SELECTING TARGETS FOR NEW MARKET TRANSFORMATION INITIATIVES IN NORTHERN CALIFORNIA

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Introduction

This report is part of a XENERGY/American Council for an Energy-Efficient Economy (ACEEE) project conducted for Pacific Gas & Electric Company (PG&E) on market transformation. The overall project is divided into two components. This report summarizes the work that has been done under the second component: identifying and analyzing measures for potential new market transformation initiatives. This report characterizes a range of technologies and practices and identifies and recommends those technologies and practices that PG&E should consider pursuing.

Approach

The goal of this component of the project is to select technologies or practices (hereafter collectively referred to as "measures") as targets for new market transformation programs that should be operated in the PG&E (and possibly neighboring) service territories. In order to reach this goal, a multi-step process was implemented. First, we developed a preliminary list of nearly 60 measures for consideration as possible new market transformation initiatives. In selecting measures for this list we focused on technologies and practices which will be suitable for full-scale market transformation programs at some point during the 1998-2000 period. Second, we identified data needs for each measure, conducted research to collect these data, and prepared a short write-up on each measure. Third, we developed and implemented a method for comparing different measures. Following review and consultation with PG&E on an initial ranking of measures, we gathered additional data, revised the rankings and expanded the write-ups for the 15 highest ranked measures. The approach taken to identify, characterize, and compare measures for this study is detailed below.

Develop Preliminary List of Measures

Initially, the project team compiled a preliminary list of nearly 60 measures for consideration as possible new market transformation initiatives. Measures were selected for this list based on three primary sources:

- A PG&E list of potential market transformation targets (listed under "Market Transformation" and "Commercialization" in PG&E's *Annual Summary Report on DSM Programs in 1995 and 1996.* (PG&E 1996);

- Measures being targeted or considered by national and regional market transformation organizations including the Consortium for Energy Efficiency (CEE), Northeast Energy Efficiency Partnership (NEEP), Northwest Energy Efficiency Alliance (NEEA), Energy Center of Wisconsin, Canadian Standards and Canadian Electrical Associations, EPA and DOE "ENERGY STAR®" and other DOE programs; and

- Additional measures including ones in ACEEE, XENERGY and E Source files on promising technologies and practices, and ones identified in discussions with PG&E staff, people on PG&E's Advisory Board, other California organizations working on market transformation (e.g., CEC and CIEE), and R&D organizations (e.g., EPRI, GRI, LBNL, and Davis Energy Group). Only energy-saving measures were included; measures which generate electricity, such as fuel cells and renewable energy systems are beyond the scope of this study.

Preliminary lists of measures are included in Appendix A. This list was winnowed down to approximately 60 measures by eliminating measures that were not suitable for initiatives in the 1997-2000 period, measures that are already being promoted by current full-scale PG&E programs[1], measures that were too vague to usefully analyze in this project, and measures with very-limited impacts which were highly unlikely to pass even the first stage of the screening process. The measures selected are summarized in Table 1.

Table 1. Measures Selected for Analysis

Current and Prospective PG&E Initiatives

1. Ground source heat pumps
2. Heat pump water heaters — residential
3. Residential duct sealing (2 measure characterizations: existing and new construction)
4. Improved kitchen ventilation — commercial
5. Efficient windows — residential
6. Fluorescent lighting fixtures — residential
7. Efficient windows — commercial
8. Light-colored roof coatings
9. Daylight dimming/high-performance glazing
10. Occupancy sensors — commercial
11. Optimization of chiller and tower systems
12. Wastewater facility energy efficiency optimization
13. Refrigeration integrated design — commercial
14. Industrial pumps, fans, and blowers
15. Integrated building design — commercial
16. Large commercial building recommissioning
17. Infiltration reduction (2 measure characterizations: existing and new construction)
18. Indirect/direct evaporative cooling
19. Window film — commercial
20. Modulating gas furnaces

Current and Prospective Initiatives by CEE, NEEP, NWEEP, ECW, EPA, DOE, and CSA

21. Residential central air-conditioning
22. Commercial package air-conditioning
23. Compact fluorescent lamp buydown
24. Gas engine-driven chillers
25. Gas absorption chillers
26. Coin-op clothes washers
27. High quality motor repair practices
28. Industrial air compressors
29. New building commissioning
30. Wastewater heat recovery
31. Commercial lighting remodeling
32. Commercial package air conditioner installation and maintenance
33. High-efficiency packaged refrigeration equipment
34. Premium efficiency motors
35. Agricultural irrigation pump systems
36. Improved education/enforcement of Title 24 standards
37. Dry-type distribution transformers
38. Integrated space/water heating heat pump systems

[1] For example, horizontal axis clothes washers and high-efficiency refrigerators are part of current full-scale PG&E programs and hence were not included in this analysis.

39. Ceiling fans
40. Furnace blowers
41. Uninterruptible power supplies
42. Halogen IR A-line lamps
43. Gas heat pumps — residential
44. Packaged gas cooling systems — commercial
45. Residential air conditioner installation and maintenance

Additional Promising Technologies and Practices

46. Integrated gas-fired space/water heating systems
47. High-efficiency storage-type residential water heaters
48. Instantaneous gas water heaters
49. Heat pump water heaters — commercial
50. Low energy/water residential dishwashers
51. High-efficiency commercial dishwashers
52. Ozonated laundry
53. LED traffic signals
54. Improved HVAC cleanroom techniques
55. Night spray thermal storage
56. Dual source heat pumps
57. Wastewater heat recovery systems - residential
58. Evaporative pre-cooler for residential air conditioning
59. Process gas refrigeration

Identify and Collect Data on Each Measure

As part of our research plan we identified four factors as our principal means for comparing, ranking, and ultimately selecting measures for new market transformation programs. The four factors include potential energy savings, cost effectiveness, likelihood of market transformation initiative being successful, and relationship to PG&E's business plan.

Potential energy savings are important because in order to justify the substantial work and effort to develop and implement a market transformation initiative, substantial savings must be achieved. Initiatives with only small savings may not justify the costs of putting an initiative into place. All other things being equal, new market transformation initiatives with high savings will be more advantageous than initiatives with smaller savings. Potential energy savings were assessed by comparing likely market trends in the absence of a program to the market trends that can be realistically achieved if a market transformation initiative is implemented. These market trends were estimated based on historic data, published projections, and discussions with industry experts. Potential energy savings need to be analyzed over a long enough time frame for the initiative to have substantial impact, but at a short enough time frame to be relevant in current planning efforts. For this study, in consultation with PG&E, we decided to key in on savings achieved in 2010 in our analyses of energy savings because 2010 is far enough away for new market transformation initiatives to have significant impact, yet 2010 is close enough to be well within current resource planning time horizons.

Measure cost-effectiveness is important for several reasons. First, measure cost-effectiveness is very important for convincing consumers to implement a measure. If measures are very expensive relative to the benefits, achieving substantial market share will be near impossible. Second, prioritizing DSM programs has typically relied on the TRC test; measure cost is a primary element in assessing TRC costs. We examined cost-effectiveness on a levelized cost of saved energy basis over the measure lifetime, resulting in $/kWh and $/therm indices.

Likelihood of a market transformation initiative being successful is perhaps the most critical factor in selecting market transformation targets. If an initiative is unlikely to be successful, it is generally not worth pursuing. Likelihood of success in turn depends on an analysis of the major market barriers that are impeding each initiative and the likelihood that program interventions can overcome these barriers. Likelihood of success also depends on how well the technology or practice addresses customer needs — does the measure have additional benefits besides energy savings, or is the measure less desirable than conventional measures from a consumer perspective?

The relationship to PG&E's business plan was assessed by PG&E staff and is designed to capture PG&E's prior experience with, interest in, and expertise related to each measure.

Based on these factors and subfactors, for each measure in Table 1 above, we compiled the following data:

Market Information:
1. Measure name
2. Measure description
3. Market sector (RES, COM, IND, AGR)
4. End-use(s)
5. Energy types (ELEC, GAS, BOTH)
6. Market segment (NEW, RETROFIT, REPLACEMENT, OEM)

Basecase Information:
7. Basecase description (typical unit size and characteristics of current practice to which new measure is being compared)
8. Base case efficiency
9. Base case annual energy use

New Measure Information:
10. New measure description (size and characteristics, for comparison to basecase)
11. New measure efficiency
12. New measure annual energy use
13. Measure life

Savings Information:
14. Electricity savings/year (of new technology relative to basecase)
15. Gas savings/year (of new technology relative to basecase)
16. Percent savings (of new technology relative to basecase)
17. Feasible applications (% of applications for which measure is feasible)
18. Savings potential in 2010 (GWh and/or trillion Btu)

Cost Information:
19. Current measure cost
20. Future measure cost (in mass use)
21. Other direct costs/savings
22. Cost of saved energy ($/kWh and/or $/therm)

23. Data Quality Assessment:
(quality/accuracy of data on each measure, rated on a A-D scale, where A=very good, B=good, C=fair, and D=poor).

Likelihood of Success:
24. Major market barriers (brief list)
25. Effect of measure on customer utility (non-energy benefits and problems)

26. Current activity promoting measure at PG&E
27. Current activity promoting measure elsewhere
28. Likelihood of success rating (1-5 scale)
29. Other factors rating (1-3 scale)

Sources:
30. Savings estimates
31. Cost estimates
32. Measure life estimates
33. Other key sources
34. Principal contacts

35. Notes

Most of these variables are self explanatory, but a few key variables require further explanation:

Feasible applications: Feasible applications are the proportion of applications where the measure is likely to be technically feasible and cost-effective over the long-term. However, for measures with substantial current market share, feasible applications do not include expected penetration in 2010 in the absence of any new initiatives. In this manner we attempted to estimate the long-term potential impact of a new initiative.

Savings Potential in 2010: Potential energy savings were estimated for the PG&E service area, using California Energy Commission and California Conservation Inventory Group forecast data on projected energy use by end-use (these data are summarized in Appendix B). Our general approach for estimating energy savings was to compute the product of projected energy use in 2010 for the specific end-use affected times the feasible applications times the proportion of the market that could be impacted by 2010. For retrofit measures, this latter figure was assumed to be 100%. For replacement measures (measures which are installed when existing equipment fails and must be replaced), this proportion is eight divided by the measure life, representing the proportion of equipment that will be replaced between 2002 and 2010.[2] For new construction measures, this proportion was based on construction during the 2002-2010 period divided by the total anticipated building stock in 2010.[3] For measures that save both electricity and natural gas, energy both electricity and gas savings were calculated, using the appropriate fuel units. For measures that save one fuel but use more of another fuel (e.g. gas air conditioning which saves electricity but uses gas), energy savings are expressed in Btu, valuing electricity at 10,615 Btu per kWh.

Cost of saved energy: Is the levelized cost of a measure over its lifetime per unit of energy saved. It is calculated by assuming each measure is financed with a loan, with a term equal to the measure life and an interest rate equal to the discount rate, and dividing the annual loan payments by the annual energy savings. These calculations are based on the future measure cost estimates and a real discount rate of 6% which is based on the rate used in PG&E's *Annual Summary Report on DSM Programs in 1995 and 1996.* For measures which save both electricity and natural gas, we allocated costs proportionately to the two fuels based on the primary energy savings achieved and calculated costs of saved energy separately for electricity

[2] For purposes of this calculation we assumed that 20% penetration would be achieved by 2000, 40% in 2001, 60% in 2002, 80% in 2003, and 100% in 2004-2010. This progression is mathematically equivalent to 100% penetration over the 2002-2010 period.

[3] The 2002-2010 was used for reasons described in the footnote above.

and gas. For measures which have annual operating costs or savings besides energy (e.g., reduced or increased maintenance costs), changes in annual maintenance costs are included in the costs calculations. For example, for a measure that increases maintenance costs, costs included in the cost of saved energy calculation are annual loan payments on incremental capital costs and incremental increase in maintenance costs. For measures which save one fuel but use more of another fuel, cost of saved energy was calculated for the fuel being saved, but including the annual cost of the other fuel in the cost part of the calculations. For example, to calculate the cost of saved energy of gas air conditioning, costs include annual loan payments on capital costs, annual natural gas costs (valued at current average retail rates), and incremental annual maintenance costs.

Likelihood of success was assessed on a qualitative basis, using the following five point scale:

1 = Will be very difficult to succeed; there are many large barriers to overcome, the benefits are limited, and little work has taken place thus far.

2 = Will be hard to succeed; similar to above but one of the above factors does not apply (e.g. benefits are not small OR some significant work has already taken place).

3 = Moderate chance of success; are substantial barriers to overcome, but also substantial benefits. Some progress has already been made.

4 = Very good chance of success; the benefits of the measure are very large and the barriers appear surmountable. Work has already begun, so trade allies somewhat familiar with measure. However, unlike a 5 rating, either there is not an obvious exit strategy, or the exit strategy will be very controversial (e.g. a mandatory efficiency standard for horizontal-axis clothes washers).

5 = Excellent chance of success; the measure has been proven technically and has significant benefits. Extensive work has taken place already, and the the measure lends itself to a clear exit strategy such as codes, mandatory standards, or an easy to meet voluntary standard as with power management in PC's.

Relationship to PG&E's business plan was assessed by PG&E staff using the following qualitative scale:

1 = Measures that do not align well with PG&E's interests, expertise and business plan;

2 = Measures that are neither inconsistent with, nor consistent with, PG&E's business plan. These measures are neutral;

3 = Measures that are consistent with PG&E's current activities, interests, expertise and business plan.

Ranking Measures

In selecting measures for further investigation, we used a mixed objective/subjective approach. This approach uses objective analysis where possible but recognizes that there is also substantial subjectivity since much of the data going into the analysis is subjective in nature and since any objective process will not be able to capture the full range of issues that need to be balanced in order to select the best program targets. Specifically, we used a three-step process: (1) objective ranking as discussed below; (2) review of initial rankings by the project team including review and adjustment for consistency of subjective factors in the rankings (e.g., likelihood of success); and (3) review of revised rankings by PG&E and the project team, resulting in further adjustments of the types noted in the previous step and subjective adjustments based on factors not fully considered in the analysis such as mix between residential and non-residential measures.

For the first step, we used the following approach:

a. Rankings were be based on four factors — likelihood of success (rated on a 1-5 scale), potential energy savings in 2010 (in trillion Btu, assuming 10,615 Btu/kWh,[4] cost of saved energy (levelized cost per kWh or therm saved over the measure lifetime), and relationship to PG&E's business plan (rated on a scale of 1 to 3). These variables are discussed above.

b. For each factor, measures were ranked from lowest to highest and points assigned, with zero points to the lowest-ranked measure and 100 points assigned to the highest ranked measure. For other measures, points were prorated based on their rank. Measures with the same rank received the same number of points. Separate rankings were made for gas vs. electric cost of saved energy with maximum points assigned to both the highest ranking gas measure <u>and</u> the highest ranking electric measure. For measures which save both gas and electricity, electric costs were ranked with other electric measures and gas costs with other gas measures. For dual-fuel measures, gas and electric cost of saved energy points were averaged so as to not give double points to low-cost measures.

c. A total measure score was determined by weighting each of the four factors. For the preliminary rankings, the following weights were used:

Factor	Weight
Potential energy savings	30%
Likelihood of success	35%
Cost of saved energy	15%
Other factors	20%

These weights were developed jointly by PG&E and ACEEE. Likelihood of success and potential energy savings were most heavily weighted. Potential energy savings was heavily weighted because saving energy is the primary objective of these market transformation programs. Also, it is through this factor that measures that will likely

[4] The average Btu/kWh in California in 1993 including losses at the power plant and in transmission and distribution. EIA, 1995, *State Energy Data Report 1993*, DOE/EIA-0214(93), U.S. Department of Energy, Washington, DC.

prosper in the market without intervention are ranked low (since savings are relative to expected activity in the absence of additional market intervention). Likelihood of success was heavily weighted because we are interested in savings that can be achieved in practice and not just in theory. This factor depends on barriers inhibiting each measure, chances of overcoming these barriers, non-energy benefits of each measure, and previous work toward market transformation done by PG&E and others. Cost of saved energy was weighted less than the previous two factors because measures with a high cost of saved energy will generally have a low likelihood of success score (due to the barriers of high measure costs and/or limited measure benefits) and we did not want to overweight this factor. Relationship to PG&E's business plan was considered by PG&E to be important and was assigned a medium weight.

Regarding the second step in the selection process, we compared rankings of the different measures, and where scores and rankings appeared inconsistent with each other, appropriate adjustments were made to some of the scores, resulting in some adjustments to the rankings. For example, during this step we compared likelihood of success and other factor scores for relative consistency with each other. We also examined energy savings and cost of saved energy figures with regard to the other measures and to prior analyses of these measures, and where scores appeared aberrant, corrections were made. Finally, since the purpose of this exercise is to identify measures that save energy, we eliminated several fuel-switching measures from the rankings that do not save energy on average in the PG&E region (although these measures may save money due to differential energy prices between the different fuels).

For the third step in the selection process, PG&E, XENERGY, and ACEEE staff carefully reviewed the preliminary rankings and identified areas where data and estimates needed rechecking. ACEEE, XENERGY and E Source then conducted additional research in these areas, revised data where appropriate, and prepared final rankings.

Measure Rankings

Based on the ranking scheme discussed above, final rankings were prepared. The revised rankings are summarized in Table 2 below. In examining the rankings, it is obvious that scores between adjoining measures are close together, and given the inexact nature of the scores and rankings, small differences between ranks are not significant. Thus, the primary purpose of this exercise is to separate highly ranked measures (those near the top of the list) from lower ranked measures. In particular, since the objective of this exercise is to select approximately 20 measures for possible new initiatives, these rankings allow us to identify the top measures for further investigation, and their actual rank, be it first or twentieth, holds little significance. Thus, based on these rankings, the following 20 measures were selected for further investigation:

1. High-efficiency storage-type residential gas water heaters
2. Low energy/water residential dishwashers
3. Coin-operated clothes washers
4. LED traffic signals
5. Fluorescent fixtures — residential
6. Optimization of chiller and tower systems
7. High-efficiency package commercial refrigeration equipment
8. Commissioning existing commercial buildings
9. Commercial package AC systems
10. Evaporative pre-cooler for residential AC
11. Commercial packaged AC O&M
12. Improved lighting design practices — commercial
13. Occupancy sensors — commercial
14. Residential duct sealing — existing construction
15. Dry-type distribution transformers
16. Indirect/direct evaporative cooling
17. Residential package AC systems
18. Efficient windows — residential
19. Integrated building design — commercial
20. Efficient windows — commercial

These 20 measures include eight residential and twelve non-residential measures. Fourteen of these measures are high-efficiency technologies, and six are energy saving practices. For comparison, Table 3 shows the measure rankings minus the factor that values measures according to their relationship to PG&E's business plan. Under this scenario, likelihood of success and potential energy savings are each assigned a weighting of 40% and cost of saved energy is weighted at 20%.

Table 2. Measure Rankings

Measure	Likelihood of Success	Savings GWH	Savings TBTU	TOTAL TBTU	CSE $/kWh	CSE $/therm	Other Factors	Final Ranking
High-efficiency storage-type residential water heaters	5	NA	9.8	9.8	NA	$0.18	1	71.04
Low energy/water residential dishwashers	4	68	6.9	7.6	($0.02)	($0.46)	2	70.86
Coin-operated clothes washers	5	NA	0.9	0.9	NA	($0.18)	3	68.06
LED traffic signals	5	128	NA	1.4	$0.02	NA	3	66.75
Fluorescent fixtures - residential	3	551	NA	5.9	$0.01	NA	3	66.42
Optimization of chiller and tower systems	3	507	NA	5.4	$0.01	NA	3	65.08
High-efficiency packaged commercial refrigeration equipment	3	457	NA	4.8	$0.01	NA	3	63.81
Commissioning existing comm'l buildings	3	967	1.4	11.6	$0.06	$0.98	2	61.41
Commercial package AC systems	4	229	NA	2.4	$0.05	NA	3	59.36
Evaporative pre-cooler for residential AC	3	408	NA	4.3	$0.04	NA	3	59.33
Commercial packaged AC O&M	2	473	NA	5.0	$0.01	NA	3	57.39
Improved lighting design practices - commercial	3	337	NA	3.6	$0.03	NA	3	57.25
Residential duct sealing - existing	3	186	5.1	7.0	$0.03	$0.27	2	57.10
Occupancy sensors - commercial	3	599	NA	6.4	$0.02	NA	2	56.98
Dry-type distribution transformers	4	54	NA	0.6	$0.03	NA	3	56.12
Indirect/direct evaporative cooling	2	399	NA	4.2	$0.01	NA	3	55.72
Residential package AC systems	4	244	NA	2.6	$0.10	NA	3	54.76
Efficient windows - residential	3	78	2.7	3.5	$0.05	$0.45	3	53.44
Integrated building design - commercial	3	202	NA	2.1	$0.03	NA	3	53.36
Efficient windows - commercial	3	399	1.3	5.6	$0.04	$0.37	2	50.97
High quality motor repair practices	3	63	NA	0.7	$0.02	NA	3	50.49
Refrigeration integrated design - commercial	3	110	NA	1.2	$0.04	NA	3	49.63
Residential duct sealing - new construction	3	43	1.2	1.6	$0.05	$0.44	3	47.95
Commercial heat pump water heater	3	6	NA	0.1	$0.03	NA	3	47.44
Heat pump water heaters - residential	3	21	NA	0.2	$0.04	NA	3	46.90
Light-colored roofs	3	190	NA	2.0	($0.01)	NA	2	46.55
Furnace blowers - residential	3	130	NA	1.4	$0.07	NA	3	46.37
Improved enforcement/education of Title 24 standards	3	124	0.7	2.0	$0.01	$0.43	2	45.00
Industrial air compressors	3	191	NA	2.0	$0.02	NA	2	44.84
Agricultural irrigation pumps	3	239	NA	2.5	$0.04	NA	2	43.33
A-line halogen IR lamps	2	29	NA	0.3	$0.01	NA	3	42.45
CFL buydown - residential	3	102	NA	1.1	$0.02	NA	2	41.84
Daylight dimming w/high-performance glazing - commercial	2	52	NA	0.6	$0.03	NA	3	41.44
Laundry wastewater heat recovery - commercial	3	NA	0.3	0.3	NA	($1.43)	2	41.36
AC installation/maintenance	3	154	NA	1.6	$0.05	NA	2	39.78
Wastewater heat recovery systems - residential	3	41	2.9	3.3	$0.01	$0.14	1	38.08
Integrated space/water heating heat pump systems	3	6	NA	0.1	$0.03	NA	2	37.70
Window film - commercial	3	372	NA	4.0	$1.45	NA	2	37.38
Industrial fan and blower systems	2	489	NA	5.2	$0.02	NA	1	36.29
Commercial lighting remodeling	3	324	NA	3.4	$0.04	NA	1	36.11
Improved HVAC cleanroom techniques	3	241	NA	2.6	$0.02	NA	1	36.01
Ground source heat pumps	2	60	NA	0.6	$0.09	NA	3	34.90
Gas booster heaters for commercial dishwashers	3	13.47	NA	0.1	$0.05	NA	2	34.87
Residential infiltration reduction - existing	2	106	2.9	4.0	$0.07	$0.62	2	34.48
Premium efficiency motors	3	123	NA	1.3	$0.01	NA	1	32.74
Wastewater facility energy efficiency optimization	3	110	NA	1.2	$0.03	NA	1	31.10
Dual source heat pumps	3	71	NA	0.8	$0.03	NA	1	29.15
Ceiling fans	2	2	NA	0.0	$0.06	NA	2	26.61
Pilotless gas instantaneous water heaters	2	NA	6.1	6.1	$0.42	NA	1	26.20
Residential infiltration reduction - new construction	2	31	0.8	1.2	$0.07	$0.65	2	25.55
New building commissioning	2	83	0.1	1.0	$0.01	$0.07	1	25.15
Commercial kitchen ventilation	2	80	NA	0.8	$0.03	NA	1	23.81
C/I power conversion equip (UPS)	2	8	NA	0.1	$0.00	NA	1	23.06
Night spray thermal storage	2	19	NA	0.2	$0.01	NA	1	21.99
Packaged gas cooling systems - commercial	2	104	(1.0)	0.1	$0.04	NA	1	18.43
Integrated gas-fired space/water heating systems	2	NA	1.8	1.8	NA	$0.46	1	18.30
Process gas refrigeration - industrial/agricultural	2	0	0.0	0.0	$0.05	NA	1	16.68
Modulating gas furnace	2	NA	1.2	1.2	NA	$0.61	1	13.32
Gas chillers (engine-driven) 150-300 tons - comm'l/ind'l	2	145	(1.8)	(0.2)	$0.09	NA	1	11.31
Gas chillers (engine-driven) 300 tons or more - comm'l/ind'l	2	145	(2.1)	(0.6)	$0.11	NA	1	8.53
Ozonated laundry	2	NA	0.1	0.1	NA	$0.69	1	8.27
Gas chillers (absorption) 150-300 tons - comm'l/ind'l	2	130	(2.6)	(1.2)	$0.16	NA	1	4.33
Gas chillers (absorption) 300 tons or more - comm'l/ind'l	2	128	(2.8)	(1.4)	$0.14	NA	1	3.78
Gas heat pumps - residential	1	181	(3.1)	(1.2)	$0.94	NA	1	0.00

Table 3. Measure Rankings without Other Factors

Measure	Likelihood of Success	Savings GWH	Savings TBTU	TOTAL TBTU	CSE $/kWh	CSE $/therm	W/O Other Factors
High-efficiency storage-type residential water heaters	5	NA	9.8	9.8	NA	$0.18	89.02
Low energy/water residential dishwashers	4	68	6.9	7.6	($0.02)	($0.46)	76.70
Coin-operated clothes washers	5	NA	0.9	0.9	NA	($0.18)	63.50
Commissioning existing comm'l buildings	3	967	1.4	11.6	$0.06	$0.98	61.79
LED traffic signals	5	128	NA	1.4	$0.02	NA	61.47
Occupancy sensors - commercial	3	599	NA	6.4	$0.02	NA	58.90
Residential duct sealing - existing	3	186	5.1	7.0	$0.03	$0.27	58.67
Fluorescent fixtures - residential	3	551	NA	5.9	$0.01	NA	58.45
Optimization of chiller and tower systems	3	507	NA	5.4	$0.01	NA	56.94
High-efficiency packaged commercial refrigeration equipment	3	457	NA	4.8	$0.01	NA	55.55
Efficient windows - commercial	3	399	1.3	5.6	$0.04	$0.37	51.35
Commercial package AC systems	4	229	NA	2.4	$0.05	NA	50.99
Evaporative pre-cooler for residential AC	3	408	NA	4.3	$0.04	NA	49.88
Wastewater heat recovery systems - residential	3	41	2.9	3.3	$0.01	$0.14	48.80
Dry-type distribution transformers	4	54	NA	0.6	$0.03	NA	47.73
Improved lighting design practices - commercial	3	337	NA	3.6	$0.03	NA	47.52
Light-colored roofs	3	190	NA	2.0	($0.01)	NA	47.49
Commercial packaged AC O&M	2	473	NA	5.0	$0.01	NA	46.88
Improved HVAC cleanroom techniques	3	241	NA	2.6	$0.02	NA	46.45
Commercial lighting remodeling	3	324	NA	3.4	$0.04	NA	46.08
Improved enforcement/education of Title 24 standards	3	124	0.7	2.0	$0.01	$0.43	45.41
Industrial fan and blower systems	2	489	NA	5.2	$0.02	NA	45.32
Industrial air compressors	3	191	NA	2.0	$0.02	NA	45.21
Indirect/direct evaporative cooling	2	399	NA	4.2	$0.01	NA	45.11
Residential package AC systems	4	244	NA	2.6	$0.10	NA	44.76
Integrated building design - commercial	3	202	NA	2.1	$0.03	NA	43.16
Agricultural irrigation pumps	3	239	NA	2.5	$0.04	NA	42.90
Premium efficiency motors	3	123	NA	1.3	$0.01	NA	42.81
Efficient windows - residential	3	78	2.7	3.5	$0.05	$0.45	42.47
CFL buydown - residential	3	102	NA	1.1	$0.02	NA	41.74
Laundry wastewater heat recovery - commercial	3	NA	0.3	0.3	NA	($1.43)	41.56
Wastewater facility energy efficiency optimization	3	110	NA	1.2	$0.03	NA	40.70
High quality motor repair practices	3	63	NA	0.7	$0.02	NA	40.17
Refrigeration integrated design - commercial	3	110	NA	1.2	$0.04	NA	38.75
AC installation/maintenance	3	154	NA	1.6	$0.05	NA	38.68
Dual source heat pumps	3	71	NA	0.8	$0.03	NA	38.34
Integrated space/water heating heat pump systems	3	6	NA	0.1	$0.03	NA	36.80
Commercial heat pump water heater	3	6	NA	0.1	$0.03	NA	36.46
Residential duct sealing - new construction	3	43	1.2	1.6	$0.05	$0.44	36.23
Heat pump water heaters - residential	3	21	NA	0.2	$0.04	NA	35.64
Furnace blowers - residential	3	130	NA	1.4	$0.07	NA	34.28
Window film - commercial	3	372	NA	4.0	$1.45	NA	34.14
Gas booster heaters for commercial dishwashers	3	13.47	NA	0.1	$0.05	NA	32.98
New building commissioning	2	83	0.1	1.0	$0.01	$0.07	32.86
Pilotless gas instantaneous water heaters	2	NA	6.1	6.1	$0.42	NA	31.37
Commercial kitchen ventilation	2	80	NA	0.8	$0.03	NA	31.17
C/I power conversion equip (UPS)	2	8	NA	0.1	$0.00	NA	30.60
Residential infiltration reduction - existing	2	106	2.9	4.0	$0.07	$0.62	30.27
A-line halogen IR lamps	2	29	NA	0.3	$0.01	NA	29.73
Night spray thermal storage	2	19	NA	0.2	$0.01	NA	29.11
Daylight dimming w/high-performance glazing - commercial	2	52	NA	0.6	$0.03	NA	28.18
Packaged gas cooling systems - commercial	2	104	(1.0)	0.1	$0.04	NA	24.41
Integrated gas-fired space/water heating systems	2	NA	1.8	1.8	NA	$0.46	23.30
Process gas refrigeration - industrial/agricultural	2	0	0.0	0.0	$0.05	NA	22.15
Ceiling fans	2	2	NA	0.0	$0.06	NA	22.04
Residential infiltration reduction - new construction	2	31	0.8	1.2	$0.07	$0.65	19.97
Ground source heat pumps	2	60	NA	0.6	$0.09	NA	19.41
Modulating gas furnace	2	NA	1.2	1.2	NA	$0.61	16.99
Gas chillers (engine-driven) 150-300 tons - comm'l/ind'l	2	145	(1.8)	(0.2)	$0.09	NA	15.12
Gas chillers (engine-driven) 300 tons or more - comm'l/ind'l	2	145	(2.1)	(0.6)	$0.11	NA	11.63
Ozonated laundry	2	NA	0.1	0.1	NA	$0.69	10.88
Gas chillers (absorption) 150-300 tons - comm'l/ind'l	2	130	(2.6)	(1.2)	$0.16	NA	6.37
Gas chillers (absorption) 300 tons or more - comm'l/ind'l	2	128	(2.8)	(1.4)	$0.14	NA	5.75
Gas heat pumps - residential	1	181	(3.1)	(1.2)	$0.94	NA	0.00

Measure Characterizations

The following pages present characterizations of the measures analyzed for this study. Each characterization contains a description of the measure (including cost and energy savings, market barriers, and strategies to address those barriers), as well as a data sheet that summarizes a "typical" application of the measure and provides the basis for the measure rankings. The 20 top-ranked measures are presented first. Relative to the remaining measures, the top-ranked measures include some additional technical and market detail, as well as more specific information on market transformation strategies for PG&E to consider. Among the market transformation approaches recommended for the top- ranked measures are the following:

- Offering Incentives or Financing. PG&E, in certain cases, should consider offering financial incentives (in the form of rebates or low-cost financing) to consumers, retailers, or manufacturers to help commercialize products or to raise awareness in the marketplace. However, the use of incentives has to be carefully considered, particularly as the industry restructures. Incentives can be useful in raising awareness about product efficiency and availability. They can also contribute to increasing the market share of higher efficiency products, and improving stocking practices. As a result of economies of scale and other factors, they may ultimately contribute to price reductions. However, to avoid a situation in which incentives are supporting high-efficiency purchases (such that when incentives disappear, purchases of high-efficiency equipment fall off), their use should be coupled with an exit strategy, to ensure a self-sustaining market in the absence of incentives. Many of the strategies below can contribute to an exit strategy combined with a gradual phaseout of incentives.

- Marketing and Providing Education: The foundation of the traditional approach to market diffusion is to promote products to consumers through advertising product displays, educational materials and other similar avenues. These efforts range from promotions of specific products to broad education efforts that span a wide range of products. Utilities can continue to play a critical role in transforming markets through marketing and consumer education. Virtually all of the top-ranked measures require some marketing or education component. In a number of cases, for example, we recommend that incentives be gradually phased out and consumer education efforts stepped up in order to ensure that a given measure achieves expected market penetration.

- Providing Training and Certification. In a restructured utility environment, the role of utilities as trusted third parties performing a public purpose function becomes increasingly important. As new market players offer to provide customers with total energy services, PG&E can serve a valuable function in helping to define "best practice" by providing training and certification, and in identifying "preferred" providers for consumers.

- Research and Development including Field Testing. Before a market can be transformed, a product must be developed and tested. Much R&D takes place within private industry but frequently other parties, such as government agencies, universities, state R&D centers, and utility-industry research institutions are involved. PG&E can play a central role in increasing market acceptance of a product by providing field test sites and documenting field performance. This activity can help accelerate the market introduction of energy efficiency technologies.

- Coordinating with Pre-Existing Programs/Initiatives: The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), as well as the Consortium for Energy Efficiency and regional market transformation groups have a number of voluntary initiatives to promote products at certain efficiency levels. Activities to support and bolster these programs are, in many cases, an appropriate approach for PG&E to take to help transform the markets. This is particularly true for measures that are national in scope (i.e., typically products or services that have similar market characteristics throughout the U.S. and are typically not climate dependent). There are numerous examples among the top-ranked measures of complementary national or regional activities to PG&E's efforts (e.g., CEE's Super-Efficient Home Appliances, dry-type distribution transformers, and commercial coin-operated clothes washers initiatives; EPA's ENERGY STAR® program for residential fixtures and its developmental work on vending machines, etc.).

- Bulk Purchases and Competitions. Another way that utilities can encourage the commercialization and early diffusion of a technology is to participate in, or facilitate bulk purchases and technology development competitions. Bulk purchases, for example, can help reduce the cost of efficiency measures by increasing the scale of production and reducing distribution and marketing costs. Recent successful examples of an organized purchase include CEE's Super-Efficient Apartment-Size Refrigerator program. Among the top-ranked measure that may be considered for a bulk purchase include green LED traffic signals and fluorescent fixtures.

- Supporting Building Codes and Standards. A viable exit strategy for many market transformation programs is often to incorporate a given practice or performance level into the residential or commercial building code or efficiency standards. California is unique in that it has its own building code and is not dependent on the often lengthy code development process typically of the ASHRAE commercial code and the ICC Model Energy Code processes. In a number of cases, PG&E can also encourage the California Energy Commission (CEC) to develop efficiency standards for products not covered by the Federal standards (e.g., on dry-type distribution transformers and ice makers) and encourage U.S. DOE to develop more aggressive efficiency standards for currently covered products (e.g., central air conditioners).

The top-ranked measures are presented in the order in which they appear in Table 2 (i.e., according to their score, from highest ranked to lowest). The remaining measures are generally organized according by residential vs. non-residential, and within each of these categories, according to end-use (e.g., water heating, lighting, etc.). There are a few exceptions to this rule, however. For a few measures and practices more than one data sheet was compiled to reflect critically different market segments. Examples of these include residential duct sealing and residential infiltration reduction. The market transformation potential of these measures was analyzed for both existing and new homes. Also, market transformation potential for light-colored roofs was analyzed for residential and commercial applications. In these cases, both data sheets accompany the measure description. For example, duct sealing in existing homes (but not in new construction) is a top-ranked measures; nonetheless, the new construction data accompanies the measure description. Other examples include residential dishwashers (electric and gas dishwashers are analyzed separately) and ground source and dual source heat pumps (which are characterized separately but, because of their similarities share one write-up).

Top-Ranked Measures

High-efficiency Gas Storage Water Heaters

Conventional gas storage water heaters have low steady state efficiencies (e.g., 75 or less percent) and large standby losses, due to the limited heat transfer area and open flue, resulting in energy factors (EFs) that are typically around 0.58 (DOE 1993). Minimum EFs required under NAECA vary with tank size from 0.56 for 30-gallon tanks to 0.51 for 60-gallon tanks.

The most efficient models currently available, however, have EFs that are considerably higher. In the 40-gallon range, a number of models are available with EFs greater than 0.70 and in the 50-gallon range, a number of manufacturers produce tanks with EFs greater than 0.80. These very high-efficiency, condensing water heaters, achieve high efficiencies by capturing heat from moisture in the flue gases. The flue gas condensate, however, can lead to corrosion. Water heaters with EFs of 0.61 to 0.64 offer significant energy savings without corroding the tank and pipes. Most major manufacturers produce atmospheric water heaters in this efficiency range with recovery efficiencies of 80 percent or less (higher recovery efficiencies may result in flue gas condensation under some circumstances). Non-condensing water heaters are also available in the 0.62 to 0.66 EF range with power venting or induced draft fans (GAMA 1997). These options use a fan to help draw air through the burner and up the flue, which improves efficiency and reduces the chances of flue gas condensation damage, but also increases cost.

This analysis considers replacing a standard 40-gallon tank with an EF of 0.55 with a more efficient water heater (i.e., EF of 0.62) The incremental installed cost for this measure is estimated to be between $65 and $100 based on experience in the Pacific Northwest and the future measure cost is estimated to be $44 according to DOE (1993). Utility financing and rebates can help to create demand for high-efficiency products that should lead to increased price competition and a reduction in the first cost differential, particularly in areas with current costs at the high end of this range. In areas where utilities heavily promote high-efficiency gas water heaters, market share for these models is 40 percent or more (Stephens 1997). In the longer run, PG&E should focus on reducing first cost purchasing behavior through consumer education, communicating to consumers how much they currently pay for water heating, and potential reductions achievable through the use of more efficient alternatives.

The primary focus of a market transformation initiative should be in helping to lay the groundwork for more aggressive standards for gas storage water heaters. DOE is scheduled to issue new standards in late-1999, with the standard taking effect three years later. Decisions will be made about the level several years down the road. Between now and then, PG&E's activities can impact that level, by identifying an efficiency level to promote and encouraging local entities to provide finance or incentivize more efficient water heaters, and by promoting better stocking practices and more reasonable pricing among local distributors. A number of Oregon gas utilities have gas water heater incentive programs, from which PG&E can draw. Additionally, PG&E can promote better stocking practices and more reasonable pricing among local distributors. Once a new Federal efficiency standard is adopted, most likely at modest levels (e.g., EF in the 0.60 to 0.63 range), PG&E can promote more advanced water heaters, such as those with induced draft fans.

High Efficiency Gas Storage Water Heaters

Measure Description: Promote moderately efficient gas water heaters

Market Information:		
Market sector:	RES	
End uses:	DHW	
Energy types:	GAS	
Market segment:	NEW, REP	
Base Case Information:		
Base case description:	Standard 40-gallon gas water heater	
Base case efficiency:	0.55	EF
Base case annual energy use:	246	therms
New Measure Information:		
New measured description:	High-efficiency standard 40-gallon gas water heater	
New measure efficiency:	0.62	EF
New measure annual energy use:	218	therms
Measure life:	13	years
Savings Information:		
Electric savings/year:	NA	
Gas savings/year:	28	therms
Percent savings:	11%	
Feasible applications:	100%	
Savings potential in 2010:	10	TBTUs
Cost Information:		
Current measure cost:	$65-100	incremental, installed cost
Future measure cost (in mass use):	$44	
Other direct costs/savings:	$0	
Cost of saved energy:	$0.18	per therm
Data Quality Assessment	A	
Likelihood of Success:		
Major market barriers:	Costs, stocking, condensation concerns	
Effect on customer utility:	None	
Current activity @ PG&E:	None	
Current activity elsewhere:	Many utilities promote high-efficiency gas water heaters	
Likelihood of success rating (1-5):	5	
Relationship to PG&E business plan (1-3):	1	
Souces:		
Savings estimates:	ACEEE estimate based on EFs; GAMA (1997)	
Cost estimates:	DOE (1993); Stephens (1997)	
Measure life estimates:	DOE (1993)	
Other key sources:		
Principal contact(s):	Charlie Stephens, ODOE, 503-378-4298	

Notes: Baseline energy use from DOE/EIA (1995). Minimum standard for a 40-gallon water heater is 0.54; this has been adjusted upwards slightly to account for higher EFs of existing water heaters.

Low Energy Use Dishwashers

DOE requires dishwasher manufacturers to meet a minimum energy efficiency standard of 2.17 kWh per cycle, equivalent to an energy factor (EF) of 0.46, for residential standard-capacity dishwashers. However, Frigidaire produces a line of standard-sized (22 to 24-inches in width) low water use dishwashers, that use much less energy than their counterparts. These dishwashers have an EF of approximately 0.62, consuming 1.61 kWh per cycle — 26 percent less energy than a dishwasher that just meets the standard.

These dishwashers take advantage of European technology, using a spray system that activates the upper and lower spray arms alternately instead of simultaneously, and thereby reduces water use. A "normal" load for this line requires 6 gallons of water, instead of 8 to 10 gallons used in competitive models. In-house consumer acceptance testing performed by Frigidaire indicates that the model has excellent cleaning performance, is quiet, and otherwise meets consumer requirements. While similar European models are available on the U.S. market, the Frigidaire model and its other brands (Gibson, Kelvinator, etc) are priced very competitively vis a vis other U.S. manufacturers' models. Depending on its features, this model ranges in retail price from $279 to $419, similar to existing low- to mid-range products. Thus, for the purpose of this analysis, we have assumed $0 incremental cost.

In addition, Bosch also produces a line of dishwashers with EFs ranging from 0.58 to 0.6, and some higher efficiency imported products from Asko and Miele are available. A number of newer products feature fuzzy logic to sense water turbidity to deliver optimal washing conditions (i.e., water volume, temperature, etc.). Cleaner loads require less water and energy, while dirtier loads require more. These products, such as Maytag's Intellisense and General Electric's CleanSensor, offer the potential for lower water and energy use. However, it is difficult to measure their energy performance under the current test procedure which requires testing on clean loads only (Biermayer 1996). Under these conditions, "smart" products are their most energy efficient. But, according to tests by Consumer Reports (Consumer's Union 1997), it appears that on dirty loads, these dishwashers tend to consume either the same amount or more energy and water than less sophisticated models. Adequate measurement and comparison of the energy performance of fuzzy-logic-based dishwashers to other models will require revisions to the DOE test procedure.

To enable consumers to identify more efficient dishwashers, DOE has established voluntary energy efficiency targets for dishwashers (as well as other products) under its ENERGY STAR® program. The program promotes the purchase of highly efficient appliances through product labeling, advertising, sales staff training, and promotional activities. Utilities participating in the program share the costs of promoting ENERGY STAR® products in their service territories. Under the ENERGY STAR® program, however, the efficiency targets for dishwashers have been set at an EF of 0.52. Products that meet the ENERGY STAR® criteria, thus consume approximately 12 percent less energy than one that just meets the standard, not the 26 percent achievable by the Frigidaire products.

To drive the market toward higher-efficiency targets, the Consortium for Energy Efficiency (CEE) has recently developed a new program, the Super Efficient Home Appliance (SEHA) Initiative, that will add on to the DOE ENERGY STAR® program. Through this initiative, CEE encourages its members to support both the ENERGY STAR® appliance levels as well as higher efficiency tiers established by CEE. Participants in the initiative will work with retailers, providing information, tools, and incentives to increase the sales of products that qualify for CEE's more aggressive tiers. To avoid sending mixed messages to consumers, the distinction between ENERGY STAR® product levels and CEE levels will be transparent to the consumer. Participation in the CEE SEHA Initiative may be a very good vehicle for PG&E to support market transformation for high-efficiency dishwashers, depending in part on how the SEHA Initiative evolves. PG&E can also help to influence that course.

In the interim, PG&E could also consider working with water utilities — an alliance that has proven successful with clothes washers — to package promotions and/or incentives. High-efficiency dishwashers could even be considered as an add-on to the current clothes washer program. Note that consumer rebates are not likely to be necessary for dishwashers, given that the Frigidaire products are competitively priced. Nonetheless, PG&E should investigate the benefits of both rebates and low-cost financing for high-efficiency dishwashers offered directly to the consumer or packaged through the retailer.

Ultimately, however, customer demand for high-efficiency products and their ancillary benefits (e.g., low noise, etc.) will drive the market. PG&E can play a significant role in spurring consumer demand by promoting consumer awareness of efficient dishwashers and their benefits. This educational effort could be incorporated into current residential energy education efforts, both broad advertising and targeted customer-specific mail audits. These educational efforts could be incorporated into current residential energy education efforts.

A rulemaking for new Federal standards for dishwashers is scheduled for the future, but will probably not begin until 2000 after the clothes washer rule is finalized. Assuming the new standard takes three years to complete, and becomes effective three years later, a new dishwasher standard will be in force until 2006. This standard may be a logical exit point for market transformation activities. Until then, educating consumers about the availability of high efficiency dishwashers, and working with retailers to ensure that they are adequately prepared to market high efficiency dishwashers will be key to a successful market transformation effort. Furthermore, actions to increase the availability and market share of high efficiency dishwashers can influence the new standard.

Low Energy/Water Use Dishwasher - Electric

Measure Description: Encourage installation of dishwashers that use less energy and water than current models

Market Information:	
Market sector:	RES
End uses:	DISH
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Standard dishwasher >= 24-inch; NAECA compliant
Base case efficiency:	2.17 kWh/cycle
Base case annual energy use:	543 kWh
New Measure Information:	
New measure description:	Low energy/water use dishwasher
New measure efficiency:	1.61 kWh/cycle
New measure annual energy use:	403 kWh
Measure life:	10 years
Savings Information:	
Electric savings/year:	140 kWh, water heating only
Gas savings/year:	NA therms
Percent savings:	26% kWh
Feasible applications:	100%
Savings potential in 2010::	68 GWH
Cost Information:	
Current measure cost:	$0 incremental, based on $279-$419 actual
Future measure cost (in mass use):	NA
Other direct costs/savings:	$3 annual water savings
Cost of saved energy:	($0.02) per kWh
Data Quality Assessment	A
Likelihood of Success	
Major market barriers:	None
Effect on customer utility:	Reduced noise level
Current activity @ PG&E:	ACT2 field studies of low energy dishwashers
Current activity elsewhere:	Energy Star level (lower than that modeled here)
Likelihood of success rating (1-5):	4
Relationship to PG&E business plan (1-3):	2
Souces:	
Savings estimates:	Manufacturer sources
Cost estimates:	Manufacturer sources
Measure life estimates:	Biermayer (1996)
Other key sources:	Eckman (1997)
Principal contact(s):	Peter Biermayer, LBNL, 510-486-5983

Notes: Dishwasher motor savings not accounted for. Two hundred and fifty (250) cycles per year used in calculating energy consumption, based on Biermayer (1996). Assumes water savings of 3 gallons per cycle and avoided water and sewer costs of $4.11 per 1000 gallons per Eckman (1997).

Low Energy/Water Use Dishwasher - Gas

Measure Description: Encourage installation of dishwashers that use less energy and water than current models

Market Information:		
Market sector:	RES	
End uses:	DISH/HW	
Energy types:	GAS	
Market segment:	NEW, REP	
Base Case Information:		
Base case description:	Standard dishwasher >= 24-inch; NAECA compliant	
Base case efficiency:	0.09	therms/cycle
Base case annual energy use:	22	therms
New Measure Information:		
New measure description:	Frigidaire low energy/water use dishwasher	
New measure efficiency:	0.06	therms/cycle
New measure annual energy use:	15	therms
Measure life:	10	years
Savings Information:		
Electric savings/year:	NA	
Gas savings/year:	7	therms, water heating only
Percent savings:	31%	
Feasible applications:	100%	
Savings potential in 2010:	7	TBTU
Cost Information:		
Current measure cost:	$0	incremental, based on $279-$419 full cost
Future measure cost (in mass use):	NA	
Other direct costs/savings:	$3	annual water savings
Cost of saved energy:	($0.46)	per therm
Data Quality Assessment	A	
Likelihood of Success		
Major market barriers:	None	
Effect on customer utility:	Reduced noise level and operating cost	
Current activity @ PG&E:	ACT2 field studies of low energy dishwashers	
Current activity elsewhere:	None - potential for volume purchases	
Likelihood of success rating (1-5):	4	
Relationship to PG&E business plan (1-3):	2	
Souces:		
Savings estimates:	Manufacturer sources	
Cost estimates:	Manufacturer sources	
Measure life estimates:	Biermayer (1996)	
Other key sources:	Biermayer (1996); Consumer's Union (1997); Nadel et al. (1993	
Principal contact(s):	Peter Biermayer, LBNL, 510-486-5983	

Notes: Two hundred and fifty (250) cycles per year used in calculating energy consumption based on Biermayer (1996). Assumes water savings of 3 gallons per cycle and avoided water and sewer costs of $4.11 per 1000 gallons per Eckman (1997).

Coin-Op Clothes Washers

Residential-equivalent, coin-operated, commercial washers — basically residential machines with a coin box, shorter cycles, and in some cases, heavier bearings — present a significant opportunity for saving both energy and water in commercial laundromats, multi-family common laundry rooms, and institutions. Relative to conventional vertical-axis washer technology, horizontal-axis (H-axis) clothes washers offer substantial water and water heating energy savings. Results of a demonstration conducted by ORNL in Tampa, Florida indicate water savings of approximately 39 percent, and the Consortium for Energy Efficiency (CEE) estimates annual energy savings per machine of between 63 and 168 therms for gas water heating and drying and 1,500 and 4,000 kWh for electric water heating and drying (CEE 1997a). Because gas clothes washers are much more prevalent than electric water heating models in laundromats, and multi-family laundry facilities, this measure, in general, saves gas.

Laundromats are estimated to comprise only 15 percent of annual production volume, with multi-family buildings and institutions making up the remainder. The multi-family common area laundry market in California is currently estimated at about 200,000 washers serving approximately two million apartments (Bloomfield 1996). Of these washers, 50 to 90 percent of machines are operated by contracting companies or "route operators" who lease machines to building owners, perform installation and service, and receive a share of the coin receipts (CEE 1997a). In most cases, building owners/managers are responsible for gas, water and electricity costs in most cases. Thus, the main incentive for building owners to specify more efficient clothes washers is to reduce utility bills.

Until recently, there has been limited availability of H-axis coin-operated machines in the U.S. A Seattle-based company distributes one foreign-made model (IPSO), primarily in the Pacific Northwest. Annual production for U.S. sales is estimated in the low thousands and the incremental cost of this machine, relative to a standard-efficiency machine, is high (approximately $1,000). However, major American appliance manufacturers are beginning to enter the market, including Maytag and Wascommat (an affiliate of Frigidaire), both of which introduced new machines in early 1997. These machines are currently about $550 more expensive than standard efficiency machines, although the incremental cost to volume purchasers, such as route operators, can vary substantially (from $275 to $475) based on the volume they purchase as well as other factors (Egan 1997).

The primary markets for coin-operated clothes washers (i.e., laundromats, and multi-family buildings, and institutions) suggest the need for at least two general approaches to transforming the market. Limited effort is likely to be required for laundromats. Laundromats realize tremendous energy and water savings, so education, endorsements, and publicizing case studies are likely to be the most effective tool for transforming this market and financial incentives are probably not necessary. Maytag is already experiencing significant sales in this market.

The multi-family housing and institutional markets are a bit more complex, since the route operator pays up front cost for the washer, but the building/complex owner/manager realizes the utility savings. To compensate the route operator, contract terms may need to be adjusted, by decreasing and/or eliminating the "up-front" signing bonus typically offered in the contract to the multi-family building owner, and giving route operators a larger share of coin receipts.

One intervention that PG&E should consider is to develop and endorse a standard deal that is fair to all parties. PG&E and other independent parties can also assist in educating multi-family building owners and route operators. The route operator business is very competitive. Once provided with information on high-efficiency technology and its accompanying benefits, route operators may view choosing H-axis washers as a means to distinguish themselves in the market place. Multi-family building owner education is also important so that they are more receptive when route operators offer high-efficiency machines. High-efficiency washers should be touted for their multiple benefits in PG&E's education campaign, including better performance and gentler washing. These attributes can be leveraged by building owners to help maintain rentors (Egan 1997).

The Consortium for Energy Efficiency (CEE) Board, in December 1997, approved an initiative to expand its washer-related activities to address barriers to market acceptance of residential-equivalent commercial clothes washers. Through this initiative, CEE aims to increase route operator distributor awareness by promoting high-efficiency models and increasing building and laundromat owner/manager awareness and acceptance of high-efficiency models. CEE is still in the process of determining the best strategy to market this initiative. PG&E should consider working with CEE to promote this initiative.

Coin-Op Clothes Washers

Measure Description: Replace standard coin-op clothes washers with efficient machines

Market information	
Market sector:	COM
End uses:	WATER HTG
Energy types:	GAS
Market segment:	NEW, REP
Base case information	
Base case description:	Standard vertical axis 2.4 gal machine
Base case efficiency:	NA therms/cycle
Base case annual energy use:	NA therms
New measure information	
New measure description	H-axis 2.4 gal machine
New measure efficiency:	NA therms/cycle
New measure annual energy use:	NA therms
New measure life:	8.5 years
Savings information	
Electric savings/year:	NA
Gas savings/year:	72 therms
Percent savings:	39%
Feasible applications:	85%
Savings potential in 2010:	0.86 TBTU
Cost information	
Current measure cost:	$550 incremental
Future measure cost (in mass use):	$450
Other direct costs/savings:	$82 in water savings
Cost of saved energy:	($0.18) per therm
Data quality assessment	B
Liklihood of Success	
Major market barriers:	Few, laundry industry very supportive .
Effect on customer utility:	Cleaner clothes, less wear from washing
Current activity @ PG&E:	Investigating
Current activity elsewhere:	Seattle Water
Likelihood of success rating (1-5):	5
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	CEE (1997)
Cost estimates:	Bloomfield (1996); Egan (1997)
Measure life:	CEE (1997)
Other key sources:	Linnell (1992); Eckman (1997)
Principal contact(s)	Ted Pope, PG&E, 415-973-4856

Notes: Percent savings of 39% is based on an ORNL demonstration in Tampa, FL (per CEE 1997). Percent feasible assumes roughly 15% likely to switch without intervention. Assumes 7.6% of comm'l hot water use is for laundry in cleaning establishments per ADL (1995); laundry in in multifamily buildings and institutions makes up an additional 25% based on 15%:85% split in end-use sales per CEE (1997) and higher overall usage in comm'l claning establishments.

LED Traffic Signals

Using light-emitting diode technology to replace incandescent lamps in traffic signals promises energy savings of 60 percent or more for each of the estimated quarter of a million controlled intersections in the United States. LED units use only 9 to 25 watts instead of the 67 to 150 watts used by each incandescent lamp. Though their first cost is relatively high, energy savings result in paybacks of 1 to 5 years. LED retrofit kits are available for red signal disks and arrows, and installations in several states have proven successful, although minor improvements are addressing concerns about varying light output and controller circuitry.

Green LEDs suitable for retrofitting traffic lamps are available from a few manufacturers, but green balls and arrows cost two to four times as much as their red counterparts. As such, they have not proven cost-effective in most of the applications for which they have been considered. If prices come down, however, they could be cost-effective, particularly if maintenance savings are considered. Yellow lamps have such low duty factors (they're on only 3 percent of the time) that retrofitting with LED signals is not cost-effective at current prices.

Currently traffic lamps are routinely replaced every 10 to 12 months (or twice that if the base case lamp is an extended-life incandescent). LEDs last much longer than incandescents and thus have the potential to drastically cut maintenance costs. Retrofitting only the red signals in a traffic light can cut required maintenance schedule in half as a result of the lower duty cycle of green and yellow lamps. And if all lamps on a traffic signal (i.e., red, green, and yellow) are retrofitted with LEDs, maintenance cost savings would be even more dramatic as the system would require relamping only every 5 to 7 years. Retrofitting red and green lights with LEDs, and installing long-life incandescent lamps for the yellow signal, will also provide considerable maintenance cost savings.

Several pilot projects have been completed in California and Caltrans is planning a major purchase of red LED traffic signals for the signals for which it is responsible (e.g., approximately 75,000 units). As a result of successful pilots, many California communities are now pursuing large-scale retrofits or complete changeovers to red LED signals, including Fresno, San Diego, Hanford, Fontana, Palmdale, Davis, Sacramento, and Santa Barbara. A rebate offered through November 1997, under PG&E's Retrofit Express has been instrumental in spurring large scale retrofits in some communities.

Adopters in other states include the Oregon, New York, Minnesota, and New Hampshire Departments of Transportation, the cities of Philadelphia, Denver, West Palm Beach, St. Paul, New York City, and others. New Hampshire is retrofitting many of its traffic signals with both red and green (and in some cases yellow) LEDs; New York City is considering the feasibility of retrofitting Staten Island traffic signals with both red and green LEDs; and Philadelphia is working with several manufacturers on prototype all-LED traffic signals.

One barrier to adoption of LEDs in some localities has been the absence of standards from the Institute of Transportation Engineers (ITE). While color and luminance standards for incandescent traffic signals have been available since the 1930s, there is no standard for LED traffic signals, although there have been several attempts to develop such a standard. A draft interim specification for red, green, and yellow LED traffic signals, was voted on and approved by ITE members in May 1998. However, the intensity levels are based largely on the ITE specification for incandescent lamps. These levels are more stringent for green and yellow LEDs than for reds. The National Cooperative Highway Research Program (NCHRP) is currently conducting research on human visual requirements for traffic signals that is anticipated to result in lower intensity requirements for green and yellow LEDs and ultimately reduce their production. The results of their research, anticipated in the fall of 1999, is likely to be incorporated into the final ITE specification. In the meantime, Philadelphia, Oregon, Caltrans, and perhaps others have all developed LED specifications in advance of the ITE standard.

In addition, high first costs combined with local and state government capital constraints hinder faster adoption of LED traffic signals. LED traffic assemblies are produced in North America by several companies including Econolite, Electro-Tech, LedTronics, Relume, and Ecolux (Quebec, Canada). These companies purchase the LEDs from manufacturers in Japan and Germany and assemble them into balls and arrows for the U.S. market. Red LED prices have fallen substantially in the past several years. The current price for a 12-inch red ball is on the order of $150. Green and yellow LED prices remain quite high, with 12-inch green balls priced from $300 to $500. A number of factors are likely to drive the price of (particularly green) LED signals down. First, the NCHRP study, as mentioned above is expected to reduce intensity thresholds and thus the amount of source material required. PG&E is also funding a complementary study by the Lighting Research Center. Additionally, increased competition among producers of green LEDs will help reduce the price as has been evidenced in the market for red LEDs in the past.

To address the cost issue many utilities interested in promoting LED traffic lights initially used rebates to spur the market; now, low-cost financing is an increasingly common utility strategy. For example, Northern States Power offers financing to the City of St. Paul. The financing was originally intended to cover municipal building retrofits, but has been expanded to include material costs for retrofitting the City's red traffic signals with LEDs. The New York Power Authority (NYPA) offers low-cost financing to the New York City Department of Transportation for switching from standard incandescent traffic lamps to red LEDs and extended-life incandescent green and yellow indicators in the Borough of Queens. The City estimates that for the Borough of Queens, where a total of 18,000 lamps of each color will be replaced, it will save $200,000 in reduced maintenance per year, in addition to garnering huge energy savings. Northeast Utilities (NU) is taking advantage of state funds available through the state Distressed Cities program to cover the costs of retrofitting approximately 50 percent of the red and green traffic lamps in four Connecticut cities. The estimated payback is 5 to 6 years in energy savings alone. If maintenance savings and avoided lamp replacement costs are included in the calculation, the payback for the project is estimated to be less than 2 years.

LED traffic signals are a good candidate for what could be a relatively easy market transformation effort. And in fact, a transformation to signals appears to be occurring in the absence of significant intervention. For red and green signals to be more attractive to jurisdictions, the cost of green LEDs will have to come down and/or the additional maintenance benefits from two-color changeouts highlighted. Movement to fully-integrated three-color LED signals is proceeding more slowly.

Key opportunities to accelerate the transformation for red, green, and yellow LED traffic signals include: (1) developing and disseminating case studies, particularly where maintenance savings can be documented; (2) supporting targeted demonstrations to educate traffic engineers, where they are unaware, as well as local officials about benefits; (3) improving access to and availability of financing; (4) influencing and speeding the development of a national specification, by working with ITE or supporting outside research to supplement that being conducted currently by the NCHRP; and (5) supporting development and broader demonstration of three-color LED traffic signals (Suozzo 1998).

Possible forums for providing education on the performance and energy savings of LED traffic signals include meetings of the California Traffic Control Device Committee, American Society of Civil Engineers (ASCE) events or other conferences or local chapter meetings of traffic engineers. A direct mailing of a report or video on LED performance targeting California traffic engineers would help to initiate projects among cities that have not yet committed to the technology. A web site with detailed information on manufacturers and products, status of retrofits, and updates on the ITE specification process could support such an outreach effort. To this end, coordination with CalTrans would be beneficial.

A survey or focus group to identify traffic engineers' key questions and concerns of traffic engineers and local government decision makers could be used to target information to this audience. Literature and discussions could focus on improvements incorporated into the latest generation of LEDs that address degradation of intensity with time and temperature and other issues, as well as how well-written purchase specifications can avoid problems. The need for financing or other means of support that PG&E could provide for the purchase and installation of LEDs should also be explored in these focus groups.

Jurisdictions in PG&E's service territory could also be encouraged to initiate at least one LED signal installation, preferably in a high-visibility location. For maximum leverage, these efforts should focus on the largest cities and counties that have not yet demonstrated LED traffic signals. Because of the positive economics and additional benefits of LED traffic signals, once initial fears and concerns have been addressed, large-scale retrofits will likely follow.

Further, PG&E could determine if more work is required in researching and developing a new three-color all LED signal. Philadelphia, with funding from Public Technology Incorporated, is working with manufacturers to develop prototype three-color signals. PG&E may want to engage in discussions with Philadelphia about complementary research or demonstration for these signals. In the interim, given the current high cost of green LEDs, PG&E could offer low-cost financing for green LED retrofits.

LED Traffic Signals

Measure Description: Retrofit red traffic signal lamps by installing LED retrofit kits

Market Information:	
Market sector:	COM
End uses:	LIGHTING
Energy types:	ELEC
Market segment:	NEW, RET, OEM
Base Case Information	
Base case description:	One intersection w/ 20 red signal faces: 8 lights, 4 arrows, and 8 peds (red only)
Base case efficiency:	150W bulbs for lights and arrows and 67W bulbs for ped signals
Base case annual energy use:	14,559 kWh
New Measure Information:	
New measure description:	Red lights and signals replaced with LEDs
New measure efficiency:	20W bulbs for lights and ped signals and 9W bulbs for arrows
New measure annual energy use:	1,756 kWh
Measure life:	10 years
Savings Information:	
Electric savings/year:	12,804 kWh
Gas savings/year:	NA
Percent savings:	71%
Feasible applications:	100%
Savings potential in 2010:	128 GWH
Cost Information:	
Current measure cost:	$2,880 incremental
Future measure cost (in mass use):	$2,304
Other direct costs/savings:	$0 limited maintenance and lamp replacement benefits
Cost of energy saved:	$0.02 kWh
Data Quality Assessment:	A
Likelihood of Success:	
Major market barriers:	Locality reliance on nat'l specs; no approved ITE spec
Effect on customer utility:	some reduced maintenance, increased reliability
Current activity @ PG&E:	Rebate on LED traffic signals - no longer available
Current activity elsewhere:	Utility rebates, municipality efforts, Caltrans procurement
Likelihood of success rating (1-5):	5
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	E Source (1994); ACEEE estimate
Cost estimates:	Manufacturer data
Measure life estimates:	E Source (1997)
Other key sources	
Principal contact(s)	David Houghton, E Source, 303-440-8500 Margaret Suozzo, ACEEE, 512-443-1528

Notes: Measure savings based on retrofitting red ball signals, red arrow signals, and red ped signals (no green or amber retrofits). Future measure cost based on 20% reduction in present measure cost. Assumed California signalized intersection population: (10 million residents) * (1 intersection/1000 people) = 10,000 intersections.

Fluorescent Fixtures

Residential fluorescent fixtures present a significant opportunity for energy and maintenance savings. On a per lamp basis, compact fluorescent lamps are generally 70 percent more efficient than incandescent lamps and last 10 times longer.

Poor quality, selection, appearance and reliability of residential fluorescent fixtures have contributed to consumer aversion to fluorescent lighting. Additionally, the lack of brand loyalty among consumers coupled with the large number of manufacturers (500 including foreign companies) has led to a proliferation of inferior fluorescent fixtures. According to Calwell et al. (1996), 23 percent of new fixture sales are fluorescent while 76 percent are incandescent. The existing stock of residential fixtures is approximately 15 percent fluorescent and 85 incandescent, suggesting that fluorescent share is increasing.

In considering possible market transformation initiatives, the fixture market can and should be separated into two end-use categories: hard-wired and portable units, which differ in both the supply chain and in consumer purchasing patterns. Hard-wired fixtures are most frequently purchased for new construction and major renovations, whereas portable fixtures are most often a retrofit, replacement or remodeling purchase.

Installing hard-wired fluorescent fixtures, reduces the likelihood of reversion to incandescent lamps. Consequently, hard-wired fixtures (indoor and outdoor) that are characterized by energy efficiency, quality and safety present a significant opportunity to reduce energy consumption. Since the point-of-sale for hard-wired fixtures is relatively concentrated (and generally limited to showrooms, contractors and distributors), a fixture initiative can target these markets more effectively than lamp suppliers, for whom sales locations are more diffuse.

In contrast, portable fixtures represent less of an opportunity for market transformation because the target market is diffuse, and influencing purchasing decisions may take considerably more resources. However, new developments in torchiere lamps provides a unique market transformation opportunity. The 40 million halogen torchieres in American homes, dormitories and offices consume up to 600 watts of power and often account for 30 to 50 percent of lighting retailers' sales (Calwell et al. 1996). Whereas, the typical compact fluorescent alternative to halogen torchieres consumes 55 to 100 watts of power, representing an efficiency improvement of at least 6 times the halogen at full light output. In addition, some non-torchiere portable fixtures that use only compact fluorescent lamps are now available.

Costs of residential fluorescent fixtures vary widely, generally ranging from $20 to $100 (in 1993 dollars), although some showroom fixtures are priced in the thousands of dollars. A study by Lawrence Berkeley National Laboratory contains the following ranges for recessed fixtures (Vorsatz et al. 1997):

Recessed with incandescent lamp	$20 - $75
Recessed with CFL	$45 - $100

The primary market barriers to the penetration of fluorescent fixtures are product availability, quality of residential grade fixtures, consumer aversion to fluorescent lighting, and first cost for high quality fixtures. For hard-wired fixtures, specifier and commercial grade units are of better quality than residential fixtures. Consequently, making these fixture grades available to homeowners at reasonable cost is an important market transformation strategy. Likewise for portable fixtures, bringing to market a reasonably priced compact fluorescent torchiere is a required first step in addressing the efficiency setback caused by halogen torchieres.

Market transformation programs for lighting fixtures exist nationally and regionally. Launched in March of 1997, the ENERGY STAR® Fixture program promotes the adoption of high quality, efficient fixtures through its labeling program. Two regional fixture initiatives sponsored by NEEP and the NW Alliance have now been adopted. Both initiatives coordinate with the ENERGY STAR® program, targeting both hard-wired and portable fixtures, and encourage active retail promotions and consumer education. NEEA is offering performance awards to manufacturers and/or wholesale distributors of fixtures as a means to address limited product availability and awareness, as well as high retail costs. Similarly, a coalition of California utilities, coordinating with the Northwest, selected the ENERGY STAR® Fixtures specification as the basis of a regional lighting fixture program and plans to offer performance-based incentives to fixture manufacturers, wholesalers, and large and small retailers.

PG&E is a part of the California coalition developing a residential fixture program based on the ENERGY STAR® program specification. To complement the coalition's activities, PG&E could address lack of information and misperceptions about residential fluorescent fixtures among homeowners and builders and could encourage retailers to stock current products by offering to develop joint advertisements and promotional materials. PG&E could help to facilitate a regional bulk purchase of efficient torchieres, working with universities as a potential anchor buyer. At least two universities, Stanford, Rice, and Brown, are working to convert halogen torchieres in dormitories to more efficient portable CFL torchieres. In the long run, PG&E should work with the California Energy Commission (CEC) on amendments to Title 24 to require efficient fluorescent fixtures in new homes.

Fluorescent Fixtures - Residential

Measure Description: Install compact fluorescent fixtures in place of incandescent fixtures

Market Information:		
Market sector:	RES	
End uses:	LTG	
Energy types:	ELEC	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	Standard Edison incandescent 'A' lamp fixture	
Base case efficiency:	120	Watts (2-60 Watt lamps)
Base case annual energy use:	228	kWh
New Measure Information		
New measure description:	High quality compact fluorescent luminaire with 2-15 Watt CFL	
New measure efficiency:	30	Watts (includes ballast)
New measure annual energy use:	57	kWh
Measure life:	16	years
Savings Information		
Electric savings/year:	171	kWh per lamp
Gas savings/year:	NA	therms
Percent savings:	75%	
Feasible applications:	28%	33% of residential fixtures; 85% feasible
Savings potential in 2010:	551	GWh
Cost Information		
Current measure cost:	$35	($25 incremental fixture cost + two $5 CFLs)
Future measure cost (in mass use):	$30	($20 incremental fixture cost + two $5 CFLs)
Other direct costs/savings:	$0.50	annual lamp purchase savings
Cost of saved energy:	$0.01	kWh
Data Quality Assessment	A	
Likelihood of Success		
Major market barriers:	First cost, perceived light quality, availability of high quality fixtures	
Effect on customer utility:	HVAC impacts, less time changing lamps	
Current activity @ PG&E:	Rebates of $15 per fixture (PG&E website)	
Current activity elsewhere:	CEE, EPA, NW, NE, SMUD, SCE, many other utilities	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	3	
Sources:		
Savings estimates:	FLEX (1996)	
Cost estimates:	FLEX (1996), Vorsatz et al. (1997)	
Measure life estimates:	PG&E (1997)	
Other key sources:	EPA (1995b), CEC (1997)	
Principal contact(s):	Kate Conway, Lighting Research Center, 518-276-6872 Howard Gerber, XENERGY, 617-273-5700	

Notes: Savings from this measure overlap with CFL lamps. Characterization assumes lamp usage of 5 hrs per day. Percent feasible based on 33% of residential lighting energy use from recessed fixtures and floor and table lamps (CEC 1997), with 64% of energy from sockets with >3 hrs per day use (Vorsatz et al. 1997).

Optimization of Chiller and Tower Systems

Chilled water systems account for a significant percentage of total commercial building cooling capacity. Typical air-cooled chilled water systems contain air-handling units with chilled water coils, a chilled water loop (or loops), chilled water pump(s), and an air-cooled chiller. Water-cooled chilled water systems contain the same components as an air-cooled system plus a condenser water loop, condenser water pumps, and a cooling tower. The chiller is at the core of the system and typically is the single largest energy user; but simply selecting a high-efficiency chiller will not guarantee high performance. The supply air fan is typically the second most significant energy user; and the cooling tower, third. And the way in which these different components work together has a major impact on energy use.

Reducing energy used for cooling commercial buildings begins with managing the internal load. Tightening the building's shell and reducing the internal load can reduce the required capacity and size of the HVAC system, and in turn reduce the costs of installing and operating the system. The building developer and mechanical contractor determine overall chiller system design and must then select or specify the appropriate equipment, including coils, pumps, and towers, and equipment controls. Finally, the building owner must help to shape an installation and maintenance protocol that will ensure optimal performance of the HVAC system.

Often for equipment selection, the most cost-effective energy savings come from water cooling coils, which affect both chiller and fan energy consumption, or from the cooling tower, rather than from the chiller itself. Payback for high-efficiency chillers, close-approach water cooling coils, and close-approach cooling towers or evaporative condensers is typically less than two years (Nugent 1993). A key element of many of these strategies is that they need to be customized to a given building's load profile.

In one chiller retrofit, the owner of a 15-year old, 100,000 square foot building undertook a comprehensive strategy to reduce HVAC energy consumption. The original chiller, a 250 ton, 0.85 kW/ton chiller was replaced with a more efficient driveline and downsized to a 160 ton, 0.69 kW/ton chiller, after measures were taken to reduce the lighting load, reduce fan energy consumption, and install a water-side economizer (to turn the chiller off during cool weather). The result was 44 percent energy (1.4 million kWh) and demand savings and nearly $97,000 reduction in annual electricity costs (Robertson et al. 1994).

The barriers to more efficient chiller system upgrades are significant, but thought to be surmountable. For example, the market is dominated by concerns about keeping first costs low. Commercial building managers typically require paybacks of 2 years of less on their investments. Further, potential energy savings from system optimization are not well understood by affected parties. As such, they may be resistant to spending money on design work or on having significant engineering analysis conducted on site at their facilities. Finally, the fee structure for mechanical contractors is often fixed; and the labor for system optimization (a time-intensive process) cuts into contractor profits.

Thus far, much of the work in transforming the market toward better chiller system design comes from the San Francisco Bay area. PG&E has been a leader, providing assistance to commercial building managers in selecting and optimizing their chiller systems through its Energy Center and developing software tools to improve predictions of chiller performance based on limited data. The PG&E Cool Tools toolkit focuses on increasing the use of simulation tools by designers so that design and purchasing decisions are more informed. Making information and tools available to contractors are valuable components of a market transformation strategy.

However, some attention may need to be focused on providing incentives to improve system design practices with the goal of demonstrating to building owners that investing in design and optimization is cost-effective. With enough evidence, building owners will pay for this service themselves. Until then, however, PG&E could offer performance-based incentives to mechanical contractors for improved chiller system design and subsequent systems optimization. To receive the incentive, contractors should demonstrate, with actual performance data or simulation data, the energy savings of the mechanical system relative to "typical" or Title 24 building design practices. This information should be publicized to educate building owners on the benefits.

Performance-based contracting has been applied in Oakland, California municipal buildings (Eley 1997). However, these contracts were broader in scope, in that they targeted the whole building. Similarly, PG&E also offers performance-based incentives for commercial new construction, but again the program focuses on whole building performance. A similar approach targeting mechanical contractors for chiller systems may be more focused and easier and cheaper to implement.

Also, in the existing building market, the phase-out of CFCs, used widely in chilled water systems, provides a unique opportunity to achieve some substantial efficiency gains, particularly as chillers turn over. Buildings with older chiller systems could be targeted for a combined lighting retrofit, efficient chiller purchase, and systems optimization package. The energy savings estimated to result from the lighting improvements and chiller downsizing and system optimization, could be rewarded on the basis of estimated energy and peak savings.

Optimization of Chiller and Tower Systems

Measure Description: Promote efficient design, equipment selection, and systems optimization

Market Information:	
Market sector:	COMM
End uses:	HVAC
Energy types:	ELEC
Market segment:	RET
Base Case Information:	
Base case description:	100,000 sq ft bldg, 500-ton chiller system
Base case efficiency:	0.65 kW/ton
Base case annual energy use:	975,000 kWh
New Measure Information:	
New measured description:	Increase cooling coil surface; add evaporative condenser
New measure efficiency:	0.48 kW/ton
New measure annual energy use:	720,000 kWh
Measure life:	25 years
Savings Information:	
Electric savings/year:	255,000 kWh
Gas savings/year:	NA
Percent savings:	26%
Feasible applications:	50% of all commercial buildings
Savings potential in 2010:	507 GWH
Cost Information:	
Current measure cost:	$45,000 incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	$0
Cost of saved energy:	$0.01 per kWh
Data Quality Assessment	B
Likelihood of Success:	
Major market barriers:	Cost; complex interactions; perverse incentives; few tools
Effect on customer utility:	Increased comfort
Current activity @ PG&E:	PG&E Energy Center; diagnostic/predictive tools developmen
Current activity elsewhere:	Many utilities rebate chillers; few incent system optimization
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Souces:	
Savings estimates:	Nugent (1993); Robertson (1994)
Cost estimates:	Nugent (1993); XENERGY (1996)
Measure life estimates:	Robertson (1994)
Other key sources:	E Source (1995a); Hydeman (1996)

Principal contact(s):

Notes: Assumes costs of $90 per ton incremental cost for adding cooling coil surface and a standard evaporator condenser.

High-efficiency Packaged Refrigeration Equipment

One-half to two-thirds of the electricity used by refrigeration systems is used by systems such as display cases, small walk-in coolers, ice makers, and vending machines, and not by large built-up refrigeration systems such as those found in supermarkets. Reach-in/display cases make up the majority of the packaged refrigeration equipment load (more than 50 percent), followed by ice machines (around 20 percent), beverage vending machines (around 15 percent), and other equipment (Easton 1993).

Most of these packaged systems are very inefficient. However, savings of 20 to 50 percent are available at a relatively small incremental cost (ADL 1996a;CEA 1996a; CEA 1996b; Easton 1993). For example, the Canadian Electrical Association (CEA) suggests that 37 percent of electricity used by refrigerated display cases can be saved cost-effectively. An analysis by ADL (1996a) on vending machines estimated that through the use of electronic ballasts and improved compressors and fan motors, energy use can be reduced by 32 percent at an incremental cost of $102, which is less than 5 percent of the cost of a new vending machine.

High-efficiency commercial packaged refrigeration equipment face a number of barriers to increased market penetration. In general, manufacturers do not perceive their customers to be interested in energy efficiency and, consequently, do little research and development on efficiency improvements. Furthermore, distributors and end users who may be interested in energy efficiency have no standard performance measures by which to compare the energy efficiency of most types of packaged equipment (ice makers are an exception) (Easton 1993). Also, beverage distributors typically provide beverage merchandisers and vending machines free of charge to commercial establishments that agree to buy their products; the vendor, who owns the equipment, but does not pay operating costs, has little incentive to purchase efficient equipment (Easton 1993).

But some organizations are addressing these problems by establishing mandatory and voluntary energy-efficiency targets for packaged refrigeration equipment, and securing agreements to purchase efficient products, where available. The Canadian Standards Association (CSA) has developed efficiency rating procedures and threshold efficiency ratings for ice makers and vending machines and is developing standards for reach-ins, beverage merchandisers, and drinking fountains. The provinces of Ontario and British Columbia have adopted mandatory ice-maker efficiency standards based on the CSA standard and the Canadian government has proposed to adopt the ice-maker standard nationally. The CSA's standards for food service refrigeration (including reach-ins and beverage merchandisers) will include two levels — a minimum, to eliminate the least efficient equipment and a recommended target developed based on the best equipment available. Typically, CSA standards minimum efficiency levels are not very stringent but get manufacturers accustomed to testing their products and complying with a standard. The voluntary target, set at a higher level, will provide a goal for manufacturers to reach, and as the market develops may become the basis for future minimum efficiency standards. The CSA plans to complete its food service refrigeration standard in 1998.

Also EPA has been working on a national program to recognize equipment manufacturers who agree to produce, and large beverage companies who agree to purchase, efficient vending machines (Dolin 1998). EPA is currently proposing a voluntary energy-efficiency specification for an ENERGY STAR® Vending Machine to refrigerated beverage vending machine manufacturers and is working with the U.S. Postal Service and others large purchasers to stimulate demand for energy-efficient vending machines.

Beverage merchandisers are a logical next step for an ENERGY STAR® type program, since these are also primarily purchased by beverage distributors. Besides, the CSA will be collecting information and developing a rationale for a recommended efficiency target that is more aggressive than CSA's minimum efficiency level that may be useful to EPA in developing an ENERGY STAR® level for beverage merchandisers.

PG&E could help EPA identify large purchasers within the service territory and aggregate their purchasing power. Also, PG&E could make information on efficient packaged refrigeration products currently on the market available to commercial customers. In doing so, PG&E could draw on readily available sources, such as the Air-Conditioning and Refrigeration Institute's (ARI's) directory of ice makers, which includes energy performance data, and the California Energy Commission's (CEC's) database of reach-in coolers, both of which contain information on energy performance metrics.

PG&E could also help stimulate demand by educating its institutional customers and encouraging them to support purchases of high-efficiency vending machines. This activity could also provide an entree into providing a vending machine retrofit service. PG&E could consider providing a retrofit service itself, or work with beverage distributors to encourage them to provide a retrofit service, in which the T-12, magnetic ballasts typical in a vending machine is changed-out with a T-8, electronic ballast combination. Additional HVAC measures, i.e., replacing compressors, etc. should also be explored as possible components of a retrofit service.

For all of this equipment, a modest incentive program could encourage consumers to request more efficient equipment and manufacturer to produce more models. Also, such a program would encourage manufactures to test additional equipment so that better data are available to set standards in the future. PG&E could work with beverage distributors and building owners and operators, offering education and incentives to them to supply and specify efficient vending machines.

High Efficiency Packaged Refrigeration Equipment

Measure Description: Promote efficiency improvements to packaged commercial refrigeration equipment

Market Information:	
Market sector:	COMM
End uses:	REFRIG
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Refrigerated vending machine
Base case efficiency:	NA
Base case annual energy use:	4,000 kWh
New Measure Information:	
New measured description:	Vender w/elec ballast/improved fan motor and compressor
New measure efficiency:	32% more efficient than base case
New measure annual energy use:	2,720 kWh
Measure life:	10 years
Savings Information:	
Electric savings/year:	1,280 kWh
Gas savings/year:	NA
Percent savings:	32%
Feasible applications:	75%
Savings potential in 2010:	457 GWH
Cost Information:	
Current measure cost:	$102 incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	NA
Cost of saved energy:	$0.01 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	No apparent demand for efficiency; split incentives
Effect on customer utility:	None
Current activity @ PG&E:	Financing program for equipment retrofit and new purchase
Current activity elsewhere:	EPA, CSA, CEA
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	CEA (1996a); ADL (1996a)
Cost estimates:	CEA (1996a); ADL (1996a)
Measure life estimates:	CEA (1996a)
Other key sources:	
Principal contact(s):	

Notes: Approximately 75% of equipment are commonly stock items and 25% are more specialized.

Commissioning Existing Commercial Buildings

Recommissioning is the practice of re-tuning and calibrating major systems in existing commercial buildings to achieve and maintain anticipated energy performance of the building systems. Recommissioning is related to commissioning, which focuses on ensuring that new building systems are working properly and operating efficiently, and to continuous commissioning, which relates to the ongoing practice of documenting and maintaining expected levels of system performance. These practices are distinct from typically practiced maintenance, however, which tends to focus on keeping equipment operating reliably, but not necessarily efficiently.

Portland Energy Conservation Institute (PECI) examined commissioning practices in large, recently built office buildings (i.e., 80 percent in excess of 100,000 square feet and 78 percent built between 1970 and 1985) (Gordon & Hassl 1996). The researchers concluded that building owners were spending money and effort on equipment maintenance, but little was being done in most buildings to actually manage energy use. Most buildings had an O&M budget approaching five percent of their annual operating budget and devoted significant time and money to maintaining their facilities, but few reported equipment optimizing actions. Buildings with energy management systems in place tended to use them primarily as scheduling devices rather than for system control.

One study by Texas A&M found savings of 10 to 40 percent from recommissioning activities, with average savings exceeding 20 percent (Liu et al. 1993). While the Texas A&M study does not provide typical costs for these activities, another study indicates that, at least for well maintained buildings, continuous commissioning could be incorporated within an annual five percent O&M budget. A recent study on building commissioning suggests that existing buildings can be commissioned for $0.05 to $.040 per square foot, often resulting in 5 to 15 percent energy savings and paybacks within two years or less (Gregerson 1997).

Clearly, recommissioning can be a relatively quick payback service at a modest cost, but requires that buildings owners are educated about its benefits and that building O&M professionals have the necessary training and expertise. In this era of restructuring, many new, prospective Energy Service Providers (ESPs) may try to position themselves with customers based on value-added services, including total energy management. A public-purpose function of the utility in this environment could be to provide certification, ratings, or other ways of differentiating ESPs.

Building operator certification can help ensure that the professionals responsible for commissioning are knowledgeable about the most cost-effective approaches to achieving energy savings. Northwest Energy Efficiency Alliance (NEEA) offers a building operator certification program, which is being run by the Northwest Energy Efficiency Council (NEEC). To become certified, participants must successfully complete seven training courses in preventive and predictive maintenance practices to reduce energy consumption and costs in their buildings.

PG&E is currently exploring ways to enable HVAC and controls contractors to better commission and maintain systems (Fernstrom 1998). PG&E could serve a valuable function by educating building operators and O&M professionals about the benefits of recommissioning. Market research by PECI, and Texas A&M's experience, reveals that education has been very successful in convincing owners to commission buildings. PG&E could sponsor and publicize recommissioning demonstrations and provide owners with case studies and testimonials to demonstrate the value of recommissioning. Also, PG&E could offer regional seminars and workshops on building commissioning. This could entail coordinating efforts with existing professional organizations (e.g., ASHRAE, AIA, etc.) to deliver training, develop training materials, guide specifications, test libraries, tools, and M&V protocols. Current PG&E activity to provide tools for recommissioning provides a good example of effective distribution of commissioning tools to practitioners.

New energy service providers may position themselves with customers based on value-added services including total energy management. PG&E could consider developing a certification program for commissioning experts (including packaged and built-up HVAC, and controls specialists), a rating system, or other means of differentiating these providers.

Commissioning Existing Commercial Buildings

Measure Description: Commissioning or re-tuning existing commercial buildings, so systems perform as expected.

Market Information		
Market sector:	COM	
End uses:	HEAT, COOL, VENT, LTG	
Energy types:	ELEC, GAS	
Market segment:	RET	
Base Case Information		
Base case description:	Stock building with standard operations and maintenance rep	
Base case efficiency:	70,000	primary Btu/sf (5.5 kWh/sf and 0.13 therms/sf)
Base case annual energy use:	10,500	mmBtu (including 791 MWh and 19,950 therms
New Measure Information		
New measure description	Full commissioning of existing systems to meet existing need	
New measure efficiency:	63,000	primary Btu/sf (5.0 kWh/sf + 0.12 therms/sf)
New measure annual energy use:	9,450	million Btu (including 721 MWh and 17,955 the
New measure life:	7	years
Savings Information		
Electric savings/year:	70,000	kWh
Gas savings/year:	1,700	therms
Percent savings:	10%	heating, cooling, ventilation, and lighting energy
Feasible applications:	54%	est 63% of floor area for buildings > 25,000 sq
Savings potential in 2010:	967	GWH
	1.4	TBTU
Cost Information		
Current measure cost:	$0.19	per sq ft
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.06	per kWh — $0.98 per therm
Data Quality Assessment	B	
Liklihood of Success		
Major market barriers:	Services not available; limited expertise, high cost	
Effect on customer utility:	Improved comfort, improved system reliability	
Current activity @ PG&E:	NA	
Current activity elsewhere:	Texas A&M, Oregon Office of Energy; PGE starting a small p	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	2	
Sources:		
Savings estimates:	NWPPC (1996)	
Cost estimates:	Gregerson (1997), average of numerous studies	
Measure life estimate:	NWPPC (1996)	
Other key sources:	DOE/EIA (1995)	
Principal contact(s)		

Notes: Base case EUIs, derived from DOE/EIA (1995) represent heating, cooling, and ventilation energy in West

Commercial Packaged Air Conditioning

Packaged air conditioning is the most popular form of commercial air conditioning, particularly in the 5- to 20-ton cooling range. These units are easy to install and engineer, particularly in low-rise buildings where multiple single-zone units can be placed on a roof.

California Title 24 requires a minimum EER of 8.9 at 95°F (1.34 kW per ton of cooling), for a 10-ton unit (120,000 Btu per hour). Many manufacturers have come out with units with EERs just over 10. The new ASHRAE 90.1R standard, the precursor to federal standards, calls for a minimum EER of 10.3 for 10-ton units. In 1995, researchers at Texas A&M tested a high-EER prototype unit. They found a 30 percent savings over the standard 8.9 EER unit, and assuming $0.08 per kWh estimated a simple payback of 2.4 to 2.9 years (O'Neal & Davis 1995).

In the current market, the highest efficiency units are available from three manufacturers, Carrier, Lennox, and Trane. Carrier and Lennox produce 10-ton units with an EER of 11, and Trane produces a unit with an EER of 11.5. Industry sources suggest that there is a 35 percent retail cost premium for the highest efficiency models (I.e., for a unit of EER 11 relative to an EER of 9), but this is somewhat variable by market and could decrease with competition as more manufacturers enter this market segment.

Up to this time there has been a limited market for high-efficiency rooftop units. In large part this stems from the speculative construction of many of the facilities in which rooftop units are used. Commercial building developers don't ultimately pay for the electricity and therefore have no incentive to purchase and install energy-efficient equipment. Other barriers include limited availability of high-efficiency units. Additionally, specifiers and developers tend to trade off expenses on building systems, such as air conditioning systems, in favor of expenses on aesthetics (e.g., building atria, lobbies, hallways), to attract high-rent tenants.

However, some organizations are currently working to expand the availability of products in the market place through research and development, and by sending manufacturers a clear market signal about desired efficiency levels. An example of the former is the Oregon Energy Office's work with the heat exchanger producer Modine Manufacturing to develop high-efficiency heat exchangers for incorporation into residential air conditioners. As a result of some of these efforts, Modine is currently partnering with a manufacturer to develop a packaged rooftop air conditioner anticipated to have significantly better energy performance than standard existing equipment (e.g., 30 percent more efficient on a system basis) at an incremental cost of between 0 and 5 percent. The companies would like to have a product ready for commercialization in late 1998 (Stephens 1997).

To solidify market demand, the Consortium for Energy Efficiency (CEE), through its High-Efficiency Commercial Air Conditioner (HECAC) initiative, has established a performance specification for commercial packaged air conditioner products. Participating utilities can promote products that meet the CEE levels through rebates, financing, or education. Uniform qualifying standards by type and size of unit should encourage more manufacturers to enter this market at the levels of efficiency supported by utility programs. Tier 1 levels have been modified in the last year to be consistent with levels in the proposed ASHRAE Standard 90.1R; these products are becoming increasingly available and market transformation is occurring.

By early 1998, in anticipation of the adoption of ASHRAE 90.1R, CEE had finalized a new Tier 2 specification. Products that meet Tier 2 levels save generally 10 percent more energy than Tier 1 products. According to a California Energy Commission (CEC) database, in each equipment category there are generally a few models that meet this draft Tier 2 level, however, these models are not available in all capacities.

At this point, we recommend that PG&E continue to support marketing of Tier 1 products, but focus on promoting products with higher efficiency levels. To promote Tier 2, PG&E should consider more aggressive promotions and offering significantly higher incentives for these models. PG&E and other major HECAC utilities should also consider meeting with major manufacturers to encourage them to develop full Tier 2 lines, emphasizing that leading utilities (e.g., PG&E, New England Electric System) have a multi-year commitment to this effort. Finally, PG&E should work with local distributors to encourage stocking Tier 2 equipment and should consider developing some well-publicized applications of Tier 2 equipment to further support this market.

On the demand side, PG&E should engage in market education efforts to inform bill-paying property managers and tenants on the value of efficient units in reducing operating costs. EPA, though its ENERGY STAR® Buildings program, has been compiling information on leasing arrangements between property managers and tenants in commercial buildings as well as factors that motivate investment decisions of each of these players. This information may be of value in assessing the best methods for reaching commercial building property managers and tenants. As retail competition unfolds, the more that customers, owners, and operators are aware and knowledgeable about efficiency benefits, the better positioned they will be to request and respond to offers for these services from prospective new energy service providers (ESPs).

It is anticipated that federal efficiency standards process for commercial air conditioners will begin in 2001, assuming ASHRAE standard 90.1R is approved in mid-1999 as per the current schedule. One question that DOE will need to face in this process is whether to ratify 90.1R as is (i.e., the standard is based on 1993 data) or to set a minimum level based on an analysis of more recent data. The latter approach would likely show that higher efficiency levels, perhaps along the lines of the CEE Tier 2 levels are justified. PG&E market development activities for Tier 2 products has the potential to significantly affect the minimum efficiency standard that DOE will develop in the next decade.

Commercial Packaged Air Conditioning

Measure Description: High EER packaged air conditioner

Market Information	
Market sector:	COM
End uses:	SPACE COOL
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information	
Base case description:	10 ton rooftop AC, 5000 sq ft building
Base case efficiency:	9 EER; 9.5 IPLV
Base case annual energy use:	13,000 kWh
New Measure Information	
New measure description	High EER unit rooftop AC
New measure efficiency:	11 EER; 11.8 IPLV
New measure annual energy use:	10,498 kWh
New measure life:	15 year
Savings Information	
Electric savings/year:	2,502 kWh
Gas savings/year:	NA
Percent savings:	19%
Feasible applications:	50%
Savings potential in 2010:	229 GWH
Cost Information	
Current measure cost:	$1,700 incremental, installed cost
Future measure cost (in mass use):	$1,250
Other direct costs/savings:	$0
Cost of saved energy:	$0.05 per kWh
Data Quality Assessment	B
Liklihood of Success	
Major market barriers:	Limited availabilty, few incentives for builders
Effect on customer utility:	Increased comfort
Current activity @ PG&E:	Rebates through Retrofit Express program
Current activity elsewhere:	CEE, numerous utilities, potential DOE standard
Likelihood of success rating (1-5):	4
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	ACEEE estimate, CEC (1995)
Measure life estimates:	Lennox (1997a)
Cost estimates:	Lennox (1997a); O'Neal & Davis (1995)
Other key sources:	
Principal contact(s):	Ted Gilles, Lennox Industries, 972-497-5080

Notes: Base case annual energy use based on 2.6 kWh per square foot EUI for small office bldgs in 1998 (CEC 1995) Energy savings estimate assumes 20% full-load and 80% part-load efficiencies. Percent feasible (50%) assumes approximately 60% of comm'l cooling load is served by packaged equipment, of which 10% is specialized equipment unlikely to be affected by initiative.

Evaporative Pre-Cooler for Residential Air Conditioning

Conventional residential air conditioning systems discharge heat extracted from the house by drawing outdoor air through a refrigerant-to-air heat exchanger. This heat exchanger typically is a "finned tube" coil like an auto radiator, in which hot refrigerant gas flows through the tubes while outdoor air flows across the outside tube surface and surrounding fins. The gas discharges heat by warming the air. The effectiveness of heat exchange depends on the temperature difference between the air and gas; the cooler the air, the more efficiently the system operates. Efficiency improves by approximately 12 percent for each 10°F drop in air temperature.

Midsummer outdoor air entering the condenser coil often exceeds 100°F in hot climates. If the air is relatively dry, it may be substantially cooled by evaporation before reaching the coil. In Southwestern U.S. climates where daytime "wet bulb" temperatures are typically below 70°F, 100°F air can typically be evaporatively cooled to 75°F, which can improve cooling efficiency by approximately 30 percent. However, pump energy and water use partially cancel the efficiency savings. Cooling capacity is also typically increased by seven percent per 10°F drop in air temperature. Thus, a smaller system can often be used; for the example 25°F reduction, a 16-17 percent capacity improvement means that a three ton system will deliver 3.5 tons of cooling. Cost savings from down-sizing can partially pay for the evaporative pre-cooling feature, improving economics of the technology.

The energy advantage of evaporative condenser pre-cooling has been known for many years, but maintenance costs and relatively low electric rates have conspired to limit use. The pre-coolers need a water supply to feed the evaporative cooling media, which traditionally have been aspen pads similar to those used in direct evaporative coolers. The pads and pumps typically need more frequent service than split system air conditioners do, particularly in hard water areas. The best locations for this technology are the central valley climates where daytime temperatures are hot and air is dry. However, economics are favorable in virtually all cases where cooling can be down-sized.

Bacchus Industries of Sunland Park, New Mexico has introduced several modern evaporative condenser models which offer advantages over prior systems. Their "Evapcon" unit is a cylindrical fiberglass shell which surrounds a conventional condensing unit with evaporative media, using the existing condenser fan to pull air through both the evaporative media and the condenser coil. Results from several California electric utility research houses with Evapcon coolers indicate 22 percent average performance improvement and very favorable economics. The latest Bacchus innovation is the "AC2" unit which replaces the conventional refrigerant-to-air condensing coil with a refrigerant-to-water heat exchanger and an evaporative water cooler. This unit is smaller and more efficient than the Evapcon, with better economics. An ingenious AC2 heat exchanger design prevents the winter freeze-damage which would occur with conventional refrigerant-to-water heat exchangers. Tabulated economic analyses are based on the Evapcon design.

Despite favorable economics, water use issues and low production volume will hamper market growth for these products without strong utility and government support. Consumer education and co-marketing programs might significantly accelerate their use in the California residential market. Water use for the Evapcon and AC2 systems is approximately 2 gallons per hour for a three ton system, a relatively small quantity compared to the 300 gallon/person/day summer residential water use in typical Northern California communities with unmetered city water. Since California has no restrictions on water use for evaporative coolers or swimming pools, legal barriers to evaporative condenser water use are unlikely. However, water use will likely be a hurdle among environmentally-conscious Californians.

Bacchus Industries is a relatively small participant in the HVAC industry. Despite limited resources, they have launched an initial marketing effort for Evapcon and AC2 units in Northern California as of August 1997. They have selected Manufacturers Associates of Petaluma as Northern California market representatives. This company has a sales goal of 1,500 AC2 units in their service territory in 1997. Specialty AC Products of Benicia will distribute the Evapcon and AC2 from Bakersfield North. Specialty AC is an independent distributor which currently stocks and distributes Trane products in the Bay area. One very active contractor, Solano Mechanical of Fairfield, has already launched a substantial AC2 marketing campaign in Davis, a city of 53,000 known for its interest in energy conservation. This campaign will focus on the replacement market.

One marketing hurdle faced by these evaporatively-cooled condenser technologies is the lack of an accepted rating procedure either nationally or in California. This limitation poses difficulties in the new construction market for builders seeking building permits, and in the replacement market for contractors selling to individual homeowners. While the efficiency of conventional cooling systems is typically described as a seasonal energy efficiency ratio (SEER), only an instantaneous EER is available for Evapcon and AC2. Homeowners used to comparing SEERs in considering cooling products may be confused by technical data using a different term. Bacchus Industries is discussing a compliance option with the California Energy Commission (CEC) which will allow them to claim a multiplier (up to 1.4) on the base case cooling system SEER.

Utility support in this effort, or more generally in verifying and certifying performance might substantially accelerate commercialization of these technologies. Additionally, PG&E can help promote evaporative condensers though consumer education and co-marketing and by working with manufacturers and the CEC on certification of product SEER. Other options that PG&E could pursue include offering consumers incentives and encouraging major air conditioner manufacturers to develop and market evaporative condensers. Such major manufacturer participation will increase availability of products, add to consumer education efforts, and engender competition, which will help keep prices down.

Evaporative Pre-Cooler for Residential Air Conditioning

Measure Description: Add evaporative pre-cooler to improve AC efficiency by reducing condenser air temperature

Market Information:	
Market sector:	RES
End uses:	SPACE COOLING
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Split system condenser, 3.5 ton
Base case efficiency:	8.8 EER @ 95 db
Base case annual energy use:	1,307 kWh
New Measure Information:	
New measure description:	Evaporative condenser air pre-cooling
New measure efficiency:	11 EER @ 95 db
New measure annual energy use:	719 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	588 kWh
Gas savings/year:	NA
Percent savings:	45%
Feasible applications:	90%
Savings potential in 2010:	408 GWH
Cost Information:	
Current measure cost:	$24 incremental, based on down-sizing to 3 ton system
Future measure cost (in mass use):	NA
Other direct costs/savings:	$19 annual water and O&M costs
Cost of saved energy:	$0.04 per kWh
Data Quality Assessment:	A
Likelihood of Success:	
Major market barriers:	Small manufacturer, limited marketing capability, water use issues
Effect on customer utility:	Increased maintenance, but extended compressor life
Current activity @ PG&E:	ACT2 field study
Current activity elsewhere:	None - potential for volume purchases
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	Davis Energy Group (1995)
Cost estimates:	PG&E/DEG ACT2 (1994)
Measure life estimates:	PG&E/DEG ACT2 (1994)
Other key sources:	Bacchus Industries (1996)
Principal contact(s):	Marc Hoeschele, Davis Energy Group, 916-753-1100 Rocky Bacchus, Bacchus Industries, 505-589-5431

Notes: Savings estimates from detailed hourly monitoring data.
Evaporative media requires replacement at eight year point in product life.

Commercial Air Conditioner Operation and Maintenance

About half of U.S. commercial square footage is cooled by rooftop "unitary" packaged equipment. Although some buildings use residential-sized equipment or very large packaged units, the bulk of the market is in 5- to 20-ton units. These devices can be maintained for maximum energy efficiency, but typical maintenance practices are inadequate.

The potential energy benefits of improved rooftop unit operation and maintenance include efficiency improvements from clean heat exchangers, reduced air leakage, better motors and air-side operation. Based on the order of magnitude of component improvements and field results of programs to improve rooftop unit efficiency, we assume an increase in energy efficiency ratio (EER) from 7.0 to 8.0, an energy savings of about 13 percent. Demand savings are summer only, and estimated to be two percent based on field results. The potential non-energy benefits of good maintenance include improved air distribution, increased occupant comfort, extended equipment life, and an overall reduction in the life-cycle cost of owning and operating the equipment.

The cost of maintaining rooftop units is difficult to quantify. Preventative maintenance contracts are low-bid to secure hourly repair work, which varies widely year-to-year and unit-to-unit. For example, a typical O&M budget (per unit) is $100 for the maintenance contract plus an additional $100 for annual repairs. The cost to improve maintenance practices training incentives, and perhaps targeted efforts such as rebates for more-efficient blower motors or automated monitoring equipment is also difficult to quantify. For this analysis, we use an estimate of $100 per unit annually.

Among the strategies that PG&E could pursue to address barriers to better maintenance practices for commercial air conditioning equipment are educating building owners about the sizeable energy benefits and providing training and certification for building operators and maintenance contractors that successfully complete a maintenance practices training course. In general, a market transformation effort to improve maintenance practices is likely to be a longer term effort than a one-time activity. Although the potential improvement in energy efficiency is attractive, this is a difficult target for a market transformation program because the equipment owners and the maintenance workers are highly diffused. And the difficulty in reaching small owners and service contractors and their aversion to hanging current practices lead us to assign a low likelihood of success for such an initiative.

Nonetheless, a number of activities throughout the country can help guide developments of an initiative for improved maintenance of commercial air conditioning systems. The Northeast Energy Efficiency Partnership (NEEP) has recently completed a study of central air conditioner installation challenges and possible steps to address these challenges (E-Cube 1998). Some of the lessons learned through this effort can be applied to a PG&E market transformation effort focused on improving maintenance practices. For example, poor economizer operation appears to be a very frequent problem and a large source of rooftop unit inefficiencies. This and improper refrigerant charge another key source of inefficiency) can be checked and corrected during routine maintenance. PG&E could offer training and certification for building operators and service contractors to begin to address these issues.

In general, NEEP recommended several strategies for improving installation practices that PG&E could apply to improving maintenance practices. These include: assessing baseline practices in a small sample of buildings; educating building owners on the benefits of proper maintenance; promoting training and education for better practices among building operators and contractors; promoting greater awareness and action by the design community; identifying "quality" service contractors; and developing a unitary-focused commissioning program.

PG&E could conduct a baseline study to assess current practices in a small sample within its service territory. This study could help identify the and form the basis of a training and educational curriculum. PG&E could also promote training and education for better maintenance practices among building operators and service contractors leveraging existing training resources, including training and certification offered by the North American Technician Excellence (NATE) Progam and the Air Conditioning Contactors of America (ACCA).

For commissioning-related activities, PG&E could build on lessons learned from programs underway by the Northwest Energy Efficiency Alliance (NEEA) and NEEP. Among the specific commissioning-related activities that NEEP identified for commissioning new commercial air conditioner installations which are also relevant to maintenance practices are: developing standardized procedures and forms to serve as guides and documentation for the process; and identifying, modifying, and applying forms and procedures for other commissioning programs and from other sources. Finally, PG&E could consider a broader focused effort, such as building operator certification or a more general building systems commissioning program, ensuring adequate coverage for rooftop maintenance in these programs.

Commercial Air Conditioner Operation and Maintenance

Measure Description: Through training, testing, and monitoring, improve the efficiency of rooftop air conditioners.

Market Information:	
Market sector:	COM
End uses:	HVAC
Energy types:	BOTH
Market segment:	RET
Base Case Information:	
Base case description:	10-ton rooftop unit w/ elec cool, 4000 cfm nom airflow, gas htg
Base case efficiency:	7 EER
Base case annual energy use:	34,286 kWh
New Measure Information:	
New measure description:	10-ton rooftop unit w/ elec cool, 4000 cfm nom airflow, gas htg
New measure efficiency:	8 EER
New measure annual energy use:	30,000 kWh
Measure life:	5 years
Savings Information:	
Electric savings/year:	4,286 kWh
Gas savings/year:	NA
Percent savings:	13%
Feasible applications:	50%
Savings potential in 2010:	473 GWH
Cost Information:	
Current measure cost:	$100 per year
Future measure cost (in mass use):	$100 per year
Other direct costs/savings:	May be reduced equip costs from longer component life
Cost of saved energy:	0.01 per kWh
Data Quality Assessment:	B
Likelihood of Success:	
Major market barriers:	Dispersed equipment owners and servicers, lack of interest.
Effect on customer utility:	Improved comfort, extended equipment life, better air distributic
Current activity @ PG&E:	None
Current activity elsewhere:	BECO settlement board study (per Steve Nadel)
Likelihood of success rating (1-5):	2
Relationship to PG&E planning (1-3):	3
Sources:	
Savings estimates:	Houghton (1996)
Cost estimates:	Houghton (1996)
Measure life estimates:	Houghton (1996)
Other key sources	NA
Principal contact(s)	David Houghton, E Source, 303-440-8500

Notes: Annual energy use based on equivalent runtime of 2000 hours per year.
Savings potential based on: total comm'l energy use (in 2010) for space cooling and ventilation of 7273 GWH, 50% of that comes from RTUs, and 13% of that is saved through improved O&M.

Improved Lighting Design Practices

Lack of knowledge of new and emerging technologies is often a critical barrier to the acceptance of new energy-efficient technologies and design practices. Increased training and education of the relevant stakeholders can help reduce this barrier. In the new commercial building lighting design field, efforts to educate lighting design professionals could significantly increase the penetration of energy-efficient technologies and good lighting design practices.

Many lighting designers provide too much light, designing general lighting systems for demanding tasks instead of designing these systems for normal tasks and installing task lighting for more demanding tasks. Designers are also often unfamiliar or uncomfortable with the use of lighting controls, daylighting systems, and other lighting system features that directly interact with the building's fenestration system.

Utilities and state and federal governments have attempted to address the slow diffusion of knowledge on lighting technologies and design practices through a number of avenues. DOE offers lighting training courses through the Federal Energy Management Program (FEMP). EPA has undertaken a major effort to promote energy efficient design practices by highlighting successful case studies in its Green Lights program. A number of states, including California and Washington, have offered or sponsored training courses in lighting design. A growing number of utilities, including Consolidated Edison, PG&E, Seattle City Light and Portland Gas & Electric have lighting technology labs where state of the art technologies are demonstrated, expert advice is available, and successful lighting projects are featured. Additionally, an increasing number of lighting design computer programs (FLEX, Lumen Micro, BEEM, LightPAD, etc.) simplify the design tasks and calculations involved in incorporating good lighting design. The development of other design tools can further increase the penetration of energy-efficient technologies and designs.

Recent changes in PG&E's DSM programs and planned changes in California's Title 24 standards reinforce the need to reach and educate the lighting design community. Both of these changes are based in part on the recognition that T8 lamps and electronic ballasts have become standard practice in many building types. As a result, PG&E is no longer providing measure-based incentives for upgraded lighting systems in new or renovated buildings. As discussed below, PG&E is focusing its efforts on increasing the specification of lighting control systems. Similarly, the revised Title 24 lighting building performance standards, requiring lower lighting power densities, also assume a T8 lamp and electronic ballast baseline.

PG&E has undertaken a number of on-going efforts to help educate and train the lighting design community, including: developing a PC-based daylighting software package; developing an interactive internet Lighting Exchange; developing an occupancy sensors application guide; producing on-going monthly lighting seminars at the PG&E Energy Center (PEC); hosting local IES seminars at the PEC; sponsoring design awards for smaller (30,000 to 100,000 square feet) buildings; and sponsoring a lighting design class at California Polytechnical Institute and at the University of California at Berkeley, the only two architectural degree granting institutes in PG&E's service territory.

Comments received on ways to augment PG&E's current education and training activities include a number of activities and approaches, several of which PG&E is already pursuing:

- Educational efforts should expand beyond the lighting design community. While these other groups may be a "tough" sell both building owners and electrical engineers need to be educated. Building owners need to have their expectations raised regarding lighting design needs and to place more value on the contribution of design professionals. In some cases, owners will turn over good lighting design schematics to a design/build firm only to have the control specifications and the embedded quality in the original design lost. Electrical engineers, who perform some portion of commercial lighting designs, need to be educated about design issues. There was skepticism on whether EEs would be receptive to this message.

- The Lighting Research Center (LRC) is pursuing a number of training and educational initiatives, some of which PG&E is involved with. These initiatives include CD-ROM and Internet based training modules, CD-ROM calculation software, a national roundtable on controls, the Delta Publication series of case studies, and outreach efforts to architects (AIA), lighting designers (ILDA), interior space designers (ASID), and luminaire manufacturers.

- Simplify design tools, otherwise advanced design skills may reside in a small number of firms.

- Revisit/revise the Advance Lighting Guidelines. PG&E is incorporating revised guidelines in the Lighting Exchange website.

- Hold regional seminars. Not everyone can make it to the PEC. These seminars would allow designers, specifiers and installers outside of the San Francisco area to not only learn about advanced design practices but to also "touch and feel products." PG&E has offered some seminars in other locations, and recognizes the need for more, but has staffing and resource constraints.

- Video conferences. An increasing number of firms have the capability to receive down links. Alternatively, local host facilities could be located to sponsor such events.

- Internet-based bulletin boards to handle FAQs. Again, this feature is a planned component of the Lighting Exchange website.

- Influence university and college engineering and architectural programs. Efforts might include providing guest speakers, developing lighting design classroom modules, and developing certificate programs, as well as more direct efforts to modify current core curricula to explicitly address energy efficient lighting design.

- Work with other utilities and state and private agencies to develop a number of regional Energy Centers which could provide expanded training and education to a larger number of lighting design professionals and others. It was suggested that these regional centers could be established in collaboration with the state university extension services.

Improved Lighting Design Practices

Measure Description: Promote increased training and education of lighting design professionals.

Market Information:		
Market sector:	COM	
End uses:	LTG	
Energy types:	ELEC	
Market segment:	NEW, RET	
Base Case Information:		
Base case description:	Current code constrution practices	
Base case efficiency:	NA	
Base case annual energy use:	106	GWh lighting only
New Measure Information:		
New measure description:	Improved lighting design	
New measure efficiency:	NA	
New measure annual energy use:	101	GWh lighting only
Measure life:	20	years
Savings Information:		
Electric savings/year:	7	GWh, includes 30% cooling bonus
Gas savings/year:	NA	
Percent savings:	5%	
Feasible applications:	100%	
Savings potential in 2010:	337	GWh
Cost Information:		
Current measure cost:	$2,000,000	@ $500,000/yr for four years
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	labor savings not quantified
Cost of saved energy:	$0.03	kWh
Data Quality Assessment:	C	
Likelihood of Success:		
Major market barriers:	Difficulty in coordinating design team members	
Effect on customer utility:	Lower energy bills, increased occupant comfort	
Current activity @ PG&E:	PG&E Lighting Design Lab	
Current activity elsewhere:	PGE, Seattle City Light, EPA Green Lights	
Likelihood of success rating (1-5):	3	
Relationship to PG&E planning (1-3):	3	
Sources:		
Savings estimates:	XENERGY Estimate	
Cost estimates:	Turnbull (1997)	
Measure life estimates:	XENERGY estimate	
Other key sources:	E Source (1994b), Gordon (1988)	
Principal contact(s):	Peter Turnbull, PG&E, 415-973-2164	

Notes: Base case and new measure energy use are based on stock, not marginal EUIs
A 30% cooling bonus is based on a range of estimates from the E Source (1994b).
The 20 year measure life reflects a 5 percent stock turnover rate resulting from major renovation.

Occupancy Sensors

Occupancy sensors save energy by automatically turning off lights in spaces that are unoccupied. Most occupancy sensors have adjustable settings for both sensitivity and time delay. Occupancy sensors are available in ceiling-mounted and wall-mounted versions. Two motion-sensing technologies are commonly used in occupancy sensors: passive infrared and ultrasonic. Passive infrared sensors are the most common and best suited for a 15-foot range, since there are potential "dead spots" that increase with distance and since this technology depends on the heat intensity of the moving subject. Ultrasonic sensors are able to cover larger areas since they emit, rather than receive, a signal. However, these sensors are more prone to false triggering. Some manufacturers combine these two technologies into one product called a hybrid or a dual technology sensor.

Energy savings attributable to occupancy sensors vary greatly depending upon the application and how well the sensor is commissioned. The table below provides reasonable ranges of savings. The assumption used in the measure characterization is a 30 percent average power reduction calculated for a portion of the following building types: large office, small office, warehouse, hotel/motel and miscellaneous.

Energy Saving Potential with Occupancy Sensors

Application	Energy Savings
Offices (private)	25-50%
Offices (open spaces)	20-50%
Rest Rooms	30-75%
Corridors	30-40%
Storage Areas	45-65%
Meeting Rooms	45-65%
Conference Rooms	45-65%
Warehouses	50-75%

Source: EPA (1997)

The cost of occupancy sensors varies according to where it is mounted and the sensing technology used. Generally, wall mounted sensors range from $40 to $75 dollars and ceiling-mounted sensors range from $75 to $125. For this analysis, a cost estimate of $60 was used for the sensor and $50 per hour for labor. Depending upon the application, payback periods can be as short as 10 to 12 months. However, improper applications can easily yield uneconomic results. Potential misapplications include connecting the sensor to too many fixtures, connecting the sensor to incompatible ballasts, mounting the sensor in an improper location, improper settings e.g., time delay, sensitivity) and improper sensor specification.

Market barriers include first cost, the stigma associated with past misapplications, a lack of contractor/building operator knowledge, and a lack of proper commissioning. Although the problem of misapplication has been somewhat remedied in recent years, some contractors continue to improperly select, place, or set sensors. Improving contractor/building operator knowledge will help mitigate this problem and increase technology penetration.

Manufacturers are doing a good job advertising their products to building designers and operators. Information on the benefits of occupancy sensors is readily available, and even if rebate programs should end, awareness will likely remain high. The unaddressed problems are related to commissioning and customer uncertainty over performance claims.

Frequently, not enough time is spent commissioning occupancy sensors. To achieve the full energy savings possible, a careful testing process must be used to set the sensitivity, and thought should go into choosing the location and the appropriate time delay. The most common installation and commissioning problems include choosing a poor sensor location, setting the sensitivity too high or too low, and setting the time-delay too long or too short. All of these problems can cause the lights to stay on longer and use more energy than without the sensor. In cases where the lights are turned off too quickly or the sensitivity is too low, the occupancy sensor is frequently overridden or replaced with a standard switch.

Customers are sometimes skeptical of the energy savings from occupancy sensors. Tables of typical savings by space type—such as the one on the previous page—can be misinterpreted to mean the low end savings is practically guaranteed. This is definitely not the case. Actual savings varies tremendously with the usage pattern, and typical savings tables only represent average results. With retrofits, the base case occupant behavior is also an important factor.

In recognition that one of the biggest obstacles to increased use of occupancy sensors is performance uncertainty, new incentive programs should be tied directly to performance. This will be most effective in larger facilities where the necessary measurement and verification sample size is small relative to the total number of sensors installed, and the cost of the verification can be recovered from savings.

Potential activities PG&E could engage in to improve market penetration for occupancy sensors:

- Commissioning and Renovation Training. Courses for contractors and building operators at the various PG&E training centers in the proper installation and commissioning of occupancy sensors can improve the effectiveness of sensors at current and future projects. The problems with renovations must also be addressed. Building operators should be educated about the importance of moving occupancy sensors during renovations, especially in offices with high-wall modular cubicles.

- Publicize Measured Savings. Customers need information to make their own savings estimates based on their space types and usage patterns. To be credible, this information should be measured data from demonstration projects or other real-world applications. Much of this data may already exist, although it is currently inaccessible to customers.

- Performance-Based Incentives. Basing incentives of the actual energy savings serves two purposes. First, this reinforces good design; a poor design won't save energy no matter how carefully it is installed. Second, it requires proper tuning of the sensitivity and picking the best time delay. Commercial projects large enough to pay for the cost of performance verification and still provide a reasonable incentive will typically involve 150-300 sensors.

Occupancy Sensors

Measure Description: Add infrared or ultrasonic sensors that switch light on when motion is detected.

Market Information:	
Market sector:	COM
End uses:	LTG
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information	
Base case description:	Electronic ballast, 2 F32T8 lamps, 4 fixtures per zone
Base case efficiency:	252 Watts (63 Watts per fixture)
Base case annual energy use:	754 kWh
New Measure Information	
New measure description:	Occupancy sensors and interface added to baseline fixture
New measure efficiency:	176 Watts (assumes average of 70% full power)
New measure annual energy use:	527 kWh
Measure life:	15 years
Savings Information	
Electric savings/year:	227 kWh per 4 fixture zone
Gas savings/year:	NA therms
Percent savings:	30%
Feasible applications:	30%
Savings potential in 2010:	599 GWH
Cost Information	
Current measure cost:	$125 full cost
Future measure cost (in mass use):	$120
Other direct costs/savings:	NA
Cost of saved energy:	$0.02 kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, history of misapplication, specifier practices
Effect on customer utility:	Some products shut lights off when occupants are inactive
Current activity @ PG&E:	$8 rebate for wall-mouned and $22 rebate for ceiling-mounted
Current activity elsewhere:	Numerous utilities
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	FLEX (1996), CEC (1996)
Cost estimates:	FLEX (1996), LBNL (1996), XENERGY (1996), E Source (1994b)
Measure life estimates:	inter.Light web page (http://light-link.com)
Other key sources:	EPA (1995b), E Source (1995e)
Principal contact(s):	Dorene Maniccia, Lighting Research Center, 518-276-3057 Howard Gerber, XENERGY, 617-273-5700

Notes: The feasibility estimate is an in-house estimate
Average daily lamp use (8.2 hours) is from a PG&E time-of-use-study by HBRS (1994).
Measure cost assumes a $60 sensor and $65 labor for roughly 2.5 hours at $25 per hour.
Percent feasible based on use in private offices and other spaces that are intermittently used.

Residential Duct Sealing

Over the last several years, building research has identified distribution system ("duct") leakage as a major source of energy loss in homes with forced air systems (heat pumps, furnaces and/or central air conditioners). A typical house with ducts located in the attic or crawlspace asts approximately 20 to 30 percent of heating and cooling energy use through duct leaks (LBNL 1998). Sealing these leaks can have a significant impact both on building energy use and peak demand.

There are a number of ways to measure duct leakage in homes. One common way is to use a duct blaster to pressurize the air distribution system and to use a blower door to pressurize the house. By using the two in combination, one can determine the duct leakage from the HVAC system to outside of the building envelope, as opposed to duct leakage from the distribution system to the space within the conditioned envelope. Blower-door-guided infiltration and duct sealing are virtually non-existent outside the federal low-income Weatherization Assistance Program and some related utility-sponsored low-income programs, including PG&E, SDGE, Louisville Gas and Electric and other combination utilities.

A key factor determining the energy impact of duct leakage is the location of the ducts relative to the conditioned space. As the proportion of the distribution system that is located within unconditioned spaces (such as attics and crawl spaces) increases, so does the impact of duct leakage on energy use.

Measured duct leakage is generally expressed in CFM measured at 25 Pascals. Unlike air infiltration measurements, there is not yet an agreed upon conversion to determine duct system efficiency, though groups such as Advanced Energy Corporation (formerly the North Carolina Alternative Energy Corporation) are developing such methodologies. Nonetheless, a number of utility programs have established program requirements for their duct sealing programs. For example, Duke Power's new construction program has a maximum duct leakage rate (at 25 Pascals) equal or less than three percent of the conditioned floor space.

Currently, ducts in either new or existing homes are rarely checked for duct leakage and when they are checked, the appropriate sealing technique is not used. Duct leakage can be minimized in new construction with proper duct design, proper installation, and proper sealing (using products such as mastic). For existing construction, an aerosol foam technology that can seal both exposed and inaccessible ducts from the inside is now undergoing field testing (Modera 1997). This technology blows aerosolized adhesive particles into the duct system and deposits them at the leakage sites, sealing the leaks without depositing on duct surfaces (LBNL 1998) Aerosol sealing represents an improvement relative to conventional methods in existing construction (i.e., locating leaks, patching with mastic and duct tape, and the retesting to ensure leaks are sealed) because inaccessible ducts can be sealed and it is less time consuming and costly to homeowners. In a 23-home field test (of homes in Indiana, Pennsylvania, Massachusetts, New Jersey, and Oklahoma) sponsored by the Electric Power Research Institute, more than 80 percent of the supply duct leaks were sealed within two hours (compared with 60 percent when using conventional methods that typically take more than twice the time) (EPRI 1997).

One of the primary barriers to better duct sealing practices is a lack of awareness by homeowners and contractors about the impacts of leaky duct work on energy use, home comfort, and indoor air quality. Those contractors that are aware of the benefits may not have the skills or the information to successfully market improvements in duct efficiency; and in most regions no reliable means exists to identify and verify the benefits of efficient duct work.

Any effort to transform the market will require identifying and working closely with the appropriate channels for disseminating the diagnostic and repair technologies. PG&E could begin by promoting appropriate means of duct sealing among more sophisticated contractors familiar with duct blaster technology. This would be a natural and relatively low-cost extension of an already developed market. However, these contractors are in relatively limited supply. Instead, most residential contractors are unfamiliar with the duct blaster technology and appropriate duct sealing techniques. As a result, the "typical" HVAC service technician is a more important audience for PG&E to target for education and training. Initially, PG&E could focus on training those with a reputation for higher quality work. They should be trained in the proper use of duct blaster technology, as well as the application of mastic for new and existing construction and aerosol duct sealant technology for retrofit applications. This training should include some classroom training as well as a "hands-on" training component.

Additionally, PG&E can offer a duct sealing service, in which the utility maintains a list of "approved contractors," and hires skilled contractors for quality control in order to establish a valued service in customers minds. If a customer calls, PG&E could recommend that they first consider their regular contractor if the contractor is on PG&E's approved contractor list. PG&E's presence in this market should also help to establish reasonable pricing levels.

PG&E could draw on local experts, such as John Proctor from Proctor Engineering and Mark Modera of Lawrence Berkeley National Laboratory (LBNL) to develop contractor training program curriculum, and to provide on-site training and quality control services. Other examples of testing and training services that include duct leakage diagnostics and sealing can be found in the Building Performance Institute (in upstate New York) Building Technician II program, and Advanced Energy's duct sealing training (Toyanaka 1997; Neal 1997).

Further, contractors and utilities need to educate homeowners about the benefits of proper duct sealing. PG&E and other trusted third parties can compile information on the benefits of duct sealing and use these to educate homeowners, through utility mailing inserts and in co-marketing efforts with HVAC contractors.

Finally, PG&E can work on strengthening Title 24. Currently, Title 24 allows credit for verified tight ducts. Training in the proper use of duct blaster testing and duct sealing techniques, together with a requirement to verify duct tightness, would dramatically increase the use of the technology and the application of proper duct sealing techniques.

Residential Duct Sealing - New Construction

Measure Description: Locate and seal bad connections and leaks to improve new home construction.

Market Information		
Market sector:	RES	
End uses:	HEAT, COOL	
Energy types:	ELEC, GAS	
Market segment:	NEW	
Base Case Information		
Base case description:	1700 sq ft, single-fam home (gas heat/electric AC)	
Base case efficiency:	NA	
Base case annual energy use:	NA	
New Measure Information		
New measure description:	Seal bad connections, repair leaks with mastic	
New measure efficiency:	NA	
New measure annual energy use:	NA	
Measure life:	15	years
Savings Information		
Electric savings/year:	381	kWh
Gas savings/year:	30	therms
Percent savings:	18%	
Feasible applications:	100%	
Savings potential in 2010:	43	GWH
	1	TBTU
Cost Information		
Current measure cost:	$300	
Future measure cost (in mass use):	$300	
Other direct costs/savings:	$0	
Cost of saved energy:	$0.05	per kWh
	$0.44	per therm
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	Lack of contractor awareness; contractor availability	
Effect on customer utility:	Possible system downsizing, better air distribution	
Current activity @ PG&E:	On-going (exisitng construction pilot)	
Current activity elsewhere:	Duke, CP&L (proposed)	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	3	
Sources:		
Savings estimates:	PG&E (1996), ACEEE (1994)	
Cost estimates:	XENERGY (1996)	
Measure life estimates:	PG&E (1996)	
Other key sources:	ACEEE (1994), Iowa Utilities Board (1996)	
Principal contact(s):	Tom Downey, Proctor Engineering Group, 415-455-5700	

Notes: Assumes 100% penetration of CAC in Northern California
Costs in the cost of saved energy calculation are allocated 57% to electric and 43% to gas based on energy savings.

Residential Duct Sealing - Existing Homes

Measure Description: Locate and seal bad connections and seal leaks in existing forced air heating and central air conditioning ducts with aerosol duct sealant spray.

Market Information		
Market sector:	RES	
End uses:	HEAT, COOL	
Energy types:	ELEC, GAS	
Market segment:	RET	
Base Case Information		
Base case description:	High use single-fam home, gas heat/electric central AC	
Base case efficiency:	NA	NA
Base case annual energy use:	4375 kWh	450 therms
New Measure Information		
New measure description	Seal bad connections; apply aerosol-based duct sealant	
New measure efficiency:	Seals 80-90% of duct leaks	
New measure annual energy use:	3719 kWh	383 therms
New measure life:	10 years	
Savings Information		
Electric savings/year:	656 kWh	
Gas savings/year:	68 therms	
Percent savings:	15% on HVAC energy use	
Feasible applications:	36%	
Savings potential in 2010:	186 GWH	
	5 TBTU	
Cost Information		
Current measure cost::	$450 full cost, not incremental	
Future measure cost (in mass use):	$270	
Other direct costs/savings:	$0	
Cost of saved energy:	$0.03 per kWh	
	$0.27 per therm	
Data Quality Assessment	B	
Liklihood of Success		
Major market barriers:	Knowledge, contractor certification	
Effect on customer utility:	More even indoor temperature, improved air quality	
Current activity @ PG&E:	Pilot project and in low income weatherization program	
Current activity elsewhere:	Several EPRI member utilities, FP&L	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	2	
Sources:		
Savings estimates:	Modera (1997); Modera, et al. (1996)	
Measure life estimate	Modera (1997)	
Cost estimates:	Modera (1997)	
Other key sources:	XENERGY (1996)	
Principal contact(s):	Mark Modera, Aeroseal, 510-601-8575	

Notes: Base case high energy use homes per Modera (1997). Percent feasible (38%) assumes that the measure is appropriate for 90% of high-use homes, estimated at 40% of residential load. Savings based on estimated electricity savings from homes in Florida pilot study, measured savings from a Sacramento pilot, and others. Costs are allocated 50% to electric and 50% to gas based on primary energy savings.

Dry-Type Distribution Transformers

All electric power passes through one or more dry-type transformers on its way to service building office equipment, lighting, and other loads. Many office buildings, for example, have one dry-type 75 to 225 kVA transformer on every floor to step down 480Y/277 volts to 280Y/120 volts, necessary for plug loads (Hickman 1997). Commercial or industrial customers are typically responsible for purchasing and installing these step-down transformers. And in general, these customers do not factor in the costs of losses, but consider only first-cost, when evaluating these purchasing decisions. Because transformers are long-lived (e.g., with 25 to 30 year lifetimes), not considering energy costs over the life of the transformer in the purchasing decision can be very costly.

Transformers experience two types of losses: no-load and load losses. Transformer energy losses are constant at no-load and vary with the square of the load on the transformer. In typical commercial and industrial applications, transformers are loaded on average at 30 to 35 percent of their rated output (Hopkinson 1997). E Source reports that transformer losses represent two to six percent of a typical building's electricity use (E Source 1995b). Currently available materials and designs can considerably reduce both load and no-load losses. More efficient transformers, with attractive payback periods, are estimated to save 40 to 50 percent of the energy of a "typical" transformer, which translates into a one to three percent reduction in electric bills for commercial and industrial customers (E Source 1995b; Barnes et al. 1996).

The costs of greater efficiency are a bit more elusive. Oak Ridge National Laboratory (ORNL), however, has surveyed manufacturers on the increased costs of purchasing a transformer that meets a NEMA efficiency standard (i.e., Standard TP-1, discussed below) (Barnes et al. 1997). Efficiencies and costs for a prototypical low-voltage 75 kVA transformer and a medium-voltage 1500 kVA transformer are represented in the analysis.

First-cost purchasing behavior, short payback period requirements, and the fact that the building owner or developer often does not pay the utility bills, limits purchases of efficient dry-type transformers, particularly low-voltage transformers. Furthermore, until recently, no standard existed that denoted efficient transformers. In 1994, however, the Canadian Standards Association (CSA) developed a voluntary standard for both liquid-immersed and dry-type transformers (CSA 1994). This standard has been used as a minimum standard in Ontario and British Columbia, and has been proposed by the Canadian government as a national minimum efficiency standard (Sam 1998). In 1996, the National Electrical Manufacturers Association (NEMA) published a standard for energy-efficient transformers. Based on preliminary research, a small percent of transformers in the low voltage range (i.e., 600 V and below) currently meet TP-1 (NEMA 1996). In contrast, an estimated 60 percent of medium-voltage dry-type transformers meet TP-1 (deLaski 1998). The NEMA energy efficiency targets are modest, but can be achieved within payback periods desirable to commercial customers (i.e., approximately a thee-year simple payback) (Hopkinson 1997).

With the Energy Policy Act of 1992, Congress instructed DOE to investigate the potential for transformer efficiency standards and to set standards if they will save significant energy, are technically feasible and economically justified. In late 1997, DOE published a determination that standards are technically feasible and can save significant energy. DOE is now proceeding to the next stage in the standard-setting process — establishing DOE test procedures for transformer efficiency. This is the first step in an approximately three- to four-year process (e.g., concluding in 2000 or 2001) to either set standards or decide that standards are not economically justified. If standards are set, they are scheduled to take effect three years after DOE's final decision (e.g., approximately 2004). In late 1997, Massachusetts passed legislation that adopts TP-1 as a standard for dry-type and liquid-immersed transformers, which may help motivate the federal process (Commonwealth of Massachusetts 1997). Similarly, the California legislature can establish state transformer efficiency standards, both to accelerate the effective date relative to the DOE process and to push DOE to set standards.

EPA, which currently has an ENERGY STAR® program for liquid-immersed transformers (i.e., those used primarily on utility lines), has been approached by NEMA to establish an ENERGY STAR® program for dry-type transformers based on NEMA levels. EPA is moving forward on developing an ENERGY STAR® specification for a program targeting low-voltage dry-type transformers based on TP-1 and is gathering more information on the current status of, and the most effective means for transforming, the medium-voltage market.

The Consortium for Energy Efficiency (CEE), working closely with NEMA and EPA, developed a transformer market transformation initiative in late 1997. Working with CEE and the EPA ENERGY STAR® program to develop a utility-based program to promote high-efficiency transformers may be the most effective way for PG&E to influence market transformation. The CEE initiative will draw in particular from CEE's experience with successful programs to promote high-efficiency motors, as the motor and transformer markets have many similarities. The CEE initiative includes a performance specification based on TP-1. In addition, CEE is working to develop: (1) educational and technical materials and tools to make customers aware of the opportunity, availability of products, and how the efficient products can be obtained; and (2) modest incentive levels, for targeting both consumers and distributors, to help change purchasing and stocking practices.

The educational and technical materials are likely to include: brochures, sample purchase specifications, databases of available products, and selection tools such as software and slide-rules to perform economic calculations. CEE is planning to oversee development of these tools, working with other organizations such as NEMA, EPA, and DOE, and will make them available for reproduction and dissemination by participating utilities. PG&E could complement these activities by compiling a list of distributors who stock transformers that meet the specification.

For the incentive levels, the high-efficiency transformers being targeted have approximately a three-year simple payback relative to conventional transformers. PG&E can buy the first cost down to a more rapid simple payback (perhaps one year to start) in order to "kick-start" the market for high-efficiency transformers. As the market share of high-efficiency transformers increase, incentives can be gradually reduced and ultimately eliminated.

Dry-Type Distribution Transformers

Measure Description: Encourage high-efficiency dry-type transformer purchases by comm'l (and ind'l) users

Market Information:

Market sector:	COM/IND
End uses:	POWER
Energy types:	ELEC
Market segment:	NEW, REP

Base Case Information:

Base case description:	75 kVA low-voltage and 1500 kVA med-voltage transformers
Base case efficiency:	97.29% for 75 kVA; 98.56% for 1500 kVA
Base case annual energy use:	3,017 kWh for 75 kVA; 50,886 for 1500 kVA

New Measure Information:

New measured description:	NEMA standard TP-1 compliant transformer
New measure efficiency:	98.39% for 75 kVA; 98.94 for 1500 kVA
New measure annual energy use:	1,945 kWh for 75 kVA; 42,207 for 1500 kVA
Measure life:	30 years

Savings Information:

Electric savings/year:	4,115 kWh savings in reduced energy losses
Gas savings/year:	NA
Percent savings:	0.81%
Feasible applications:	80%
Savings potential in 2010:	54 GWH

Cost Information:

Current measure cost:	$1,770 incremental
Future measure cost (in mass use):	NA will likely come down as market grows
Other direct costs/savings:	$0
Cost of saved energy:	$0.03 per kWh

Data Quality Assessment: B

Likelihood of Success

Major market barriers:	First cost purchases; lack of knowledge of savings potential
Effect on customer utility:	None
Current activity @ PG&E:	None
Current activity elsewhere:	DOE, EPA, NEMA, CSA, CEE
Likelihood of success rating (1-5):	4
Relationship to PG&E business plan (1-3):	3

Souces:

Savings estimates:	Barnes et al. (1997)
Cost estimates:	Barnes et al. (1997)
Measure life estimates:	Barnes et al. (1996)
Other key sources:	

Principal contact(s): Randy Barnes, ORNL, 423-576-2729

Notes: Calculated efficiency assumes a 35% load for low-voltage and 50% load for medium-voltage transformers. Low-voltage and medium-voltage transformers represent approximately 60% and 40% of dry-type transformer losses. Average efficiency and cost are calculated using these weights. Percent feasible (80%) accounts for the fact that some medium-voltage transformers are already efficient.

Indirect/Direct Evaporative Coolers (IDEC)

Direct evaporative coolers have been widely used for years in residences in the Southwestern United States, but compared to compressor-driven air conditioning, are regarded as a low-quality cooling technology. These direct evaporative coolers, often called "swamp coolers" reduce the temperature of indoor air by adding moisture. They supply large quantities of cooled and humidified outdoor air, and require discharge of equivalent indoor air quantities through open windows or gravity vents. In hot weather, direct evaporative supply air is sometimes too humid to fall within industry standard comfort limits.

Indirect/direct evaporative cooling (IDEC) systems improve on simple direct systems by precooling outdoor air without adding moisture by using an indirect evaporative heat exchanger upstream of a direct evaporative stage. Various types of indirect evaporative heat exchangers may be used, including tubes or parallel plates fed by evaporatively cooled air and cooling coils supplied with evaporatively cooled water. Recent experimental work by Professor Hofu Wu of Cal Poly Pomona, and simulation work by Joe Huang at Lawrence Berkeley Laboratory (among others), indicated that IDEC systems have the potential to satisfy full residential cooling loads in most California climates while maintaining indoor air within accepted humidity limits. (Some questions still remain regarding the health effects of indoor humidity on public health, which could impact the viability of IDEC systems if they fall outside of indoor humidity limits. PG&E should investigate this issue by querying the ASHRAE Standard 62 (Indoor Air Quality) committee and the Office of Statewide Health Planning and Development.)

IDEC cooling capacities and efficiencies are much more sensitive to outdoor wet bulb temperature than to dry bulb; at a fixed wet bulb temperature, cooling capacity actually increases slightly as dry bulb temperature increases. IDEC systems are rated in effectiveness, defined as the percentage of the wet bulb depression to which supply air is cooled; a 100 percent effective IDEC system delivers supply air at the wet bulb temperature. Typical units have effectiveness ranges from about 95 percent to 130 percent. Higher effectiveness improves the quality of supply air but reduces efficiency because more "throw-away air" is needed in the indirect stage. IDEC systems can significantly reduce cooling loads, particularly if house discharge air is exhausted through the attic rather than windows, thereby cooling the attic. Cooling load reduction accrues from eliminating latent loads; reducing ceiling, infiltration, and duct heat gains; and increasing air flow rates.

IDEC systems are commercially available. Adobe Air of Phoenix markets a large, modular IDEC system in its Master Cool line, which is available in California. A compact vertical design was recently developed and demonstrated by Davis Energy Group (DEG) under the California Energy Commission Energy Technologies Advancement Program (ETAP) (DEG 1995). The development project started in 1992 and concluded with successful field testing in 1994. Field test results and validated computer simulations predict a full-season statewide average operating efficiency of 59 SEER for the DEG IDEC design. With 660W peak demand, the design promises 75 to 90 percent demand reduction in new and retrofit markets and full season comfort in more than 99 percent of the California new construction market. While IDEC systems are thus technically feasible in nearly all California climates, to be conservative we assumed in the accompanying spreadsheet on this technology that it will be feasible in only 50 percent of applications. This conservatism is more a reflection of the barriers to market acceptance described above than an assessment of its true technical feasibility.

The DEG design was recently licensed to IDAC Technologies of Fair Oaks, which has teamed with Hydronic Specialties Corporation, Berkeley, for commercialization of the system.

XENERGY recently completed a mini-study for PG&E that identified a series of market barriers as well as possible interventions. Some of the market barriers to increased use of indirect evaporative cooling revealed in the study include:

- High first cost;
- Perception of low quality associated with "swamp coolers" and lingering concern over legionnaires' disease;
- Engineers' difficulty with estimating energy savings of IDEC systems over DX; and
- Impact on other sectors from laws prohibiting the use of DEC systems in hospitals.

In addition, the lack of a well-established distribution and service network, and possible opposition from the HVAC manufacturing industry contribute to limiting the market for IDEC systems. These barriers, however, need to be simultaneously addressed and further understood.

Thus, PG&E should conduct baseline assessments of both the market and the technology. PG&E should pursue a better understanding of the market for IDEC systems by characterizing and describing key technologies and quantifying their sales through the various distribution channels. As a part of this effort, PG&E should identify key market decision makers and the role of efficiency within their overall decision-making calculus; and document the decision-making process including the priorities and methods used by commercial cooling industry decision makers including end users, vendors, and manufacturers. Additionally, PG&E is encouraged to collect information on sales and energy performance of IDEC systems from which to test expected potential future market effects. In addition to interviewing manufacturers and representatives, it would be useful to broaden the perspective by including engineers, architects, contractors, and customers.

In order to overcome these real and perceived negatives, high profile demonstrations, consumer education, and the support of well-trained allies with excellent reputations will be needed. PG&E can provide direct support for demonstrations and then document and publicize the results. This information can be used in educating the public and the market distribution channel for IDEC systems about system performance and energy savings advantages. Additionally, PG&E can train HVAC contractors on installing and maintaining IDEC systems (perhaps building on lessons learned through NEEP's residential central air conditioning and heat pump equipment program).

Additionally, until market volume drives the cost of IDEC systems below that of conventional vapor compression equipment, cost subsidies may be needed. In the interim, PG&E should consider providing and evaluating the effectiveness of market interventions such as performance-based incentives to manufacturers of IDEC systems or to contractors, consumer financing (similar to financing offered to customers for high efficiency residential air conditioning equipment currently), and direct consumer rebates.

Indirect-Direct Evaporative Coolers (IDEC)

Measure Description: Two-stage evaporative cooling that provides efficient cooling relative to vapor compression equipment.

Market Information:		
Market sector:	RES	
End uses:	SPACE COOLING	
Energy types:	ELEC	
Market segment:	NEW, REP	
Base Case Information:		
Base case description:	Split system air conditioner, 3.5 ton	
Base case efficiency:	10.5	SEER
Base case annual energy use:	1,307	kWh
New Measure Information:		
New measure description:	IDEC unit, 3 ton	
New measure efficiency:	59	SEER - design conditions
New measure annual energy use:	170	kWh
Measure life:	15	years
Savings Information:		
Electric savings/year:	1,137	kWh
Gas savings/year:	NA	
Percent savings:	87%	
Feasible applications:	50%	
Savings potential in 2010:	399	GWH
Cost Information:		
Current measure cost:	$400	incremental cost increase vs. vapor compression AC
Future measure cost (in mass use):	(-$200)	less than replacemnt central AC in high volume production
Other direct costs/savings:	$13	media replacement cost
Cost of saved energy:	$0.011	kWh
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	Perception of evaporative cooling as "low quality"	
Effect on customer utility:	Increase indoor relative humidity; 100% outdoor air system	
Current activity @ PG&E:	Uncertain	
Current activity elsewhere:	SMUD is committed to install 30 units in 1997.	
Likelihood of success rating (1-5):	2	
Relationship to PG&E planning (1-3):	3	
Sources:		
Savings estimates:	IDEC Development Project Final Report (CEC 1995)	
Cost estimates:	Davis Energy Group (1997)	
Measure life estimates:	Davis Energy Group (1997)	
Other key sources:		
Principal contact(s):	Dan Field, IDAC Technologies, 916-536-0828 Dave Springer, Davis Energy Group, 916-753-1100 Lance Elberling, PG&E, 510-866-5519 Bruce Vincent, SMUD, 916-732-5397	

Notes: Basecase energy use from CEC (1995).
Annual costs are estimated at approximately $13 per year based on $100 media replacement every 8 years.

Residential Central Air Conditioning

Two types of residential central air conditioning units are widely used throughout the U.S.: single package and split. They differ in that split systems separate the evaporator and condenser with the condenser located outside of the house and the evaporator inside. In a single package system, as the name implies, all elements are in a single box located outside. Single package systems are common in warm climates. A 1994 EPRI survey indicated that the markets for single package and split systems is evenly divided, and overall represent 50.6 percent of 1.5 million air conditioning units shipped nationally in that year (Gregerson and George 1995).

Split systems are generally more efficient than single package systems in residential sizes. Efficiency at this size level (65,000 Btu per hour or less) is measured as SEER. Systems above 65,000 Btu per hour are rated in EER rather than SEER. PG&E has been promoting SEER 12 models; and SEER 13 to 14 units are now available in the North American market for reasonable cost. Comparison of two 5-ton split systems manufactured by York at SEER 10.3 and 14.6 respectively, demonstrated annual savings of $209 at $0.08 per kWh. At an incremental cost of $600, simple payback was estimated at just under three years (E Source 1993c).

A number of technical developments that could improve energy performance of residential central air conditioning systems are also underway. New compressor developments offer the potential to increase efficiency by one SEER and Modine, a manufacturer of heat exchangers, is developing a unit that could increase efficiency by two SEER (Pham 1997; Modine 1996).

In much of the country, air conditioning use tends to closely coincide with utility system peaks. As a result, many utilities have sponsored efficiency programs for air conditioning equipment., although the approach used and efficiency levels adopted have varied considerably. To address this, the Consortium for Energy Efficiency (CEE) developed a national initiative with guidelines for utilities on equipment efficiency levels and installation practices to incorporate into their programs. Efficiency levels supported by CEE members are SEER 12 (tier 1), SEER 13 (tier 2) and Seer 14 (tier 3). Based originally on CEE's tier 1 levels, the EPA ENERGY STAR® program for heat pumps and air conditioners specifies a minimum of SEER 12 (and an HSPF of 7) to qualify for the ENERGY STAR® label.

A recent study by CEE (1997b) assessed the market share of high-efficiency air conditioners as well as the most appropriate market transformation tool in regions with strong utility programs. Market penetration for air conditioners of SEER 12 or greater in leading utilities' service territories (of which PG&E is one) in general is significant (for most regions, the replacement market share is 40 percent or more). But the best tool for achieving high market penetration is less clear (CEE 1997b).

Based on CEE's study, rebates appear more attractive to consumers than loan programs, even when the monetary transfer to the consumer is significantly better with the loan program. For example, when the City of Austin offered loans with a zero interest rate, where the buydown on the loan was 50 to 100 percent greater than the direct rebate for high-efficiency equipment, more customers preferred direct rebates. In part, this is attributed to the fact that consumers do not generally purchase HVAC equipment on credit. However, newer loan programs have incorporated lessons learned from earlier programs that may result in greater loan program impacts in the future. These include ensuring quick turnaround on loan approval, making loan processing easy, and making the loan products as similar to cash as possible (e.g., zero interest, etc.) (CEE 1997b).

Additionally, building and maintaining a strong relationship with contractors has been identified as key to successful market transformation programs. Transformation can also be promoted by working with the distribution network to improve and ensure adequate stocking, improve dealer sales training, and by working to improve new DOE standards. Rulemaking for the new standard is scheduled to start in 1998 and be completed by 2000, with a new standard going into effect 5 years from completion. An early DOE analysis indicated that a SEER 15 standard would be cost-effective. However, this analysis is being revisited. A standard of at least SEER 13 is highly likely, given that at least one manufacturer has indicated that a standard between 12.5 and 13.5 SEER is likely (Carrier 1994).

Residential Central Air Conditioning

Measure Description: Very high efficiency residential air conditioning

Market Information	
Market sector:	RES
End uses:	COOLING
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information	
Base case description:	Average home in California with CAC
Base case efficiency:	10 SEER
Base case annual energy use:	1,507 kWh, CAC + space heat
New Measure Information	
New measure description	3 ton split system - high efficiency
New measure efficiency:	14 SEER
New measure annual energy use:	1,077 kWh
New measure life:	15 years
Savings Information	
Electric savings/year:	431 kWh
Gas savings/year:	NA
Percent savings:	29%
Feasible applications:	85%
Savings potential in 2010:	244 GWH
Cost Information	
Current measure cost:	$1,000 incremental, installed cost
Future measure cost (in mass use):	$400
Other direct costs/savings:	NA
Cost of saved energy:	$0.10 per kWh
Data Quality Assessment	B
Liklihood of Success	
Major market barriers:	Cost, knowledge, stocking
Effect on customer utility:	Possibly improved comfort
Current activity @ PG&E:	Replacement
Current activity elsewhere:	Numerous utilities
Likelihood of success rating (1-5):	4
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	Based on change in SEER
Cost estimates:	XENERGY (1996); Proctor (1997)
Measure life estimate:	DOE (1994)
Other key sources:	Proctor (1997)
Principal contact(s)	Lorna Rushforth, PG&E, 415-972-5397

Notes: Percent feasible (85%) assumes that 15% of homes are located in climates with insufficient operating hours to justify increased cost.

Efficient Windows - Residential

Typical residential windows in existing California construction have aluminum frames, high U-values, and are single-glazed. U-value is a measure of energy transmittance, the inverse of R-value, so more efficient windows have lower U-values. California Title 24 upgraded standards for new windows to double-glazed. These were assumed by regulation to have a default value of 0.6 before standardized testing was instituted in 1992.

U-value considers only heat transmission. However, in PG&E's service territory, heat gains through windows are a major contributor to building cooling load. The Solar Heat Gain Coefficient (SHGC) is an additional measure of window performance that considers heat gains which affect cooling energy. SHGC depends primarily on a window's ability to block infrared wavelengths of light through tints and selective coatings. More efficient windows have lower SHGC values.

For this analysis, the base case window is a double-glazed, clear window with U-value of 0.65 and SHGC of 0.66, a typical new window that meets California's Title 24. The replacement window analyzed is a wood or vinyl-framed double-glazed window, low-e, and argon-filled. Its U-value and SHGC are 0.33 and 0.44 respectively.

High costs are the primary market barrier to customers adopting efficient windows. But costs for energy-efficient windows are highly variable regionally, and even locally. According to Reilly, et al. (1996), the incremental cost for high-efficiency windows in Pheonix is as high as $14 per square foot. However, in the Pacific Northwest, where high-efficiency windows have been heavily promoted for some years, incremental costs can be as low as $3 per square foot (Eto et al. 1996). Continued promotion by PG&E should have a similar effect in its service territory, resulting in long-term market stimulus and transformation. PG&E promotion can take the form of customer education and research and development aimed at reducing manufacturing costs. Regional approaches to transforming residential window markets, in particular, appear to be productive.

Two relevant and recent activities to address window efficiency include DOE and EPA's ENERGY STAR® labeling program (labels are expected to be found in stores in 1998) and the formation of the Efficient Windows Collaborative (EWC). The EWC is a coalition of manufacturers, researchers, and government agencies that aims to expand the market for high-efficiency fenestration products. To achieve its goals, the EWC:

- Provides consumer education;
- Offers training and education to company sales forces and trade ally audiences;
- Develops demonstration projects to create region-specific marketing and education opportunities;
- Works to strengthen national and state building codes to incorporate efficient window standards; and
- Communicates information on market trends, technical information, training opportunities and demonstration results to a broad audience.

PG&E is already working with the EWC to identify the technical criteria for its program focusing on energy efficient windows. And the EWC is working with several states including California to provide training for producers, specifiers and state officials. PG&E can also provide regional education, publicity, and other support for the EWC activities and ENERGY STAR® programs in PG&E's service territory. In addition, PG&E can help to coordinate regional training programs for the EWC. To address the high first cost barrier, PG&E can work with local lenders (and together with EWC with national lenders) to help facilitate the availability of financing for the window replacements. PG&E can also work to strengthen Title 24 to gain wider recognition for efficient window technology.

Efficient Windows - Residential

Measure Description: Double-glazed, argon -filled windows

Market Information				
Market sector:	RES			
End uses:	COOL, HEAT			
Energy types:	ELEC, GAS			
Market segment:	NEW, REP			
Base Case Information				
Base case description:	Double glazed, clear window, 300 sq ft glazing, 2000 sq ft home			
Base case efficiency:	U-value 0.64, SHGC 0.65			
Base case annual energy use:	1,307	kWh	353	therms
New Measure Information				
New measure description	Double glazed,wood/vinyl, low-e, argon filled			
New measure efficiency:	U value 0.33, SHGC 0.44			
New measure annual energy use:	1,111	kWh	307	therms
New measure life:	35	years		
Savings Information				
Electric savings/year:	196	kWh		
Gas savings/year:	46	therms		
Percent savings:	15%	elec cool;	13%	gas heat
Feasible applications:	66%			
Savings potential in 2010:	78	GWH		
	3	TBTU		
Cost Information				
Current measure cost:	$438	per home, incremental		
Future measure cost (in mass use):	NA			
Other direct costs/savings:	NA			
Cost of saved energy:	$0.05	per kWh		
	$0.45	per therm		
Data Quality Assessment	B			
Liklihood of Success				
Major market barriers:	Cost, availability, consumer interest			
Effect on customer utility:				
Current activity @ PG&E:				
Current activity elsewhere:	SRP, Seattle City Light			
Likelihood of success rating (1-5):	3			
Relationship to PG&E business plan (1-3):	3			
Sources:				
Savings estimates:	Carmody (1996)			
Measure life estimates:	Frost et al. (1996)			
Cost estimates:	Reilly (1996), XENERGY (1996), Frost et al. (1996)			
Other key sources:				
Principal contact(s)	Lauren Casentini, Pacific Gas & Electric, 415-973-8890			

Notes: Savings estimated on basis of fenestration heating and cooling ratings (FCR and FHR) in Carmody (1996). Incremental cost based on Xenergy (1996) assumes high volume purchase at $1.46 per sq ft. Costs allocated 31% to electric and 69% to gas based on primary energy savings.

Integrated Commercial Building Design

Energy savings in new commercial buildings can often be increased by treating the building as a whole, integrated system, as opposed to a set of independent building subsystems, i.e., lighting, building envelope, HVAC equipment, etc. This approach allows designers and engineers to better capture the synergies among building subsystems. For example, improving lighting systems will decrease building cooling loads, potentially allowing the downsizing of the cooling plant. A number of utilities including PG&E, New England Electric Systems and Northeast Utilities have included an integrated, or comprehensive, building design pathway as part of their new construction program offerings.

To be effective, an integrated building design initiative must identify new buildings very early in their design or conceptual stages. Coordination among the various design and engineering professionals, as well as the building owner/occupant, is also required. Further, building commissioning is typically necessary to ensure the success of integrated design efforts. Failure to do so often results in lost savings, particularly where sophisticated controls are involved. Recently, performance contracting approaches to energy savings in new buildings have been pursued. A new municipal building is under construction in Oakland where design professional compensation is tied to two years of monitored energy performance (Eley 1997).

Energy savings and cost inputs for the attached measure characterization were derived from the Energy Edge commercial new construction program. The Energy Edge Program in the Pacific Northwest monitored the performance of 28 buildings that were built using integrated building design procedures (Piette et al. 1994). The energy use goal for these buildings was to save 30 percent relative to the Model Conservation Standards -- guidelines developed by several Northwest organizations. This goal, however, was met in only some of the buildings. Average savings estimates ranged from 13 to 71 percent depending on the savings methodology employed, and how the results were weighted (observations vs. floor space). The lower estimate reflects the poor performance for one very large building in the tuned-building subsample (tuned simulation models were only developed for 18 of the 28 buildings in the program). Further, the end uses included in the savings estimates varied by building type. Based on the Energy Edge savings data, we have assumed a 17 percent reduction in electric heating, cooling, ventilation and lighting across all new building square footage (most of the Energy Edge buildings had little, if any, gas usage). Measure costs in the attached cost of saved energy calculation are based on the most cost-effective applications in Piette et al. (1994), adjusted at four percent per year from the 1991 cost basis reported.

Barriers to effective integrated building design include: uniform construction specifications (i.e., national builders may develop specifications in all buildings designed under a given national account); reluctance to change fee schedules and inadequate allowance in the current fee schedules for design optimization time; uncertainty about energy savings (calculating savings arising from more complex building interactions and control strategies can be complicated); lack of easy to use software tools to perform design tasks and savings calculations, particularly for smaller buildings; and reluctance on the part of system designers to downsize HVAC systems to realize capital cost reductions.

Like other California utilities, PG&E had linked components if its commercial new construction program to the Title 24 energy performance budgets. Incentives were paid for estimated savings calculated from a code baseline. Recently, however, PG&E has moved away from incentivizing measures and estimated energy savings. While distributor and vendor rebates are still available for packaged HVAC equipment and for motors, PG&E is now only offering financial incentives for design assistance. This approach emphasizes a multi-end use, integrated approach to new building energy efficiency. PG&E is also supporting the New Buildings Institute which is working on the Multi-state Working Group Code. Finally, through its Energy Standards Program, the utility is working with the California Energy Commission to influence the direction and stringency of future Title 24 building standards.

There are two tiers of program offerings in the Design Assistance Program, depending on the facility size. In Tier 1, smaller buildings of 30,000 to 100,000 square feet are eligible for design awards; cash incentives to help defray the costs associated with additional design fees. For larger Tier 2 buildings, PG&E consultants work directly with the design team to optimize building performance.

Potential areas of activity that PG&E could pursue to further support integrated building design include:

- System or state-wide market research activities - the Northwest Energy Efficiency Alliance (NEEA) sponsored six months of surveys of current attitudes and practices in new construction prior to recently announcing their three-year, $6.7 million campaign to develop and support energy-efficient building practices.

- Develop simplified simulation tools - while the recent introduction of Windows based-PowerDOE holds the promise of making DOE2 more accessible, there is still be a need for a simplified simulation tool, particularly for smaller commercial buildings. NEEA is developing such a tool for designing smaller buildings. However, a simulation or design tool which does not have DOE2 as its calculation engine raises questions regarding compliance with Title 24 standards.

- Simulation tool training - training could be done in conjunction with ASHRAE at the PG&E Energy Center.

- Promote case studies - PG&E can highlight successful case studies of integrated building design.

- Leverage PG&E Exchange websites - the lighting, HVAC and architectural Exchange websites should all explicitly address the integrated design concept.

- Develop a handbook and/or set of templates of recommended practices - these would be useful for smaller buildings where integrated building design skills are likely to be the most limited. These practice guidelines could also be incorporated into one or more of the Exchange websites.

- Support building commissioning - commissioning helps ensure that the savings promised by more sophisticated HAVC and control systems are realized. Development of building commissioning protocols could be included under this task.

- Emphasize non-energy benefits of integrated design - good design should also maintain, if not increase, customer comfort and indoor air quality.

Integrated Building Design

Measure Description: Promote integrated building design practices in the commercial sector

Market Information:		
Market sector:	COM	
End uses:	HEAT, COOL, VENT, LTG	
Energy types:	ELEC	
Market segment:	NEW	
Base Case Information:		
Base case description:	Current code constrution practices	
Base case efficiency:	NA	
Base case annual energy use:	182	GWH annually for specified end uses
New Measure Information:		
New measure description:	Improved building design/commissioning	
New measure efficiency:	NA	
New measure annual energy use:	151	GWH annually for specified end uses
Measure life:	30	years
Savings Information:		
Electric savings/year:	31	GWH for commercial new construction
Gas savings/year:	NA	
Percent savings:	17%	electricity
Feasible applications:	80%	not appropriate for smaller buildings
Savings potential in 2010:	202	GWH
Cost Information:		
Current measure cost:	$3.16	per sq ft
Future measure cost (in mass use):	$1.58	per sq ft assumes current cost could be cut in half
Other direct costs/savings:	NA	
Cost of saved energy:	$0.03	kWh
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	Difficulty in coordinating design team members, extra design time	
Effect on customer utility:	Increased occupant comfort	
Current activity @ PG&E:		
Current activity elsewhere:	NEES, UI, PacifiCorp, NU	
Likelihood of success rating (1-5):	3	
Relationship to PG&E planning (1-3):	3	
Sources:		
Savings estimates:	Piette (1994)	
Cost estimates:	Piette (1994)	
Measure life estimates:	Gordon (1988)	
Other key sources:	Eley (1997)	
Principal contact(s):		

Notes: Base case and new measure energy use are based on stock, not marginal EUIs
Electricity savings based on Piette et al. (1994) impact evaluations of Energy Edge program.
Cost of saved energy based on selected highly cost–effective applications reported in Piette et al.

Efficient Windows — Commercial

Window conduction and solar heat gain represent a substantial portion of aggregate commercial building loads. These loads can be decreased through greater use of advanced windows. Standard existing windows for the PG&E service territory consist primarily of aluminum frame, single-pane windows, with high solar gains and conductivity losses. Typical U-value for this type of window is 1.3 according to Carmody & Crooks (1996), and we have assumed a solar heat gain coefficient (SHGC) of 0.69. California Title 24 established a minimum standard U-value of 0.6 for new and replacement windows. But better-performing windows are available with U-values as low as 0.35 (Reilly et al. 1996). Advanced windows include low-e, tinted, dual-glazed windows with thermal breaks. Foam-filled frames, strengthened in cross section can reduce U-value even further, to as low as 0.29. Glazings can be made spectrally-selective, creating a glazing unit with a SHGC of 0.5 while still maintaining 70 percent visible transmittance (Nadel et al. 1993). An increasing number of windows use larger thermal breaks and/or inert gases as additional insulating features.

For this analysis we have examined a low-e double-glazed window, assumed to reduce heating and cooling energy use by 30 percent relative to single-pane windows. However, actual savings are highly sensitive to building prototype assumptions and will vary widely in the field as a function of window-to-wall ratios, orientation, external shading, etc. Current incremental cost of these windows can be significant -- approximately $6 more per square foot, but costs could decrease substantially in heavily promoted markets, as is evidenced by residential window market transformation efforts in the Pacific Northwest (XENERGY 1996; Eto et al. 1996).

The principal barriers to adopting advanced windows are lack of knowledge about products and an unwillingness on the part of commercial buildings owners to take on additional costs involved in purchase and installation, particularly if costs cannot be easily be passed through to tenants. Additionally, better windows are not routinely stocked by distributors and are often premium-priced items.

The National Fenestration Rating Council (NFRC) rating system has helped to address the lack of knowledge about products, by developing a technical standard by which all manufactured, not site-built, windows can be measured. One of NFRC's chief successes has been getting the NFRC rating method referenced in major residential building codes. The 1995 Model Energy Code (MEC) and California Title 24 both require that windows be rated according to the NFRC procedure, for example. SHGC has recently been incorporated into the NFRC rating and is likely to be referenced in the 1998 update to Title 24. The current review draft of the ASHRAE 90.1R commercial building code also requires that manufactured windows be rated in accordance with NFRC procedures. While their principal focus has been on rating and certifying residential-type windows, applicable to many low-rise commercial buildings, the NFRC is also currently working on a certification system for curtain wall, which comprises the majority of glazing in larger commercial windows.

Many commercial and residential utility programs have attempted to influence the windows market. PG&E through its non-residential new construction program offers incentives for efficient windows. Equally important is educating those in the market distribution system who select, specify, and purchase windows. Architects and engineers, for example, require educational materials for their own information and to pass on to their clients; technical assistance; and improved specifications for fenestration performance. PG&E could be a conduit of information on window rating, demonstration projects, and new research and development. To promote use of high-efficiency window options to architects, PG&E could highlight the fact that efficient glazing together with other skin and internal load reductions may reduce the size of HVAC components located on the rooftop, and hence increase the building's aesthetic value. Additionally, PG&E could offer recognition to architects that incorporate efficient windows into their building design. To major commercial developers and building owners, PG&E could provide education on the costs and benefits of more efficient glazing systems (including reduced glare and worker eye strain in addition to improved thermal comfort and energy savings), so that these groups begin to request that high-efficiency systems be incorporated into their buildings.

PG&E should also be aware of a number of primarily residential-focused national market transformation activities are underway. The Efficient Windows Collaborative (EWC), for example, spearheaded by the Alliance to Save Energy, Lawrence Berkeley National Laboratory (LBNL) and others will make information on efficient window performance and new technologies widely available, and offer technical assistance and training to a builders, architects, engineers, and others. Their focus, at least initially, will be the residential market, although they plan to expand to deliver these services to the commercial windows market as well (Prindle 1997). PG&E should identify how it can work with the Collaborative to efficiently deliver training and education to the market place.

Also, DOE has recently unveiled an ENERGY STAR® windows program to identify residential windows with high performance in different climate regions. A draft specification for that program is currently undergoing review. At the same time, the Oregon Office of Energy is organizing a similar market transformation effort to distinguish high-efficiency windows from standard windows that meet code.

Efficient Windows - Commercial

Measure description: Replace windows with high performance commercial windows, double-glazed, low-e windows

Market Information	
Market sector:	COM
End uses:	HEAT, COOL, VENT
Energy types:	ELEC, GAS
Market segment:	NEW, REP
Base Case Information	
Base case description:	Single-glazed windows
Base case efficiency:	1.3 U-value; 0.69 SHGC
Base case annual energy use:	42,700 Btu/sf (including 2.9 kWh/sf and 0.13 therms/sf)
New Measure Information	
New measure description	Double-glazed, low-e windows
New measure efficiency:	0.45 U-value; 0.45 SHGC
New measure annual energy use:	34,324 Btu/sf (including 2.3 kWh/sf and 0.10 therms/sf)
New measure life:	35 years
Savings Information	
Electric savings/year:	0.61 kWh per sq ft floor area
Gas savings/year:	0.03 therm per sq ft floor area
Percent savings:	20% of HVAC energy use
Feasible applications:	85% of all comm'l buildings
Savings potential in 2010:	399 GWH
	1 TBTU
Cost Information	
Current measure cost:	$1.46 per sq ft floor area
Future measure cost (in mass use):	$0.50
Other direct costs/savings:	NA
Cost of saved energy:	$0.04 per kWh
	$0.37 per therm
Data Quality Assessment	C
Liklihood of Success	
Major market barriers:	Initial cost
Effect on customer utility:	Improved lighting, decreased fading from UV protection
Current activity @ PG&E:	Possible in new construction program
Current activity elsewhere:	In some utility new construction programs, NFRC
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	Carmody & Crooks (1996)
Cost estimates:	XENERGY (1996), Frost et al. (1996)
Measure life	Frost et al. (1996)
Other key sources:	E Source (1995); baseline derived from DOE/EIA (1995)
Principal contact(s)	Gary Fernstrom, PG&E, 415-973-6054

Notes: Base case EUIs derived from DOE/EIA (1995) represent heating, cooling, and ventilation energy in West. Cost per square foot could decrease substantially in a heavily promoted market as in the Pacific Northwest per Eto (1996). Savings from decreased fabric wear from UV protection not quantified.
Costs are allocated 68% to electricity and 32% to gas based on energy savings.
Assumes exterior wall area equals floor area and that 25% of wall area is windows.

Water Heating - Residential

Heat Pump Water Heaters - Residential

An electric heat pump water heater (HPWH) uses a vapor-compression thermodynamic cycle similar to that found in an air-conditioner or a refrigerator. The electrical work input to the process allows a HPWH to extract heat from an available source (e.g., the air) and reject that heat to a higher temperature sink, in this case, the water in the water heater. Since HPWHs make use of available ambient heat rather than generating all of the heat required to heat the water, their energy factors (EFs — the ratio of heat output to energy input) can be greater than one. Most units have EFs ranging from 2.0 to 2.6. In contrast, conventional water heaters must generate 100 percent of the energy required to heat the water, usually with a gas burner or electric resistance heating element.

The heat pump can be integrated with a traditional water storage tank or installed remote to the storage tank (add-on). Because of their relatively low cost and attractiveness for retrofit applications, add-on HPWHs are the focus of this analysis. Electric resistance hot water heaters typically provide backup for quick recovery during periods of high water consumption and for operation at low ambient temperatures.

Residential HPWHs were commercially introduced to the U.S. market in the 1970s. Due in large part to utility incentive programs, HPWH sales in the early 1980s were significant. However, equipment reliability problems and infrastructure shortcomings resulted in the termination of most utility support. The anticipated non-incentivized sales never materialized as a result of HPWHs high initial cost and other consumer and infrastructure barriers. In the early 1990s, EPRI issued an RFP for the production of a low-cost HPWH appropriately-sized for the residential market. The result of these efforts was the development of Crispaire Corporation's E-Tech WB-6 add-on HPWH. Since its introduction, this unit has undergone a number of modifications and improvements. Currently, Crispaire is the only company that produces an add-on residential HPWH. The Dairy Equipment Corporation (DEC) produces an integral HPWH which it sells at twice the cost. A number of other companies (e.g., Florida Heat Pump, Lennox), however, have integrated or plan to integrate HPWHs into combined space conditioning/water heating systems (ACEEE 1996). DOE is also funding development of a low-cost integrated HPWH. However, these products are not appropriate for retrofit applications.

Many utilities have been reluctant to support the technology through their own programs until HPWH performance and reliability are proven. Northeast Utilities (NU) is one of the few utilities with significant field experience with the Crispaire models and has had a large hand in fostering continuous product improvement. NU has ordered 2,600 HPWHs from Crispaire and is offering these to its residential electric water heating customers at the cost of installation. Thus far, NU has installed more than 300 HPWHs in homes throughout its service territory (Stone 1998).

In other developments, the President's 1998 budget proposal includes federal tax credits to spur the development of advanced technologies. As of this writing, the tax credit proposal includes a 20 percent tax credit for HPWHs (with EFs most likely in the range of 1.5 to 1.8) as part of a package of tax credits for advanced building technologies. It is uncertain, however, whether Congress will enact such a tax credit, and if Congress does enact such a credit, details of the program are likely to change significantly from the President's proposal.

At this time, concerns about reliability, infrastructure, and consumer satisfaction remain. PG&E could support field testing to assess performance, and build consumer confidence, and work with pluming and electrical contractors to build infrastructure for HPWHs. These activities could greatly improve the long term market potential for HPWHs.

Heat Pump Water Heaters - Residential

Measure Description: Retrofit existing electric resistance water heater with add-on heat pump water heater

Market Information:	
Market sector:	RES
End uses:	DHW
Energy types:	ELEC
Market segment:	RET
Base Case Information:	
Base case description:	Existing 40 gal elec WH: add on HPWH
Base case efficiency:	0.9 EF for a typical hot water heater
Base case annual energy use:	4,012 kWh
New Measure Information:	
New measured description:	6000 Btu per hour -- Crispaire E-Tech WH-6-bx
New measure efficiency:	2.0 EF
New measure annual energy use:	1,805
Measure life:	15 years
Savings Information:	
Electric savings/year:	2,207 kWh
Gas savings/year:	NA
Percent savings:	55%
Feasible applications:	23% of all homes with electric water heating
Savings potential in 2010:	21 GWH
Cost Information:	
Current measure cost:	$900 incremental
Future measure cost (in mass use):	$600
Other direct costs/savings:	$20 annual maintenance costs
Cost of saved energy:	$0.04 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, reliability, infrastructure, education
Effect on customer utility:	Cooling/dehumid impacts in some cases
Current activity @ PG&E:	None: Removed from plan for reliability reasons
Current activity elsewhere:	NE and NW utilities, DOE, ACEEE, EPRI
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Souces:	
Savings estimates:	Crispaire Corp. manufacturer literature, Stone (1997)
Cost estimates:	Stone (1997)
Measure life estimates:	NWPPC (1996)
Other key sources:	ADL (1996b), ADL (1996c)

Principal contact(s):

Notes: Baseline energy use assumes household of four persons or more (ADL 1996b).
Percent feasible (23%) represents the percent of homes, nationally, with electric water heating and 4 or more occupants.

Integrated Electric Space Conditioning/Water Heating Heat Pumps

Integrated space conditioning and water heating heat pumps, or multi-function, full condensing systems, provide on-demand water heating and space heating and cooling. In these systems, rejected heat from space cooling provides "free" water heating; if the water heating load exceeds the rejected heat from space cooling, the integrated heat pump operates in air source heat pump mode to heat water; and when space heating is required, water is heated in ambient air source heat pump mode with the heat output shared between the water and space heating. When the ambient temperature falls below the balance point, the water is heated by back-up electric resistance heat. The combined effect of all these modes is a 50 to 60 percent reduction in water heating energy consumption compared to electric resistance (Thorne 1998).

The primary manufacturer of residential, multifunction, full-condensing heat pumps is Nordyne. Nordyne's Powermiser, developed in conjunction with EPRI is a single compressor heat pump system. Their highest efficiency model is SEER 13, and thus eligible for a wide range of utility incentive programs. Several utilities are actively promoting the Powermiser to compete with gas appliance manufacturers for water heating market share.

Lennox has launched a competing product. Like other multi-function systems, Lennox's AquaPlus system, combines a heat pump water heater with a central air conditioning system, to provide heat, cooling, and water heating on demand. Lennox's model has separate compressors for space and water heating, allowing it to function for water heating and space conditioning independently, differentiating it from the Nordyne model. As such the product can be added to an existing space conditioning or water heating system, providing greater installation flexibility and lowering installation costs relative to installing a new heat pump (Lennox 1996). Other manufacturers of multi-function units include Colmac Coil and Wallace Energy Systems. The Hydrotech 2000, a very high-efficiency, variable-speed integrated heat pump developed by Carrier and the Electric Power Research Institute (EPRI) was pulled from the market in 1993. Its high price, unproven track record, and concerns about the system's reliability contributed to the product's slow sales.

These systems' installed cost premium is between $1000 and $1500 over a standard heat pump, although full system costs (currently ranging from about $4000 to $5500) are anticipated to decline by 10 to 15 percent as production volume increases (Thorne 1998). Water heating energy and cost savings of 50 percent are typical, with overall space conditioning and water heating savings of approximately 10 percent. Typical payback periods relative to standard electric resistance water heater range from 3.6 to 6.6 in Northern California climates (ADL 1996b).

At this point, however, there are a number of barriers to their increased penetration, including; high first costs, minimal contractor knowledge, uncertainties about system performance and reliability, and little consumer awareness about the energy and cost savings potential. Also, the lack of a standard performance measure for these systems hinders this market. DOE granted a waiver to Nordyne to allow the use of a new rating procedure for measuring the performance of the Powermiser, which arrives at "combined heating (and cooling) performance factors" to reflect space conditioning and water heating loads during the heating (and cooling) season. Utility efforts to educate consumers, financing to alleviate the first cost hurdle, and direct incentives can help promote this technology particularly in regions with all-electric households.

Integrated Electric Space Conditioning/Water Heating System

Measure Description: Promote integrated heat pumps, which both space conditioning and water heating

Market Information:	
Market sector:	RES
End uses:	HEAT, COOL, DHW
Energy types:	ELEC
Market segment:	NEW
Base Case Information:	
Base case description:	3 ton heat pump/40-gal electric water heater
Base case efficiency:	10 SEER heat pump; 0.90 EF water heater
Base case annual energy use:	8,225 kWh
New Measure Information:	
New measured description:	High-efficiency multifunction heat pump system
New measure efficiency:	12 SEER heat pump; ~ 50% avg. water heating savings
New measure annual energy use:	5,848 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	2,378 kWh
Gas savings/year:	NA
Percent savings:	29%
Feasible applications:	100% of new homes with HPs and electric water heating
Savings potential in 2010:	6 GWH
Cost Information:	
Current measure cost:	$1,200 incremental
Future measure cost (in mass use):	$600
Other direct costs/savings:	$0
Cost of saved energy:	$0.03 per kWh
Data Quality Assessment	B
Likelihood of Success:	
Major market barriers:	High first cost, lack of familiarity with technology
Effect on customer utility:	Very little
Current activity @ PG&E:	None
Current activity elsewhere:	Manufacturer efforts; EPRI; some utilities
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Souces:	
Savings estimates:	Carr (1997); Thorne (1998)
Cost estimates:	Carr (1997); Thorne (1998)
Measure life estimates:	DOE (1994)
Other key sources:	Nordyne (1997); Lennox (1996b)
Principal contact(s):	Tom Carr, Lennox Industries, 214-497-5082

Notes: Assumes 4,800 new electric homes each year from 1998 to 2010 based on CEC (1996).

Integrated Gas-Fired Space/Water Heating System

A range of gas- and oil-fired technologies that integrate space and water heating have been developed. Manufacturers offer products ranging from truly integrated systems to components, such as storage tanks and controls, for use with standard boilers. The market is characterized by products designed for warm-air and hot-water distribution systems.

Two types of integrated warm-air distribution systems are currently available. The first couples a furnace with a water storage tank and electronic control logic to meet both space and water heating demands. Water in a heat exchanger coil is heated in the furnace and circulated through the water heater to maintain the required domestic water temperature. A second type uses a powerful hot water heater to meet space conditioning needs. Heated water from the water heater tank passes through a heat exchanger in a fan-coil unit. Heated air is then sent through ducts to heat the home. These systems are often referred to as combination systems. Several combination models are on the market, and models that incorporate a high-efficiency condensing hot water heater (such as the American Water Heater Polaris and Lennox CompleteHeat) realize efficiency gains over traditional equipment.

Integrated hot water distribution systems consist primarily of conventional boilers that provide water heating by passing heated boiler water through a heat exchanger in a separate water storage tank. The water storage tank is insulated to reduce heat losses and improve efficiency. Electronic control logic determines when water in the tank falls below the preset temperature and triggers the boiler to turn on and provide heat as long as needed. These systems make use of the boiler year-round. Space heating can be provided via hydronic baseboards or radiators, forced-air, or radiant heat. Efficiency gains are realized through the use of sealed-combustion, condensing burners and heat purging. The more sophisticated of these systems rely on a heat purge cycle to circulate residual heat remaining in the heat exchanger into the water storage tank after the boiler shuts down.

Integrated water heating systems realize efficiency gains over conventional equipment in several ways: by eliminating the need to power multiple appliances; by using the primary appliance more fully; and by incorporating high-efficiency components. Integrated boiler and furnace units operate at high efficiencies with annual fuel utilization efficiencies (AFUE) ranging from 86 to 91 percent. By comparison, the sales weighted average for new boilers and furnaces is 81 to 82 percent. Condensing hot water heaters used in high-efficiency combination systems have energy factors (EFs) of 0.82 to 0.86, much higher than the sales weighted average of new gas water heaters (0.55) and even of the most efficient models which have EFs ranging from 0.60 to 0.64. Overall efficiencies for combination systems are typically reported as combined annual efficiency (CAE), and a CAE of 90 percent is typical of these systems (Thorne 1998).

Integrated gas-fired boiler systems and combination systems can reduce total energy use for space heating and water heating by 11 to 18 percent, with water heating savings on the order of 31 to 36 percent. Savings associated with high-efficiency combination systems tend to be higher than those for boiler-based systems due to gains in water heating efficiency provided by the condensing water heater (Thorne 1998).

For the purpose of this analysis, we have assumed an high-efficiency combination system with a CAE of 90 percent replaces both a standard 40-gallon gas water heater with an AFUE of 80 percent and an energy factor (EF) of 0.54. Baseline incremental equipment costs are from Thorne (1998): current costs are reported as $1,265, and future costs estimated at $515.

Chief market barriers to integrated gas-fired systems include: limited active promotion of high-efficiency gas water heating, lack of comparable performance indicators for consumers, and poor infrastructure for distribution, installation and service. Key market transformation opportunities lie in working with manufacturers and trade organizations to develop training and training materials for installers and educational information for consumers.

Integrated Gas-Fired Space/Water Heating System

Measure Description: Promote installation of high-efficiency gas space/water heating systems in new gas homes

Market Information:		
Market sector:	RES	
End uses:	HEAT, COOL, DHW	
Energy types:	GAS	
Market segment:	NEW	
Base Case Information:		
Base case description:	Average energy use for space cond/water heating	
Base case efficiency:	0.54	EF w/approx 80 AFUE furnace, 60 KBtu
Base case annual energy use:	730	therms
New Measure Information:		
New measured description:	Condensing gas water heater/space heat provider	
New measure efficiency:	Combined annual efficiency = 90%	
New measure annual energy use:	635	therms
Measure life:	20	years
Savings Information:		
Electric savings/year:	NA	
Gas savings/year:	95	therms, includes space heating savings
Percent savings:	13%	
Feasible applications:	100%	of new homes w/gas space heat
Savings potential in 2010:	2	TBTUs
Cost Information:		
Current measure cost:	$1,265	incremental
Future measure cost (in mass use):	$515	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.47	per therm
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	Lack of info, dealer stocking, no stnd measure of perform.	
Effect on customer utility:	None	
Current activity @ PG&E:	None	
Current activity elsewhere:	Manufacturer activities, SCG	
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Souces:		
Savings estimates:	Thorne (1998)	
Cost estimates:	Thorne (1998)	
Measure life estimates:	Thorne (1998)	
Other key sources:	American Water Heater (1997)	
Principal contact(s):	Jennifer Thorne, ACEEE, 202-429-8873 American Water Heater, 800-288-1899	

Notes: This analysis assumes 500 therms per year UEC for gas furnaces. The number of new homes w/gas furnaces is estimated at 27,000 based on CEC data on electric furnace fan saturation.

Instantaneous Gas Water Heaters

The vast majority of water heating needs in California are served by gas storage-type water heaters. Storage water heaters, however, lose considerable energy through the tank walls when the heater is idle. These "standby" losses are estimated to be on the order of 30 to 50 percent, depending on hot water draws. Instantaneous or "tankless" gas water heaters, widely used in Europe and Japan, can minimize these losses. These water heaters do not store hot water but heat water on-demand.

Two types of instantaneous water heaters exist — those with standing pilots and those with intermittent ignition. Unlike a conventional water heater where the standing pilot contributes to heating the water, standing pilots in instantaneous water heaters result in wasted energy. These models show only modest savings compared to tank-type water heaters. Here, we focus on intermittent ignition instantaneous water heaters.

Intermittent ignition instantaneous water heaters are assumed to save 30 percent of the energy of conventional storage water heaters (i.e., attributable to standby losses). The most popular model that one company distributes, the Aquastar 125, has an input capacity of up to 125,000 Btu per hour and can heat almost 4 gallons of water per minute 50°F (from 65°F to 115°F) — enough for a small household's maximum hot water demands. This model costs $782 (before installation) and installation costs are assumed to be the same as for tanks (Controlled Energy Corp. 1997). Although more information is needed to assess servicing costs, at least one manufacturer indicated that costs for maintaining instantaneous gas water heaters is minimal.

One barrier to their widespread adoption is that instantaneous gas water heaters are perceived to have limited heating capacity. In fact, for households with several occupants or in cases where hot water is required for several tasks at one time, instantaneous water heaters may not be appropriate. Thus, instantaneous water heaters are assumed to be applicable only in 50 percent of households.

Utility rebates, financing, and educational programs could accelerate the market acceptance of this technology. California Title 24 allows a trade-off between water heating energy consumption and space conditioning loads that benefits households with intermittent ignition instantaneous water heaters.

Instantaneous Gas Water Heaters

Measure Description: Install intermittent ignition tankless gas water heaters in new/replacement markets

Market Information:	
Market sector:	RES
End uses:	DHW
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Gas storage WH
Base case efficiency:	30% standby losses
Base case annual energy use:	230 therms
New Measure Information:	
New measure description:	125,000 Btuh input tankless water heater
New measure efficiency:	0% standby losses
New measure annual energy use:	161 therms
Measure life:	40 years
Savings Information:	
Electric savings/year:	NA
Gas savings/year:	69 therms
Percent savings:	30%
Feasible applications:	75%
Savings potential in 2010:	6 TBTU
Cost Information:	
Current measure cost:	$432 incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	$0 yearly maintenance cost
Cost of saved energy:	$0.42 per therm
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Consumer confidence, plumbers knowledge
Effect on customer utility:	Lower operating costs
Current activity @ PG&E:	PG&E demonstrations through ACT2
Current activity elsewhere:	Title 24 provides credit for measure
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Souces:	
Savings estimates:	Controlled Energy Corp. (1996)
Cost estimates:	Controlled Energy Corp. (1996)
Measure life estimates:	Controlled Energy Corp. (1996)
Other key sources:	Nadel et al. (1993)
Principal contact(s):	Anne Eddy, Controlled Energy Corp., 800-642-3111 Ned Nisson, Energy Design Associates, ned@energy.com

Notes: Savings are highly sensitive to measure life estimates. Percent feasible (75%) reflects the fact that simultaneous loads in some homes are too large to be served by an instantaneous water heater.

Wastewater Heat Recovery Systems

A significant amount of potentially useful energy is contained in wastewater streams from residential and commercial hot water usage applications. A substantial portion of this wasted energy could be recovered using one of a small number of currently available wastewater heat recovery/exchanger systems. Until recently, most such systems included a storage tank (Earthstar Graywater Heat Reclaimer and the Drain Gain), which increases heat recovery performance, but also adds both size and cost.

A recently commercialized product, the GFX (Gravity Film Xchange), is now being produced by Vaughn Manufacturing Corporation, a small but established electric water heater manufacturer. The GFX is a relatively simple technology consisting of 3 or 4 inch diameter central pipe surrounded by tightly coiled ½ - or ¾-inch diameter copper tubing which makes positive contact with the central pipe along its entire length. The central pipe replaces a portion of a vertical run of the existing wastewater pipe. Cold water running up through the coiled tubes recovers heat from the wastewater as it travels down the inside wall of the central tube. The recovery efficiency is directly related to the height of the central tube. The GFX is available in heights of 20 inches to 15 feet.

In tests sponsored by Virginia Power a 31°F rise was attained with an entering wastewater temperature of 115°F and an entering cold water temperature of 61°F. Heat recovery rates of 55 to 55 percent are achieved. Actual, in-home savings are estimated to be 30 to 53 percent (an average of 41 percent was used for the characterization) depending on inlet water temperature and hot water usage patterns. The Virginia Power research also showed that the GFX outperformed an electric heat pump water heater, though actual long term, in-home performance might differ. In addition to energy savings, the GFX can increase the effective hot water capacity of a conventional electric hot water tank three-fold.

The technology is appropriate for both new construction and retrofit applications, though the new construction market is being targeted (e.g., the unit is being tested in new homes by the NAHB Research Center and the Canadian Advanced Houses program). Also, while the technology is being promoted primarily to the residential market, there are appropriate commercial and agricultural applications, such as laundries. The attached characterization examines only the residential potential in new homes with electric hot water.

The major market barrier is the low level of recognition/understanding of the technology and its savings potential. A market transformation effort directed to new homes in areas without gas might be very successful.

Wastewater Heat Recovery Systems

Measure Description: GFX waste water heat recovery system

Market Information:		
Market sector:	RES	
End uses:	DHW	
Energy types:	ELEC, GAS	
Market segment:	NEW	
Base Case Information		
Base case description:	Standard electric resistance water heater	
Base case efficiency:	NA	
Base case annual energy use:	3,346	kWh
New Measure Information		
New measure description:	Standard electric resistance water heater w/GFX installed	
New measure efficiency:	NA	
New measure annual energy use:	1,974	kWh
Measure life:	25	years
Savings Information		
Electric savings/year:	1,372	kWh
Gas savings/year:	NA	therms
Percent savings:	41%	
Feasible applications:	85%	of new construction
Savings potential in 2010:	41	GWh
	2.86	TBTU
Cost Information		
Current measure cost:	$242	materials plus 1.5 hours labor @ $35/hr
Future measure cost (in mass use):	$242	
Other direct costs/savings:	$0	
Cost of saved energy:	$0.01	per kWh
	$0.14	per therm
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	Lack of familiarity among builders and plumbers, product availability	
Effect on customer utility:	Greater effective hot water capacity. Possible warm "cold" water	
Current activity @ PG&E:	None	
Current activity elsewhere:	VA Power, NAHB RC model home, Canada AHP	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	Energy Design Update reprint - no date	
Cost estimates:	Energy Design Update reprint - no date	
Measure life estimates:	XENERGY estimate	
Other key sources:		
Principal contact(s):	Carmine Vasile, Water Film Energy 516-758-0438	

Notes: Percent feasible reflects some new homes for which these systems are not appropriate or are difficult to accomodate.

HVAC - Residential

Improved Air Conditioner Maintenance and Installation

A growing body of evidence suggests that HVAC equipment often is improperly installed and that poor installation practices decrease energy efficiency (increasing energy bills), compromise occupant comfort, and lead to higher maintenance costs. The predominant problems encountered in studies to assess energy and demand savings from improved residential air conditioner installation and maintenance include oversizing, low air-flow across the coils, improper refrigerant charge, and duct leakage. In most cases, proper installation would eliminate these problems (Proctor & Pernick 1992; Neal 1992)

In a series of pilot projects for PG&E, Proctor Engineering Group (PEG) found air-flow problems and incorrect charge each occur in approximately 50 percent of existing homes, while duct leakage was found to occur in about 70 percent of homes. From pre- and post-retrofit measurements, PEG found that cooling energy savings of 24 percent was achievable through system repair and proper maintenance (including savings from reduced duct leakage). Examined separately, repairing duct leakage, correcting low air-flow, and adjusting charge accounted for 18 percent, 7.7 percent, and about 11.5 percent of cooling energy use reductions, respectively, not accounting for interactions. For homes with gas heat, an additional 12 percent heating energy savings was realized primarily from sealing leaky ducts (Proctor & Pernick 1992).

In addition, a number of studies have shown that residential air conditioning units often are oversized by 50 percent of required capacity. Downsizing alone is estimated to result in energy savings of about five percent and significant peak demand reduction. And downsizing together with appropriate equipment charge can result in electricity savings of up to 20 percent (Neme 1997; Neal 1992).

This analysis draws primarily on the work of PEG, assuming that cooling energy savings of 15 percent are achievable in existing homes from correcting air-flow and adjusting charge (allowing for some interactions). Costs associated with these activities are estimated at $240 based on a study conducted in Southern California (PEG 1995). (Note that for new systems, these costs would be substantially lower since air flow rates, charge, and size, would be determined appropriately at the project outset. Further, costs would be lower if these corrections were made during routine service calls.) We have not included the benefits of downsizing in this analysis, because of its complicated interactions with other factors, and its relevance primarily in new construction. However, downsizing from a 3-ton to a 2-ton unit could save an estimated $700 installed.

At this point, there is virtually no market for quality installations. This is in part because information on the benefits of improved residential air conditioner maintenance and installation has never been adequately consolidated or made easily accessible to homeowners or HVAC contractors. In addition, some contractors, in an attempt to maximize the number of jobs completed per day, do not spend the time needed for proper installation. Further, many installation and service contractors simply lack proper training. Recently, the North American Technician Excellence (NATE) Program and the Air Conditioning Contractors of America (ACCA) began offering training and certification programs for HVAC contractors. Contractors must pass 10 test modules to become NATE-certified. The passing rate for early test takers on each individual module averaged 63 percent. However, only about 20 percent of these test takers are now certified (Wolpert and Proctor 1998).

Despite these barriers, the potential to reduce peak load through this measure is attractive to many utilities. As such, the Consortium for Energy Efficiency (CEE) incorporates an installation component into its Residential Central Air Conditioning Initiative. However, because it is fairly general and not used by many utilities, CEE is currently considering was to improve upon it. PG&E requires contractors to receive installation training in order to participate in its rebate program, and a number of New Jersey utilities require installers to submit sizing calculations to receive incentives.

Potential approaches to stimulating this market include working with manufacturers, and contractors associations on training programs, developing contractor training and "preferred " contractor programs, and by educating consumers on the benefits of proper air conditioning system installation and maintenance.

Improved Air Conditioner Maintenance and Installation

Measure Description: Improve installation and maintenance practices for residential air conditioners/heat pumps

Market Information:		
Market sector:	RES	
End uses:	COOL	
Energy types:	ELEC	
Market segment:	RET	
Base Case Information:		
Base case description:	Average central AC unit energy consumption	
Base case efficiency:	NA	
Base case annual energy use:	1,307	kWh
New Measure Information:		
New measured description:	Improve air-flow, charge, and seal ducts	
New measure efficiency:	19%	reduction in cooling energy use
New measure annual energy use:	1,056	
Measure life:	10	years
Savings Information:		
Electric savings/year:	251	kWh
Gas savings/year:	NA	
Percent savings:	19%	
Feasible applications:	70%	
Savings potential in 2010:	154	GWH
Cost Information:		
Current measure cost:	$180	$240 for full service - $60 for standard call
Future measure cost (in mass use):	$90	midpoint between $0 - $180
Other direct costs/savings:	NA	
Cost of saved energy:	$0.05	per kWh
Data Quality Assessment	B/C	
Likelihood of Success		
Major market barriers:	Uninformed consumers and contractors	
Effect on customer utility:	Improved comfort	
Current activity @ PG&E:	Pilot projects to gather data and increase awareness	
Current activity elsewhere:	Oher CA utilities (e.g., SCE), PSE&G, CEE, EPA, AEC	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	2	
Souces:		
Savings estimates:	Proctor & Pernick (1992); Neal (1992)	
Cost estimates:	Proctor (1995); Neme (1997)	
Measure life estimates:	Neme (1997)	
Other key sources:	CEC (1995)	
Principal contact(s):	John Proctor, Proctor Engineering Group, 415-455-5700 Chris Neme, VT Energy Investment Corp., 202-296-3172	

Notes: Basecase energy use from CEC (1995). Future measure cost is midpoint between $0 and $180, where $0 incremental cost can be realized if proper sizing allows for downsizing.

Ground Source/Dual Source Heat Pumps

Ground source heat pumps (GSHPs) use the earth rather than outdoor air as the energy source/sink for space heating and cooling. Utilizing the relatively constant temperature of the earth has a number of advantages. In heating mode, GSHPs can maintain higher capacity at low outdoor temperature and no defrost cycle is necessary; therefore supplemental resistance heat is seldom required. During cooling operation, GSHPs benefit from much cooler ground temperatures as compared to typical 95 to 105°F peak ambient temperatures. Steady state efficiencies can be as high as 4.5 COP heating and 16 EER cooling at standard conditions.

GSHP systems show great potential for energy conservation, demand reduction, and improved indoor comfort. However, significant market penetration has not occurred in California due to the high cost of both equipment and installation of ground heat exchangers. Potential developments in heat exchanger materials, configurations, and installation methods could reduce incremental costs from the current $1,800-$2,000 per ton to around $1,000 per ton.

Dual source heat pumps (DSHPs) are hybrid systems which take advantage of the best of both air source and ground source heat pumps. DSHPs are basically an air source heat pump modified to also use a ground loop, about one-third to one-half the size required for a traditional GSHP. The flexibility of the DSHP allows these units to take advantage of either or both the air or ground as a heat source/sink depending on ambient conditions and space heating or cooling load.

Performance of DSHP, like all heat pumps, depends on many factors but generally is in the range of 80 to 95 percent as high as a GSHP and according to one manufacturer, can out perform them in some climates and applications (Berry 1997; Braud & Kelly 1995). Depending on climate and manufacturer. defrost cycling and resistance backup heat may not be needed. The reported costs for the smaller ground loops are generally under $1,000 per ton and often around $500 per ton (Berry 1997). Additionally, the equipment used to install DSHP loops is much smaller than typically used for GSHP and therefore generally causes less disruption to landscaped areas-often a major hurdle to the retrofit market in established neighborhoods. With slightly lower performance and significantly lower installation costs, DSHPs can have simple paybacks of half that of GSHPs.

Research aimed at developing lower cost ground loop technologies continues. These developments should benefit both GSHPs and DSHPs. PSI Energy of Indianapolis, Indiana found that pre-installation of horizontal ground loops in entire subdivisions as other site trenching work is occurring can reduce ground loop costs to about $450 per ton. This "bulk installation" is basically a once in a lifetime opportunity that should be carefully evaluated.

The CEC, SMUD, and Truckee Donner PUD are currently sponsoring research to evaluate GSHP performance in California. Fourteen sites with different system types and ground loop configurations are being monitored in the Truckee and Sacramento areas. A 1995 residential retrofit feasibility assessment for PG&E concluded that in California, GSHPs are not currently viable in areas where natural gas is available: however cost-effectiveness improves significantly in areas where propane or electric heating are the primary source of heat.

Other improvements include full water heating heat pump systems. Desuperheaters, which provide water heating when the system is providing heat or air conditioning, are fairly common and generally cost-effective. Some manufacturers also offer "triple function" (full water heating) ground source heat pump systems. These systems use a separate heat exchanger to meet all of a households hot water needs. These units are very efficient in hot water heating mode, which can improve system economics substantially. In general systems with water heating functions are considerably more cost effective than without, especially in areas not served by natural gas.

The opportunities for PG&Es to contribute to GSHP market transformation include continuing to work with the Geothermal Heat Pump Consortium (GHPC) to promote GSHPs to homeowners and homebuilders (particularly for key target markets, such as large homes where gas is unavailable), and to strengthen or establish the regional sales and service infrastructure, providing installer and contractor training on state of the art installation practices as well as on marketing their services. Additional efforts may also be required to address the high costs of geothermal systems, and to further explore applications of DSHPs.

Ground Source Heat Pumps

Measure Description: Heat pumps coupled to buried hydronic loops for highly efficient operation

Market Information:		
Market sector:	RES	
End uses:	COOL, HEAT, DHW	
Energy types:	ELEC	
Market segment:	NEW, RET, REP	
Base Case Information:		
Base case description:	3-ton air source heat pump	
Base case efficiency:	9/2.2	9 EER (cooling)/2.2 COP (heating)
Base case annual energy use:	8,912	kWh
New Measure Information:		
New measure description:	3-ton ground source heat pump	
New measure efficiency:	15/4.0	15 EER (cooling)/4.0 COP (heating)
New measure annual energy use:	3,943	kWh
Measure life:	25	years
Savings Information:		
Electric savings/year:	4,969	kWh
Gas savings/year:	NA	
Percent savings:	56%	
Feasible applications:	4%	75% of new; 25% of replacmnt in all elec areas
Savings potential in 2010:	60	GWH
Cost Information:		
Current measure cost:	$9,000	$2,000/ton (heat/cool) +$3,000 (DHW)
Future measure cost (in mass use):	$5,500	$1,000/ton (heat/cool) + $2500 (DHW)
Other direct costs/savings:	0	
Cost of saved energy:	$0.087	kWh (mature market)
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	System cost, infrastructure, permitting difficulties	
Effect on customer utility:	Improved comfort	
Current activity @ PG&E:	GHP Demonstration Projects	
Current activity elsewhere:	Nationally: GHPC, CEC GHP Collaborative	
Likelihood of success rating (1-5):	2	
Relationship to PG&E planning (1-3):	3	
Sources:		
Savings estimates:	Cler (1997)	
Cost estimates:	IGSPHA & GHPC web sites	
Measure life estimates:	Davis Energy Group and E Source (1997)	
Other key sources:	Berry (1997); Braud & Kelly (1993)	
Principal contact(s):	Mike L'Ecuyer, GHPC, 202-508-5500 Jim Bose, OSU, IGSHPA, 405-744-5175 Ted Pope, PG&E, 415-973-4856 Gary Cler, E Source, 303-440-8500	

Notes: Baseline energy use from CEC (1995).
The majority of the incremental cost for the GSHP is due to the installation of the ground loop and its life should exceed 25 years. Therefore a 25 year life is used to calculate the cost of saved energy. compressor change-out will be longer than typical air source heat pump life of about 15 years.
HP manufacturers claim 50% or greater cost savings using heat pump desuperheater & HP to heat DHW.

Dual Source Heat Pumps

Measure Description: Heat pumps w/outside air coil coupled to a buried hydronic loop for highly efficient operation

Market Information:		
Market sector:	RES	
End uses:	COOL, HTG, DHW	
Energy types:	ELEC	
Market segment:	NEW, RET, REP	
Base Case Information:		
Base case description:	3-ton air source heat pump	
Base case efficiency:	9/2.2	9 EER (cooling)/2.2 COP (heating)
Base case annual energy use:	8,912	kWh
New Measure Information:		
New measure description:	3-ton dual source heat pump	
New measure efficiency:	13.8/3.6	13.8 EER (cooling)/3.6 COP (heating)
New measure annual energy use:	5,169	kWh
Measure life:	25	years (ground loop)
Savings Information:		
Electric savings/year:	3,743	kWh
Gas savings/year:	NA	
Percent savings:	42%	
Feasible applications:	6%	75% new; 50% of replacemnt in all elec areas
Savings potential in 2010:	71	GWH
Cost Information:		
Current measure cost:	$2,250	($750/ton) incremental cost
Future measure cost (in mass use):	$1,500	($500/ton) incremental cost + $500 (DHW)
Other direct costs/savings:	0	
Cost of energy saved:	$0.031	kWh (mature market)
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	System cost, infrastructure, permitting, lack of dealers	
Effect on customer utility:	Improved comfort	
Current activity @ PG&E:	None	
Current activity elsewhere:	Units being installed in southeast US.	
Likelihood of success rating (1-5):	3	
Relationship to PG&E planning (1-3):	1	
Sources:		
Savings estimates:	Cler (1997)	
Cost estimates:	Berry (1997), Cler (1997)	
Measure life estimates:	E Source (1997)	
Other key sources	Berry (1997); Braud & Kelly (1993)	
Principal contact(s):	Mike L'Ecuyer, GHPC, 202-508-5500 Jim Bose, OSU, IGSHPA, 405-744-5175 Ted Pope, PG&E, 415-973-4856	

Notes: The majority of the incremental cost for the DSHP is due to the installation of the ground loop and its life should exceed 25 years. Therefore a 25 year life is used to calculate the cost of saved energy. compressor change-out will be typical of air source heat pump life of about 15 years.
HP manufacturers claim 50% or greater cost savings using heat pump dsuperheater & HP to heat DHW.

Modulating Gas Furnaces

The typical natural gas furnace mixes air and gas in a firing chamber at fixed rates, determined by the size of gas nozzle and by an adjustable air supply; single speed fans move heated air through the distribution system; and the system is controlled by a thermostat inside the living area of the house. Thus, the typical home furnace either is off or operating at full throttle. A modulating gas furnace is capable of adjusting this throttle.

Since 1990, a number of major manufacturers of heating and cooling equipment, such as York, Rheem, Carrier, and Williamson have entered the modulating gas furnace market. Modulating gas furnaces use an electronic monitoring system to determine a home's current heating needs, examine recent history of heating cycles (generally between 5 and 20 cycles), and adjust the frequency of the cycles and system output accordingly.

Several modulation designs are currently available, including those with high, low, and continuously adjustable burner firing rates; and those with two-speed and variable-speed distribution fans. Some systems also monitor outside temperature in addition to inside temperature to determine the system output. These systems are able to precisely maintain internal house temperatures, improving resident comfort.

There are premiums for these gains, however. The highest-performing systems currently add 40 to 50 percent to the installed price of a gas furnace (i.e., $1000 to $1,500 per home) The median incremental cost is estimated at $600 per unit (Feldman 1991). No information is available on long-term operational requirements compared to standard efficient furnaces, but servicing intervals are assumed to be more frequent. These systems might even need to be commissioned upon installation for optimal performance.

Savings for the mid-range units (fully modulating at the burner, but fewer controls on distribution and internal temperature monitoring only) average 92 percent AFUE, compared to typical "power combustion" furnaces at 82 percent AFUE.

Utility support for this technology appears to be limited. One utility expressed concern at the added installation cost should modulating system's require commissioning to perform at their design specifications (Wong 1997). Also, manufacturers and contractors appear to be most heavily promoting the "Cadillac" systems, with high cost premiums and long payback periods. Finally, technicians might require additional installation training.

Modulating Gas Furnaces

Measure Description: Efficient furnaces that vary output heat rate by varying firing rate or controlling distribution fans

Market Information	
Market sector:	RES
End uses:	HEAT
Energy types:	GAS
Market segment:	NEW, REP
Base Case Information	
Base case description:	Standard AFUE furnace
Base case efficiency:	78 % AFUE
Base case annual energy use:	438 therms
New Measure Information	
New measure description	Modulating gas furnace
New measure efficiency:	92 % AFUE
New measure annual energy use:	371 therms
New measure life:	23 years
Savings Information	
Electric savings/year:	NA
Gas savings/year:	67 therms
Percent savings:	15%
Feasible applications:	20%
Savings potential in 2010:	1 TBTU
Cost Information	
Current measure cost: incr.	$590 incremental
Future measure cost (in mass use):	$500
Other direct costs/savings:	NA
Cost of saved energy:	$0.61 per therm
Data Quality Assessment	B
Liklihood of Success	
Major market barriers:	Lesser known technology, possible high maintenance
Effect on customer utility:	Increased comfort, less temp variation
Current activity @ PG&E:	None known for this technology
Current activity elsewhere:	NA
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	Feldman (1991)
Cost estimates:	Nadel et al. (1993)
Other key sources:	Damon (1997)
Principal contact(s)	Lorna Rushforth, PG&E, 415-972-5397 Brad Wong, Commonwealth Gas, 508-481-7900 Bob Damon, Delta Tech, 617-893-0800 (contractor)

Notes: Percent feasible (20%) based on portion of market with sufficient heating load to justify system.
Base case energy use based on large house (approx 3500 sq ft) in PG&E service territory.
Cost of saved energy does not include increased maintenance costs.

Furnace Blowers

The efficiency of furnace blower motors has been ignored in most efforts to improve the energy efficiency of gas warm air furnaces. These fractional horsepower motors have efficiencies of approximately 52 percent. Higher efficiency versions, with efficiencies in the 72 percent range, are available from a limited number of vendors. Current Federal standards for motors do not address fractional horsepower units. From a new installation perspective, both furnace and blower motor manufacturers must be targeted. The replacement market requires increased OEM product availability and education of both trade allies (HVAC contractors) and customers, though customers are unlikely to shop around for multiple bids/quotes.

To date there has been little incentive for manufacturers to incorporate high-efficiency motors into their products. Current product efficiency ratings (i.e., annual fuel utilization efficiency, AFUE) do not include energy use by the blower fan. An interim strategy for PG&E could be to work in a collaborative setting with other utilities and third parties to create a market for these products. Rebates might be required initially and the replacement market might also be targeted, though less than four percent of furnace blower fans are replaced each year (E Source 1993). An eventual exit strategy might the establishment of efficiency standards for fractional horsepower motors, which is apparently under consideration in Canada.

Furnace Blowers - Residential

Measure Description: Replace failed, belt-driven blower motors with high-efficiency motors in residential furnaces

Market Information:		
Market sector:	RES	
End uses:	HEAT, COOL	
Energy types:	ELEC	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	Motor replacement with a standard efficiency motor (0.5 hp)	
Base case efficiency:	52%	at full load
Base case annual energy use:	313	kWh
New Measure Information		
New measure description:	High efficiency blower motor	
New measure efficiency:	72%	at full load
New measure annual energy use:	226	kWh
Measure life:	22	years
Savings Information		
Electric savings/year:	87	kWh
Gas savings/year:	NA	therms
Percent savings:	28%	
Feasible applications:	60%	100% penetration of gas furnace market
Savings potential in 2010:	130	GWH
Cost Information		
Current measure cost:	$75	incremental
Future measure cost (in mass use):	NA	possibly lower, but no cost estimates available
Other direct costs/savings:	$0	
Cost of saved energy:	$0.07	per kWh
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	First cost; availability; contractor awareness	
Effect on customer utility:	None	
Current activity @ PG&E:	None	
Current activity elsewhere:	Research at Ontario Hydro	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	3	
Sources:		
Savings estimates:	E Source (1993b)	
Cost estimates:	E Source (1993b)	
Measure life estimates:	E Source (1993b)	
Other key sources:		
Principal contact(s):	John Howard, General Electric, 219-439-2000	

Notes: Measure life based on estimated furnace life and information that 2.7 percent of motors are replaced annually (E Source 1993b).

Ceiling Fans

Ceiling fans improve home comfort, blowing air down to cool the conditioned space in the summer, and for models capable of reverse flow, destratifying the warm air that has risen to the ceiling in the winter. The number of blades (four to six), their length (typically from 36 to 52 inches), and their angle determine how much air they move.

The Canadian Standards Association (CSA) has recently issued a minimum efficiency standard for ceiling fans that aims to reduce ceiling fan energy use by 10 percent. Based on Canadian Electricity Association (CEA) tests of a few dozen ceiling fans, the typical household ceiling fan was found to consume 60 watts of power. Data on Canadian ceiling fan usage indicated that fans are operated for approximately 2,025 hours per year, for a total annual energy consumption of 121 kWh per year. Alterations in blade design and fan speed, consistent with currently available designs, could reduce energy consumption to 109 kWh per year (Dodd 1997; Stricker 1997). More aggressive measures, including more efficient motors and controls, could further reduce fan energy consumption.

In the western U.S., 39 percent of households have one or more ceiling fans (a little over half of these houses have one fan and the remainder have two or more fans) (DOE/EIA 1995). The characterization of this measure assumes that 39 percent of California homes have one ceiling fan and 45 percent have two ceiling fans; with each fan consuming 121 kWh per year. New ceiling fan energy consumption is assumed to be 109 kWh, achievable at a low incremental cost (estimated at 10 percent of base case cost).

Prices for ceiling fans vary depending on the manufacturer and service, style and size. Ceiling fans range in price from $29 for low-end ceiling fan to as much as $299 for a higher-end, 52-inch ceiling fan (Lamp Depot 1997). For this analysis, we've assumed a cost of $50 for the baseline ceiling fan.

Few barriers are anticipated on the supply side and through the distribution chain, given that all manufacturers whose products were tested by the CSA had several products on the market that met the Canadian standard. Other than the CSA standard, however, no energy performance standard is available for ceiling fans. Thus, consumers are unlikely to know which fans are more energy-efficient than others. Utilities could promote more efficient ceiling fans that meet the CSA standard for efficiency through consumer education and financial incentives and could incorporate more efficient ceiling fans into new construction programs. Currently ceiling-fan-related efforts by utilities, such as some Florida utilities, Northern Indiana Power Service Company, and others, focus on improving homeowner comfort and potentially reduce space cooling and heating energy consumption, and not on the efficiency of the fan itself.

Ceiling Fans

Measure Description: Encourage use of more efficient ceiling fans

Market Information:	
Market sector:	RES
End uses:	MISC
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Standard 48" ceiling fan, 2025 hours usage
Base case efficiency:	60 Watt average
Base case annual energy use:	122 kWh
New Measure Information:	
New measure description:	Reduced energy use 48" ceiling fan, 2025 hours usage
New measure efficiency:	54 Watt average
New measure annual energy use:	109 kWh
Measure life:	10 years
Savings Information:	
Electric savings/year:	12 kWh
Gas savings/year:	NA
Percent savings:	10%
Feasible applications:	100%
Savings potential in 2010:	2 GWH
Cost Information:	
Current measure cost:	$5 incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	$0
Cost of saved energy:	$0.06 per kWh
Data Quality Assessment	B/C
Likelihood of Success	
Major market barriers:	
Effect on customer utility:	Possible lower air movement
Current activity @ PG&E:	Some studies of performance in ACT2 project
Current activity elsewhere:	CSA developed new standard
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	2
Souces:	
Savings estimates:	Dodd (1997); Stricker (1997)
Cost estimates:	Lamp Depot (1997)
Measure life estimates:	DOE (1993)
Other key sources:	DOE (1995)
Principal contact(s):	Mike Dodd, CSA, 416-747-4111 Saul Stricker, Stricker Assoc., 905-770-5595

Notes: Assumes 39% of homes use ceiling fans, based on EIA (1995); of which 45% have two or more fans. Also assumes savings achievable at a 10% increase in cost for a $50 fan.

Building Shell - Residential

Improved Enforcement/Education of Title 24 Building Standards

Increased enforcement and education activities focused on California's Title 24 building standards could generate greater code compliance and additional energy savings. Compliance with new energy codes is often considerably less than 100 percent. The California Energy Commission (CEC) periodically performs compliance reviews for regions within the state. The most recent of these studies shows that of 63 homes examined for compliance, approximately half did not meet their Title 24 energy budgets. A study (Baylon et al. 1995) of compliance with the 1994 non-residential energy code (NREC) in Washington showed that 44 percent of sampled commercial buildings not receiving special plan review services failed to comply with the then new code standards. These findings suggest that adopting a new code does not guarantee that all of the energy savings will be obtained.

Among the barriers to higher code compliance are the following:

- Complexity of the standard - this affects the ability of design professionals to implement the code and the ability of code officials to enforce the code. This may be a particular concern for the California commercial code.
- Inadequate or insufficient training of design professionals and code officials.
- Overworked code officials - while much of California code enforcement relies on third party certification, code officials may not pick up differences between filed energy compliance documents and the actual "as built" structure. The recently completed CEC study on residential code compliance (discussed below) notes that furnaces and water heaters with lower efficiencies then specified in compliance documents are sometimes installed.
- Lack of simplified compliance materials and/or software.

While the need for code support has been recognized, few efforts have been made to quantify the potential benefits from increased code compliance. In Washington and Oregon, a study quantified through plan review and simulation analysis the additional savings that would have been obtained from full compliance with an earlier version the Washington NREC. These impacts have been used to determine the potential benefits of Title 24 commercial building support efforts by PG&E in the attached characterization. Actual savings will depend on the frequency of any California code revisions, their stringency, complexity, and other factors (Kennedy & Baylon 1992).

Results from a statewide compliance and post-occupancy study on residential code compliance shows that 90 percent of homes are within ±4 percent (defined as "noise" by the CEC evaluation manager) of their Title 24-specified energy budget. The remaining homes are either above or below their allowed energy budget. Most of the residential savings potential is likely to be concentrated in a small number of homes that fail to meet their energy budgets (by a significant margin). Further, the study showed that potential savings (expressed as dollar savings from the perspective of the homeowner) among non-compliant homes tended to be much higher in climate zones with more extreme weather.

As the savings estimates for the commercial and residential code enforcement initiatives are from different sources (the commercial estimates reflect program experience in the Northwest, while the residential estimate reflects an evaluation of PG&E residential new construction, they are not directly comparable).

To improve code compliance there are a small number of recent, on-going, or proposed code related activities that might provide direction for PG&E to pursue.

In Washington state, utilities funded a three year effort to address code enforcement issues. The Utility Code Group (UCG) undertook a number of initiatives including training, newsletters, a circuit rider program, and development of simplified compliance materials. A recently completed study found that the training efforts, directed to both code officials and design professionals, had the largest impacts. While the benefits from the circuit rider and compliance material efforts were smaller, they were found to be useful to selected, target groups (Tumidaj 1997). The UCG was disbanded in 1997. The Northwest Energy Efficiency Council is providing some continuity on the UCG's prior efforts, though at reduced level of effort.

Circuit rider programs have also been found to be effective in Oregon. These efforts are being funded in part by DOE and by the Northwest Energy Efficiency Alliance (NEEA). Oregon is also investigating how building commissioning efforts can be used to support code compliance efforts. Over time, a viable market for commissioning agents may develop and/or commissioning requirements might be adopted as part of a revised NREC.

Increased regional activity on codes in the Northwest is expected to be addressed next year. A study to develop a long-term code strategy in the Northwest will be completed by the end of this year. The study is being funded by the NEEA. Based on the study's findings, regional code initiatives may be pursued in the Northwest.

In the Northeast, the Northeast Energy Efficiency Partnership (NEEP) is proposing to pursue a Northeast Regional Building Energy Code Project. Among its goals are to develop regional support for building energy code implementation and training. Stated objectives include promoting the use of software compliance tools and developing a regional infrastructure for training and technical support. NEEP also proposes to have utilities use ratepayer funds to support energy code upgrades and implementation efforts.

Improved Enforcement of Title 24 Building Standards - Residential

Measure Description: Improved enforcement, education, and compliance for Title 24 building standards

Market Information:		
Market sector:	RES	
End uses:	HEAT, COOL, LTG, OTHER	
Energy types:	ELEC, GAS	
Market segment:	NEW	
Base Case Information:		
Base case description:	1,700 square foot home built to current practice	
Base case efficiency:	32	kBtu per sq ft yr estimate
Base case annual energy use:	NA	
New Measure Information:		
New measure description:	1,700 square foot home built to Title 24 standards	
New measure efficiency:	30.99	kBtu per sq ft yr state avg. energy budget
New measure annual energy use:	NA	
Measure life:	30	years
Savings Information:		
Electric savings/year:	0.15	kWh per sq ft
Gas savings/year:	0.01	therms
Percent savings:	5%	from buildings not yet in compliance
Feasible applications:	51%	based on 1995-1996 monitoring report
Savings potential in 2010:	109	GWH
	1	TBTU
Cost Information:		
Current measure cost:	$0.04	per sq ft estimate
Future measure cost (in mass use):	$0.03	per sq ft estimate
Other direct costs/savings:	$0	
Cost of saved energy:	$0.01	per kWh
	$0.43	per therm
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	Low priority of energy code among code officials	
Effect on customer utility:	Increased occupant comfort	
Current activity @ PG&E:		
Current activity elsewhere:	Washington state, NW, NE states/utilities	
Likelihood of success rating (1-5):	3	
Relationship to PG&E planning (1-3):	2	
Sources:		
Savings estimates:	CEC (1996); PG&E (1997)	
Cost estimates:	NWPPC estimate	
Measure life estimates:	XENERGY estimate	
Other key sources:	Dotty Horgan, CEC, 916-654-5198	
Principal contact(s):	Stephen Williams, CEC, 916-654-4050 Kevin Madison, WA UCG, 206-236-1473	

Notes: Electric and gas consumption are assumed to each account for half of the estimated 1 kBtu per sq ft energy savings. Cost are allocated to electric and gas CSE equally.

Improved Enforcement/Education of Title 24 Building Standards - Commercial

Measure Description: Improved enforcement, education, and compliance with Title 24 Standards

Market Information:	
Market sector:	COM
End uses:	HEAT, COOL, LTG, OTHER
Energy types:	ELEC, GAS
Market segment:	NEW
Base Case Information	
Base case description:	Current code enforcement of Title 24 NREC
Base case efficiency:	NA
Base case annual energy use:	315 GWH for commercial new construction
New Measure Information	
New measure description:	Improved enforcement, training of Title 24 NREC
New measure efficiency:	NA
New measure annual energy use:	299 GWH for commercial new construction
Measure life:	15 years
Savings Information	
Electric savings/year:	16 GWH for commercial new construction
Gas savings/year:	0.01 TBTU for commercial new construction
Percent savings:	5%
Feasible applications:	85%
Savings potential in 2010:	75 GWH per year
	0.13 TBTU
Cost Information	
Current measure cost:	$1,400,000 based on annual UCG budget
Future measure cost (in mass use):	$1,400,000
Other direct costs/savings:	NA
Cost of saved energy:	$0.01 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Low priority among code offcials, complexity of NREC
Effect on customer utility:	Generally minimal but may increase occupant comfort
Current activity @ PG&E:	
Current activity elsewhere:	UCG in Washington
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	Kennedy and Baylon (1992)
Cost estimates:	Madison (1997)
Measure life estimates:	XENERGY estimate
Other key sources:	Johnson (1997), Baylon et al., (1995)
Principal contact(s):	Jeff Johnson, PNNL, 509-375-4459 Kevin Madison, UCG 206-236-1473

Notes: Base case annual energy use is based on stock, not marginal EUIs.
Assumes electricity savings of 0.35 kWh per sq ft and gas savings of 0.38 MBtu per sq ft.

Residential Infiltration Reduction

Air leakage is a major contributor to energy use in residential construction, both new and existing. Air infiltration rates are influenced by a number of factors including indoor/outdoor temperature differential, wind speed, terrain and the "leakiness" of the construction. The influence of temperature and wind speed result in air infiltration having a proportionally greater impact on heating loads than on cooling loads. Also, the operation of forced air systems can exacerbate air leakage in a home.

Uncontrolled infiltration is measured by a number of metrics including air changes per hour (ACH), cubic feet per minute (CFM), and CFM as a function of either shell area or conditioned floor space. These metrics are typically expressed at the artificial pressure at which blower door measurements are made, e.g., 50 Pascals. These measured values are then adjusted to derive an estimate of an annual air infiltration rate. Alternatively, a calculated leakage rate can be used to initialize a model that more accurately models seasonal, daily, or hourly air infiltration.

Using a blower door to measure air infiltration and to locate building shell leaks in new and existing home construction, and sealing leaks with a variety of long-life sealants, including caulk, aerosol foam, and others can yield substantial energy savings. For this analysis, we assume that infiltration reduction can save an average of 8.5 percent on heating and cooling in existing homes and about 15 percent in new construction.

Currently, few building codes specify maximum air infiltration rates. Title 24 standards do not include specific air infiltration levels. Builders, and to a lesser extent gas utilities, have expressed concerns regarding indoor air quality in tighter homes. Articles in the popular press on "sick buildings" represent another barrier to customer acceptance of tight homes. However, building research has shown that a combination of tight construction and controlled ventilation may be the most appropriate way to address both energy savings and occupant health.

To be effective in transforming the market in air sealing, PG&E must first identify and work through the most appropriate delivery channels to deliver blower door testing and air sealing services; partners in improving home fitness in new homes will often be different than those for existing housing. In new homes, for example, builders may train their own crews or hire specialists in blower door testing and air sealing services. As part of its residential new construction offering, PG&E can provide incentives to builders that offers them flexibility in determining how best to deliver blower door testing. PG&E could also provide training, provide funding for training, or require that builders have training or trained contractors to participate in the program. As builders become more familiar and experienced with addressing infiltration, PG&E could consider establishing a maximum air infiltration rate as part of its residential new construction program. Potomac Electric Power Company and Energy Crafted Homes have established maximum rates of about 0.35 CFM. Alternatively, PG&E can work with the state to incorporate incentives and/or requirements into the state building code. In the near term, Title 24 could provide a credit to get builders accustomed to using blower doors to verify air tightness, and in the long term, an air tightness standard could be specified in Title 24.

For existing homes, the costs associated with hiring independent infiltration specialists are likely to be too high for the consumer to bear or the utility to support in a sustainable manner. Despite the fact that reducing air infiltration in existing homes was highly ranked, market transformation for this measure is likely to be very difficult outside of a few niche markets. This is reflected in its low likelihood of success ranking.

As indicated, PG&E could focus on niche markets for this measure, such as high energy use customers or low-income customers. Public Service Electric and Gas Company (PSE&G) is working with weatherization program delivers (in some cases, program staff and in other cases, contractors) to deliver a series of retrofit measures, including infiltration diagnostics and reduction, to low-income customers and customers who are in arrears on their bills. What the utility is not authorized to fund or cannot cost-justify, the weatherization program can often cover. PG&E could explore the potential for working with weatherization program deliverers to co-sponsor home performance retrofits.

PG&E could also consider working with duct sealing contractors to encourage them to gain infiltration reduction skills. However, the approach to transforming the market for duct sealing recommended in this report, suggests that PG&E work to incorporate duct sealing practices into the menu of services provided by HVAC service contractors. It is unlikely that these service providers will also take on air infiltration reduction services. To reach a broader market, PG&E would have to effectively buy the market, paying for home by home infiltration diagnostics and air sealing.

PG&E should explore whether this measure is cost-effective to pursue. But at the very least, PG&E should continue to provide consumer education about the potential energy savings that can be achieved from air sealing and promote air sealing through its other retrofit programs, such as an HVAC maintenance program.

Residential Infiltration Reduction - Existing Homes

Measure Description: Air sealing guided by blower door

Market Information			
Market sector:	RES		
End uses:	HEAT, COOL		
Energy types:	ELEC, GAS		
Market segment:	RET		
Base Case Information			
Base case description:	High use single-fam home, gas heat/electric central AC		
Base case efficiency:	NA	NA	
Base case annual energy use:	4375 kWh	450 therms	
New Measure Information			
New measure description	Blower door test to seal and repair leaks		
New measure efficiency:	NA		
New measure annual energy use:	4,003 kWh	412 therms	
New measure life:	10		
Savings Information			
Electric savings/year:	372 kWh		
Gas savings/year:	38 therms		
Percent savings:	9%		
Feasible applications:	36%		
Savings potential in 2010:	106 GWH		
	3 TBTU		
Cost Information			
Current measure cost:	$354 incremental		
Future measure cost (in mass use):	$354		
Other direct costs/savings:	NA		
	$0.07 per kWh		
	$0.62 per therm		
Data Quality Assessment	B		
Liklihood of Success			
Major market barriers:	Knowledge, contractor certification		
Effect on customer utility:	Decreased drafts, more even indoor temp		
Current activity @ PG&E:	Low income weatherization		
Current activity elsewhere:	PEPCO, Commonwealth Electric, other utilities		
Likelihood of success rating (1-5):	2		
Relationship to PG&E business plan (1-3):	2		
Sources:			
Savings estimates:	Affordable Comfort, Home Energy Magazine		
Measure life estimates:	ACEEE estimate		
Cost estimates:	XENERGY (1996)		
Other key sources:			

Principal contact(s):

Notes: Base case high use homes UEC per Modera (1997). Percent feasible assumes that the measure is appropriate for 90% of high-use homes, estimated as 40% of residential load. Costs are allocated 51% to electric and 49% to gas based on primary energy savings.

Residential Infiltration Reduction - New Construction

Measure Description: Use of blower door to locate building shell leaks in new home construction.

Market Information:	
Market sector:	RES
End uses:	HEAT, COOL
Energy types:	ELEC, GAS
Market segment:	NEW
Base Case Information	
Base case description:	1700 sq ft, single-fam home (standard practice construction)
Base case efficiency:	0.63 ACH
Base case annual energy use:	NA
New Measure Information	
New measure description:	
New measure efficiency:	0.35 ACH
New measure annual energy use:	NA
Measure life:	15 years
Savings Information	
Electric savings/year:	156 kWh (cooling season savings only)
Gas savings/year:	40 therms
Percent savings:	15% of HVAC energy use
Feasible applications:	85%
Savings potential in 2010:	31 GWH
	1 TBTU
Cost Information	
Current measure cost:	$354
Future measure cost (in mass use):	$354
Other direct costs/savings:	$0
Cost of saved energy:	$0.07 per kWH
	$0.65 per therm
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Lack of awareness/trained personnel, inspections rare
Effect on customer utility:	Reduced drafts/increased comfort
Current activity @ PG&E:	
Current activity elsewhere:	Energy Crafted Homes, Cinergy
Likelihood of success rating (1-5):	2 accepted technology, but high CSE
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	PG&E(1996), ACEEE(1994)
Cost estimates:	XENERGY (1996)
Measure life estimates:	PG&E(1996)
Other key sources:	ACEEE(1994), Iowa Utilities Board (1996)
Principal contact(s):	Tom Downey, Proctor Engineering Group. 415-455-5700

Notes: Assume 100% penetration of CAC in northern California
Costs for CSE calculation are allocated 29% to electric and 71% to gas based on savings.

Light-Colored Roof Surfaces

Summer temperatures in urban areas are now typically two to eight degrees higher than their rural surroundings. Some of the factors that contribute to this heat accumulation, such as climate, topography, and weather patterns, cannot be altered. However, humans can influence other contributors to this "heat island effect," such as the amount of vegetation and the color of surfaces (e.g., building roofs and siding). Light-colored surfaces increase the albedo (or reflective index) of a building, decrease the radiant heat load on the building, and reduce internal cooling loads. According to research by Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory and the Florida Solar Energy Center, and others, light roofs can reduce cooling energy use by 10 to 50 percent, depending on the amount or thermal resistance of insulation under the roof (Mestel 1995).

A number of materials can be used to lighten roof surfaces. Light-colored roof coatings, or paints applied to the roof surface, tend to be the be the most cost-effective for existing roofs. Light-colored surfaces for common residential roofing materials (e.g., asphalt shingles) have an incremental cost of less than $0.03 per square foot of roof area; and appropriate materials for common commercial roofs (e.g., built-up gravel systems) cost around $0.10 per square foot of roof area (Akbari 1997).

In both the residential and commercial cases, we have assumed light-colored surfaces result in an increase in surface reflectance from 20 percent to 55 percent. These numbers are fairly typical for residential roofing materials, but light-colored commercial surfaces can exhibit initial reflectance of as much as 85 percent. However, because they tend to get dirty, the initial reflectance degrades considerably (Akbari 1997). For the purpose of the analysis, we assume these materials result in cooling energy savings of 10 percent (with a 1 percent heating energy penalty) in the commercial sector and 20 percent overall energy savings in the residential sector based in part on "Cool Communities" work of Rosenfeld and Romm (1996) in the Los Angeles basin as well as the experience of Akbari (1997) and Parker (1997).

Barriers to highly reflective roof coatings include a lack of information and awareness about the energy and non-energy benefits, concerns about aesthetics (principally in the residential sector), lack of product standards, and a lack of predictive performance tools (particularly in the commercial sector). As a result, vendors at least in PG&E's service territory were found to stock only a few high-albedo roof coating products (PG&E 1996).

In some respects, commercial building market transformation efforts may be easier to achieve than residential market transformation efforts, because of the greater ease of implementation and acceptability in this sector. The most cost-effective commercial applications for cool roofs is generally in small buildings (e.g., elementary schools, small office buildings, and retail stores), where the ratio of roof surface area to floor area is high, and in buildings with high internal cooling loads, such as refrigerated warehouses.

PG&E has a 5-year plan to effect market transformation to high-albedo roofing materials in the commercial sector. This plan includes initially conducting a market assessment of the types of high efficiency roof coatings currently in place, demonstrating and documenting the benefits of these materials, and surveying customers for their valuations of non-energy benefits (e.g., longer life, improved building surface protection). Then, PG&E through an informational campaign will help to build customer awareness of highly reflective roof coatings and provide credible valuations of claimed energy and non-energy benefits. Over the course of the 5-year program PG&E plans to support the application of high albedo roof coating to 2500 buildings. Other utilities, principally in the Southeast U.S. are testing the potential cooling demand reductions from white roofs in their regions (Parker 1997). A number of municipalities, as well as utilities and state energy organizations, also participate in DOE's Cool Communities program, an energy conservation program with the goal of cutting energy by planting trees and lightening the color of roofs and pavement.

EPA and the roofing materials industry are currently working to address the issue of lack of product standards through the development of an ENERGY STAR® program to differentiate highly reflective roof coatings from others. EPA has drafted a program specification with three components: efficiency; durability (i.e., demonstrated resistance to weathering); and reliability. The efficiency component establishes a minimum initial reflectivity and requires that it be maintained for several years. EPA is now working with manufacturers to finalize the specification and anticipates launching the program in mid to late 1998 (Schmeltz 1998). A new industry group, the Cool Roofs Rating Council, is also now forming around issues of rating and testing roofing materials (Latham 1998).

The EPA program will go a long way toward providing residential and commercial end users with the information they need to make an informed decision about the energy savings achievable with cool roofs. Utilities can support the ENERGY STAR® program through regional educational activities and promotions, conduct demonstrations in their service territories, and work with manufacturers and distributors, encouraging them to offer training and demonstrations on their products. In focusing efforts, organizations interested in transforming the market for light-colored roof surfaces should be aware that the South and Midwest markets are currently exhibiting the greatest commercial sector re-roofing activity, whereas the most active regions for residential re-roofing are the Midwest and Northeast (Bretz 1996).

Two characterizations, one for residential roof coating and another for commercial are presented on the following pages.

Light-Colored Roof Surfaces - Commercial

Measure Description: Promote use of light colored roofing materials in commercial buildings targeting those with a high ratio of roof to floor area and high internal load

Market Information:	
Market sector:	COM
End uses:	COOL
Energy types:	ELEC
Market segment:	RET
Base Case Information:	
Base case description:	Baseline cooling energy consumption
Base case efficiency:	20% reflectance
Base case annual energy use:	3.90 kWh per sq ft
New Measure Information:	
New measured description:	Light-colored roofing material/coating
New measure efficiency:	55% reflectance - delta = 0.35
New measure annual energy use:	3.51 kWh per sq ft
Measure life:	5 years
Savings Information:	
Electric savings/year:	0.39 kWh per sq ft
Gas savings/year:	NA
Percent savings:	9% heating penalty reflected in percent savings
Feasible applications:	30% of all commercial buildings
Savings potential in 2010:	105 GWH
Cost Information:	
Current measure cost:	$0.10 per sq ft, incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	$0.14 per sq ft savings in prolonged roof life
Cost of saved energy:	($0.02) per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	No standards/prediction tools
Effect on customer utility:	Coatings can prolong roof life
Current activity @ PG&E:	Market transformation program underway
Current activity elsewhere:	FSEC, LBNL, EPA, SMUD, FP&L, other utility pilot projects
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	Gartland, et al (1996), Akbari (1997)
Cost estimates:	Akbari (1997)
Measure life estimates:	Akbari (1997)
Other key sources:	Parker (1997)
Principal contact(s):	Hashem Akbari, LBNL, 510-486-4287 Danny Parker, FSEC, 407-638-1405

Notes: Percent savings includes 10% cooling electricity savings minus a heating penalty equal to 10% of these savings. Thirty percent of all commercial buildings are assumed to be appropriate targets for light-colored roof surfaces. Other savings include prolonged roof life, estimated to equal 3 times the dollar value of cooling energy savings.

Light-Colored Roof Surfaces - Residential

Measure Description: Promote use of light colored roofing materials in new and existing homes

Market Information:		
Market sector:	RES	
End uses:	COOL	
Energy types:	ELEC	
Market segment:	NEW, REP	
Base Case Information:		
Base case description:	Baseline cooling energy consum. w/typical reflectance roofing	
Base case efficiency:	20%	reflectance
Base case annual energy use:	1,307	kWh
New Measure Information:		
New measured description:	Light-colored roofing material/coating	
New measure efficiency:	55%	reflectance
New measure annual energy use:	1,046	kWh
Measure life:	20	years
Savings Information:		
Electric savings/year:	261	kWh
Gas savings/year:	NA	
Percent savings:	20%	savings typically range from 10 to 30 percent
Feasible applications:	54%	estimated 68% of electric load for CAC; 85% feasible
Savings potential in 2010	85	GWH
Cost Information:		
Current measure cost:	$60	incremental
Future measure cost (in mass use):	$20	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.01	per kWh
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	Few products; roofing contractor selection; lack of knowledge	
Effect on customer utility:	Aesthetic concerns	
Current activity @ PG&E:	None in residential sector	
Current activity elsewhere:	FSEC, LBNL, EPA, DOE, SMUD, SCAQMD	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	2	
Sources:		
Savings estimates:	Mestel (1995); Rosenfeld (1996); Parker (1997)	
Cost estimates:	Akbari (1997)	
Measure life estimates:	Parker (1997)	
Other key sources:		
Principal Contact(s):	Danny Parker, FSEC, 407-638-1405 Hashem Akbari, LBNL, 510-486-4287	

Notes: Assumes 2000 sq. ft. roof area with a current added cost of $0.03 per sq ft and a future cost of $0.01 per sq ft (Akbari 1997). Percent feasible assumes 68% of electric cooling load in residential sector is from CAC (EIA 1995), but some homes are located in districts with color restrictions.

Lighting - Residential

Compact Fluorescent Lamp Buydown

Compact fluorescent lamps (CFLs) present a significant opportunity for energy and maintenance savings. On a per lamp basis, CFLs are generally 70 percent more efficient than incandescent lamps and last 10 times longer. Over the past 15 years numerous utilities, including PG&E, have recognized the savings potential of this technology and attempted to saturate homes with CFLs through DSM rebate programs. These programs increased stocking, consumer familiarity, contributed to long-term price reductions, and the availability of more compact sizes. However, while many programs were fairly efficient, some programs, in lowering the purchase price to consumers through purchaser rebates, incurred large administrative costs associated with handling thousands of rebate applications.

In a CFL buydown, the utility (or other sponsoring party) pays lighting *manufacturers* a per lamp rebate to lower the purchase price of CFLs. This approach has multiple benefits. Offering the rebate to manufacturers rather than to each consumer, reduces the administrative burden of the program. Additionally, a manufacturer rebate of $5 dollars is equivalent to a customer rebate of $10, assuming a 100 percent mark-up by distributors and/or retailers. The buydown, however, represents only one of several methods to promote CFLs. A market transformation initiative would likely combine this effort with a promotional campaign (marketing the program to retailers and customers) and educational efforts.

The three most significant barriers to the CFL market are first cost, lumen quality, and stocking practices. High quality CFLs range from $12 to $20 per lamp, depending upon wattage and ballast type (Foley 1998). In contrast, incandescent lamps range from $0.50 to $1.00 per lamp. With regard to lumen quality, the general consensus among buydown program managers and others associated with the CFL market is that, in order to improve consumer opinion and thereby increase market share, lamp quality must be addressed through a program specification (e.g., rebate eligibility criteria). This is in response to the proliferation of poor quality, relatively inexpensive lamps (often imported). Specifications should delineate minimum power factor, efficacy, rated lifetime, CRI, flicker and start-time, as well as maximum total harmonic distortion (THD). A good CFL specification is the key to improving consumer perception of fluorescent lighting. Finally, stocking practices of retailers slow market penetration since often CFLs are poorly displayed or, worse, not found on retailer shelves. Thus, any market transformation strategy should also address retailer stocking practices.

Compact Fluorescent Lamp Buydown

Measure Description: Manufacturer rebate to lower retail price of high quality compact fluorescent lamps.

Market Information:	
Market sector:	RES
End uses:	LTG
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information	
Base case description:	Standard Edison incandescent 'A' lamp
Base case efficiency:	75 Watts
Base case annual energy use:	110 kWh
New Measure Information	
New measure description:	High quality 18 Watt screw-in CFL
New measure efficiency:	22 Watts (includes ballast)
New measure annual energy use:	32 kWh
Measure life:	7 years
Savings Information	
Electric savings/year:	78 kWh per lamp
Gas savings/year:	NA therms
Percent savings:	71%
Feasible applications:	45% 64% energy use from high-use sockets; 70% feasible
Savings potential in 2010:	102 GWH
Cost Information	
Current measure cost:	$16 full cost
Future measure cost (in mass use):	$10 full cost
Other direct costs/savings:	($0.50) annual lamp purchase savings
Cost of saved energy:	$0.02 kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, perceived lumen quality, compatibility
Effect on customer utility:	HVAC impacts, less time changing lamps
Current activity @ PG&E:	$4 - $7 rebate per integral screw-in CFL (PG&E website)
Current activity elsewhere:	SCE, NW, SMUD and CEE
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Sources:	
Savings estimates:	FLEX (1996)
Cost estimates:	Eckman (1997) (per Lightwise experience)
Measure life estimates:	FLEX (1996)
Other key sources:	U.S. EPA (1995b), Vorsatz et al. (1997)
Principal contact(s):	Kate Conway, Lighting Research Center Howard Gerber, XENERGY, 617-273-5700

Notes: Savings from this measure overlap with fluorescent fixtures. Characterization assumes lamp usage of 4 hours hours per day. Percent feasible based on 64% of residential lighting energy from sockets with >3 hours per day per day per Vorsatz et al. (1997), with 70% applicability .

Halogen Infrared Reflecting A-Line Lamp Replacement

The Defense General Supply Center (DGSC) of the U.S. Department of Defense (DOD) is leading an effort to procure more efficient lamps for standard incandescent A-line lamp applications. Their efforts are being coordinated with, and supported by EPA and DOE. The government has thus far developed a request for technical proposals (RFTP), received bids, and amended the RFTP. It is not clear when they will go out for re-bid.

Based on the requirements in the proposal, the most likely candidate technology is a tungsten halogen bulb with an infrared reflective coating (i.e., HIR). This technology uses a thin film coating on the inside of the lamp surface to reflect wasted infrared energy back onto the lamp filament, which makes the lamp burn hotter, and in turn, increases lamp efficacy.

In June 1995, Osram Sylvania introduced a prototype HIR bulb for general service at a trade show, but has since been slow to develop and commercialize the product. The HIR A-line replacement bulb is expected to be applicable particularly in cases where compact fluorescent lamps (which offer greater efficiency) are not cost-effective or are not applicable because of size or color requirements. For the purpose of this analysis, we have assumed that HIR replacement would be applicable in 100 percent in current residential low-use applications (i.e., less than 3 hours per day). Low-use applications represent approximately 36 percent of residential lighting energy use (Vorsatz et al. 1997). More data are required to include commercial sector impacts in the analysis.

The Federal procurement requires that the lamp be 30 percent more efficient than standard incandescent bulbs, which is achievable with HIR; burn for at least 3000 hours, which is thought to be achievable based on the life of similar products (e.g., the HIR PAR lamps are rated at 2000 to 3000 hours); and cost no more than $3. The price point that the Federal buyers have established may be the limiting factor in attracting manufacturers into the market. For the purpose of this analysis, the HIR lamps are assumed to cost $3 in a mature market based on the value put forth in the procurement. Lower maintenance costs as a result of longer lamp life has not been captured.

General Electric, which produces HIR PAR lamps and double-ended linear lamps for general lighting, was reported to be working on an HIR lamp as a drop-in replacement for the typical incandescent A-line lamp in the early 1990s. At this point, however, General Electric has no immediate plans to further pursue the technology as a result of technical problems encountered. In particular, the HIR A-line replacement involves a pressurized filament tube, which presents a potential shattering hazard. A heavy glass outer shell can address the shattering but is relatively expensive (McGowan 1997).

Utility support for the government procurement process (e.g., agreeing to purchase a quantity of lamps for use in utility programs) could bolster the effort and speed the process of getting an energy-efficient drop-in replacement for the standard incandescent lamp.

Halogen Infrared Reflecting A-Line Replacement

Measure Description: Promote halogen IR technology in high use residential applications

Market Information:	
Market sector:	RES
End uses:	LTG
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Standard incandescent 'A' lamp (75 W); 17-18 lumens per watt
Base case efficiency:	75 Watts
Base case annual energy use:	55 kWh
New Measure Information:	
New measure description:	Coating of HIR relects infrared energy onto filament; 26 lumens
New measure efficiency:	~50 Watt HIR
New measure annual energy use:	37 kWh
Measure life:	3.5 years
Savings Information:	
Electric savings/year:	18 kWh
Gas savings/year:	NA
Percent savings:	33%
Feasible applications:	36% feasible in all low/med use sockets
Savings potential in 2010:	32 GWH
Cost Information:	
Current measure cost:	NA product not currently available
Future measure cost (in mass use):	$3 estimated
Other direct costs/savings:	($0.50) annual lamp purchase savings
Cost of saved energy:	$0.01 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Possible technical constraints
Effect on customer utility:	Increased measure life; reduced O&M costs
Current activity @ PG&E:	None; technology not yet comm'l available
Current activity elsewhere:	DOD and IEA procurement activities; CEC investigating potentia
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	3
Souces:	
Savings estimates:	Rubenstein et al. (1997), CEC (1997)
Cost estimates:	DOD (1995), XENERGY (1996)
Measure life estimates:	DOD (1995), EPA (1995a)
Other key sources:	CEC (1997)
Principal contact(s):	Terry McGowen, General Electric, 216-266-3234 Francis Rubenstein, LBNL, 510-486-4096 Lisa Heschong, Heschong & Mahone Group, 916-962-7001

Notes: Assumes usage of 3 hrs or less per day (i.e., low-use sockets) per Rubenstein et al. (1998); 3000 hour lifetime (e.g., 3.5 years). Percent feasible assumes applicability in residential recessed lamps, and floor and table lamps,

HVAC and Water Heating Systems - Non-Residential

Packaged Commercial Gas Cooling Systems

A small number of manufacturers (Napp, GasAir, and Alturdyne) currently sell gas fired, engine driven direct-exchange packaged systems. These systems make use of a gas engine driven compressor. Currently, units are available in the 15- to 25-plus-ton range. The lack of smaller-sized systems significantly limits their ability to displace electric rooftop DX units in many commercial applications. Further, where there is a need for both larger and smaller sized units, developers may be reluctant to mix units of different types as this would require multiple maintenance contractors. The units also require more extensive and regular maintenance than similar electric units, and some distributors now offer service contracts to address this need.

Some of these units have the capability to provide hot water for service hot water purposes. As these hot water applications vary significantly, they have not been considered in the attached savings calculations.

Currently, gas-fired packaged DX units have captured a very small percentage of the commercial cooling market and there is a limited distribution and maintenance infrastructure in place. Some utilities like Brooklyn Union have offered significant rebates (several hundred dollars per ton) to reduce the higher first cost for these units. Also, most HVAC contractors are unfamiliar with the technology and might benefit from seminars or technical assistance provided by PG&E in new construction or retrofit applications.

Packaged Commercial Gas Cooling Systems

Measure Description: Single-package, air-cooled, direct expansion, natural gas engine-driven air conditioner

Market Information:		
Market sector:	COM	
End uses:	COOL	
Energy types:	ELEC,GAS	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	25 ton single-package, air-cooled, DX electric air conditioner.	
Base case efficiency:	9.0 EER	8.8 IPLV - range varies by manufacturer
Base case annual energy use:	34,000	kWh
New Measure Information		
New measure description:	25 ton gas-engine driven package unit	
New measure efficiency:	10.0	IPLV
New measure annual energy use:	2,000	kWh and 3,000 therms
Measure life:	20	years
Savings Information		
Electric savings/year:	32,000	kWh
Gas savings/year	(3,000)	therms
Feasible applications:	15%	est of large package cooling apps w/gas available
Savings potential in 2010:	104	GWh
	0.13	TBTU (net)
Cost Information		
Current measure cost:	$10,000	incremental vs $25,000 full measure cost
Future measure cost (in mass use):		
Other direct costs/savings:	($500)	plus $1200 per yr in gas usage @$0.40/therm
Cost of saved energy:	$0.043	per kWh
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	First cost, maint cost, perception of quality, local air quality regs	
Effect on customer utility:	None	
Current activity @ PG&E:		
Current activity elsewhere:	Brooklyn Union Gas	
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	XENERGY estimate	
Cost estimates:	Manufacturer interviews, XENERGY (1996)	
Measure life estimates:	Hufford (1997)	
Other key sources:	PG&E (1996) XENERGY (1996)	
Principal contact(s):	Eddie Napps, Napps Technology, 903-984-2112 Paul Hufford, GasAir, 713-360-0893 Joe Browning, Alturdyne, 619-565-2131	

Notes: Analysis does not include potential water heater savings.

Gas Absorption Chillers

Gas absorption chillers do not use a vapor compression cycle like other electric and gas compressor-based cooling systems. Instead, they use an absorption cycle utilizing a solution containing lithium bromide (LiBr). These units require a heat source such as steam (indirect fired), gas or oil (direct fired). Cooling efficiencies range from COPs of approximately 0.50 (single effect chillers) to 1.0 (double effect chillers). In addition to gas consumption by the compressor engine there is also electricity use associated with internal pumps and with increased cooling tower energy use. These auxiliary electricity usages have been included in the attached characterizations.

In addition to cooling, gas absorption chillers can provide hot water for either service hot water purposes or for simultaneous heating and cooling applications. These system applications are site specific and are not quantified in the attached characterizations. Because absorption units do not have as many moving parts as gas-engine driven chillers (though there are a number of internal solution pumps), maintenance costs are estimated to be similar to those of electric chillers.

To date, market penetration of gas absorption chillers is small, though American Yazaki estimates it has 100 units in PG&E's service territory. Some utilities such as Brooklyn Union have offered rebates to reduce the significant first cost barrier associated with this technology. PG&E could take a similar approach and/or work with manufacturers and distributors to educate engineers and large end users on the potential benefits of the technology.

To better characterize this technology, two measure descriptions are provided. Gas absorption chillers in the 150 to 300 ton range and those with capacities greater than 300 tons are described separately. A different baseline electric cooling technology is used in each of the characterizations.

Gas Absorption Chillers (150 - 300 tons)

Measure Description: Direct-fired, double-effect absorption greater than 150 ton chiller of less than 300 ton capacity

Market Information:		
Market sector:	COM, IND	
End uses:	SPACE COOLING	
Energy types:	ELEC, GAS	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	Reciprocating, water-cooled electric chiller.	
Base case efficiency:	0.70	kW per ton
Base case annual energy use:	125,000	kWh
New Measure Information		
New measure description:	Gas fired double effect absorption unit	
New measure efficiency:	1.05	COP
New measure annual energy use:	21,000	therms and 20,000
Measure life:	25	years
Savings Information		
Electric savings/year:	105,000	kWh
Gas savings/year:	(21,000)	therms
Percent savings:	-74%	on BTU basis
Feasible applications:	20%	in specified building types
Savings potential in 2010:	130	GWh
	(1,217,954)	net MMbtu savings
	(1.22)	TBTU (net)
Cost Information		
Current measure cost:	$112,500	incremental
Future measure cost (in mass use):		
Other direct costs/savings:		plus $8,400 in gas usage
Cost of saved energy:	$0.16	per kWh
Data Quality Assessment	B	wide variation in gas unit costs
Likelihood of Success		
Major market barriers:	First cost, knowledge, low cooling tower capacity, local air quality regs	
Effect on customer utility:	None, possible provision of hot water/space heat	
Current activity @ PG&E:	None	
Current activity elsewhere:		
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	XENERGY estimate	
Cost estimates:	Manufacturer interviews, XENERGY (1996)	
Measure life estimates:	Contacts listed below	
Other key sources:	E Source (1995a)	
Principal contact(s):	Ian McGavisk, York International, 717-771-7514. Dave Wiggins, McQuay International, 540-248-9557. Trevor Judd, American Yazaki Corp., 214-385-8725.	

Notes: Analysis does not include potential water/space heater savings.

Gas Absorption Chillers (300 tons or more)

Measure Description: Direct-fired, double-effect absorption chillers of 300 ton or more capacity, w/ or w/o heating capacity

Market Information:		
Market sector:	COM, IND	
End uses:	SPACE COOLING	
Energy types:	ELEC, GAS	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	300 ton centrifugal, water-cooled electric chiller	
Base case efficiency:	0.65	kW per ton
Base case annual energy use:	230,000	kWh
New Measure Information		
New measure description:	300 ton double effect absorption chiller	
New measure efficiency:	1.05	COP
New measure annual energy use:	41,000	therms and 4000 kWh
Measure life:	25	years
Savings Information		
Electric savings/year:	190,000	kWh
Gas savings/year:	(41,000)	therms
Percent savings:	-85%	on BTU basis
Feasible applications:	20%	in specified building types
Savings potential in 2010:	128	GWh
	(1,399,297)	net MMbtu savings
	(1.40)	TBTU (net)
Cost Information		
Current measure cost:	$120,000	incremental
Future measure cost (in mass use):		
Other direct costs/savings:		plus $16,400 in gas usage
Cost of saved energy:	$0.14	per kWh
Data Quality Assessment	B	wide variation in gas unit costs
Likelihood of Success		
Major market barriers:	First cost, knowledge, cooling tower capacity, local air quality regs	
Effect on customer utility:	None, possible provision of hot water/space heat	
Current activity @ PG&E:	None	
Current activity elsewhere:		
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	XENERGY estimate	
Cost estimates:	Manufacturer interviews, XENERGY (1996)	
Measure life estimates:	Contacts listed below	
Other key sources:	E Source (1995a)	
Principal contact(s):	Ian McGavisk, York International, 717-771-7514. Dave Wiggins, McQuay International, 540-248-9557. Trevor Judd, American Yazaki Corp., 214-385-8725.	

Notes: Analysis does not include potential water/space heater savings.

Gas Engine Driven Chillers

A number of leading chiller (Carrier and York) and marine/industrial diesel engine manufacturers currently market gas fired engine driven chillers in a large range of cooling capacities. These units compete with both electric reciprocating and centrifugal chillers. Unit efficiencies range from 1.20 to 2.0 COP, based on gas usage only, with larger units typically more efficient. In addition to gas consumption by the compressor engine there is also electricity use associated with internal pumps and with increased cooling tower energy use. These auxiliary electricity usages have been included in the attached characterizations.

Like other gas engine-driven cooling equipment, engine driven chillers require more comprehensive and regular maintenance than electric chillers. Manufacturers and local distributors now offer service contracts to meet this need and to help overcome end-user concerns of system reliability and performance.

In addition to cooling, gas chillers can provide hot water for either service hot water purposes or for simultaneous heating and cooling applications. These system applications are site specific and are not quantified in the attached characterizations.

To date, market penetration of gas engine chillers is small. Some utilities such as Brooklyn Union have offered rebates to reduce the significant first cost barrier associated with this technology. PG&E could take a similar approach and/or work with manufacturers and distributors to educate engineers and large end-users on the potential benefits of the technology.

To better characterize this technology, two measure descriptions are provided. Gas chillers in the 150 to 300 ton range and those with capacities greater than 300 tons are described separately. A different baseline electric cooling technology is used in each of the characterizations.

Gas Engine Driven Chillers (150 - 300 tons)

Measure Description: Natural gas engine-driven, water-cooled, chillers greater than 150 tons and less than 300 tons of capacity

Market Information:	
Market sector:	COM/IND
End uses:	SPACE COOLING
Energy types:	ELEC, GAS
Market segment:	NEW, REP
Base Case Information	
Base case description:	150 ton reciprocating water-cooled electric chiller
Base case efficiency:	0.70 kW per ton
Base case annual energy use:	130,000 kWh
New Measure Information	
New measure description:	150 gas-engine driven chiller
New measure efficiency:	1.50 COP
New measure annual energy use:	15,000 therms and 7800 kWh
Measure life:	25 years
	265,375
Savings Information	
Electric savings/year:	122,200 kWh
Gas savings/year:	(15,000) therms
Percent savings:	-15% on BTU basis
Feasible applications:	20% in specified building types
Savings potential in 2010:	145 GWh
	(241,070) net MMbtu savings
	(0.24) TBTU (net)
Cost Information	
Current measure cost:	$52,500 incremental
Future measure cost (in mass use):	
Other direct costs/savings:	($0.01) per ton-hour maintenance cost = $6,000 in gas usage
Cost of saved energy:	$0.09 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, high maint costs, quality concerns, and local air quality regs
Effect on customer utility:	None, possible provision of hot water
Current activity @ PG&E:	None
Current activity elsewhere:	Brooklyn Union Gas
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	XENERGY
Cost estimates:	Manufacturer interviews, XENERGY (1996)
Measure life estimates:	Contacts listed below
Other key sources:	E Source (1995a)
Principal contact(s):	Paul Hufford, GasAir, 713-360-0893 Bill Martini, Tecogen, Inc., 415-668-5842. Joe Browning, Alturdyne Energy Systems, 619-565-2131.

Notes: Analysis does not include potential water/space heater savings.

Gas Engine Driven Chillers (300 tons or more)

Measure Description: Natural gas engine-driven, water-cooled, chillers of 300 tons or more capacity

Market Information:	
Market sector:	COM/IND
End uses:	SPACE COOLING
Energy types:	ELEC, GAS
Market segment:	NEW, REP
Base Case Information	
Base case description:	300 ton centrifugal, water-cooled electric chiller
Base case efficiency:	0.65 kW per ton
Base case annual energy use:	230,000 kWh
New Measure Information	
New measure description:	300 water cooled gas engine driven chiller
New measure efficiency:	1.50 COP
New measure annual energy use:	32,000 therms and 13800
Measure life:	25 years
Savings Information	
Electric savings/year:	216,200 kWh
Gas savings/year:	(32,000) therms
Percent savings:	-37% on BTU basis
Feasible applications:	20% in specified building types
Savings potential in 2010:	145 GWh
	(607,933) net MMbtu savings
	(0.61) TBTU
Cost Information	
Current measure cost:	$100,500 incremental
Future measure cost (in mass use):	
Other direct costs/savings:	($0.01) per ton-hour maintenance cost + $12,800 in gas use
Cost of saved energy:	$0.11 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, local air quality regs, lack of information on technology
Effect on customer utility:	None, possi possible provision of hot water
Current activity @ PG&E:	None
Current activity elsewhere:	Brooklyn Union Gas
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	XENERGY
Cost estimates:	Manufacturer interviews, XENERGY (1996)
Measure life estimates:	Contacts listed below
Other key sources:	E Source (1995a)
Principal contact(s):	Paul Hufford, GasAir, 713-360-0893 Bill Martini, Tecogen, Inc., 415-668-5842. Joe Browning, Alturdyne Energy Systems, 619-565-2131. Ian McGavisk, York International, 717-771-7514.

Notes: Analysis does not include potential water/space heater savings.

Gas Engine Driven Heat Pumps

Gas engine driven heat pumps (GEHP) were developed in the late 1980's and field tested in the early 1990's. This development effort was supported by GRI, York International and a number of individual gas utilities Currently, the only commercially available product is a 3-ton York unit. The gas engine driven heat pump was developed largely to increase gas utility summer load and to address electric utility efforts to maintain/increase fuel market share through air source heat pump (ASHP) promotional activities.

The refrigeration cycles in an ASHP and a GEHP are similar. The GEHP compressor is driven by a reciprocating gas-fired engine rather than by an electric motor. Waste heat from the engine is used to supplement the heat derived from the heat pump's refrigeration cycle. Currently, GEHP are rated using either COP measurements of performance (for both heating and cooling) or "economic" SEERs (for cooling). This latter descriptor was developed by York and is region specific taking into account both cooling loads and average electric and gas prices.

The technology is likely to be inappropriate for market transformation efforts by PG&E given the high cost of these units, the low penetration of ASHPs in PG&E's service territory, and the service territory's relatively mild climate.

Gas Engine Driven Heat Pumps

Measure Description: Natural gas engine-driven heat pumps as substitute for gas furnace w/ split-unit central air conditioner

Market Information:	
Market sector:	RES, COM
End uses:	SPACE H/C
Energy types:	ELEC, GAS
Market segment:	NEW
Base Case Information	
Base case description:	Gas furnace w/ split A/C (see note 1)
Base case efficiency:	SEER 12 CAC and 85%+ AFUE furnace
Base case annual energy use:	1,071 kWh cooling
	372 therms heating
New Measure Information	
New measure description:	3 ton gas-fired heat pump
New measure efficiency:	1.34 COP cooling/ 1.26 COP heating
New measure annual energy use:	476 therms and 464 kWh
Measure life:	13 years
Savings Information	
Electric savings/year:	607 kWh
Gas savings/year:	(104) therms
Percent savings:	-8% on BTU basis
Feasible applications:	90%
Savings potential in 2010:	181 GWh - residential only
	(1,182,260) net MMbtu savings
	(1) TBTU
Cost Information	
Current measure cost:	$3,800 incremental vs $8,000 full measure cost
Future measure cost (in mass use):	$3,800
Other direct costs/savings:	($75) annual maintenance cost
Cost of saved energy:	$0.94 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, maint cost, perception of increased noise/vibration, availability
Effect on customer utility:	Higher register temperatures in heating mode (vs ASHP)
Current activity @ PG&E:	None
Current activity elsewhere:	GRI/AGCC
Likelihood of success rating (1-5):	1
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	EPRI (1991), E Source (1995c)
Cost estimates:	E Source (1995c), Bedard (1997), XENERGY (1996)
Measure life estimates:	E Source (1995c)
Other key sources:	PG&E (1996)
Principal contact(s):	Gary Bedard, York International, 717-771-6227

Notes: Savings based on residential application.
Furnace AFUE's and heat pump COPs are not directly comparable.

Commercial Heat Pump Water Heater

Commercial heat pump water heaters (HPWH) use a vapor compression cycle to extract heat from the ambient air to raise the temperature of water contained in the unit's storage tank. The heat pump cycle reduces the temperature of the surrounding air. Therefore, commercial HPWHs are often located in unconditioned spaces, spaces with low grade waste heat, and/or locations that would benefit from space cooling. The "waste" heat availability and space cooling benefits have made restaurants and laundries the most common applications for commercial HPWHs. These business types also have large hot water loads. Larger units have remote evaporators which allow cooling to occur distant from the HPWH's tank location. HPWHs generally have efficiencies of 1.5 to 3.0 EF, compared to a maximum of 0.97 for conventional electric hot water tanks (though larger, commercial units are not rated using a DOE-defined EF). Most HPWHs also rely on a resistance back up coil to meet peak hot water demands.

While the cooling benefits increase the attractiveness of the technology, the units are sold primarily on their water heating economics. The "free" cooling rarely displaces existing or proposed space cooling systems. Usually, a HPWH provides cooling to a space that would not otherwise be cooled. An Arthur D Little report for DOE showed that, in general, the technology has short pay backs against electric resistance hot water, even if the cooling benefits are not quantified (ADL 1996c). However, in most situations, the units do not have a pay back when compared to the costs to own and operate a new gas hot water heater. The attached characterization uses cost and savings data from the ADL report's analysis of a restaurant application in San Diego. No avoided cooling benefits were calculated.

Commercial HPWHs have been used for more than ten years in commercial applications. A number of utilities including Alabama and Georgia Power have promoted the technology, particularly to the food service industry. In addition to the first cost barrier of the technology, typical vendors and installers of resistance or gas water heaters are less comfortable with the more sophisticated technology associated with HPWHs.

Success in PG&E's service territory is likely to be limited due to the low penetration of electric hot water systems in commercial buildings, although their application in appropriate market niches, such as restaurants, laundries, hospitals, and hotels, should be explored. Interestingly, according to the CEC (1995), elementary schools had the greatest projected commercial building hot water electricity usage in 2010 — seven times that of the restaurant sector.

Commercial Heat Pump Water Heater

Measure Description: HIgh-efficiency electric water heater for use in laundries, restaurants, etc.

Market Information:		
Market sector:	COM, IND	
End uses:	WATER HTG	
Energy types:	ELEC, GAS	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	120 gallon, 45 kW, 184 gph recovery electric resistance unit	
Base case efficiency:	NA	
Base case annual energy use:	33,178	kWh, based on WATSIM analysis for San Diego
New Measure Information		
New measure description:	33,200 Btuh HPWH w/ two remote evaporators	
New measure efficiency:	NA	
New measure annual energy use:	19,023	kWh, including back up electric resistance
Measure life:	14	years
Savings Information		
Electric savings/year:	14,155	kWh
Gas savings/year:	NA	therms
Percent savings:	43%	
Feasible applications:	80%	in specified building types
Savings potential in 2010:	6	GWh
Cost Information		
Current measure cost:	$3,700	incremental installed cost
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.03	per kWh
Data Quality Assessment	A	
Likelihood of Success		
Major market barriers:	First cost, installer/contractor knowledge,	
Effect on customer utility:	"Free" cooling	
Current activity @ PG&E:	None	
Current activity elsewhere:	Alabama and Georgia Power	
Likelihood of success rating (1-5):	3	but in limited market
Relationship to PG&E business plan (1-3):	3	
Sources:		
Savings estimates:	ADL (1996b)	
Cost estimates:	ADL (1996b)	
Measure life estimates:	XENERGY estimate	
Other key sources:	EPRI and manufacturer websites	
Principal contact(s):	David Ritchie, Addison, 407-292-4400 Bernie Mittlestaedt, DEC/Therma-Stor, 800-533-7533 Charlie Watt, Georgia Power, 404-526-3039	

Notes:

Building Shell - Non-Residential

Window Film

Window films are used to achieve the benefits of solar control glazing in retrofit applications. Typical films have a total thickness of 0.001 to 0.004 inches, although special safety and security versions are available in thicknesses up to 0.012 inches. The films are made with a variety of adhesives and can be applied on-site to single- or double-glazed windows.

Window films have been available for many years and are a relatively low-cost means for reducing cooling load associated with solar heat gain. As such, the most cost-effective installations of window film will be in buildings with large solar loads (i.e., buildings with large amounts of glass relative to floor area). Early versions of window films had problems with fading, color shift, poor adhesive performance, and installation problems. These problems no longer exist with current window film technology. Most films come with a with a 10-year warranty for commercial buildings and lifetime warranty for residential applications. The films must be applied by a qualified installer.

In offices, window films also increase the comfort of occupants next to glazing. In convenience stores, chocolates and other meltables can be displayed next to windows. Spectrally-selective films, with high visible light transmission, are popular in retail applications because customers outside can see the merchandise displayed inside. When daylight dimming systems are in place, spectrally-selective films work well because they continue to let in most of the visible light; low transmittance films may cause an increase in lighting energy when used with daylighting. For the purposes of this model, we did not distinguish between selective and non-selective films. The lower light transmission of a non-selective film would require additional lighting energy if the building had a daylighting system installed. Since a market transformation program would target all commercial buildings, we do not assume daylight dimming systems, and thus calculate no lighting energy increase with a low visible transmittance window film.

To estimate the savings due to window film, a typical all-electric small office building in Fresno, CA was modeled (with DOE-2). The base case building windows were light-tint, single pane glass. The building with window film used Solis spectrally-selective window film over this glass. The overall energy reduction was two percent or 0.36 kWh per square foot. The overall reduction in cooling and ventilation energy was 6.4 percent. These reductions include an increase in heating consumption, because the window film admits less useful heat gain in the winter. From the CEC End-Use Forecast for PG&E, the cooling and ventilation energy estimated to be used in all commercial buildings in 2010 is 7273 GWh. We assume that it is not practical or cost-effective to install window film in 20 percent of commercial buildings due to climate, building shading, or architectural and application considerations. Given that, the total estimated savings due to installation of window film is 372 GWh.

Window film costs range from $2 to $10 per square foot. The lowest cost is for non-spectrally selective film applied to a very large building. The highest cost is for Solis film applied to a very small building (residential). An average cost is about $5 per square foot today. Half to three-quarters of this cost is installation, which will not decrease with volume. We assume a cost in mass use of $4 per square foot.

Window film must be installed by qualified installers. There are probably not sufficient installers in PG&E's territory currently for a market transformation program; however, were one to start, it is quite likely that the number of qualified installers would increase to meet the need. There is currently only one manufacturer of spectrally-selective film (Southwall). It is not clear that the manufacturing could scale up to meet the required production capacity.

As a market transformation target, window film would only be used for retrofits. Controlling unwanted solar heat gain is an excellent target for a market transformation program, but in new buildings would be better addressed by heat control glazing systems. It is worth noting, though, that Southwall reports many instances where they have installed Solis over shaded glass. The building owners/builders put in the shaded glass for "sun control" not realizing the difference between visible transmittance and shading coefficient.

Caveats:

- A small office building was modeled, but the results applied to all commercial buildings. Buildings with a higher glass to floor area ratio (e.g.: strip retail) would have higher savings per square foot of floor area.
- The base case assumed that the windows had a light tint; savings from window film applied to clear windows would be larger.
- No increase in energy due to less daylighting with window film is assumed for this analysis; this is justified because it is unlikely that all commercial buildings would have automatically dimming fixtures which would dim less because less daylight was coming through the filmed windows.
- Window film in the residential market was not accounted for, although though there could be significant savings in homes with lots of unshaded glass and air-conditioners running all day.
- The cost of $4 per square foot is fairly low for Solis spectrally-selective film, but a bit high for non-selective film.

Window Film

Measure Description: Spectrally-selective window film used to reduce cooling load

Market Information:	
Market sector:	COM
End uses:	COOL, VENT
Energy types:	ELEC
Market segment:	RET
Base Case Information:	48,000 sq ft ofc bldg, 6,150 sq ft glazing, 4,100 sq ft E,S,
Base case description:	W glazing, single-pane, light blue-green tint, 1/4" glass
Base case efficiency:	Tvis=0.75; U-values = 1.09; SHGC = 0.72
Base case annual energy use:	872,375 kWh bldg total (18.17 kWh per sq ft)
New Measure Information:	
New measure description:	Solis spectrally-selective film on E,S,W glazing
New measure efficiency:	Tvis=0.58; U-value = 0.95; SHGC = 0.47
New measure annual energy use:	854,377 kWh bldg total (17.80 kWh per sq ft)
Measure life:	10 years
Savings Information:	
Electric savings/year:	17,998 0.36 kWh per sq ft
Gas savings/year:	NA
Percent savings:	2%
Feasible applications:	80% of commercial buildings
Savings potential in 2010:	372 GWH
Cost Information:	
Current measure cost:	$5 $ per sq ft (range 2-10) inclding installation
Future measure cost (in mass use):	$4 $ per sq ft
Other direct costs/savings:	NA
Cost of saved energy:	$1.45 per kWh
Data Quality Assessment:	B/C
Likelihood of Success:	
Major market barriers:	High cost; sold on individual basis; installed by certified installer
Effect on customer utility:	Pot'l productivity increases; reduces fading and melting of objects
Current activity @ PG&E:	Rebate of $0.50/sq ft for SHGC <0.45 and single-pane windows
Current activity elsewhere:	Several other utilities also have or have had rebates
Likelihood of success rating (1-5):	3
Relationship to PG&E planning (1-3):	2
Sources:	
Savings estimates:	Boulder Energy Associates (1996)
Cost estimates:	Sharfstein (1997)
Measure life estimates:	Sharrstein (1997)
Other key sources:	
Principal contact(s):	Lynn Fryer, E Source, 303-440-8500
Notes:	

Night Roof Spray Thermal Storage

Many non-residential buildings have large, low-slope roof surfaces with an unobstructed view of the sky. In California summer weather, these roofs become much warmer than outdoor air in daylight hours and cooler than outdoor air at night. They cool by radiation to the night sky, whose temperature as a radiative receiver is usually below freezing. White roofs, a complementary energy technology, promise lower daytime roof temperatures but fail to take advantage of cool night conditions, and darken with time (thus heating up) because moisture condensed at night captures dirt which is baked on by the daytime sun.

Night Roof Spray Thermal Storage (NRSTS) cooling uses the roof surface at night to "spray cool" water on low-slope roofs. While its primary purpose is to cool storage water to 55 to 570 F on midsummer nights, the roof spray system also cleans the roof. The spray loop includes a sand filtration system with automatic backwash to remove collected dirt. The system also offers fire protection advantages in addition to its energy-saving and roof cleaning, benefits. NRSTS cooling is best suited to low-rise buildings in dry climates, where reliably clear summer night skies contribute to reduced sizing or elimination of conventional cooling components.

The NRSTS concept was developed by Davis Energy Group under the California Energy Commission's Energy Technologies Advancement Program (ETAP), and is marketed by Roof Science Corporation (RSC) of Davis, California. Seven projects were operating by the end of 1996, displaying a range of thermal storage options. One ETAP demonstration project in a 6,500 square foot system on a state building in Sacramento, uses storage water under rigid insulation and over a membrane roof to provide superior roof protection. Despite continuing success of that project, resistance to storing water on the roof has caused RSC to focus on "off-roof" cooling storage in water tanks or floor mass.

Two 1996 projects exemplify NRSTS configurations for new and retrofit applications, respectively. In the "charge" mode both systems spray water on the roof which is captured at roof drains, in each, the cooled water then drains to a large water storage tank. The new 27,000 square foot. Employment Development Department building in Los Angeles supplements the water tank with floor mass storage. In this case, water from the tank pumped to the spray heads, first passes through plastic tubing under the floor slab, precooling earth, sand, and concrete, thereby storing cooling for later use. The floor steadily delivers cooling throughout the day in addition to "storing cooling" at night. On thermostat demand, cool tank water is pumped to cooling coils added at the rooftop air conditioning units. This combination of floor cooling and forced-air coils typically justifies 50 percent reduction of conventional air conditioning capacity in new construction projects.

An 8,000 square foot retrofit NRSTS system at a U.S. Customs border station in Nogales. Arizona typifies opportunities for existing buildings. A l0,000-gallon chilled water storage tank was added near the central air handler, to which a large NRSTS precooling coil was added in the mixed air stream. Later, when the existing chiller is replaced, it may be downsized and coupled to the NRSTS tank to reduce installed cost and electrical demand charges, further enhancing NRSTS economics. Where improved lighting and other measures reduce cooling loads, existing chilled water coils will often be large enough to integrate with NRSTS retrofits designed to cool from 600 F water, eliminating the cost of adding NRSTS cooling coils.

Based on monitoring and calibrated computer simulations, NRSTS systems will provide 50 to 90 percent cooling energy savings in typical applications, saving from $0.15 per square foot per year in lightly-loaded coastal buildings to $0.75 per square foot per year in high-load inland valley climates (Bourne 1997). While new construction is the ideal time to consider this technology, retrofits are possible and are most cost effective when replacing a roof and simultaneously upgrading HVAC equipment.

Night Roof Spray Thermal Storage

Measure Description: NRTS takes advantage of the cold night sky in dry climates by spray-cooling water at night on large flat roofs, cleaning the "reflective" white roof and storing cooling for the next day's use.

Market Information:	
Market sector:	COM
End uses:	SPACE COOLING
Energy types:	ELEC
Market segment:	NEW
Base Case Information:	
Base case description:	50,000 square foot roof, 180 ton rooftop unit, Sacramento, CA
Base case efficiency:	5.5 SEER (including cooling and blower energy)
Base case annual energy use:	300,500 kWh 6.0 kWh per sq ft
New Measure Information:	
New measure description:	Roof spray system
New measure efficiency:	13.9 SEER (including cooling, blowers, and pump energy)
New measure annual energy use:	118,700 kWh 2.4 kWh per sq ft
Measure life:	30 years
Savings Information:	
Electric savings/year:	181,800 kWh 3.6 kWh per sq ft
Gas savings/year:	NA
Percent savings:	61%
Feasible applications:	10% share of single story comm'l buildings
Savings potential in 2010:	19 GWH
Cost Information:	
Current measure cost:	$70,000
Future measure cost (in mass use):	$30,000
Other direct costs/savings:	Reduce installed electric capacity in new constructing
Cost of saved energy:	$0.01 kWh (mature market)
Data Quality Assessment:	B
Likelihood of Success:	
Major market barriers:	Added cost, new tech, water on roof "fears", resistance from ind.
Effect on customer utility:	Reduced operating cost, improved comfort
Current activity @ PG&E:	Being reviewed by customer service engineers
Current activity elsewhere:	FEMP case study being developed for Nogales, CEC literature
Likelihood of success rating (1-5):	2
Relationship to PG&E planning (1-3):	1
Sources:	
Savings estimates:	Bourne (1997)
Cost estimates:	Bourne (1997)
Measure life estimates:	Bourne (1997)
Other key sources	Bourne (1997)
Principal contact(s):	Dick Bourne, Roof Science Corp., 916-757-4844 Steve Smith, Roof Science Corp., 916-757-4844 Gary Cler, E Source, 303-440-8500

Notes: Savings based on new construction only. Retrofit applications are possible but not as cost-effective unless roof replacement and HVAC up-grades are required simultaneously.

Whole Building Systems - Non-Residential

New Building Commissioning

Commissioning is "a systematic process of assuring by verification and documentation, ideally from the design phase to post-occupancy, that all building systems perform in accordance with the design intent and the owner's needs" (Peterson & Hassl 1996). With respect to energy-efficient projects, commissioning is the process of ensuring that a building and its equipment use energy as intended. This can mean taking actions such as: calibrating energy management systems; examining actual illumination levels; monitoring critical temperatures at heat exchangers; checking air volumes, control sequences and demand characteristics of HVAC equipment; calibrating thermostats; and so on.

Operating cost savings from new building commissioning of 7 to 15 percent in one case, and, in another case, 15 to 30 percent are reported by Bjornskav et al. (1994). Commissioning provides other benefits too, including increased occupant comfort, improved indoor air quality, and improved building system functioning. Despite these benefits, even in large facilities (in excess of 100,000 square feet), where systems are acknowledged to be complex, the practice of commissioning is not very widespread.

Several barriers inhibit building commissioning as a standard practice. Developers are reluctant to plan for a substantial additional up-front cost, since commissioning is rarely required by codes or ordinances. And equipment suppliers are pressured to minimize first costs. Some engineers place the average commissioning cost at about five to six percent of project cost, varying significantly with the size and complexity of the facility. Contractors do not want to be held liable for equipment performance beyond very narrowly defined operational limits. Tenants or building managers who will bear the costs and headaches of systems that don't operate well are more concerned about problem-free operation. Attending to building comfort is the highest priority in most facilities.

To promote new building commissioning, the Portland Energy Conservation Institute holds a national conference on the subject. In addition, a number of utilities have programs supporting commissioning of new buildings, including PG&E, FP&L, NEES, and Pacificorp. Recently, the Northwest Energy Efficiency Alliance (NEEA) contracted for the development of a market assessment on commissioning and a strategic plan for market interventions. Five objectives were identified for these studies, including determining which parts of the commercial building market are most appropriate for commissioning; establishing techniques to measure commissioning practices; identifying barriers to widespread adoption; determining opportunities to overcome those barriers; and creating an action plan with priorities for market intervention. In addition, through an initiative designed to increase commissioning in public buildings, NEEA has included start-up funding for a regional commissioning service providers' association that will, among other work, create standards for qualified providers. And an intern program will be established to train new commissioning providers (NEEA 1998).

The results of NEEA's strategic planning process will prove useful to those interested in promoting the practice of commissioning in new commercial buildings. In the meantime, among actions that PG&E can take to address this market are providing education to building owners on the need for commissioning services and providing education, training, and certification to increase the expertise of typical installation contractors and/or to train special commissioning experts.

New Building Commissioning

Measure Description: Develop protocols and tests to assure that high-efficiency equipment performs as expected

Market Information		
Market sector:	COM	
End uses:	HEAT, COOL, LTG	
Energy types:	ELEC, GAS	
Market segment:	NEW	
Base Case Information		
Base case description:	150,000 sq ft new buildings	
Base case efficiency:	34,995	primary Btu/sf (5.1 kWh/sf and 0.12 therms/sf)
Base case annual energy use:	5,249	mmBtu (including 761 MWh and 18,000 therms)
New Measure Information		
New measure description	Commissioning new building HVAC and lighting systems	
New measure efficiency:	31,846	primary Btu/sf
New measure annual energy use:	4,777	mmBtu/sf (including 3,550 MWh and 25,900 therms)
New measure life:	30	years
Savings Information		
Electric savings/year:	350,000	kWh
Gas savings/year:	2,600	therms
Percent savings:	9%	heating, cooling, lighting, and ventilation savings
Feasible applications:	62%	est 73% of floor area in bldgs >25,000 sq ft; 85% feasible
Savings potential in 2010:	83	GWH 0.1 TBTU
Cost Information		
Current measure cost:	$0.25	per sq ft
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.01	per kWh $0.07 per therm
Data Quality Assessment	C	
Liklihood of Success		
Major market barriers:	Services not available; limited expertise, high cost	
Effect on customer utility:	Improved comfort, improved system reliability	
Current activity @ PG&E:	None	
Current activity elsewhere:	PGE, Pacificorp, NW Collaborative, UI, SCL, NEES,Texas A&M, BC Hydro	
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	Harris (1997)	
Cost estimates:	Bjornskov et al. (1994), NWPPC (1996)	
Measure life estimates:	NWPPC (1996)	
Other key sources:		
Principal contact(s)		

Notes: Base case EUIs, derived from DOE/EIA (1995) represent heating, cooling, and ventilation energy in West.
For savings of approximately 9%, we use costs of $0.25 per sq ft based on NWPPC (1996).
Costs allocated 93% to electricity and 7% to gas based on primary energy savings.

Lighting - Non-Residential

Commercial Lighting Remodeling

While most commercial facilities remodel in five to seven year cycles, lighting is generally remodeled much less often, perhaps every second or third cycle (Hinge 1997). An opportunity to improve lighting efficiency is, therefore, often lost for a decade or more. When lighting is included in remodeling, energy-efficiency is not normally high on the list of retail managers/owners or lighting designer priorities.

A study for the Boston Edison Demand Side Management Settlement Board (Gordon et al. 1995) estimated that with an existing 1.7 billion square feet of commercial floor space in Massachusetts, initial illumination levels of 2.3 watts per square foot, 4,000 annual lighting hours, remodeling lighting savings of 30 percent, and a market penetration of 25 percent starting in 1996, annual savings of 58,650 MWh could be achieved by the year 2,000. This strategy was estimated to save 79 peak megawatts after 10 years.

There are significant barriers to incorporating efficient lighting into remodeling. While efficient lighting fixtures and lamps have greatly expanded and diversified in the past several years this message has not reached all players. Lighting is often designed by contractors or engineers, who may not be attuned to energy efficiency. Many office and retail build-outs are performed on an expedited schedule so the opportunity to intervene is brief.

The most productive interventions include educating owners and the design and design/build communities, who are most likely to influence cost-conscious clients. At the facility level, the time to begin these educational activities is before they are even planned; assembling databases of likely facility remodels and being proactive in marketing to facility owners and managers is the most fruitful approach and a very low cost one. In a further development, the recently formed Northeast Energy Efficiency Partnership (NEEP) intends to develop some standardized models that could be adopted off the shelf, simplifying the process and insuring that the new fixture choices would be cost-effective.

Commercial Lighting Remodeling

Measure Description: Replace existing lighting with efficient fixtures in commercial facility remodelling.

Market Information		
Market sector:	COM	
End uses:	LIGHTING	
Energy types:	ELEC	
Market segment:	REP	
Base Case Information		
Base case description:	30,000 sq ft store	
Base case efficiency:	2.30	watts per sq ft
Base case annual energy use:	276,000	kWh
New Measure Information		
New measure description	Replace with energy-efficient fixtures	
New measure efficiency:	1.61	watts per sq ft
New measure annual energy use:	193,200	kWh
New measure life:	20	years
Savings Information		
Electric savings/year:	82,800	kWh
Gas savings/year:	NA	
Percent savings:	30%	
Feasible applications:	25%	
Savings potential in 2010:	324	GWh
Cost Information		
Current measure cost:	$38,000	calculated based on cost of saved energy
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.04	per kWh
Data Quality Assessment	C	
Liklihood of Success		
Major market barriers:	Awareness, interest, timing, prioriites	
Effect on customer utility:		
Current activity @ PG&E:	Promotion of energy management program	
Current activity elsewhere:	NEEP prototype development	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	Gordon et al. (1995)	
Measure life estimates:	Gordon et al. (1995); Skumatz & Hickman (1994)	
Cost estimates:	Gordon et al. (1995)	
Other key sources:		
Principal contact(s)	Adam Hinge, NEEP, 914-631-9061 Fred Gordon, PEA, 503-233-6543	

Notes: Base case and efficiency case assume 4000 hours of operation for lighting.
Feasible applications assumes 50% of the market is transforming and another 25% will be difficult to capture (Gordon 1996).

Daylight Dimming Controls and High-Performance Glazing

Daylight dimming systems consist of photosensors that are wired to dimmable electronic ballasts along with a control interface that translates information from the sensor into a control voltage to the ballast. Dimming electronic ballasts are available in both step-dimming and continuously dimming models. Since step-dimming models cut light output by discrete amounts, daylighting applications are best designed with continuously dimmable ballasts.

There are significant market barriers associated with daylighting systems, including a lack of end-user, specifier and installer awareness and knowledge of daylighting systems themselves, as well as proper specifications and installation techniques. First cost and the perceived risk of adopting a new technology present additional barriers. For the most part, daylighting applications are best suited as new construction projects where a systems approach is taken, although some retrofit applications, generally large projects in suitable buildings, can be economic. The commercial energy savings potential from daylighting is small relative to other lighting measures, since applications are limited to areas that receive sunlight. Measures such as T8 lamping, electronic ballast upgrades and on-off switching should be implemented before daylight dimming measures have been installed.

Savings potential varies by application, but a range of 30 to 50 percent is reasonable. In a 1994 study by the Lighting Research Center, savings from three daylighting projects were reported as follows: (1) a PG&E project saved 33 percent (north side of building) and 48 percent (south side of building) of lighting energy; (2) the National Resources Defense Council used 52 percent less lighting energy, equaling 6 kW per year; and, (3) a Canadian study reported 30 percent energy savings over an 8-month monitoring period (Rea and Maniccia 1994).

In addition to direct lighting savings, additional energy savings are generated from reduced cooling loads. These benefits can be further increased if high performance windows are incorporated into the building design. These windows minimize solar heat gain yet have a high enough visible transmittance (40 to 60 percent) to ensure adequate daylight.

The cost of daylight dimming systems varies greatly, depending upon the application. Although the cost of dimmable ballasts and photocells is relatively easy to quantify ($40 - $90 for dimmable ballasts; $40 - $60 for photocells), identifying the average cost of a system is very difficult. Daylight dimming systems can use a variety of technologies (i.e. light tubes, sky lights, window design, building design) for a variety of applications (i.e. office, hospital, school, warehouse). The measure characterization assumes that a dimmable ballast, control interface and photocell are added to the baseline fixture. The cost assumption of $325 for a 4 fixture system included four $45 ballasts, a $50 photocell, a $20 interface, and $40 labor for roughly 1.5 incremental hours at $25 per hour. The incremental cost of the system equaled $185, given a baseline 4 fixture ballast plus installation cost of $140.

Currently, most lighting designers do not incorporate daylighting systems into their new building designs or into extensive renovation or remodeling projects. Increased training and education activities by professional organizations (e.g., IES), utilities, states and others can help lower designer reluctance to incorporate daylighting systems and teach them how to properly specify systems.

Daylight Dimming Controls and High Performance Glazing

Measure Description: Perimeter floor space uses high performance glazing, dimmable ballasts and photocells to control artificial light levels based on daylighting and reduce cooling loads.

Market Information:	
Market sector:	COM
End uses:	LTG
Energy types:	ELEC
Market segment:	NEW
Base Case Information:	
Base case description:	Electronic ballast, 2 F32T8 lamps, 4 fixtures per zone
Base case efficiency:	252 Watts (63 Watts per fixture)
Base case annual energy use:	754 kWh
New Measure Information:	
New measure description:	Dimmable ballast, control interface, and photocell added to baseline fixture
New measure efficiency:	176 Watts (assumes average of 70% full power)
New measure annual energy use:	527 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	335 kWh per zone, includes 30% cooling bonus and 40 kWh from glazing
Gas savings/year:	NA therms
Percent savings:	30% lighting only
Feasible applications:	20% perimeters with adequate daylight
Savings potential in 2010:	52 GWH
Cost Information:	
Current measure cost:	$185 incremental cost
Future measure cost (in mass use):	$125 incremental cost (decrease of $15 per fixture)
Other direct costs/savings:	$30
Cost of saved energy:	$0.03 kWh
Data Quality Assessment:	B
Likelihood of Success:	
Major market barriers:	Consumer/installer knowledge, first cost, misapplication, technology risk
Effect on customer utility:	Benefits associated with exposure to sunlight, reduced fabric fading
Current activity @ PG&E:	$3.50 rebate on photocells (PG&E website)
Current activity elsewhere:	Some utilities in CA and NE offer rebates
Likelihood of success rating (1-5):	2
Relationship to PG&E planning (1-3):	3
Sources:	
Savings estimates:	FLEX (1996), LRC (1994), CEC (1996), E Source (1994b)
Cost estimates:	FLEX (1996), LBNL (1996), XENERGY (1996), E Source (1994b)
Measure life estimates:	ACEEE estimate
Other key sources:	EPA (1995b)
Principal contact(s):	Dorene Maniccia, Lighting Research Center, 518-276-3057 Howard Gerber, XENERGY, 617-273-5700

Notes: The feasibility estimate is the high range given in an LRC scoping study for North America (10 to 20 percent)
Average daily lamp use (8.2 hours) is from a PG&E time-of-use-study by HBRS (1994).
Measure cost ($325) assumes four $45 ballasts, one $50 photocell, $20 interface, and 3 hours labor at $25 per hour.
Baseline cost ($140) assumes four $25 ballasts and 1.5 hours labor at $25 per hour.
Assumes each 4 fixture dayligting zone is 230 sq ft @1.1 W per sq ft (or a 15 ft square) and daylighting zone is three squares deep.
Four foot high windows yield 60 sq ft glazing per three zones at a cost of $1.50/sq ft future cost.

Refrigeration, Cleaning, and Other - Non-Residential

Refrigeration Integrated Design

Incorporating supermarket refrigeration compressors, condensers and evaporators into an integrated piping and controls design can optimize overall system efficiency. The integrated refrigeration compressor plant enables better control of part loading, reduced compressor short cycling, and improved suction pressure control. The integration of condensers optimizes the available condenser surface for reduced head pressure operation and, with proper control, minimizes condenser fan energy use. Refrigerated case measures may also be incorporated into the integrated design. These measures include high-efficiency case replacement, energy-efficient case lighting, and anti-sweat controls. The case evaporator fans can be replaced with higher efficiency fans, and the evaporator defrost can be converted from electric to hot gas. For new installations some/many of these energy-efficient options, e.g., hot gas defrost, may be part of the baseline design. One possible drawback to an integrated design is that a loss of refrigeration load could involve more refrigerant.

The cost and savings for this measure characterization are from a XENERGY engineering study. Emphasis in this characterization is on the hardware upgrades. A successful market transformation effort would need to address the significant first cost for improvements associated with an integrated refrigeration design, and address barriers to more efficient design. PG&E might, for example, offer design and technical assistance.

Refrigeration Integrated Design - Commercial

Measure Description: Integrated system of refrigeration compressors, condensers and evaporators in an integrated piping and controls design to optimize overall system efficiency

Market Information:	
Market sector:	COM
End uses:	REF
Energy types:	ELEC
Market segment:	NEW, RET
Base Case Information	
Base case description:	Copeland individual split condensing units with air cooled condensers
Base case efficiency:	Freezer: 2.4 kW per ton refrigeration, Cooler 1.4 kW per ton refrigeration
Base case annual energy use:	846,000 kWh
New Measure Information	
New measure description:	
New measure efficiency:	Freezer: 1.9 kW/TR, Cooler 0.95 kW/TR
New measure annual energy use:	632,000 kWh
Measure life:	12.5 years
Savings Information	
Electric savings/year:	214,000 kWh
Gas savings/year:	NA therms
Percent savings:	25%
Feasible applications:	50% of supermarkets
Savings potential in 2010:	110 GWh
Cost Information	
Current measure cost:	$70,000 incremental @ $875 per ton vs $130,000 for full measure cost
Future measure cost (in mass use):	$70,000 incremental
Other direct costs/savings:	$0
Cost of saved energy:	$0.04 per kWh
Data Quality Assessment	B though estimates will vary depending on base design
Likelihood of Success	
Major market barriers:	Higher first cost, and larger potential refrigerant charge losses
Effect on customer utility:	None
Current activity @ PG&E:	Not known
Current activity elsewhere:	Often handled as custom measure, e.g., NEES
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Sources:	
Savings estimates:	XENERGY engineering analysis
Cost estimates:	XENERGY engineering analysis
Measure life estimates:	XENERGY estimates based on industry experience
Other key sources:	

Principal contact(s):

Notes: Percent feasible recognizes that many new and existing systems already have some or all of the measures as part of an integrated system design.

Industrial Process Gas Refrigeration

Using gas-engine-driven compressors to produce refrigeration for industrial/agricultural process applications, including refrigerated warehouses, can lower operating costs. This measure addresses the replacement of one or more of the electric compressors with base-load gas-engine-driven compressors to reduce electric demand and/or electric energy costs. Favorable economics for this conversion may require a mix of gas and electric compressors with the gas unit(s) handling the base refrigeration load. The higher first cost, but lower operating costs, for gas units requires that the units operate a certain minimum number of hours to yield a lower life cycle cost than electric units. As a result, it may not be cost effective to replace electric units that are lightly loaded.

Costs and savings from the attached characterization are based on an actual installation in PG&E's service territory engineered by XENERGY. In this case, one of two electric compressors in a 270-ton system (the other is a 135-ton back-up compressor) was converted to a gas compressor. This base load unit represents 1,064,000 ton-hour per year out of a total system load of 1,400,000 ton-hours per year. The savings from this measure are attributed to the cost differential between natural gas and electricity (combined demand and electric energy components) for the replaced compressor only.

Currently, most process refrigeration compressors are electric. Both end users and designers/contractors are less familiar with the gas technology. Also, the gas compressors have a significantly higher first cost. PG&E could help address this first cost barrier with rebates and/or could provide technical design assistance to increase acceptance of the technology.

Industrial Process Gas Refrigeration

Measure Description: Utilize gas-engine-driven compressors to produce process refrigeration

Market Information:	
Market sector:	IND, AG
End uses:	REF
Energy types:	ELEC, GAS
Market segment:	NEW, REP, RET
Base Case Information	
Base case description:	Electric reciprocating compressors (MYCOM N6WA) 50 HP @ 92.4% eff.
Base case efficiency:	0.85 BHP per ton refrigeration
Base case annual energy use:	730,200 kWh
New Measure Information	
New measure description:	Baseload gas-driven reciprocating compressors
New measure efficiency:	NA
New measure annual energy use:	38,000 kWh
Measure life:	12.5 years
Savings Information	
Electric savings/year:	692,200 kWh
Gas savings/year:	(92,100) therms
Percent savings:	-24% on BTU basis
Feasible applications:	25%
Savings potential in 2010:	0.00 GWH
	0.00 TBTU net
Cost Information	
Current measure cost:	$33,000 incremental vs $50,000 for full measure cost
Future measure cost (in mass use):	$28,000 incremental
Other direct costs/savings:	$2,700 additional maintenance cost + $31,330 in gas use
Cost of saved energy:	$0.055 per kWh
Data Quality Assessment	C
Likelihood of Success	
Major market barriers:	First costs & maintenance requirements perceived higher than for electric
Effect on customer utility:	Likely to give facility leverage in negotiating future energy contracts
Current activity @ PG&E:	NA
Current activity elsewhere:	NA
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	XENERGY case study (rates from PG&E/SoCal Gas tariffs)
Cost estimates:	Equipment and O&M cost from actual, installed project
Measure life estimates:	XENERGY estimates based on industry experience
Other key sources:	
Principal contact(s):	

Notes: Industrial/agricultural floorspace, EUI and/or annual end use data not available.
Savings are thus underestimated.

High-efficiency Commercial Dishwashers

The lion's share of a commercial dishwasher's energy use comes from heating water. Three types of technologies target water heating and, therefore, characterize high-efficiency dishwashers: ultrasonic washing, improved rinse design, and booster heaters.

Ultrasonic dishwashers are an infant technology first developed in 1990 and commercially introduced in mid-1996. This new dishwashing process operates at 100°F - although a booster heater is still used for the rinse cycle (180°F). The technology, patented and registered globally by Ultrasonic Products, Inc., uses an ultrasonic transducer that can be molded into the shape that best fits the geometry of the dishwashing unit (Evans 1997). The transducer generates sound waves that result in micro-bubbles imploding on the dish surface at a rate of 40,000 times per second. The mechanical scrubbing and cleaning action derived from this implosion allows cooler water to be used. This new system is also omnidirectional, allowing waves to permeate into the interior of objects with no "dead spots."

Given that this technology is commercially unproven and that cost data are not available, it was not included in the screening analysis. Initial indications are promising in terms of energy savings (at least 40 percent), and the manufacturer asserts that the average payback period is one year. According to the manufacturer, several utilities in Florida, Vermont, Illinois, Iowa, New York, and New Jersey are investigating this technology.

Improved rinse design reduces the amount of high temperature water needed for the rinse cycle. Multiple rinse technologies, including fewer nozzles, improved nozzle design and improved system design, present an opportunity for increased energy savings. These technologies are incorporated in high-end commercial dishwashers and carry a price premium. Generally, European manufacturers, such as Electrolux, have the most advanced products which can cost over three times as much as a standard dishwasher and consume 50 percent less energy.

The technology deemed in the short term to have the most potential for cost-effective energy savings is the gas booster heater, and has, therefore, been characterized for the screening analysis. Restaurants and institutions with conventional high-temperature commercial dishwashing equipment must rinse dishes in water that is at least 180°F in order to sterilize them, according to code requirements. A booster heater is needed to raise the temperature of the water coming from the service water heater to the required level. Booster heaters most often use electric resistance immersion elements to heat the water, but gas booster heaters are available. A booster heater has an outer housing that contains a burner composed of a burner box and a combustion chamber. Booster heaters are built into some machines but are an add-on option for others. For most dish machines, a gas booster heater can replace an electric heater, except where there are venting limitations or in some cases sizing issues (gas models are slightly larger than electric models).

Commercial establishments that commonly have dish machines include restaurants, hospitals and nursing homes, hotels, and dormitories. Available data, unfortunately 10 years old, indicate that on a national basis "seventy percent of high-temperature (180°F) commercial dishwashing machines use electric booster heaters, the other 30 percent use gas booster heaters or generate hot water from the buildings' steam distribution system" (Liljenberg 1987). Discussions with manufacturers suggest that over the past three or four years the popularity of gas booster heaters has increased. A reasonable saturation estimate for gas booster heaters is 30 percent.

Energy usage of booster heaters varies depending upon the size of the dishwasher. Small under-counter commercial dishwashers can use booster heaters that intake as little as 17,000 Btu per hour (4 kW equivalent) and large, automated conveyer washers may have gas boosters that use as much as 360,000 Btu per hour (81 kW equivalent). For the measure comparison, a single-rack door type dishwasher, which comprises 85 percent of the commercial dishwasher market, was used as the new measure case (Sachi, et al. 1990). This unit draws 133,000 Btu per hour, while the baseline electric equivalent draws 15 kW.

Barriers to gas booster heaters include first cost, corporate approval for restaurant chains, owner aversion to the risk of new technologies including concern about possible venting requirements and sizing issues. Probably the most significant barrier is the first cost differential. One manufacturer stated that the cost of a gas booster heater is twice that of an electric heater and that the retail price of gas heaters will not decline in the near future, absent any third-party incentives.

The prognosis for a gas booster heater program is good. The technology is often cost-effective. Depending upon peak coincidence, payback periods can be as short as 9 months. The class of end-users is small which translates into small savings, but an easy target. Additionally, there are only a handful of manufactures of gas booster heaters, so market push efforts can be highly focused. A market transformation initiative should include an education component to inform installers of availability and installation requirements and to inform end-users of the economic benefits - annual operating savings of large units have amounted to $2,000 to $5,000 (GRI 1997).

High Efficiency Commercial Dishwashers

Measure Description: Pre-packaged gas-fired booster heater used in single-rack door type dishwasher

Market Information:		
Market sector:	COM	
End uses:	WATER HTG	
Energy types:	ELEC, GAS	
Market segment:	NEW, REP	
Base Case Information		
Base case description:	Electric hot water booster heater	
Base case efficiency:	15	kW
Base case annual energy use:	11	MWh
New Measure Information		
New measure description:	Gas-fired hot water booster heater	
New measure efficiency:	67,000	Btu/hour
New measure annual energy use:	48	MMBtu
Measure life:	10	years
Savings Information		
Electric savings/year:	11	MWh per unit
Gas savings/year:	-48	MMBtu per unit
Percent savings:	58%	
Feasible applications:	60%	(10% technically infeasible, 30% already gas)
Savings potential in 2010:	13.47	GWh
Cost Information		
Current measure cost:	$2,000	incremental, installed
Future measure cost (in mass use):	$2,000	
Other direct costs/savings:	$289	annual cost of gas + $50 increased maintenance
Cost of saved energy:	$0.05	per kWh
Data Quality Assessment	B	
Likelihood of Success		
Major market barriers:	First cost, restaurant chain bureaucracy, fear/risk of new technology	
Effect on customer utility:	None	
Current activity @ PG&E:	None	
Current activity elsewhere:	Minnegasco	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	2	
Sources:		
Savings estimates:	Sachi et al. (1990), Westerlund (1997)	
Cost estimates:	Sachi et al. (1990), Westerlund (1997)	
Measure life estimates:	Westerlund (1997)	
Other key sources:	Liljenberg (1987), GRI (1997)	
Principal contact(s):	Lance Westerlund, Raypak, 818-889-1500 Don Fritzsche, Gas Reseach Institute, 773-399-8382 Allan Bowers, Hobart Corp, 937-332-2781	

Notes: Cost of gas assumed to be $0.50 per therm
Daily usage is assumed to be two hours (derived from Sachi et al. 1990)
Baseline cost is assumed to be $1,600 and gas booster heater installed cost is $3,600

Optimized Commercial Kitchen Ventilation

Due to a combination of ill-founded code requirements and a tradition of poor design practice, ventilation and makeup air conditioning for commercial and institutional kitchens is one of the most wasteful areas of building energy use. A market transformation effort in this area would focus on at least two areas: reforming kitchen ventilation codes to encourage efficient, effective ventilation; and educating designers and clients in the principles and applications of optimized kitchen ventilation systems. Such an effort would build on existing efforts of the PG&E Food Service Technology Center, EPRI, ASHRAE, and others.

In new kitchen installations, optimized ventilation design can yield energy savings of 50 to 75 percent; in retrofit, savings of 10 to 50 percent are achievable, typically with paybacks of under 3 years. Kitchen ventilation and the heating or cooling of makeup air can comprise 25 percent of the entire energy load of a food service establishment, so improving the ventilation system can yield significant savings. Averaging across new construction and all existing facilities, a plausible savings level from a market transformation effort is 20 percent of the projected kitchen ventilation load in 2010 (Fisher 1997).

An average restaurant (the size of a large McDonalds) ventilates at about 3,000 cubic feet per minute. If all the makeup air is conditioned, such ventilation costs about $1 per year cfm, since many California climates don't require year round makeup air conditioning, a more typical rule of thumb for PG&E's territory is about $0.50 per year per cfm (Fisher 1997). There are an estimated 30,000 commercial food service facilities in PG&E territory; 20,000 to 25,000 restaurants; and 5,000 to 10,000 food service facilities in schools, hospitals, office complexes and other buildings (Fisher 1997). The ventilation of these facilities costs on the order of $45 million per year ($0.50 per cfm-yr x 3,000 cfm, x 30,000 facilities). At $0.10 per kWh, that's an electric load of 450 GWh. This estimate matches fairly well with the CEC data predicting ventilation and space cooling loads in restaurants in PG&E territory in 2010 of 400 GWh (CEC 1995). Using the CEC end use projections, a market transformation effort that reduces this load by 20 percent would thus save on the order of 80 GWh in the year 2010.

The cost of optimized ventilation varies wildly. Better design takes more time and costs more, but these costs may be somewhat offset by smaller, less costly equipment. Retrofits generally will cost more then new construction measures. Some specific opportunities such an effort would target include:

- Change codes that currently require 1,500 cpm of exhaust duct air flow;
- Group cooking equipment with similar ventilation needs under properly sized hoods;
- Facilitate better design team communication. Mechanical engineers currently design the fan system and kitchen consultants design the hoods;
- Use hood enclosures, which can cut ventilation needs in half;
- Stop the use of short circuit hoods, which meet code requirements but often result in inadequate ventilation;
- Pull makeup air from the dining room — McDonalds has done so for several years and cut ventilation load in half;
- Eliminate duplicate makeup air conditioning and use controls that are sensitive to space and ambient temperature; and
- Turn off ventilation during idle periods.

The technology is proven and available. The real challenge is designer and client education which will be difficult because of the diffuse nature of the target.

Optimized Commercial Kitchen Ventilation

Measure Description: Code reform and education on optimized design of kitchen ventilation systems

Market Information:	
Market sector:	COM
End uses:	Food service ventilation and makeup air conditioning
Energy types:	ELEC
Market segment:	NEW, RET
Base Case Information:	
Base case description:	3,000 square foot restaurant conventional design
Base case efficiency:	3,000 cfm ventilation load
Base case annual energy use:	15,000 kWh
New Measure Information:	
New measure description:	Enhanced design
New measure efficiency:	2,400 cfm ventilation load
New measure annual energy use:	12,000 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	3,000 kWh
Gas savings/year:	NA
Percent savings:	20%
Feasible applications:	100%
Savings potential in 2010:	80 GWH
Cost Information:	
Current measure cost:	$1,200
Future measure cost (in mass use):	$900
Other direct costs/savings:	NA
Cost of saved energy:	$0.03 kWh
Data Quality Assessment:	B
Likelihood of Success:	
Major market barriers:	Diffuse opportunity, need to influence many design professionals
Effect on customer utility:	Improved workplace comfort and often better ventilation.
Current activity @ PG&E:	PG&E FSTC working on code reform/optimized design seminar
Current activity elsewhere:	EPRI has active research on kitchen ventilation, ASHRAE considering
Likelihood of success rating (1-5):	2
Relationship to PG&E planning (1-3):	1
Sources:	
Savings estimates:	Fisher (1997)
Cost estimates:	E Source estimate
Measure life estimates:	Fisher (1997)
Other key sources:	
Principal contact(s)	Don Fisher, PG&E FSTC, 510-866-5770 Michael Shepard, E Source, 303-440-8500

Notes: Savings are average across a wide range of applications.
Costs are illustrative, to fit 3-year payback.
FSTC — Food Service Technology Center

Ozone Laundry

Ozone, the triatomic form of oxygen, acts as a powerful oxidant and is commonly used for disinfecting drinking water and swimming-pool water. When wash water contains or is saturated with ozone, less chemicals and a lower water temperature are needed to achieve high-quality cleaning. The amount of water needed for rinse cycles is reduced because less chemicals need to be removed. This also shortens the time required to complete the laundry cycle. Tests also indicate that ozone laundering can extend fabric life as much as 35 percent.

The relative water temperature, ozone concentrations, and amount of chemicals needed depends on the type of fabric and its soil level. The greatest savings occur with lightly soiled laundry, such as linens and towels, which allow for the low water temperatures and concentrations of cleaning chemicals. Manufacturer claims of natural gas savings of about 30 percent are typical. A test conducted by Georgia Power Company found that one manufacturer's system reduced a laundry facility's gas consumption by 32 percent. However, electricity consumption will increase somewhat to power ozone system pumps, an ozone generator, and an air compressor.

Field data show typical payback of investment in ozone laundry of two to four years. The economic benefit of ozone laundry systems comes not just from energy savings achieved as a result of lower water temperatures but also from increased productivity and lowered costs of water, sewer, and chemicals. According to the EPRI, because rinse cycles can be reduced, ozonated laundry systems can cut total wash times by about 20 to 40 percent per load (EPRI 1996). For operations that need to expand, this presents an opportunity to increase productivity around the clock. Alternately, it can allow for reduced labor costs.

Manufacturer data and field tests show that chemicals such as detergent, brighteners, and water softeners can be reduced by 30 to 70 percent. Water use can be reduced by about 12 to 30 percent for open-loop ozone laundry systems in which wash and rinse water drains into the sewer. For close-looped systems which recycle water, savings in water volume of up to 75 percent have been achieved. Further, a smaller amount of wastewater leads to lowered sewer costs.

Three U.S. manufacturers supply ozone laundry systems: Tri-O-Clean Systems, Cyclopss Textiles, and Oxygen Technologies (OxyTech). Each manufacturer sells open-loop systems in which wash and rinse water drains into the sewer. Tri-O-Clean also offers the closed-loop system that recycles a significant portion of the wash water. All target facilities that handle at least 1,500 pounds of laundry per day (equivalent to that generated by a 200-room hotel). This enables an adequate return on investment on the initial cost of ozone equipment. Good target markets for ozone laundry systems include facilities that are operating close to capacity and/or that need to expand, and can avoid buying additional conventional washing equipment by investing in an ozone system. Over a hundred installations of ozone laundry systems exist in the U.S., in facilities such as hotels, prisons, hospitals, and commercial laundries.

Ozone laundry was introduced in 1991. So it is relatively new technology and many potential users are unfamiliar with it or skeptical of its economic benefits and performance. To overcome such barriers, publicity about existing installations, demonstrations sponsored by trusted organizations, and more data on performance from reputable third parties could all enhance the rate of market penetration.

Ozone Laundry

Measure Description: Commercial laundry system that uses ozone-saturated water and reduces detergent and water use.

Market Information:		
Market sector:	COM	
End uses:	CLOTHES WASHING	
Energy types:	GAS	
Market segment:	NEW, RET	
Base Case Information:		
Base case description:	Conventional 2,000 lb.day laundry system	
Base case efficiency:	1,308	Btu/lb. of laundry
Base case annual energy use:	9,458	therms per year
New Measure Information:		
New measure description:	Same equipment plus 25 gpm ozone generator system.	
New measure efficiency:	915	Btu/lb of laundry
New measure annual energy use:	6669/6,000	6669 therm of gas; 6,000 additional kWh
Measure life:	10	years
Savings Information:		
Electric savings/year:	None	Increases base case use by 6,000 kWh/yr
Gas savings/year:	2,879	therms
Percent savings:	30%	
Feasible applications:	33%	
Savings potential in 2010	0.09	TBTU
Cost Information:		
Current measure cost:	$35,000	
Future measure cost (in mass use):	$35,000	
Other direct costs/savings:	$3,252	
Cost of energy saved:	$0.69	per therm
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	New technology; little unbiased evaluation; concerns re laundry quality	
Effect on customer utility:	Reduces wash-cycle time; reduces chemical, water, and sewer costs	
Current activity @ PG&E:	NA	
Current activity elsewhere:	Several electric utilities; EPRI's Health Initiative promotes systems for use in health-care facilities.	
Likelihood of success rating (1-5):	2	
Relationship to PG&E planning (1-3):	1	
Sources:		
Savings estimates:	Pearsall (1997) EPRI (1996)	
Cost estimates:	Pearsall (1997)	
Measure life estimates:	Pearsall (1997)	
Other key sources	NA	
Principal Contact(s):	Dusty Pearsall, Tri-O-Clean Laundry Systems, 407-595-6500 Natalie Brown, Cyclo3pss Textile Systems, Inc., 800-972-9091 Dan Katz, Oxygen Technologies, Inc., 800-972-9091	

Notes: Assumes four 50-lb. capacity washers and seven 85-lb. capacity washing machines, using 4,725 gallons of rinse and wash water. Assumes 325 installations (hotels, nursing homes, hospitals, and commerical laundries) based on 33 percent of an estimated 988 potential installations equivalent to the base case size based on DOE/EIA (1992). Other cost savings represent reduced chemical, water, and sewer costs.

Laundry Wastewater Recovery

Commercial laundries represent a significant potential for wastewater recovery. Savings are generated from a reduction in energy used to heat water, lower water use and lower sewage use. Currently, a small number of manufacturers produce waste water recovery systems. Some recover only less dirty rinse water (Hydrokinetics), while others recover water from the entire wash cycle (Wastewater Resources Inc.). The former involves only a lint filter, has a lower capital cost, but also has lower water and energy savings. The latter system, which is the one characterized, utilizes membrane micro-filtration units (MFU). Particulates are removed from the wastewater by a series of membrane filters, and the water is then recycled.

Pacific Northwest National Laboratory (PNNL) conducted five months of detailed monitoring of an MFU wastewater recovery unit installed in a central laundry facility for a group of hotels in Portland (Ledbetter et al. 1996). Based on the findings of this study, the technology is estimated to have a 1.2 to 2.7 year payback, depending on local utility rates. Marc Ledbetter of PNNL estimates that, on average, one-third of the dollar savings are from reduced gas use (there is an increase in electricity use), and two-thirds are from reduced water and sewage use (Ledbetter 1997) The Portland unit achieved 52 percent savings in water consumption and 44 percent savings in energy to heat water. Manufacturer claims of further savings from recovery of soaps and conditioners were not examined as part of the Portland study. The Portland unit used three levels of membranes to filter out particulates from the wash water. Subsequently, the manufacturer reduced the number of filtration steps to two, resulting in lower initial capital cost. This re-design also eliminates the need to periodically replace the third filtration membrane. The membranes are cleansed by scheduled automatic back flushes.

The PNNL study made a number of recommendations to improve the use of an MFU system. These include installing a pH controller if a solid chemical dispenser is used and isolating one machine, that would not be connected to the MFU, for heavily soiled or oily loads. The cost of saved energy calculations in the accompanying measure characterization are based on the monthly savings from the Portland unit, adjusted to reflect PG&E gas and electric prices. Water and sewage rates are for San Francisco and are from the PNNL report. Maintenance cost savings of $166 per month are also included. Capital costs are $100,000 plus an additional $10,000 for facility modifications prior to installation. The potential number of facilities (at an assumed base case of 25,000 lbs per day) that could use the technology are an estimate and should be reviewed before PG&E commits to further action on this technology.

Currently, the technology has a negligible penetration. Primary market barriers are cost and lack of familiarity with the technology.

Laundry Wastewater Recovery

Measure Description: Commercial laundry wastewater recovery

Market Information:	
Market sector:	COM
End uses:	WATER HTG
Energy types:	GAS
Market segment:	NEW, REP
Base Case Information:	
Base case description:	Six machine, 25,000 lbs/day laundry facility
Base case efficiency:	1,410 Btu/lb laundry - gas and steam
Base case annual energy use:	NA
New Measure Information:	
New measure description:	Same facility w mirco-filtration watewater recovery unit
New measure efficiency:	820 Btu/lb laundry - gas and steam
New measure annual energy use:	NA
Measure life:	10 years
Savings Information:	
Electric savings/year:	(69,600) kWh
Gas savings/year:	36,480 therms
Percent savings:	42%
Feasible applications:	-- in specified building types
Savings potential in 2010:	0.29 TBTU (net)
Cost Information:	
Current measure cost:	$82,000
Future measure cost (in mass use):	$82,000
Other direct costs/savings:	$70,158 reduced annual maintenance, water, and sewage cost
Cost of saved energy:	(1.43) per therm
Data Quality Assessment:	A/C cost and savings/potential sites
Likelihood of Success:	
Major market barriers:	First cost, abd installer, contractor, and end user knowledge
Effect on customer utility:	NA
Current activity @ PG&E:	NA
Current activity elsewhere:	NA
Likelihood of success rating (1-5):	3 if promoted in areas with high water/sewage rates
Relationship to PG&E planning (1-3):	1
Sources:	
Savings estimates:	Ledbetter et al. (1996)
Cost estimates:	Ledbetter et al. (1996)
Measure life estimates:	XENERGY estimate
Other key sources:	
Principal contact(s):	Marc Ledbetter, PNNL, 503-417-7557 Louis Vuilleumer, Conservation Consortium, 508-362-2484 Randall Jones, Wastewater Resources Inc., 602-391-9939

Notes: Electricity usage evaluated @ $0.10 per kWh. Estimated no. of sites (100) at base load usage of 25,000/da should be examined before PG&E proceeds further with this initiative.

Motors Systems - Non-Residential

Premium Efficiency Motors

Electric motors, which consume more than half of the electricity in the U.S. and almost 70 percent of manufacturing sector electricity, generally turn electrical energy into mechanical energy very efficiently. Nevertheless, for most motor types, a range of efficiencies is available. Because even small efficiency improvements often make economic sense for equipment operated thousands of hours per year, the overall opportunity for energy savings from more efficient motors remains large.

Typically, the annual operating cost of a motor far outstrips the initial purchase price. For instance, a typical 75 horsepower (hp) motor running at full load for 8,000 hours per year would consume about $24,000 worth of electricity at $0.05 per kWh. A typical purchase price for such a motor is about $4,000. Even the incremental cost of buying a new "premium efficiency" motor rather than repairing a standard efficiency motor can be recovered in less than two years for most motors less than 75 hp.

Motors programs are already among the most common programs offered by utilities to their commercial and industrial customers. With new minimum efficiency standards for electric motors that took effect in October 1997 under the Energy Policy Act of 1992 (EPAct), ongoing utility programs will need to raise qualifying levels that they've established for their motors programs.

The Consortium for Energy Efficiency (CEE) developed a "premium efficiency" motors initiative that sets minimum efficiency levels above those specified in EPAct. This program provides a common definition for a nominal full-load efficiency level above the "energy-efficient" level in EPAct, for all electric motors covered under the law: National Electrical Manufacturers Association (NEMA) design A and B, three phase, integral horsepower, general purpose, open drip proof (ODP) and totally enclosed fan cooled (TEFC) motors with six poles (1200 rpm), four poles (1800 rpm) and two poles (3600 rpm).

In analyzing this measure, we consider savings associated with a 25 hp motor. The full-load efficiency of a 25 hp, open-dripproof, 1800 RPM, premium efficiency motor, compared to an EPAct energy-efficient motors is approximately two nominal full-load efficiency percentage points (i.e, approximately 94 percent versus 92 percent). Typically, premium efficiency motors cost between 15 and 30 percent more than energy-efficient motors. This analysis assumes an incremental cost of $1,000 for the premium efficiency motor.

A recent study of the motor marketplace identified several barriers to the adoption of energy-efficient motors, including: higher first cost, inadequate planning for motor replacement decisions, lack of knowledge regarding actual performance and true savings, and confusion as to the definitions of "high-efficiency," "premium-efficiency" and "energy-efficient" motors (Friedman et al. 1996). The CEE Motors Subcommittee is coordinating its efforts with those of individual manufacturers as well as NEMA, the Energy Efficient Procurement Collaborative (EEPC), and the DOE Motor Challenge Program, to address many of these barriers. To contribute to national shifts in efficient product availability, PG&E should participate in the CEE initiative by adopting the CEE levels for their motors program.

Premium Efficiency Motors

Measure Description: Promote the purchase a premium efficiency motor in place of a standard EPAct motor

Market Information:	
Market sector:	IND
End uses:	MOTORS
Energy types:	ELEC
Market segment:	NEW, REP
Base Case Information:	20 HP, 4000 hours, 75% load, fan motor
Base case description:	Standard EPAct Motor
Base case efficiency:	91% @ full load
Base case annual energy use:	49,187 kWh
New Measure Information:	
New measured description:	Premium efficiency, CEE-qualifying motor
New measure efficiency:	93% @ full load
New measure annual energy use:	48,129 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	1,058
Gas savings/year:	NA
Percent savings:	2%
Feasible applications:	100%
Savings potential in 2010:	123 GWH
Cost Information:	
Current measure cost:	$150 incremental
Future measure cost (in mass use):	$150
Other direct costs/savings:	NA
Cost of saved energy:	$0.01
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Expertise limited; lack of awareness of energy svgs pot'l
Effect on customer utility:	
Current activity @ PG&E:	Several programs to improve industrial efficiency
Current activity elsewhere:	NEMA, DOE, CEE and numerous utilities
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	1
Souces:	
Savings estimates:	Friedman et al. (1996)
Cost estimates:	Elliott (1997)
Measure life estimates:	Elliott (1997)
Other key sources:	Friedman et al. (1996)
Principal contact(s):	Neal Elliott, ACEEE, 202-429-8873

Notes: Assumes total California industrial electricity consumption of 13,350 GWh in 2010.

High-Quality Motor Repair Practices

It is estimated that there are more than a billion electric motors in operation. These motors consume more than half of the electricity in the U.S. and almost 70 percent of manufacturing sector electricity. According to research by Bonneville Power Administration (BPA) and a number of Canadian utilities, approximately two million integral horsepower AC motors are repaired in the U.S. annually. (For comparison, note that fewer than 700,000 new motors are purchased annually). Motors are typically repaired for ailments such as seized bearings, winding burnout, or broken fans every five to seven years — or three to five times in their lifetime.

Motors are generally very efficient. If properly repaired at time of failure, most motors can be restored to their original efficiency. However, improper motor repair can decrease motor efficiency by up to five percent, and most studies report average full-load efficiency losses for repaired motors of one percent for motors under 100 hp and 0.5 percent for larger motors. While this change may appear small, when summed across all motors in use, the energy losses are significant (Schueler et al. 1994).

Motor repair can involve several possible procedures. Reconditioning is performed on motors that are electrically sound but whose bearings have worn out. If the motor has experienced an electrical failure due to a short or overloading, the motor is then rewound. Rewinding involves removal of the old windings, placement with new windings, and reconditioning. This analysis assumes a 50 hp motor is rewound by a quality repair shop (see below) at a cost of 20 percent more than assumed baseline rewind costs.

Canadian utilities, which lead efforts to counter efficiency losses that result from repair, have found a strong link found between shop quality assurance efforts and the likelihood that motors will be repaired without decreasing efficiency (WSEO 1994). By working with the motor repair industry, utilities can provide information and services critical to helping industrial and commercial customers manage their energy use and improve productivity.

Recently, the Electrical Apparatus Service Association (EASA), the trade association for the repair industry in North America, established a standard for a quality repair, EASA-Q, which is ISO-9000 compliant. Because of its rigor and burdensome record-keeping requirements, however, thus far only three shops in the U.S. qualify as EASA-Q certified. To address this, Alternative Energy Corporation developed a motor repair shop certification program. The first "class" entered in December 1997. The program, which has relatively limited record-keeping requirements, offers on-site assessment of competency in motor repair, as well as a performance evaluation of repaired motors. Two shops are currently nearing completion of the certification process, and six others are in various stages in the process.

In addition, EASA and BPA have developed guidelines for repair shops and customers to identify the key points that characterize a quality repair. EASA and Motor Challenge are also developing educational materials for customers on quality repairs.

Several utilities and the Energy Center of Wisconsin (ECW) are now designing repair programs to encourage repair shops to perform, and customers to request, quality repairs. Utilities can also assist small repair shops in acquiring equipment to perform quality repairs. CEE and DOE's Motor Challenge are working with the Washington State Energy Office to develop specifications and informational materials for a national motor repair initiative. It is anticipated that utilities can begin deploying programs using these materials by the Fall 1998. PG&E can work with CEE to develop and implement a motor repair program.

High Quality Motor Repair Practices

Measure Description: Promote quality motor repair practices

Market Information:	
Market sector:	IND
End uses:	MOTORS
Energy types:	ELEC
Market segment:	RET
Base Case Information:	50 HP motor; 75% loaded; 5000 hours
Base case description:	Full-load eff rating decrease of 1%; 8% increase in losses
Base case efficiency:	90%
Base case annual energy use:	154,935 kWh
New Measure Information:	
New measured description:	Efficiency loss of 0% of full-load efficiency
New measure efficiency:	91%
New measure annual energy use:	153,709 kWh
Measure life:	7 years
Savings Information:	
Electric savings/year:	1,226 kWh
Gas savings/year:	NA
Percent savings:	1%
Feasible applications:	85%
Savings potential in 2010:	63 GWH
Cost Information:	
Current measure cost:	$240 incremental
Future measure cost (in mass use):	$120
Other direct costs/savings:	NA
Cost of saved energy:	$0.02 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	Quality repair ill-defined; difficult to promote
Effect on customer utility:	Higher quality motors, more efficient, more reliable
Current activity @ PG&E:	Several programs to improve industrial efficiency
Current activity elsewhere:	Motor Challenge, CEE, EASA, EPRI, some utilities
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	3
Souces:	
Savings estimates:	WSEO (1994); Elliott (1997)
Cost estimates:	WSEO (1994)
Measure life estimates:	WSEO (1994)
Other key sources:	Friedman et al. (1996)
Principal contact(s):	Neal Elliott, ACEEE, 202-429-8873

Notes: Assumes total electricity consumption of 13,350 GWh in industry in 2010.
Assumes current quality motor repair costs 20% more than baseline repair practices, estimated to cost $1200. Future incremental cost is expected to be reduced to 10% of current standard practice.

Industrial Pumps, Fans, and Blowers

Pumps, fans, and blowers — key motors applications in the manufacturing sector — comprise an estimated 25 to 30 percent of the total motor-related electricity consumption in the manufacturing sector, but represent more than 70 percent of the electrical energy savings potential in the sector (Easton 1994).

XENERGY Inc. is currently preparing a study updating information on the share of pumps, fans. blowers, and other industrial motors applications for the DOE Motor Challenge program. This study, however, was not available at the time of this writing.

Industrial *pumps*, which are used both to serve specific production processes (e.g., process pumps) and to support ancillary systems (e.g., cooling water loops or boiler feed systems) consume approximately 20 percent of motor-driven electricity consumption in the manufacturing sector, or approximately 15 percent of the total manufacturing electricity consumption. Initial field research indicates that industrial process pumping electricity consumption could be reduced by as much as 30 to 40 percent, although this savings potential may be difficult to capture. Opportunities exist to improve pump package efficiency by approximately 5 to 10 percent. More efficient system design could reduce process pump systems consumption by an estimated 10 to 20 percent, and increased use of speed control could reduce pump systems consumption by anywhere from 10 to 40 percent (Easton 1994).

Industrial *fans and blowers* comprise roughly 8 to 10 percent of total motor-driven electricity consumption or six to seven percent of total industrial electricity consumption. Moderate savings potential exists at the equipment-level (5 to 15 percent) and in system design improvements (5 to 25 percent), and modest savings are possible from improving motor, drive train, and impeller selection practices (20 to 50 percent with high-end savings applying to variable flow systems) (Friedman et al. 1996, Easton 1994).

For the purpose of this analysis, more efficient industrial fan, pump, and blower systems are assumed to result in motor-driven equipment savings of 20 percent. This savings potential is applied to the approximately 30 percent of total motor-related electricity consumption that these applications comprise. Based on ACEEE experience, this analysis assumes a cost of saved energy of $0.02 (Elliott 1997).

Several challenges to achieving potential energy savings exist, however. First, a "systems" approach to improved equipment selection is complicated, and in general, end-users (and even the consulting engineers they hire) often lack knowledge regarding appropriate equipment (e.g., pump impeller types, or ASDs) for particular applications and their energy savings potential. The absence of a common rating guideline on energy efficiency and other performance features contributes to this problem. Second, key purchasing decisions often are based on first cost, not lifecycle costs. Additional criteria used in evaluating purchasing decisions include reliability and performance, but rarely energy efficiency. Also, purchasers typically do not take the time for proper system optimization.

Parties interested in promoting motor-driven equipment efficiency need to work with manufacturers, distributors, contractors, and specifiers, all of whom influence efficiency, and to educate end-users about the energy and cost savings opportunities. A number of utilities (including PG&E) and non-regulated subsidiaries of utility holding companies are now successfully using a "systems" approach as the platform for developing various marketing, training, and trade ally programs to promote efficient compressor, pump, and fan and blower systems (Carroll et al. 1994).

Industrial Pumps, Fans, and Blowers

Measure Description: Promote improved selection/optimization practices for fan, pump and blower systems

Market Information:	
Market sector:	IND
End uses:	MOTORS
Energy types:	ELEC
Market segment:	NEW, REP, RET
Base Case Information:	
Base case description:	Improved equipment design, system optimization
Base case efficiency:	NA
Base case annual energy use:	NA
New Measure Information:	
New measured description:	Savings of 20% relative to existing practices
New measure efficiency:	20% savings in motor-driven electricity consumption
New measure annual energy use:	NA kWh
Measure life:	7 years
Savings Information:	
Electric savings/year:	NA kWh
Gas savings/year:	NA
Percent savings:	20%
Feasible applications:	50% of all facilities
Savings potential in 2010:	489 GWH
Cost Information:	
Current measure cost:	$150,000 incremental cost per facility
Future measure cost (in mass use):	NA
Other direct costs/savings:	NA
Cost of saved energy:	$0.02 per KWh
Data Quality Assessment	C
Likelihood of Success	
Major market barriers:	Systems approach not well understood, tools unavailble
Effect on customer utility:	Can improve reliability, productivity
Current activity @ PG&E:	Pilot project planned for 100 sites
Current activity elsewhere:	A number of utilities, DOE
Likelihood of success rating (1-5):	2
Relationship to PG&E business plan (1-3):	1
Souces:	
Savings estimates:	Friedman et al. (1996)
Cost estimates:	Elliott (1997); PG&E (1996)
Measure life estimates:	Friedman et al. (1996)
Other key sources:	
Principal contact(s):	Neal Elliott, ACEEE, 202-429-8873

Notes: Assumes total electricity consumption of 13,350 GWh by California industry in 2010. Percent feasible (50%) represents systems with significant potential for cost-effective energy savings; other systems have low loads or are already quite efficient.

Industrial Compressed Air System Improvements

Compressed air is heavily used in industrial processes, accounting for 10 to 13 percent of electrical energy consumption. The systems vary widely in configurations, but have several similar characteristics consisting of one or more electric motors, compressor air-ends/packagers, filters and/or dryers, pressurized air reservoirs, distribution piping and valves, and point-of-use tools.

One study suggests that the technical potential for improving the efficiency of air compressors ranges from 25 to 40 percent of end-use consumption. A more recent study, suggests that equipment efficiency improvements, improved system design, and proper operation and maintenance could reduce electricity consumption by 50 percent or more when applied in combination (Friedman et al. 1996). This analysis assumes electricity savings of 40 percent.

Measures for improving efficiency of a compressed air system include those that affect the distribution of compressed air (e.g., redesigning piping layout and pipe sizing, eliminating air leaks, etc.), those that deal with system controls (i.e., compressor controls) and point-of-use improvements (i.e., installing and automating point-of-use controls), and the production of compressed air (e.g., replacing inefficient air compressors with more efficient machines). In addition, compressed air system efficiency programs are fairly maintenance intensive. A good maintenance program provides for daily recording of critical performance parameters, and checking air filters and oil levels, periodic draining of the system of water, monthly checks and air-leak repairs; and semi-annual and annual inspections of mechanical components. Many of these maintenance requirements can be automated to reduce costs. The cost of saved energy associated with improvements to compressed air systems is estimated to be $0.015 per kWh according to Elliott (1997).

Activities to improve compressed air system efficiency, however, face a number of barriers. These include: a lack of end-user awareness of energy consumption of compressed-air systems, a lack of knowledge of high-efficiency options including more efficient compressors, ASDs, control systems, etc. These are compounded by loose test standards which make it difficult to compare compressor performance and by the absence of "watchdog organizations" to certify test results and encourage greater adherence to test standards. Further, expertise in compressed air systems is rare; as a result, most system designs, specifications, and equipment selection are sub optimal. Finally, compressed air systems are often given low priority in plant operation and maintenance programs.

Utilities, their affiliated energy service businesses, controls companies, and others, including Duke Solutions, NEES, and Honeywell and Johnson Controls are becoming increasingly interested in compressed air systems as an opportunity to provide value-added services to their customers. A number of utilities are currently either offering compressed air services themselves or are teaming with partners such as Honeywell and Plant Air Technologies, which have technical expertise in efficient compressed air systems.

In January 1998, the Compressed Air Challenge, an innovative national partnership, was launched. This partnership includes stakeholders from the federal government, public interest groups, utilities, compressed air equipment manufacturers, distributors, and consultants, facility engineers, and end users. It was formed to: (1) assemble state of the art information on compressed air system design, performance, and assessment procedures; (2) deliver best-practice information to the plant floor via a professional development program for plant operations staff with operator certification; and (3) create a consistent national market message that supports application of these best practices. Four working groups (promotional, technical, training, and certification) were established to develop and implement the Compressed Air Challenge's agenda. Work on the technical content of the project began in October 1997 (Elliott 1997).

Industrial Compressed Air System Improvements

Measure Description: Improve efficiency of existing compressed air systems through more efficient equipment system design improvements, system optimization and improved O&M practices

Market Information:	
Market sector:	IND
End uses:	COMPRESSED AIR
Energy types:	ELEC
Market segment:	RET
Base Case Information:	
Base case description:	100 hp two-stage flooded screw compressed air system
Base case efficiency:	NA
Base case annual energy use:	NA
New Measure Information:	
New measured description:	Repair leaks, optimize system with controls and equip staging
New measure efficiency:	NA
New measure annual energy use:	NA
Measure life:	10 years
Savings Information:	
Electric savings/year:	NA
Gas savings/year:	NA
Percent savings:	30%
Feasible applications:	85%
Savings potential in 2010:	191 GWH
Cost Information:	
Current measure cost:	NA
Future measure cost (in mass use):	NA
Other direct costs/savings:	NA
Cost of saved energy:	$0.02 per kWh
Data Quality Assessment	C
Likelihood of Success	
Major market barriers:	Expertise limited; lack of awareness of energy svgs pot'l
Effect on customer utility:	None
Current activity @ PG&E:	Several programs to improve industrial efficiency
Current activity elsewhere:	CAGI, DOE/LBNL, ACEEE, SCE, Cinergy, and other utilities
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Souces:	
Savings estimates:	Friedman et al. (1996)
Cost estimates:	Elliott (1997)
Measure life estimates:	Elliott (1997)
Other key sources:	Friedman et al. (1996)
Principal contact(s):	Neal Elliott, ACEEE, 202-429-8873

Notes: Assumes total California industrial electricity consumption of 13,350 GWh in 2010.
Percent feasible (85%) assumes that some systems will not be cost-effective to optimize, given low loads or reasonable efficiencies.

Agricultural Irrigation Pumps System Optimization

Agricultural energy use comprises about 5 percent of PG&E's electric load. This energy is largely used for deep-well irrigation pumping. Savings of approximately 25 percent of the energy used in deep-well pumping (and demand savings of over 15 percent) are thought to be achievable based on a simulation conducted in conjunction with a PG&E-sponsored demonstration project. The site selected for the project was a 288 acre (1,165.5 square kilometer) vineyard in the Salinas Valley using a single 250 horsepower (186.5 kW) pump to provide water from a stable 260 foot (79 meter) deep aquifer (Bouma 1994).

In evaluating the savings potential, 17 measures were considered. These measures are detailed in Bouma (1994). The final approved package of energy efficiency measures, their estimated costs and energy savings are shown in the table below. In total, annual savings are estimted to be 110,000 kWh achievable at an initial investment of $43,700. (No information is available at this time in changes in operating costs pre- and post-retrofit). This case is used to represent a "typical" case for the purpose of this analysis.

Energy Efficiency Measure	Installed Cost ($)	Energy Saved (kWh/yr)	Cost of Saved Energy ($/kWh)	Ann. Energy Use (kWh/yr)
Base Case	--	--	--	434,000
Replace pump bowls (67% to 80% eff)	15,000	67,000	$0.22	367,000
Smooth impeller/bowl surfaces, add skirts	2,000	9,000	$0.22	358,000
Replace electric motor (90% to 95% eff)	17,500	19,000	$0.92	339,000
Drag reducing additives	1,200	9,500	$0.13	329,500
Replace motor control	8,000	4,000	$2.00	325,500

Source: Bouma (1994)

For the purpose of the technology characterization, we have assumed that 75 percent of agricultural energy is for pumping and 75 percent of pumping energy is for deep-well pumping.

Lack of information, knowledge about energy savings potential, has led PG&E to offer both demonstrations and financing to help farmers reap the savings from more efficient pumping systems. More demonstrations, an intensive education campaign, and low-cost capital, could increase the use of both technologies and practices that result in greater agricultural irrigation system efficiency.

Agricultural Irrigation Pump Systems Optimization

Measure Description: Encourage use of high-efficiency agricultural pumps for deep-well irrigation

Market Information:	
Market sector:	AG
End uses:	MOTORS
Energy types:	ELEC
Market segment:	RET
Base Case Information:	
Base case description:	250 HP pump for deep well on 250-300 acre vineyard
Base case efficiency:	NA
Base case annual energy use:	434,000 kWh
New Measure Information:	
New measure description:	Improved pump, motor, motor controls, auxiliaries
New measure efficiency:	25% more efficient than
New measure annual energy use:	325,500 kWh
Measure life:	15 years
Savings Information:	
Electric savings/year:	108,500 kWh
Gas savings/year:	NA
Percent savings:	25%
Feasible applications:	25%
Savings potential in 2010:	239 GWH
Cost Information:	
Current measure cost:	$43,700 incremental
Future measure cost (in mass use):	NA
Other direct costs/savings:	NA
Cost of saved energy:	$0.04 per kWh
Data Quality Assessment	C
Likelihood of Success	
Major market barriers:	Lack of expertise/energy savings info; and high capital costs
Effect on customer utility:	None
Current activity @ PG&E:	ACT2 demonstration; several add'l non-res programs
Current activity elsewhere:	NW working on ag irrigation systems
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	2
Souces:	
Savings estimates:	Bouma (1994)
Cost estimates:	Bouma (1994)
Measure life estimates:	Friedman et al. (1996)
Other key sources:	
Principal contact(s):	
Notes:	

Other - Non-Residential

Uninterruptible Power Supplies

Uninterruptible power supplies (UPSs) are devices that will maintain a supply of AC power in the event of a power failure or disturbance in the regular supply of electricity. UPSs are currently used in commercial, industrial, institutional, and residential markets. Although initially intended to provide power for large data centers, the growing importance of maintaining communication links and networks and to protect client-server-based data, has expanded the use of UPSs to include business LAN and WAN sites. The computer and telecommunications industries account for approximately 80 percent of the end-use applications of UPS systems.

Generally, two types of power supplies, used in different applications, are available. On-line systems (approximately 70 percent of the market in terms of sales) route the utility or source power through a battery to the load which precludes any time lag of switching from the utility power to the backup battery. These systems, used typically in industrial applications, tend to be relatively inefficient (e.g., 55 percent), and cost from $400 to $4000. Off-line power supplies, or standby systems (roughly 30 percent of the dollar sales volume) provide backup power that requires a switch from the main power supply to the battery. These standby UPSs are generally low-powered units that tend to be much more efficient (i.e., 85 percent) and cost between $100 and $500.

The results of efficiency tests reported by the Canadian Electricity Association (CEA) suggest that off-line UPS efficiency varies from 70 to 94 percent efficiency for rated computer loads; this efficiency increases by zero to seven percent for resistive loads. For partial loads, however, efficiency drops off considerably, varying from 24 to 66 percent (CEA 1996c).

End-users require reliability in a UPS. The system design, installation, maintenance, and battery quality play a substantial role in the reliability of the UPS. (Battery problems are a primary cause of UPS failure). Energy-efficiency is rarely, if ever, a concern in the purchase of a UPS. According to the CEA, meaningful energy-efficiency figures would benefit users by providing another basis of comparison among the ever-expanding array of UPS products in the market. For the purpose of this analysis, the maximum energy savings for UPSs can be represented by replacing on-line systems with off-line systems

Uninterruptible Power Supplies

Measure Description: Encourage use of more efficient standby uninterruptible power supplies (UPSs)

Market Information:		
Market sector:	COMM	
End uses:	OFFICE EQUP/TELECOM	
Energy types:	ELEC	
Market segment:	NEW, REP	
Base Case Information:		
Base case description:	Typical on-line UPS, 5 kVA	
Base case efficiency:	55%	
Base case annual energy use:	59,727	kWh
New Measure Information:		
New measured description:	Typical off-line or standby UPS, 5 kVA	
New measure efficiency:	85%	
New measure annual energy use:	38,647	kWh
Measure life:	10	years
Savings Information:		
Electric savings/year:	21,080	kWh
Gas savings/year:	NA	
Percent savings:	30%	
Feasible applications:	50%	
Savings potential in 2010:	8	GWH
Cost Information:		
Current measure cost:	$2,000	typical on-line UPS, CEA
Future measure cost (in mass use):	$500	typical off-line UPS, CEA
Other direct costs/savings:	$0	
Cost of saved energy:	$0.00	per kWh
Data Quality Assessment	C	
Likelihood of Success:		
Major market barriers:	NEC sizing requirements, lack of information	
Effect on customer utility:	Potential decrease in reliability, impoved power quality	
Current activity @ PG&E:	R&D re switchmode power supplies at PG&E	
Current activity elsewhere:	CSA stnds proposal; Green UPS in development	
Likelihood of success rating (1-5):	2	
Relationship to PG&E business plan (1-3):	1	
Souces:		
Savings estimates:	CEA (1996c); Stevens & Eyer (1994)	
Cost estimates:	CEA (1996c)	
Measure life estimates:	CEA (1996c)	
Other key sources:		

Principal contact(s):

Notes: Savings in 2010 based on applicability of switchmode power supplies only; greater potential is likely in expanding the use of off-line UPSs. A 5 kVA UPS was chosen as the basecase. This market segment is the fastest growing in the UPS market because of its application in protecting LANs.

Improved HVAC Cleanroom Techniques

The HVAC systems for high-tech cleanroom-level manufacturing plants represent a significant "lost opportunity" for improved energy efficiency in new plant construction. Improved design techniques have been developed in recent years to reduce the kW per ton of cleanroom ventilation systems from an industry standard of 1.2 to 2 kW per ton to 0.54 to 0.6 kW per ton, a 50 percent or better reduction. These techniques include optimized low-friction piping design, low velocity heat exchange, and super-efficient cooling towers. Acceptance of these techniques has been slow because energy-efficient cooling has been a low priority for innovation in this sector and "rule-of-thumb" design practices prevail. A typical new $1 billion semiconductor fabrication facility will install 10,000 tons of cooling capacity at a cost of $3,000 per ton. One estimate, indicates that improved cooling techniques, while increasing the first cost by 20 percent, will result in energy savings of 52.6 GWh per year and reduced peak load of 5.8 MW per plant in 2010 (Houghton 1997). Savings of this sort are particularly attractive given the explosive growth of the high-tech manufacturing industry, and the significant amount of electric energy it uses:

The high-tech manufacturing industry is growing rapidly:

- Private industry has recently announced (from beginning of 1995 through 2006) an estimated $8 billion in new expansion in the state of California and Arizona, with an estimated $2 billion in PG&E's service area.

- Global sales in semiconductors is projected to grow from $165 billion in 1996 to about $1 trillion by 2005 an annual growth rate of 19.7 percent. One high-tech product, photovoltaic (PV) cells, is expected to grow from an annual global demand of 70 MW to over 5000 MW over the next decade.

The high-tech industry is a significant user of electric power:

- Electric energy represents nearly 40 percent of the operating expense of high-tech manufacturing (excluding the cost of capital). About a third of a typical semiconductor facility's electric power is consumed by HVAC.

- Planned new high-tech construction in the Pacific Northwest, Arizona, and California, is estimated at to be significant over the next 10 years.

- New high-tech semiconductor fabrication facilities have peak loads ranging from in 30 to 50 MW and present relatively flat load profiles, making them very attractive base-load customers.

Market hindrances to implementing HVAC efficiency-improving innovations are primarily ones of culture and education. The high financial return on the products produced (microprocessors and other chips, hard disks and other storage media, and pharmaceuticals) is so high, and new facility construction schedules so tight, that little thought is given to energy efficiency during the design and construction phase.

Improved HVAC Cleanroom Techniques

Measure Description: Semiconductor cleanroom HVAC system improvements

Market Information:		
Market sector:	IND	
End uses:	HVAC	
Energy types:	ELEC	
Market segment:	NEW	
Base Case Information:		
Base case description:	Microelectronics cleanroom w/conventional HVAC design	
Base case efficiency:	1.2	kW per ton; 15,000 ton system
Base case annual energy use:	142	GWH per fabrication facility
New Measure Information:		
New measure description:	Cleanroom fabricated with high efficiency design	
New measure efficiency:	0.6	kW per ton; HVAC use reduced by 50%
New measure annual energy use:	71	GWH
Measure life:	10	years
Savings Information:		
Electric savings/year:	71	GWH
Gas savings/year:	NA	
Percent savings:	50%	overall in HVAC loads
Feasible applications:	85%	of all new fabrication facilities
Savings potential in 2010:	241	GWH
Cost Information:		
Current measure cost:	$9,870,000	per plant, incremental @ $658 per ton
Future measure cost (in mass use):	NA	
Other direct costs/savings:	NA	
Cost of saved energy:	$0.02	per kWh
Data Quality Assessment:	B	
Likelihood of Success:		
Major market barriers:	Incorporation into original design, market acceptance	
Effect on customer utility:	Reduced cooling load	
Current activity @ PG&E:	None	
Current activity elsewhere:	NW, NE, SuperSymmetry in Singapore and US, and EPA	
Likelihood of success rating (1-5):	3	
Relationship to PG&E business plan (1-3):	1	
Sources:		
Savings estimates:	Robertson et al. (1997)	
Cost estimates:	Harris (1997)	
Measure life estimates:	Robertson (1997)	
Other key sources:	Williamson (1997)	
Principal contact(s):	Chris Robertson, Energy Consultant, 503-287-5477 Lee Eng Lock, SuperSymmetry, Singapore, 65-777-7755 Matt Williamson, EPA, 202-564-9094	

Notes: Savings estimate assumes approximately 10% of new fab facilities built by 2010 will be located in California. Number of new facilities in the U.S. is estimated at 40 (approximately 1/3 of 120 facilities worldwide) per Robertson (1997b); this estimate is based on projections by Electronics Business News.
Incremental costs include savings due to downsizing per Harris (1997).

Wastewater Facility Energy Efficiency Optimization

Wastewater treatment covers a variety of processes ranging from simple oxidation and evaporation-percolation ponds to complex advanced wastewater treatment plants. Nationally, there are an estimated 16,000 wastewater treatment facilities. However, a small number of facilities are responsible for more than 90 percent of estimated wastewater treatment energy use. Approximately 80 percent of facilities have capacities of less than one million gallons per day (mgpd), but these facilities process less than 10 percent of the wastewater generated For the wastewater industry, about 75 percent of the electricity used is for wastewater aeration and pumping.

There are a variety of energy efficiency opportunities available in these plants, depending on the type of wastewater treatment technologies that are employed. Measures range from the use of properly sized, energy-efficient motors to installing fine-pore diffused aeration systems.

The attached characterization is based in part on an earlier PG&E market transformation assessment for this market segment. The PG&E study assumes (conservatively) 20 percent savings (four year or less pay back criteria) at a 10 mgpd facility using 2,500 kWh per mg treated. An earlier EPRI report notes savings of up to 40 percent for certain facilities. We have assumed an average savings potential of 30 percent.

Barriers to improvements to wastewater treatment plants include lack of capital (many are municipal facilities), lack of technical expertise, and lack of awareness of savings opportunities. PG&E could provide financing and technical assistance to municipalities to help improve the design and operation of these systems.

Wastewater Facility Energy Efficiency Optimization

Measure Description: Energy efficiency improvements at municipal and industrial wastewater treatment facilities

Market Information:	
Market sector:	IND, MUN
End uses:	PROCESS
Energy types:	ELEC
Market segment:	NEW, RET
Base Case Information	
Base case description:	10 mgpd municipal wastewater treatment facility - 2500kWh/mg treated
Base case efficiency:	NA
Base case annual energy use:	9,125,000 kWh
New Measure Information	
New measure description:	Optimized wastewater treatment facility
New measure efficiency:	NA
New measure annual energy use:	6,387,500 kWh
Measure life:	12 years
Savings Information	
Electric savings/year:	2,737,500 kWh
Gas savings/year:	0 thems
Percent savings:	30%
Feasible applications:	100%
Savings potential in 2010:	110 GWH
Cost Information	
Current measure cost:	$580,000
Future measure cost (in mass use):	$580,000
Other direct costs/savings:	
Cost of saved energy:	$0.025 per kWh
Data Quality Assessment	B
Likelihood of Success	
Major market barriers:	First cost, lack of technical expertise
Effect on customer utility:	None
Current activity @ PG&E:	Investigated opportunity
Current activity elsewhere:	NA
Likelihood of success rating (1-5):	3
Relationship to PG&E business plan (1-3):	1
Sources:	
Savings estimates:	PG&E (1997)
Cost estimates:	EPRI (1993)
Measure life estimates:	XENERGY estimate
Other key sources:	
Principal contact(s):	

Notes: Savings in 2010 assumes PG&E represents 3.5 percent of nationally estimated usage for wastewater treatment.

Appendix A: Current Market Transformation Programs and Explorations

Pacific Gas & Electric

Existing Programs:
1. SERP (not screened)
2. Ground source heat pumps
3. Residential clothes washers (not screened)
4. Heat pump water heaters (discontinued in 1997)
5. Aerosol duct sealing
6. Commercial food service technology

New Programs:
7. Residential energy-efficient windows
8. Residential fluorescent lighting fixtures
9. Advanced commercial window glazing
10. Energy-efficient roof coatings
11. High-efficiency lighting systems
12. Equipment simulation models (e.g., for chillers and towers)
13. Industrial and municipal water/wastewater facility energy efficiency optimization
14. Commercial refrigeration integrated design
15. Optimization of industrial turbomachine systems (e.g., fans, pumps and blowers)
16. Improve high-efficiency commercial building systems integration and operation

Other Ideas:
17. Diagnostic equipment
18. Next generation evaporative coolers
19. Electric water heater timers
20. Low-e film coatings for existing windows
21. Modulating gas furnaces
22. Phase change wallboard

Consortium for Energy Efficiency (CEE)

Existing Programs:
1. Clothes washers (PG&E participating)
2. Residential central a/c (PG&E participating)
3. Commercial packaged a/c (PG&E participating)
4. Apartment.-size refrigerators (PG&E participating)
5. Premium-efficiency motors (PG&E participating)
6. Dry-type transformers

Active Explorations:
7. Electric chillers
8. Gas chillers
9. Residential CFL fixtures
10. Coin-op clothes washers
11. Motor repair practices
12. Air compressors

Other Ideas:
13. Industrial fans
14. Industrial pumps
15. Motor system performance optimization
16. Building commissioning
17. Aerosol duct sealing
18. Heat pump water heaters
19. Wastewater filtration

Northeast Energy Efficiency Partnerships (NEEP)

New Programs:
1. Residential lighting fixtures
2. Commercial lighting remodelling
3. Premium efficiency motors (part of CEE initiative)
4. Residential HVAC installation
5. Commercial building code upgrades and implementation
6. Commercial HVAC equipment, installation, and maintenance
7. High efficiency clothes washers

Explorations:
8. Residential water heating
9. Major residential appliances
10. Blower door assisted infiltration reduction
11. Duct sealing
12. New residential construction practices
13. Residential rooftop PV
14. Efficient motors and motor systems
15. Commercial building systems commissioning
16. Enhanced building system operation and maintenance
17. Integrated building energy design and new construction practices
18. Chiller system replacement
19. Energy-efficient office equipment
20. Packaged refrigeration equipment efficiency

Northwest Energy Efficiency Alliance (NEEA)

Existing Programs:
1. Residential fixtures (based on ENERGY STAR® specification)
2. Compact fluorescent lamps (LightWise)
3. Commercial lighting specifier/buyer education (Lighting Design Lab)
4. Commercial and residential lighting research (Lighting Research Center)
5. Residential duct systems
7. High efficiency clothes washers (WashWise)
6. High efficiency residential window products
7. National standards (appliances, lighting, and windows)
8. Premium efficiency motors (part of CEE initiative)
9. In-service motors testing
10. Evaporator fan VFDs (w/focus on refrigerated warehouses)
11. Public housing energy efficiency
12. Super Good Sense manufactured housing

13. Commercial building commissioning (market study)
14. Commercial building energy use simulation tool
15. Builder operator certification
16. Commissioning public buildings in the Pacific Northwest
17. Agricultural irrigation scheduling
18. Microelectronics industry efficiency
19. Silicon chip facilities (improved furnace efficiencies)
20. Building practices (education and code support)
21. Commercial building designer awards
22. Energy Education Institute
23. Energy Ideas Clearinghouse
24. On-line lighting resource
25. On-line newsletter

Other Ideas:
26. Chiller system optimization
27. Heat pump water heaters

U.S. Environmental Protection Agency

Existing ENERGY STAR® Programs:
1. Personal computers
2. Monitors
3. Faxes
4. Copy machines
5. Residential central a/c
6. Ground source heat pumps
7. Gas-furnaces (and boilers?)
8. Gas-fired heat pumps
9. Exit signs
10. New homes
11. Utility distribution transformers
12. Thermostats
13. Insulation
14. Residential lighting fixtures
15. Televisions and VCRs

Explorations:

16. Other consumer electronics (audio equipment, cable boxes)
17. Reflective roofs
18. Vending machines
19. Refrigerated display cases
20. Lawn mowers
21. Weed wackers
22. Commercial packaged a/c

U.S. Department of Energy*

Note: The following initiatives include that fall under DOE's ENERGY STAR®, Motor Challenge, Window Collaborative, Lighting Collaborative, Cool Communities programs. In addition to initiatives devoted to technologies and practices, DOE is also working with specific communities (utilities, hospitality industry, ESCOs) to develop market transformation initiatives.

Existing Programs (and Programs Underway):
1. High-efficiency major appliances (labeling, bulk sales, creative financing)
2. Wastewater filtration (demonstrations)
3. Sulphur lighting (demonstrations and R&D)
4. Window labeling (NFRC, Energy-Star being planned)

Explorations (and Planning):
5. Heat pump water heaters
6. Other electric water heater technologies (primarily integrated space/water heating) (w/ EEI)
7. Motor system optimization
8. Motor-driven equipment (fans, pumps and compressors)
9. Reflective roofs
10. Super-windows
11. Luminaires with improved heat dissipation

Canadian Initiatives

Residential:
1. Major appliances (Power Smart label)
2. Wall thermostats (performance standard and Power Smart label)
3. Mechanical ventilating equipment (developing standard and product endorsement initiative)
4. Ceiling fans (performance standard, developing product endorsement initiative)
5. Dehumidifiers (performance standard, developing product endorsement initiative)
6. Ground source heat pumps (performance standard, developing product endorsement initiative)
7. Heat recovery ventilators (developing standard and product endorsement initiative)
8. Furnace blowers (developing standard and product endorsement initiative)

Commercial:
9. Exit signs (performance standard, developing product endorsement initiative)
10. CFL lamps and ballasted adaptors (performance standard, developing product endorsement initiative)
11. Luminaire systems (based on NEMA initiative)
12. Electronic ballasts (developing product endorsement initiative)
13. C&I fans (future work)
14. Air-to-air heat recovery (future work)
15. Commercial HVAC (Power Smart labels under review)
16. Refrigerated display cabinets (performance standard, developing product endorsement initiative)
17. Automatic ice-makers and storage bins (performance standard, developing product endorsement initiative)
18. Vending machines (performance standard, developing product endorsement initiative)
19. Drinking water coolers (performance standard, developing product endorsement initiative)
20. Food service refrigerators (developing performance standard and product endorsement initiative)
21. Walk-in commercial refrigeration systems (planning performance standard and product endorsement initiative)
22. Office equipment (based on EPA ENERGY STAR® program)

Industrial:
23. Air-compressors (performance standard, planning performance optimization initiative)
24. ASDs (planning performance optimization initiative)
25. Small pumps (developing performance standard, planning performance optimization initiative)
26. Power and distribution transformers (performance standard, developing product endorsement initiative)
27. Roadway lighting luminaires (performance standard, developing product endorsement initiative)
28. High mast lighting (developing performance standard and product endorsement initiative)
29. HID lighting ballasts (developing performance standard and product endorsement initiative)
30. Electric arc welding equipment (developing performance standard and product endorsement initiative)
31. Power conversion equipment (UPS, battery chargers, electroplating equipment) (developing performance standard and product endorsement initiative)

Other Programs and Explorations

1. Commercial building design — pay for performance (RMI)
2. Halogen IR lamps (DOD)
3. Residential gas heat pumps (AGCC)
4. Commercial gas cooling (AGCC)
5. Luminaire labeling and information (NEMA)
6. Distribution transformers (C&I, utility) (NEMA)

Other Ideas

1. Integrated gas-fired space/water heating systems
2. High-efficiency storage-type residential water heaters (gas)
3. Instantaneous gas water heaters
4. Commercial heat pump water heaters
5. Low energy/water residential dishwashers
6. High-efficiency commercial dishwashers
7. Ozonated commercial laundering
8. LED traffic signals
9. Dual-fuel heat pumps
10. Night spray thermal storage
11. Dual source heat pumps

Appendix B: Energy End Use Breakdown for Pacific Gas & Electric Company's Service Territory

COMMERCIAL ELECTRIC

	GWH	TBTU
Space Heating	487	5.2
Space Cooling	3879	41.2
Fans/Pumps	3395	36.0
Water Heating	194	2.1
Cooking	265	2.8
Refrigeration	2162	22.9
Indoor Lighting	10806	114.7
Miscellaneous	9032	95.9
Office Equipment	723	7.7
Outdoor Lighting	1229	13.0
Subtotal Electric	**35,365**	**341.5**

COMMERCIAL GAS

	TBTU
Space Heating	22.3
Space Cooling	3.3
Water Heating	7.9
Cooking	4.1
Refrigeration	0.3
Other	42.6
Subtotal Gas	**80.5**

Souce: CEC (1995); Nadel et al. (1993)

RESIDENTIAL ELECTRIC

	GWH	TBTU
Central Air Conditioning	1668	17.1
Room Air Conditioning	131	1.4
Evaporative Air Conditioning	236	2.5
Space Heating	991	10.5
Furnace Fan	789	8.4
Water Heating - Dishwasher	303	3.2
Water Heating -Clotheswasher	442	4.7
Water Heating - Basic	936	9.9
Refrigeration	4575	48.6
Freezer	1072	11.4
Color TV	1434	15.2
Cooking	1993	21.2
Diswahser Motor	800	8.5
Clothes Dryer	3182	33.8
Clotheswasher Motor	279	3.0
Water Bed	1127	12.0
Lighting	4598	48.8
Miscellaneous	9666	102.6
Pool Pump	755	8.0
Pool Water Heater	20	0.2
Tub Pump	300	3.2
Tub Water Heater	70	0.7
Subtotal Electric	**35,365**	**375.4**

RESIDENTIAL GAS

	TBTU
Space Cooling	2.4
Space Heating	93.8
Cooking	13.3
Clothes Drying	7.5
Water Heating - Dishwasher	25.5
Water Heating -Clotheswasher	18.1
Water Heating - Basic	56.1
Miscellaneous	7.3
Pool Heat	5.2
Tub Heat	5.0
Subtotal Gas	**234.3**

Souce: CEC (1995); Nadel et al. (1993)

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