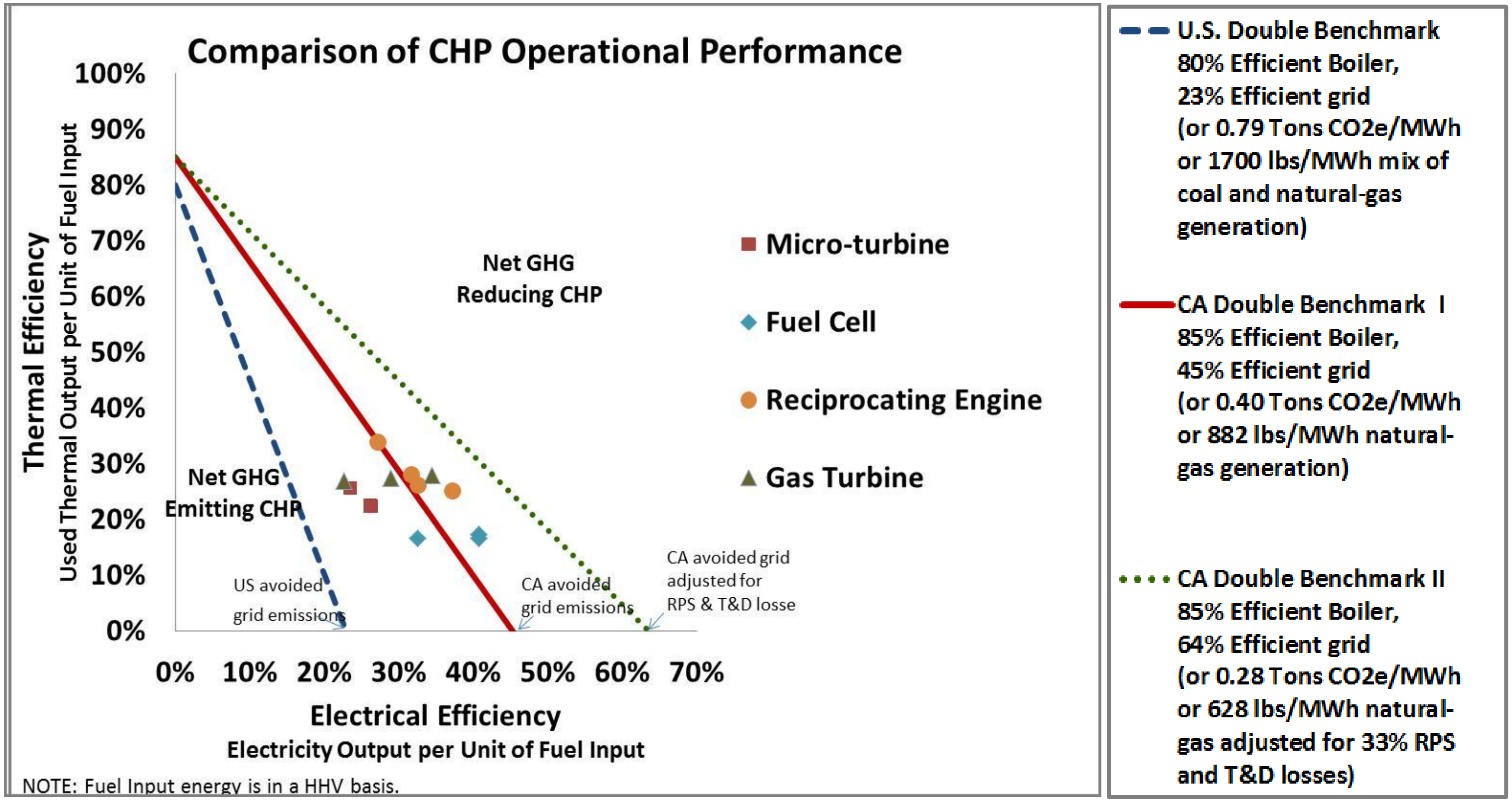

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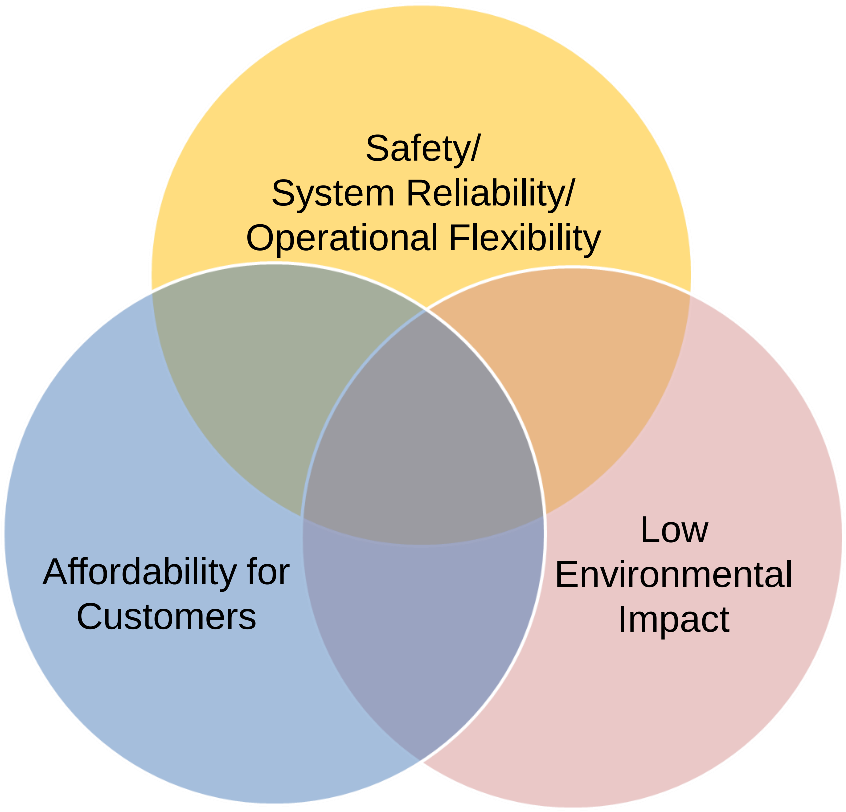
GHG performance of CHP depends on regional avoided emissions and CHP operational performance

Discussion and Final Thoughts

- Studied Conventional Gas-fired CHP systems
  - ✓ Have limited GHG emissions reduction potential in California.
    - ✓ CHP operational performance is critical
  - ✓ Have greater GHG emissions reduction potential at the national level
- Well-constructed policies which encourage efficient gas-fired CHP facilities to perform as-designed are necessary for CHP to maximize the potential for emission reductions
- Other CHP configurations, such as renewable or bottoming cycle CHP, may provide more GHG reduction opportunity

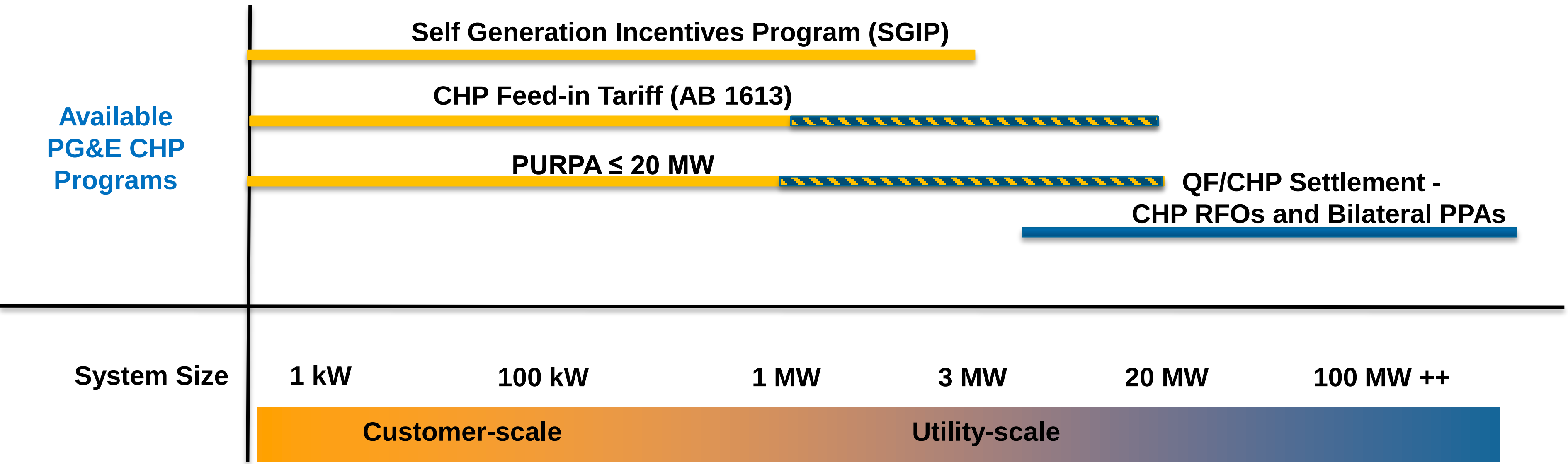
PG&E's Perspective on CHP

PG&E supports clean combined heat and power that provides a cost-effective, reliable source of electricity to our customers and helps to reduce greenhouse gases statewide



APPENDIX

Programs Available to Support CHP



- Programs exist to incent CHP across all MW sizes
- Programs support both on-site and export configurations
  - Since 2000, PG&E 195 customers have interconnected over 122 MW of CHP to meet their energy needs. CHP representing over 70% of the SGIP funded capacity.
  - PG&E has made significant progress towards implementing the QF/CHP Settlement. Progress so far:
    - 98% of the 2015 MW target , 62% of the 2020 GHG target
    - Primarily GHG emissions reductions achieved by running inefficient CHP less, and by cleaner forms of CHP such as renewable and bottoming-cycle CHP