APPENDIX B: CALIFORNIA-SPECIFIC EMERGING TECHNOLOGIES AND PRACTICES, AND DIFFERENTIATED SCREENING OF CLIMATE-SENSITIVE MEASURES[9]

Summary

In the main section of this report, ACEEE, Davis Energy Group, and Marbek Resource Consultants describe emerging technologies and practices that could lead to greater efficiency in the buildings sector. The methods used were adapted from those of two earlier ACEEE-led studies (Nadel et al. 1993; Nadel et al. 1998). The sub-study described in this appendix added two principal tasks: to use the main report's national study methods with costs from California to evaluate technologies that might have particularly great value there; and to create a more fine-grained evaluation of the climate-sensitive emerging technologies and practices evaluated in the national study.

In the first task, we evaluated three emerging technologies and prepared descriptions of two others for which savings potential could not be estimated:

- **Variable-output compact fluorescent lamps** (CFLs), units that either have multiple, discrete lighting outputs or have a continuous dimming range. The three-way lamps studied cost less than the sum of the shorter-lived incandescents they replace, so the simple payback calculates as immediate, and the cost of saved energy is negative (-\$0.01/kWh). Dimmable CFLs are almost as attractive: despite a \$12 price premium over the inexpensive conventional bulbs they replace, the cost of saved energy is still only \$0.01/kWh. (In both cases, our calculations do not include labor for bulb changes or other maintenance.) The total savings possible from substituting these advanced CFL types are 3,000 and 14,500 GWh/yr, respectively, in California in 2020.[10] These lamp types and controls are not very common, compared to mainstream products.
- **Advanced controls for packaged HVAC** (heating, ventilating, and-conditioning) units for light commercial applications. Packaged units, typified by roof-top units (RTUs), are rated by refrigeration efficiency only, but also provide ventilation and *economizer* services, the latter being the ability to bring in cooler outside air when available to avoid use of the refrigeration cycle. In hot-dry climates with large daily temperature cycles, economizers alone can save almost half of the energy use of RTUs but are often absent or not operating. Advanced controls would optimize use of ventilation for savings and indoor environmental quality (IEQ) and give key fault diagnostics—but look and work much like thermostats. With very conservative assumptions, we compute potential California savings of 1,740 GWH in 2020, at a cost of saved energy of \$0.03/kWh.[11] Demand savings would be real, but depend on the ability of CO_2 or equivalent monitors to estimate occupancy (and thus ventilation requirements) at peak times.
- **Integrated whole-house ventilation systems**. Houses in areas with hot days and large diurnal temperature swings can significantly reduce summer peak load and cooling energy use through nighttime ventilation cooling. Residential air conditioning is responsible for about 45% of California's peak load but only consumes about 7% of household electric energy (Coito 2003). Such ventilation systems could be considered as integrated replacements for whole house fans, with air filtration. Projected energy savings vary widely with climate, ranging from less than 5% for coastal climates to greater than 60% in transition climates (coastally influenced inland areas). Savings in hot inland areas range from 20 to 50%. If combined with measures to improve building envelope summer performance, ventilation cooling is projected to

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[9] Commissioned by the California Energy Commission, through the California Institute for Energy Efficiency, Office of the President, University of California.

[10] Lau (2004) reports that CFLs have a much shorter life than the manufacturers' claims, based on findings from the SCE measurement and verification (M&V) program. Consequently, the DEER database will be revised to reduce energy savings by about 22%, mainly due to early burnout in the field. This would somewhat increase the cost of saved energy, but it remains about \$0.01/kWh.

[11] Lau (2004) reports that 5-ton or smaller packaged HVAC units do not need an economizer cycle. Further, some building owners who require a 10-ton AC will prefer two 5-ton units to avoid the first cost increment of the economizer.

eliminate the need for mechanical air conditioning in some coastal areas.[12] NightBreeze systems (including the variable speed hydronic air handler with heating coil, damper, and controls) are expected to sell for about $2,800. The cost of saved energy is high ($0.22), but the measure may be justified by peak reduction. The potential electricity saving is 879 GWH reduction in 2020, but interest may be warranted by the opportunity to reduce peak demand by night-time pre-cooling with this technology. The projected incremental cost of $1,200 with mechanical air conditioning would avoid 1.3 kW of peak demand, which will be attractive in some areas. Where NightBreeze eliminates the need for mechanical air conditioning, first costs are reduced, leading to $0 cost demand and energy savings.

In addition, within this task we developed descriptions of two other technologies, with qualitative evaluation of their potential roles in energy efficiency. One of these is a wireless thermostat that just replaces conventional units. It does not itself save energy relative to conventional units but may enable savings (or increase use), depending on the application. The other is a (pre-commercial) load monitor/diagnostic tool.

Wireless thermostats (WTs) use batteries and radio signals instead of "hard" wiring, but otherwise have the same features of comparable standard thermostats, including programmability. Wall-mounted WTs are available for residential units, fan-coils, baseboard electric heat, window air conditioners, "mini-split" air conditioners, and PTACs (packaged terminal air conditioners and heat pumps). Wall-mounted WTs are simply wireless replacements for conventional units in situations such as: (1) system modernization, where new equipment functions may not be compatible with older wiring; (2) thermostat placement that does not meet user needs; and (3) rezoning, so controls match new distribution systems. Counting installation, WTs may be less expensive than wired units. Another class of WT is portable, analogous to remote controls for televisions. These allow the user to adjust the temperature to the desired level in the room where she is. This is likely to be used particularly in houses or other structures where construction defects (insulation, infiltration, fenestration, or ductwork) lead to wide temperature differences from room to room, during the day (as the sun moves), or as seasons change. Wireless thermostats may facilitate energy savings by enabling better control where otherwise cost-prohibitive or less flexible.

The other technology described, the Non-Invasive Load Monitor (NILM), is a pre-commercial concept to improve diagnostics by continuous monitoring of system performance as reflected in motor dynamics (particularly at start-up). By itself, NILM does not save energy, but its diagnostics can lead to energy-saving maintenance actions. NILM and HVAC Fault Detection and Diagnosis (FDD) use quick-sampling power meters and computer analyses to monitor and/or diagnose problems in HVAC systems. They detect on and off switching of major HVAC loads in commercial buildings, track variable-speed drive loads, and detect operating faults from a centralized location at moderate cost. The data can help optimize operations, and aid commissioning and diagnostics. The advantage of NILM methods is the ability to monitor several motors with a single device and to "look" at systems purely with motor electric load information, without needing flow or other sensors. The drawbacks are that the motors to be monitored must be relatively large compared to the total current in the branch circuit, and that applicability to motor systems with variable speed drive is very limited. The first "production" application may be as part of a controller (or a free-standing device) for roof-top packaged air conditioners for light commercial applications, work being funded now by the California Energy Commission. The concept is still pre-commercial, so no information on costs or benefits is available.

The second major task for this sub-study is to produce a more fine-grained evaluation of the climate-sensitive emerging technologies and practices evaluated in the national study. In particular, our goal was to look at the variability of savings with climate for three selected areas of California—coastal, transition, and inland. These areas were selected to include as much of the population and as diverse a suite of climates as feasible. From the list of all emerging technologies and practices, we first isolated the 33 measures for which savings would be reasonably climate-sensitive. These include HVAC, building shell, glazing/windows, and similar measures. Some HVAC measures were excluded because they are specifically designed for climates that are rare or non-existent in California, such as air-conditioners for hot-humid climates and cold-climate heat pumps. We also excluded those measures for which climate effects were small, such as lighting (hours needed per year varies little with climate per se). For the 33 measures for which climate may affect savings and the cost of saved energy in California applications, we estimated savings from base case annual energy use compared with efficiency case energy use. We did this for the three different California climate areas noted above by applying appropriate degree-day corrections for each zone relative to the national savings. This gave a total of 99 zone-measure evaluations. We used California-

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[12] Lau (2004) reports that field performance tests continue.

specific costs of saved energy for screening. In particular, we started with \$0.1244/kWh as the average residential tariff and \$0.1447/kWh as the average commercial tariff.[13] Adapting the methods of the national study, we divided these values by two for our screening parameters for high-priority measures, thus using \$0.062 residential and \$0.072 commercial.

Highlights of this analysis are:

- *Most measures are either cost-effective in all climate areas, or not cost-effective in any climate area: climate is rarely a key discriminating variable.* Twenty-four of the 33 measures are cost-effective in all climate zones considered. Conversely, six are not cost-effective in *any* climate zone. Only three are cost-effective in some zones but not others, and one of those is borderline.
- Of the 33 measures, 12 are commercial, seven have both residential and (light) commercial applications, and seven are almost purely residential.
- In addition, of the cost-effective zone/measure combinations, 18 are coastal, 21 are transitional, and 24 are inland climate zones. As would be expected, more measures are cost-effective in hotter regions.
- Finally, our 33 measures included 25 that are predominantly technologies, six are considered practices, and two combine technology and practice.

The analysis of climate sensitivity also has policy implications for California. First, the potential value of many emerging technologies is fairly insensitive to climate for the relatively small variability considered among coastal, transitional, and inland zones in California. Of the 33 technologies and practices considered, 24 were projected to be cost-effective in all climate zones and six were considered too expensive (in cost of saved energy or "CSE") in all zones. Only three measures were cost-effective in some climate areas but not in others. Indeed, for most of the measures that were cost-effective in some but not all zones, the variability in estimated CSE for the measure is only about \$0.005/kWh. From this, we infer that climate is not a very important variable in screening emerging technologies for California. On the other hand, the variation in estimated savings in 2020 is very large, more than a factor of 200. This strongly suggests that the most attractive measures are those that combine reasonable cost of saved energy with relatively large (>100 GHW) out-year savings.

We found a wide variation in the savings per measure and zone. Three measure groups gave savings estimates greater than 20 TBtu of source energy in 2020: micro CHP (whether using fuel cells or micro-turbines), integrated design process (LEED or 30% better than code), and aerosol-based duct sealing. The first two were for the commercial sector and the last for the residential. Another six zone/measure combinations would save more than 10 TBtu, but 40 zone/climate combinations would save less than 1 TBtu in 2020.

Finally, we again see the relatively high importance of "human-ware," the emerging *practices* that improve efficiency through proper design and sizing, installation, and maintenance. Increasingly, continuing the trajectory of improved efficiency will require investing directly in people and incentives for people, and in showing customers (decision-makers) the economic, comfort, and other values of investments in doing the right jobs the right ways.

Background

This appendix is designed to treat some emerging technologies and practices issues that could be particularly important in California. In the main body of this report, almost 200 national measures were screened. We then selected 72 for detailed analysis, based on estimates of their likelihood of success. Using these analyses, we classified measures as high, medium, or low priority. This was based on three parameters: magnitude of prospective energy savings; cost of saved energy; and likelihood of success. The **high priority measures** are diverse. Two (leak-proof ducts and duct sealing) are distribution system improvements and two are practices (design of high-performance commercial buildings and retrocommissioning.) Automated diagnostics complements retrocommissioning as a building operation improvement. The final high-priority measure, 1 Watt standby power for home appliances, is the only "pure" equipment measure in the high priority list. These measures were described more fully in the main body.

Seven of the 20–26 **medium priority measures** are lighting, primarily commercial measures (premium T8 lighting, one-lamp fluorescent fixtures, commercial LED lighting, and scotopic lighting). However, at least two (airtight

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[13] These are average investor-owned rates, from http://www.energy.ca.gov/electricity/current_electricity_rates.html.

compact fluorescent downlights and CFL portable fixtures) are primarily residential. Twelve of the measures are primarily residential. Five of these deal with refrigeration-cycle equipment: improved refrigerators, air conditioners, and heat pump water heaters. Commercial measures include better management of networked computer energy use and carbon dioxide-controlled ventilation to reduce fan power as well as chiller energy. The common element among **low priority measures** is the low likelihood of success, frequently because they represent major changes from present methods and technologies. Low likelihood of success in the near term is exemplified by the very large savings associated with commercial "combined heat and power" (CHP) technologies incorporating microturbines and fuel cells, and even for residential CHP with Stirling engines. We also noted "**special" measures** that have high value for specific regions or new construction, even though they may not have enough countrywide savings to warrant national priority. About half of the special measures are feasible for new construction, but prohibitively expensive as retrofits. These measures include low energy designs and construction methods. "Special" also includes half a dozen measures specific to hot or hot and humid climates, typically advanced air conditioners such as the Cromer Cycle (combining desiccant and refrigerant systems in a single unit). The category also includes air conditioners optimized for hot-dry climates and two-speed pool pumps. Northern climates rate three special measures, including gas-fired absorption heat pumps, advanced condensing boilers for commercial applications, and roof-top year-round units with condensing furnace sections. Two further measures are applicable to guest rooms in the hospitality industry. These include "smart" door card keys that incorporate energy management and bathroom lighting that better matches use patterns. These may be indicative of opportunities that will arise when other industries are targeted for close examination.

Perhaps the most important finding of this study is that the well of emerging technologies and practices continues to yield many promising measures. Including special measures for new construction or regional applicability, we found more promising measures than in the 1998 study: the sum of high and medium in 1998 was 33, compared with 20–26 this time, but this study added 10–21 special measures that warrant serious consideration. Of course, the reservoir is changing. Some of the measures that would result in the largest savings would also require the greatest changes in the present mode of operations, such as CHP at commercial and residential scales with emerging technologies such as fuel cells and Stirling engines. Measures to assure ductwork integrity are another example of the need to change the business model. Achieving real results will require that industry and consumers recognize the importance of energy distribution within the building (for comfort and air quality). Finally, retrocommissioning and advanced design practices have great importance and potential, as do training, incentives, and other "human-ware" services.

Goals

In this context, this California-specific analysis has two specific goals:

1. To analyze technologies of particular interest in the state, specifically, variable-output compact fluorescent bulbs, advanced controls for small commercial air conditioners (roof-top units), and integrated whole house ventilation systems for climates with large diurnal temperature swings. We also provide descriptions of two other technologies, wireless thermostats and Non-Invasive (motor) Load Monitors.
2. To extend the national study to examine costs and benefits for specific California climate areas. We isolated 33 measures for which savings would be reasonably climate-sensitive. These include HVAC, building shell, glazing/windows, and similar measures. We excluded those measures for which climate effects were small, such as lighting (hours needed per year varies little with climate per se), and those specific to climates not important in California.

Methods

Analysis of California Technologies

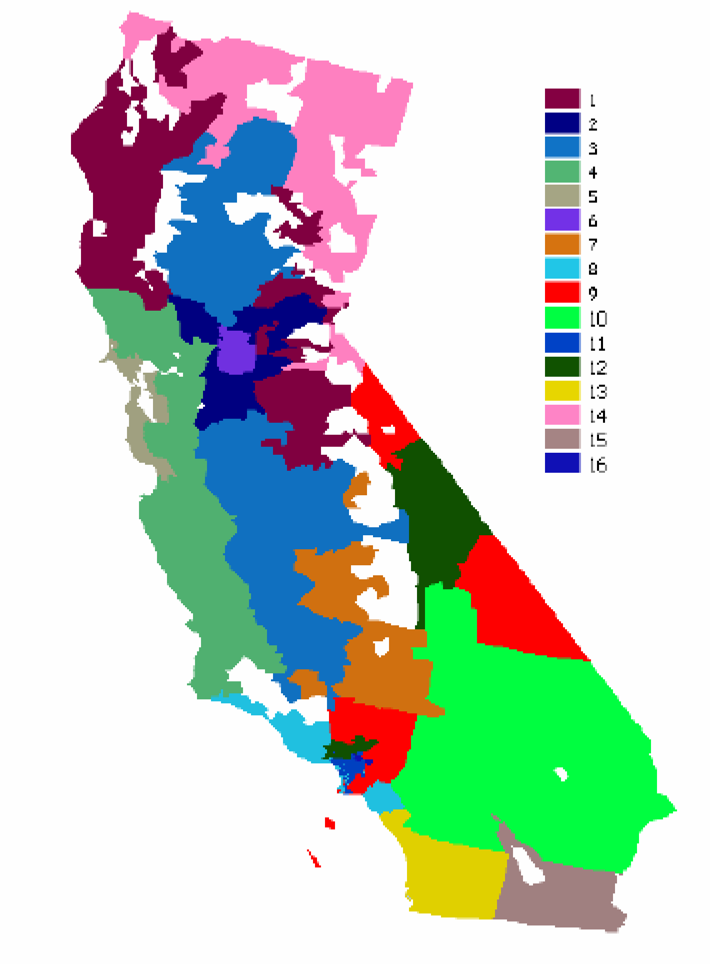
The methods used to evaluate the three technologies are those of the national study, except that we have used California base case and energy use data in calculating savings, as noted below.

Selection of Climate Zones

California consists of many unique and diverse climate zones, varying from cool coastal to hot inland-valley to mountain. Accurate estimates of energy use and savings potential require that the analyses be done in multiple zones, rather than using an average climate. Building standards and simulation analyses for California rely on 16 standard climate zones, each represented by weather data from a single city. On the other hand, utility survey and forecast data, such as is needed for this analysis, use climate zones based on utility service areas, and climate boundaries that are entirely different. Most of the areas with significant population can be grouped into one of three climate types: coastal, transition, and inland-valley. Coastal climates are moderated by the ocean and have small daily ranges and low heating and cooling loads. Transition climates are influenced by nearby marine effects, but have higher heating and cooling loads and can have hot peak conditions. Inland-valley climates have hot, dry summers and moderate winters. Climate data for this analysis was derived from CEC (2004a) for residential unit energy consumption (UEC) and PG&E (1999) for commercial end-use intensities (EUIs).

CEC (2004a) uses 12 of the16 CEC forecast climate zones shown in Figure 1 to provide regional summaries (zones 6 and 14–16 are for utilities that did not participate in the study). Each of the climate zones was assigned to one of the three climate areas based on their cooling degree days (CDD) shown in Table B-1. Climate zones with less than 1,000 CDD were mapped to coastal, zones with greater than 1,000 CDD but less than 1,500 CDD were mapped to transition, and zones with greater than 1,500 CDD were mapped to inland, using CEC (2004a).

Figure B-1: California Forecast Climate Zone Map



Note: If reading this information as a printed black-and-white document,

please refer to the posted Acrobat Reader version at http://aceee.org/pubs/a042_apndxb.pdf,

which preserves the color information that differentiates climate zones.

Figure 2 shows the climate zones used by the PG&E (1999). The coastal zone was used as is, the hill zone was used for transition, and the valley and desert/mountain zones were combined into inland. Clearly, the broad outlines of these climate areas track the climate zones of Figure 1.

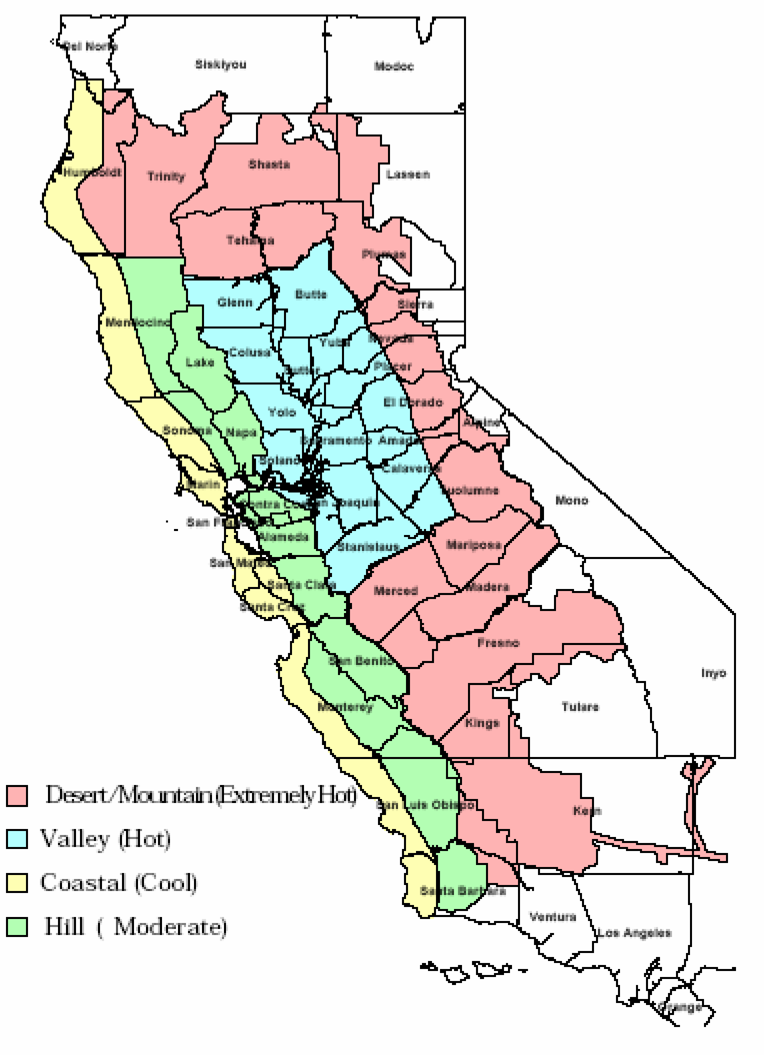
Table B-1: Summary of California Forecast Climate Zones

CZ	*Area*	*Climate*	*Population*	*CDD*
1	North Coast	Coastal	272,949	767
2	Delta Effect	Transition	340,998	1,173
3	Central Valley	Inland	816,480	1,880
4	Central Coast	Coastal	1,592,666	619
5	Bay Area	Coastal	1,227,998	133
7	South Valley	Inland	193,170	1,919
8	South Coast	Coastal	1,567,414	590
9	LA Transition	Transition	1,233,479	1,072
10	Desert	Inland	1,017,247	2,028
11	Coastal LA	Coastal	624,270	879
12	LA Transition	Transition	270,932	1,101
13	San Diego	Coastal	1,190,204	433
State		Coastal	6,475,501	570
		Transition	1,845,409	1,115
		Inland	2,026,897	1,942
		All	10,347,807	1,050

What We Did for the Climate Zone Study

The national study used national average unit energy consumption (UECs) or end-use intensity (EUIs) to calculate energy savings and cost of saved energy, and used projected 2020 sector energy uses to estimate potential savings. Analysis of weather-sensitive emerging technologies and practices requires estimates of UECs or EUIs and 2020 statewide energy use for each selected climate area. Residential UECs and commercial EUIs for each climate area were calculated by combining the UECs and EUIs from each climate zone based on the mapping described previously (see Table B-2). Residential AC and HP heating and commercial electric heating exhibit the largest variation with climate. Most of the other end-uses are less variable. Surprisingly, commercial cooling and gas heating show very small variation with climate area.

Figure 2: Pacific Gas & Electric Climate Zone Map



Note: If reading this information as a printed black-and-white document,

please refer to the posted Acrobat Reader version at http://aceee.org/pubs/a042_apndxb.pdf,

which preserves the color information that differentiates climate zones.

Statewide 2020 energy use estimates were derived from the end-use projections in CEC (2003a). Growth rates from 2003 to 2013 were extrapolated to 2020 and the resulting total end-use was distributed between climate areas by weighting by population and EUI. Although the coastal zone has the lowest EUIs for most of the end-uses, its large population results in it having the largest share of energy use.

Table B-2: Unit Energy Consumption and End-Use Intensity Variation by Climate Area

End-Use	*Inland*	*Transition*	*Coastal*
Residential Electric (kWh) Total	7,223	5,726	5,605
Air Conditioning	1,786	1,253	743
Resistance Heat	1,145	886	886
HP Heat	957	471	580
DHW	2,930	2,043	2,113
Furnace Fan	495	495	495
Pool Pump	2,671	2,671	2,671
Residential Gas (TBtu) Total	4.0	3.2	3.0
Heat	2.4	1.9	1.9
DHW	2.1	2.0	1.9
Commercial Electric (kWh/sq. ft.) Total	16.11	13.77	11.96
Cooling	4.16	4.69	3.99
Heating	5.14	5.91	2.72
Ventilation	1.27	1.38	1.20
Commercial Gas Heat (kBtu/sq. ft.)	19.93	20.92	21.64

Note: some technologies, including electric water heating and pool pumps, have large unit consumption but less than 10% market share.

Table B-3: Statewide Energy Use Projections

End-Use	*2003*	*2013*	*2020*	*2020 Inland*	*Transition*	*Coastal*
Residential Electric (GWh) Total	78,416	94,534	105,817	25,189	18,179	62,449
Air Conditioning	4,864	5,420	5,810	1,957	1,251	2,602
Resistance Heat	3,376	3,317	3,275	784	552	1,938
HP Heat						
DHW	4,869	5,484	5,915	1,502	954	3,460
Air handler fan	1,420	1,581	1,694	332	302	1,060
Pool Pump	3,590	4,068	4,403	862	785	2,755
Residential Gas (TBtu) Total	523	572	606	144	108	354
Heat	229	227	226	54	37	135
DHW	211	243	265	54	49	162
Commercial Electric (GWh) Total	92,142	107,601	118,422	28,542	22,205	67,675
Cooling	13,746	15,443	16,630	3,267	3,353	10,010
Heating	2,472	3,213	3,731	998	1,045	1,688
Ventilation	9,449	10,937	11,979	2,400	2,365	7,215
Commercial Gas Heat (TBtu)	96	106	113	21	20	72

Sources: CEC (2004a) for residential; PG&E (1999) for commercial

Results for the 3 Technologies Evaluated

Variable output, screw-base CFLs. We differentiate between two categories of screw-in CFLs: 3-way and dimmable lamps. The former replace 30–70–100 and 50–100–150 incandescent bulbs in table and floor lamps. The latter can be used in portable and ceiling fixtures with current-limiting dimmers designed for incandescent lamps. Although considered largely residential, there are some 200 million dimmable incandescents in the commercial sector, typically in conference room and hospitality industry applications (IAEEL 1997). Variable output pin-based CFLs were implicitly considered previously in the main body of this report as part of national study measure L13, High Quality Residential CFL Portable Fixtures.

At least three major manufacturers sell both dimming and 3-way CFLs, and they are available from on-line retail sources. They are important niche products to fill in gaps where consumers now continue to use incandescents.

As developed below, we infer 85W and 75W respectively for base case 3-way and dimmable lamps, but with one lamp in each 3-way fixture and two lamps in each dimmable fixture. The respective CFL new measures are 12–18–29W 3-way, and 29W dimmable lamps. For 3-way fixtures, we compare a $2 incandescent with a $10.50 Phillips CFL; for dimmable fixtures, we compare a $0.50 incandescent with a $14.75 GE dimmable (costs from Web catalogues and exclude delivery). These costs are a substantial reduction from the >$20 costs that prevailed a few years ago. Cost scaling for reflector bulbs should be approximately the same. We use 10,000 hr for CFL life and 1,200 hr for incandescent. Although these products have significant incremental costs ($9 for 3-way and $14.25 for dimmable), they outlast base case products by a factor of 8 (3-way) or 5 (dimmable, since incandescents should last longer at lower voltage).

Based on Tacoma Public Utilities data on lamp control types as reported by HMG (1997), 3-way switches control about 8% and dimmers about 4.5% of residential fixtures. For simplicity, we analyze one 3-way lamp per fixture, an equal mix of 30–70–100W and 50–100–150W incandescents, operated in the medium position, or an average of 85W (medium output). Three-way fixtures are dominantly portable (plug-in). For dimmables, we assume two lamps/fixture, rather than the overall 1.6 lamps/fixture in HMG (1997), and 75 watts/lamp.

One key barrier is low visibility in the market. These devices must compete for shelf space with an ever-broader array of (fixed output) CFLs and incandescents. The other is high first cost relative to incandescent bulbs. We recommend that market transformation organizations use the same stimuli that have accelerated acceptance of single-output CFLs, such as incentives (or coupons) for consumers and incentives to retailers to improve product visibility and price. Variable output CFLs have an additional significant advantage over incandescents: they maintain color temperature better at lower light output (Rea 2000).

The 3-way lamps studied cost less than the sum of the shorter-lived incandescents they replace, so the simple payback calculates as immediate, and the cost of saved energy is negative (-$0.01/kWh). Dimmable CFLs are almost as attractive: despite a $12 price premium over the inexpensive conventional bulbs they replace, the cost of saved energy is still only $0.01/kWh. (In both cases, our calculations are “residential,” in that they do not include labor for bulb changes or other maintenance.) The total savings possible from substituting these advanced CFL types are 3,000 and 14,500 GWh/yr, respectively, in California in 2020. The lamp types and controls are not very common.

The combination of cost of saved energy less than half of the residential rate, relatively large energy savings potential, and high likelihood of success makes this a high priority measure. We deem the likelihood of success high, since the products are closely related to other compact fluorescent bulbs.

Table B-4: Analysis of Variable Output Compact Fluorescent Bulb Technologies

Emerging Technology Database	**Units**	**Measure**	**Notes**
Number	CA1		
Name		Variable Output CFLs	
Description		3-way CFLs	
Market Information:			
Market sector		RES	
End-use(s)		LIGHT	
Energy types		ELEC	
Market segment		RET, ROB	
Basecase Information:			
Description		3-way incandescents	
Efficiency		30-70-100W	mix of 30-70-100+50-100-150 3-way, medium base
Electric use	kWh/year	62	Operating hours from HMG 1997
Summer peak demand	kW	0.004	5-20% res. Lights on from 2:00-6:00 pm
Winter peak demand	kW	0.02	5-20% res. Lights on from 2:00-6:00 pm
Gas/Fuel use	MMBtu/year	0	
New Measure Information:			
Description		3-way CFL	
Efficiency		12-18-29W	
Electric use	kWh/year	13	
Summer peak demand	kW	0.001	
Winter peak demand	kW	0.004	
Gas/Fuel use	MMBtu/year	N/A	
Current status		COMM	
Date of commercialization		ca. 2000	
Life	Years	13.7	GE-rated 10,000 hours, 2 hr/day
Savings Information:			
Electricity	kWh/year	49	
Summer peak demand	kW	0.003	
Winter peak demand	kW	0.013	
Gas/Fuel	MMBTU/year	N/A	
Percent savings	%	79%	
Feasible applications	%	90%	of 3-way fixtures
2020 Savings potential	GWH	1,202	CA only, about 12% of residential fixtures
2020 Savings potential	TBtu (source)	12	CA only
Industrial savings > 25%	(YES/NO)	NO	
Cost Information:			
Projected Incre. Retail Cost	2003 $	($7)	Wash. Electric Co-Op Prices; CFL= 8.3 incan. Lives
Other cost/savings	$/year	$0	no credit taken for avoided bulb change labor
Cost of saved energy	$/kWh	-$0.01	
Cost of saved energy	$/MMBtu	-$1.47	
Data quality assessment	(A-D)	B	
Likelihood of Success:			
Major market barriers		first cost, awareness	
Effect on utility			far fewer bulb replacements
Current promotion activity		mfgs, some utility groups	
Rating	(1-5)	3	
Rationale	low CSE, small technology step		
Priority / Next Steps			
Priority	L		saves about 0.1% of CA electricity
Next steps	promotion and incentive programs		
Sources:			
Savings	Lighting data sheets, comparison with specified base cases		
Peak demand	Used L13, HMG 1999, PGE 2000.		
Cost	Washington Electric Co-Op, http://www.washingtonco-op.com/pages/order.htm		
Feasible applications	Analyst judgment: simple plug-and-play substitution		
Measure life	General Electric Energy Star CFL data sheet		
Other key sources	HMG 1997 Lighting Efficiency Technology Report		
Principal contacts			
Notes			

Advanced HVAC controls. Packaged roof-top units (RTUs) are ubiquitous, accounting for almost half (44%) of the air-conditioned commercial floor space in California (AEC undated). They are typically small (mode = 5 tons) commodity products. They are rated only on refrigeration efficiency, i.e., steady-state EER for larger units or seasonal efficiency (SEER) for units up to 65,000 Btuh. On the other hand, conventional applications rely on the packaged unit to provide outdoor air to meet ventilation requirements and often to implement and control an *economizer cycle* that uses cool outside air instead of mechanical refrigeration when cost-effective. In some cases (particularly cold climates and humid climates), *energy* or *enthalpy recovery ventilation (ERV/HRV)* would also improve efficiency. Thus, a product rated on one parameter is expected to provide multiple services, generally relying on third-party components (economizers, heat recovery, controls) with field integration. This measure explores an alternative, an advanced RTU designed, installed, operated, and maintained to efficiently provide the full range of required services.

Fully optioned units from major manufacturers combine an impressive array of characteristics. As one example, consider the Lennox L Series, which offers SEER up to 13.25 and EER up to 12.2, integrated DDC control with humidity control (hot gas reheat) and demand control (CO_2) options, multi-stage cooling, heat recovery wheel, and premium fan motors (Lennox 2004). On the other hand, neither the CEE High Efficiency Commercial Air Conditioner program (CEE 2004) nor the FEMP procurement (PNL 2004) includes controls or non-refrigeration aspects of performance.

Lennox (2004) claims 45% energy savings in California from optimum economizer use alone, because the California climate is generally dry with large diurnal temperature swings. In contrast, Jacobs (2003) shows that 53% of 123 economizer-equipped California RTUs studied were working badly or not at all. We used 45% as total savings from working economizers in the 50% of units at 5 tons or larger with the advanced controls package.[14] For costs, we assumed the cost of national measure H1, Advanced Roof-Top Packaged Air Conditioners, plus $750 for an advanced controls package. With economizers, we computed a cost of saved energy of $0.06/kWh. This number excludes the value of demand savings.

We assume that the baseline performance is 10.3, as per measure H1b, but correct for absent and non-working economizers (80% of units). We do *not* correct for low airflow, which would raise fan energy to 0.34 kW/ton and reduce efficiency from 10.3 to 9.1, since this correction would be difficult to carry forward to the new measure in a controls measure analysis.

The principal barriers in California seem to be inertia and lack of knowledge about the savings that can be readily achieved, since the economics would be very attractive (CSE of $0.06 /kWh, compared to light commercial tariffs in the range of $0.18/kWh). One measure that would help greatly is an integrated rating method that would account for the contribution of the economizer and recognize the need for continuous ventilation. New FEMP and CEE programs could augment California utility efforts in this area.

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[14] Lau (2004) reports savings less than 20% in field studies, which would impact economic calculations. The reasons for the discrepancy between these results and those of Lennox (2004) remain to be resolved.

Table B-5: Advanced HVAC Controls Analysis

Emerging Technology Database	**Units**	**Measure**	**Notes**
Number	CA2		
Name	Advanced packaged-A/C controls		
Description	Packaged Rooftops with optimized performance		
Market Information:			
Market sector	COM		
End-use(s)	COOL		
Energy types	ELEC		
Market segment	NEW, ROB		
Basecase Information:			
Description	10 ton, 90.1-Compliant; 20% with working optimizers, standard controls		
Efficiency		10.3	ASHRAE 90.1 for 65-135 packaged equipment
Electric use	kWh/year	15,903	FEMP calculator, 1500 hr/yr
Summer peak demand	kW	10.5	.9 coincidence
Winter peak demand	kW	1.8	ventilation fan only, CA average
Gas/Fuel use	MMBtu/year	0	
New Measure Information:			
Description	10-ton, with working economizer and optimum controls		
Efficiency		12.2	
Electric use	kWh/year	8,115	FEMP+Lennox 45% economizer gain, proxy for ctrls+econ.
Summer peak demand	kW	9.4	.9 coincidence, 10% savings from control in real time
Winter peak demand	kW	1.8	ventilation fan only, CA average
Gas/Fuel use	MMBtu/year	0	
Current status		COMM	Fully optioned Lennox L series as example
Date of commercialization	ca. 2002		
Life	Years	15	
Savings Information:			
Electricity	kWh/year	7,788	
Summer peak demand	kW	1.0	10% savings estimated from controls staging, etc.
Winter peak demand	kW	0	ventilation fan only, CA average
Gas/Fuel	MMBTU/year	0	
Percent savings	%	49%	
Feasible applications	%	22%	Packaged units 5 tons and larger
2020 Savings potential	GWH	1,161	corrected for CA population
2020 Savings potential	TBtu (source)	12	corrected for CA population
Industrial savings > 25%	(YES/NO)	NO	
Cost Information:			
Projected Incre. Retail Cost	2003 $	$2,250	Current cost of super-efficient GEG (measure H1)+ $750 controls
Other cost/savings	$/year	$0	
Cost of saved energy	$/kWh	$0.03	
Cost of saved energy	$/MMBtu	$2.76	
Data quality assessment	(A-D)	C	
Likelihood of Success:			
Major market barriers	first cost, poor understanding, poor maintenance		
Effect on utility	improved IAQ from continuous operation and economizer		
Current promotion activity	manufacturer activity only		
Rating	(1-5)	3	
Rationale			Savings very large because economizers can contribute so much.
Priority / Next Steps			
Priority	H		
Next steps	Education re economizers and controls, Promotion and Incentives		
Sources:			
Savings	FEMP 2003		
Peak demand	Power draw corrected for coincidence		
Cost	Inferred from H1 analysis		
Feasible applications	Design Brief: Integrated Design for Small Commercial HVAC (Pier)		
Measure life	FEMP 2003		
Other key sources	FEMP 2003		
Principal contacts	Peter Jacobs, Architectural Energy (303) 444-4149; Cathy Higgins, NBI, (509) 493-4468,x11		
Notes			

Residential integrated whole house ventilation systems. Houses in areas with hot days and large diurnal temperature swings can significantly reduce summer peak load and cooling energy use through nighttime ventilation cooling. Residential air conditioning is responsible for about 45% of California's peak load, but only consumes about 7% of household electric energy (Coito 2003). Night ventilation cooling could be considered as an alternative integrated replacement for whole house fans, with air filtration. A project titled *Alternatives to Compressor Cooling* (ACC) was initiated by the California Institute for Energy Efficiency in 1994 to develop attractive house designs and mechanical systems that take maximum advantage of this resource. The most recent phase, supported by the Public Interest Energy Research (PIER) program, was completed in March 2004 and has resulted in commercialization efforts by PIER contractor Davis Energy Group of a product called NightBreeze. This product integrates ventilation cooling with variable speed hydronic forced-air heating, air conditioning, and fresh air ventilation functions (EDU 2004). A similar product (SmartVent) was developed by a Sacramento HVAC contractor and has demonstrated market success.[15] The systems use the same damper for the outside air intake and indoor air relief. Sensitivity studies performed by Davis Energy Group indicate that ~1cfm/sqft of night ventilation is optimal in most California locations. Duct sizing and damper space requirements make retrofit opportunities impractical in some cases.

A current PIER project is integrating control functions developed for NightBreeze systems in the prior ACC project phases with the furnace-based SmartVent system to improve comfort, offset more air conditioner load, and reduce fan energy use, while retaining the superior market acceptability of furnace systems. Ultimately, SmartVent and NightBreeze control functions may be nearly identical, except that SmartVent branding will apply to add-on controls for gas furnace systems and NightBreeze to packaged "hydronic furnace" systems with variable speed heating and ventilation cooling.

The SmartVent system is commercially available from RCS of Sacramento and is being marketed by Beutler Corporation to builders in Northern California. RCS, who manufactures the controls, sells a small quantity to other HVAC contractors. According to RCS, over 25,000 SmartVent systems have been installed. Nine prototype NightBreeze systems, which utilize variable speed hot water air handlers, have been installed for testing and demonstration purposes; extensive monitoring has been completed at three of these sites. Southern California Edison is installing eight more in Habitat for Humanity homes. Production units are expected to be available from Advanced Energy Products by September 2004.

No energy savings data for the SmartVent system are available. Dealer price for the SmartVent system from RCS is $613[16] and builders pay $750. Builders offer the SmartVent option to homebuyers for $1,200 to $2,000. Extensive monitoring and simulations have been completed for prototype NightBreeze systems (Springer 2004). Energy savings vary widely with climate, ranging from less than 5% for the coastal areas to greater than 60% in coastally influenced inland areas (roughly, the transition area of this study). Savings in hot inland areas range from 20 to 50%. If combined with measures to improve building envelope summer performance, ventilation cooling is projected to eliminate the need for air conditioning in many coastal and some transition areas. Energy savings of 88% were measured for a NightBreeze demonstration house located in Livermore (a transition area), compared to an identical control house. Peak demand reduction is projected to be from 40 to 80%. NightBreeze systems, including the variable speed hydronic air handler with heating coil, damper, and controls, are currently available commercially from Advanced Energy Products through the Davis Energy Group for about $2,850.

Energy savings for other California climates were calculated using a DOE-2 model that includes a specially written function to emulate NightBreeze control operation. This model was calibrated against one of the demonstration houses by matching the rate of change of indoor air temperatures over 24 hour periods. Annual cooling energy use predicted by the model was 5% lower than monitored energy use. The house monitored and modeled is a 3,080 ft² one-story house located in Livermore. The NightBreeze analysis cases included envelope modifications to improve summer performance.[17]

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[15] Lau (2004) reports that a retrofit product, "DuroDyne" is also available.

[16] Dealer costs for a ZCV2 control, TS-40 user interface (thermostat), and RS12 outdoor sensor total $388. The Model 2030DD damper adds another $225.

[17] These include radiant barrier roof sheathing and 50% hard floor coverings over the concrete slab plus 5/8" drywall (for added thermal mass).

The projected incremental cost is about $1,200 compared to a standard furnace and air conditioning system. The 1.3 kW of peak demand savings will be attractive in some areas and could provide added savings if combined with time-of-use rates. Where NightBreeze eliminates the need for mechanical air conditioning, first costs are reduced, leading to no-cost demand and energy savings.

The furnace-based SmartVent system will continue to be successfully marketed to Northern California production builders with current controls, and after completion of the funded PIER project, with advanced controls that improve energy savings. The primary barriers to extending its application to other appropriate regions are marketing and education. Defective installation has also been identified as a potential barrier to achieving potential savings. These barriers can be overcome through implementing utility programs that would attract market attention by providing modest incentives, and that would provide contractor training. Implementation of a Title 24 compliance option that requires inspection by a HERS rater would also mitigate installation defects.

Despite superior performance and quiet operation compared to SmartVent systems, the hydronic air handler-based NightBreeze system has not been well received by production builders and contractors to date because it requires a hot water heat source with sufficient capacity, because of the mixture of plumbing and HVAC trades involved in its installation, and because it lacks name recognition. However, there is increasing use of tankless water heaters by both production and custom homebuilders, and demonstrations have shown that they are appropriate heat sources for NightBreeze systems. Currently, the best application for these systems is custom homes. This market would also benefit from utility programs and a Title 24 compliance option. Paybacks can be short when the air conditioning is eliminated, but this option is difficult to market in most parts of California due to the perceived need for air conditioning.

Table B-6: Integrated Whole House Ventilation

Emerging Technology Database	**Units**	**Measure**	**Notes**
Number		CA3	
Name		Residential Night-Time Ventilation Cooling	
Description		Low-latent fraction air conditioner systems	
Market Information:			
Market sector		RES	
End-use(s)		COOL	
Energy types		ELEC	
Market segment		NEW	
Basecase Information:			
Description		3 ton central AC/furnace	
Efficiency		12	SEER
Electric use	kWh/year	1,154	Average CA central AC use from 2001 RECS
Summer peak demand	kW	3.24	10 EER on peak
Winter peak demand	kW	NA	
Gas/Fuel use	MMBtu/year		
New Measure Information:			
Description		NightBreeze System	
Efficiency		12	no change to compressor or condenser
Electric use	kWh/year	692	40% energy savings
Summer peak demand	kW	1.94	40-80% demand savings
Winter peak demand	kW	NA	
Gas/Fuel use	MMBtu/year	NA	
Current status		COMM	
Date of commercialization		2004	
Life	Years	18.4	
Savings Information:			
Electricity	kWh/year	462	
Summer peak demand	kW	1.3	
Winter peak demand	kW	0	
Gas/Fuel	MMBtu/year		
Percent savings	%	40%	
Feasible applications	%	80%	
2020 Savings potential	GWh	879	
2020 Savings potential	TBtu (source)	9	
Industrial savings > 25%	(YES/NO)	NO	
Cost Information:			
Projected Incre. Retail Cost	2003 $	$1,200	
Other cost/(savings)	$/year	$0	
Cost of saved energy	$/kWh	$0.22	
Cost of saved energy	$/MMBtu	$21.73	
Data quality assessment	(A-D)	B	
Likelihood of Success:			
Major market barriers		Lack of knowledge, design tools	
Effect on utility		Improved indoor air quality, higher comfort	
Current promotion activity		PIER research, SBIR support	
Rating	(1-5)	4	
Rationale		Significant demand savings, air quality	
Priority / Next Steps			
Priority	L	High CSE, unless we can value avoided peak.	
Next steps		Contractor education, utility incentives	
Sources:			
Savings		DEG 2004	
Peak demand		DEG estimate	
Cost		DEG 2004	
Feasible applications		DEG estimate	
Measure life		DOE TSD	
Other key sources			
Principal contacts		David Springer, Davis Energy Group 530.753.1100	
Notes			

Notes on Two Technologies Described

In our review of three specific technologies (above), we developed complete narratives and analyses. We also developed narratives without analyses of savings potential and cost of saved energy for two additional technologies, wireless thermostats and "Non-Invasive Load Monitors" (NILMs). In both cases, the technologies may facilitate savings by making other measures more feasible or cost-effective. However, they do not themselves save energy, so our analytical methods are not applicable.

Wireless thermostats (WTs). Thermostats are conceptually simple: a local temperature sensor turns heating and/or cooling on or off depending on the temperature where the thermostat is located. In small buildings with a single zone (most houses), a single thermostat is situated in a "living" area away from sunlight and drafts, an area which is considered to represent user needs. Hall and dining room installations are common. During the past decades, the basic controller has evolved into a programmable unit that allows varying the setpoint by time of day and day of the week. The thermostat is typically connected to the boiler, furnace, or other equipment by low-voltage (24v AC) wiring. More recently, many manufacturers have begun selling WTs that provide the same functionality as "hard-wired" units but promise much easier installation—or portability, if desired by the user. They differ only in including a low-powered radio transmitter in the thermostat and a receiver at the equipment controller.

Wireless thermostats can control many types of equipment. In addition to residential-style central units, controllers are available for fan-coils, baseboard electric heat, window air conditioners, "mini-split" air conditioners, and PTACs (packaged terminal air conditioners and heat pumps).

WTs are available with two different "user interfaces." Some are designed to be wall-mounted and are simply wireless replacements for conventional units. These are alternatives in several common situations, including: (1) system modernization, where new equipment functions may not be compatible with older wiring—it may be less expensive to convert to a wireless thermostat than to open and repair walls to change the wiring; (2) bad thermostat placement—whether because of poor judgment by the original installer, changes in use of the building, or a building addition, moving the thermostat may make the system serve needs better; and (3) rezoning—in some commercial buildings, subdividing spaces (for example, into closed offices instead of an open area) may require changing ductwork in a multi-zone system. In all of the cases, a thermostat that is just hung on the wall can be more cost-effective than a hard-wired alternative.

The other "user interface" is a portable thermostat, analogous to the remote control for televisions. This allows the owner to adjust the temperature to the desired level in the room where she is. This is likely to be used particularly in houses or other structures where construction defects (insulation, infiltration, fenestration, or ductwork) lead to wide temperature differences from room to room, during the day (as the sun moves) or as seasons change.

Available wireless thermostats offer a spectrum of capabilities and features (see Table B-7).

Wireless thermostats are not inherently energy-saving devices. However, they can make large energy savings easier. Consider, for example, a house with baseboard electric heating and window air-conditioners, where there is no central thermostat. If a retrofit to high-efficiency central equipment were done properly, a wall-mount or free-standing wireless thermostat could simplify installation and help achieve the savings potential of the new equipment. As a counter-example, consider a single-zone house with poor ability to maintain the same temperature in each room. The homeowner wants to be comfortable in summer in her home office, which is a converted bedroom. She might choose to carry her portable WT to that room during the day, so she could keep it at 75º. It would keep her office cool, but only at the cost of making the rest of the house much colder, thereby using much more energy. This could be ameliorated by zoning the HVAC system, but that is a substantial additional expense.

The principal barriers are cost and lack of awareness. In addition, the wireless thermostat is not inherently an energy-saving or demand-reducing device, but a means by which a motivated user can more easily achieve savings in some situations. The wireless thermostat competes with the conventional thermostat on the basis of price, convenience, and comfort; it will be chosen when it saves on installation cost (no hard wiring in walls) or provides substantial amenity (portability, for example). In this situation, the WT can allow a person to move from one zone to another, while the temperatures in unoccupied zones can be allowed to drift. This can save air conditioning and heating energy and money.

Table B-7: Features of Some Wireless Thermostat Models

	Carrier 33CS250-RC Debonair	Honeywell T8665A Chronotherm IV Wireless Thermostat	Enernet T900 Wireless Thermostat
Feature	Hand held / table stand	Wall mount	Wall mount
2-Stage Heat & 2-Stage Cool for use with gas / electric or heat pump systems	x	x	
Auto changeover	x	x	
Multiple thermostats can be used with one receiver	x		x
Frequency	418 Mhz	345 MHz	916.5 MHz
Adjustable deadband	x		x
Programming stored in nonvolatile memory	x	x	Change batteries in sequence to retain programming
Backlit display	x	x	
Display shows both set and room temperature simultaneously	x		x
Compressor time guard and adjustable cycle limit		x	x
Fan control to operate the fan for a preset period of time each hour for air circulation	x		
Limitable (maximum heating T, minimum cooling T)	x		x
Occupancy sensor compatible	x		x
Via plug node controls window AC, window fan, or other device not part of the central AC			x
Estimated street price	$219	$320	Depends on array of RCNs

NOTE: All have range of hundreds of feet, 7 day programmability with 4 time periods/day, setpoint adjustment range from 45F to 95F, multiple digital codes to limit interference.

Education must be part of any program, lest the amenity be subverted to increase energy consumption. It may help to bundle other amenities with the WT. In the UK, Honeywell markets wireless thermostats as part of their Hometronic home automation system, offering wireless capabilities analogous to the wired X10 standard: the ability to induce various appliances to wake up and perform their task according to a schedule, seeking greater convenience (coffee is ready when the user wakes) or money savings (laundry is washed when cheaper off-peak electricity is available.) Other “next steps” will be critically dependent on finding situations in which substantial savings are probable.

Non-Invasive Load Monitors (NILMs). Non-Invasive Load Monitoring (NILM) and HVAC Fault Detection and Diagnosis (HVAC FDD) refer to methods to use quick-sampling power meters or submeters with computer analyses to monitor and/or diagnose problems in HVAC systems. The purpose of the NILM is to detect on and off switching of major HVAC loads in commercial buildings, track variable-speed drive loads, and detect operating faults from a centralized location at affordable cost. This information can be used to optimize operations, aid commissioning and diagnostics, or simply to provide the energy manager with short- and long-term energy use intensity information that is key to maintaining and improving plant efficiency. NILM originated in residential studies and FDD for commercial buildings research. Their hardware needs are similar, using rapid sampling power meters (often differentiating real and reactive loads) and personal computers to capture and analyze the data streams. In practice, the terms now seem to be used more-or-less interchangeably.

Conceptually, the simplest FDD systems have one electrical power meter on each motor of interest (e.g., chiller, air handlers, or pumps). As noted by Shaw et al. (2002), generally other sensors are used to develop correlations between motor power (steady state or transient) and airflow, water pressure or flow, and other variables that represent system effects caused by the motors. These submeters would measure motor operation at steady-state, correlating with one of more of these dependent variables. Deviations from the expected ("trained") correlation indicate problems. This approach can be applied to systems as diverse as air handlers, chiller motors, and pumps. It can detect many classes of problems, including slipping fan belts, stuck dampers or fouled filters, and valve failures. Some, but not all, patterns can be given unique diagnoses. Whether or not a particular problem has a unique cause often depends on the operating mode of the system, which generally varies with outdoor temperature. (As a trivial example, a leaky cooling coil valve may not be detected when the chilled water system is shut down during winter conditions with cold outside air being used for cooling when needed. On the other hand, differentiating between a damper stuck closed and one that leaks air depends on the operating mode.) Unique diagnoses mean that mechanics can be dispatched with exactly the right parts to do needed repairs, which is a significant advantage in restoring comfort.

The steady state, one-motor-one-meter approach can be extended in two directions: using a single power meter to centrally monitor multiple motors and looking at motor transients as a source of additional diagnostic information.

Although it is possible to isolate and monitor a single motor with an individual monitoring system, the cost rises rapidly with the number of motors involved. Thus, a central approach is of great interest for FDD in commercial buildings. Shaw et al. (2002) studied the ability of such a system to detect and diagnose faults in a test building. A single sampling meter (NILM) monitored the power line that fed five fans and ten pumps; another NILM was installed on the whole building service entrance. Motor start-up signals can reveal a great deal about condition and loads. In general, short-interval sampling of power shows step changes in real and reactive power when motors turn on or off. For FDD, intensive computer analysis of these data isolates the "behavior" of individual motors, allowing fault detection and (under some circumstances) diagnoses.

In their investigation of the use of start-up transients, Shaw et al. (2002) determined that comparison of a physical model (mathematical description) of the motor with actual start-up transient data from the NILM allowed some fault detection. However, the motors of interest must be relatively large compared to the total current flowing, and the slow ramp-up of variable speed drives drastically limits the utility of transient information for motors with such drives. In theory, these disadvantages are compensated for by freedom of the technique from the need for flow or other sensors that are themselves subject to drift and failure.

We do not find Non-Intrusive Load Monitors available as commercial products now. The most recent work was funded by the California Energy Commission (CEC 2003b). Selkowitz (2003) provided research results for a small commercial building design. The project presentation suggested that a FDD system can be applied to roof-top packaged air conditioners, and that a unit for smaller commercial buildings could be marketed at a price of about $200 if the market exceeds 10,000 units (CEC 2003b). Further, they suggested that information generated by application of NILM will be less expensive than that created using traditional power sub-metering and acoustic/vibration monitoring.

Results from the Climate-Sensitivity Study

We turn now to analyses of the climate-sensitive data (see Table B-8). The table looks at each measure by climate zone. We considered 33 measures, each in three climate zones, for a total of 99 zone-measure evaluations. For the California analysis, we used California-specific costs of saved energy for screening. In particular, we started with $0.1244/kWh as the average residential tariff and $0.1447/kWh as the average commercial tariff.[18] Adapting the methods of the national study, we divided these values by two for our screening parameters for high priority measures, thus using $0.062 residential and $0.072 commercial, but CSE less than $0.1244/kWh and $0.1447/kWh, respectively, for medium and low priority measures.

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[18] These are average investor-owned rates from http://www.energy.ca.gov/electricity/current_electricity_rates.html.

Table B-8: Results from the Climate Sensitivity Study*

Measure	Region	Name	2020 Savings Potential (TBtu Source)	% Saved in 2020	Total for Measure	CSE ($/kWh)	CSE ($/MMBtu)	Likelihood of Success Rating	California Priority
H11	Inland	Leakproof Duct Fittings	6.30	0.27%		$0	$0.23	4	H
H11	Transition		4.82	0.21%		$0	$0.31	4	H
H11	Coastal		15.20	0.66%	1.15%	$0	$0.31	4	H
H12	Inland	Aerosol-Based Duct Sealing	8.88	0.39%		$0.01	$1.43	3	H
H12	Transition		7.34	0.32%		$0.02	$1.89	3	H
H12	Coastal		22.69	0.99%	1.69%	$0.02	$1.93	3	H
PR3	Inland	IDP LEED level (30% > Code)	8.34	0.36%		$0.01	$1.05	3	H
PR3	Transition		6.59	0.29%		$0.01	$1.2	3	H
PR3	Coastal		20.39	0.89%	1.54%	$0.01	$1.35	3	H
PR4	Inland	Retrocommissioning	6.49	0.28%		$0.02	$2.34	3	H
PR4	Transition		5.25	0.23%		$0.03	$2.67	3	H
PR4	Coastal		16.62	0.72%	1.23%	$0.03	$3	3	H
P2a	Inland	Commercial Micro-CHP Using Fuel Cells	24.54	1.07%		$0.07	$6.74	2	H
P2a	Transition		12.12	0.53%		$0.07	$6.76	2	H
P2a	Coastal		10.91	0.48%	2.07%	$0.07	$6.77	2	H
P2b	Inland	Commercial Micro-CHP Using Micro-Turbines	24.14	1.05%		$0.05	$4.64	2	H
P2b	Transition		11.76	0.51%		$0.05	$4.65	2	H
P2b	Coastal		9.65	0.42%	1.98%	$0.05	$4.66	2	H
D2	Inland	Advanced Air-Conditioning Compressors	2.03	0.09%		$0.04	$3.64	3	M
D2	Transition		1.30	0.06%		$0.05	$5.19	3	M
D2	Coastal		2.70	0.12%	0.26%	$0.09	$8.76	3	M

Measure	Region	Name	2020 Savings Potential (TBtu Source)	% Saved in 2020	Total for Measure	CSE ($/kWh)	CSE ($/MMBtu)	Likelihood of Success Rating	California Priority
D4	Inland	Hi-Eff. Pool and Domestic Water Pump Systems	3.52	0.15%		$0.07	$6.54	3	M
D4	Transition		3.21	0.14%		$0.07	$6.54	3	M
D4	Coastal		11.26	0.49%	0.78%	$0.07	$6.54	3	M
H1b	Inland	Advanced Roof-Top Packaged Air-Conditioners	1.95	0.08%		$0.07	$6.67	3	M
H1b	Transition		2.00	0.09%		$0.06	$5.92	3	M
H1b	Coastal		5.97	0.26%	0.43%	$0.07	$6.96	3	M
H7	Inland	"Robust" A/C	2.87	0.13%		$0.06	$6.8	3	M
H7	Transition		1.83	0.08%		$0.11	$11.73	3	M
H7	Coastal		3.82	0.17%	0.37%	$0.32	$38.57	3	M
PR1	Inland	Advanced Automated Building Diagnostics	1.63	0.07%		$0.05	$5.05	3	M
PR1	Transition		1.63	0.07%		$0.05	$4.51	3	M
PR1	Coastal		5.24	0.23%	0.37%	$0.06	$6.31	3	M
P1b	Inland	Residential Micro-CHP Using Stirling Engines	6.39	0.28%		$0.06	$6.14	2	M
P1b	Transition		3.21	0.14%		$0.06	$5.91	2	M
P1b	Coastal		2.02	0.09%	0.51%	$0.06	$5.85	2	M
S2b	Inland	"Active Window Insulation (Automated), Commercial "	6.89	0.3%		$0.07	$6.46	2	M
S2b	Transition		2.25	0.1%		$0.06	$5.73	2	M
S2b	Coastal		2.31	0.1%	0.5%	$0.07	$6.74	2	M
H10a	Inland	Ground Coupled Heat Pumps, Commercial	0.84	0.04%		$0	$0	2	L
H10a	Transition		0.87	0.04%		$0	$0	2	L
H10a	Coastal		2.32	0.1%	0.18%	$0	$0	2	L

Measure	Region	Name	2020 Savings Potential (TBtu Source)	% Saved in 2020	Total for Measure	CSE ($/kWh)	CSE ($/MMBtu)	Likelihood of Success Rating	California Priority
PR2	Inland	Ultra Low Energy Designs & Zero Energy Buildings	2.66	0.12%		$0	$0.48	2	L
PR2	Transition		2.10	0.09%		$0.01	$0.55	2	L
PR2	Coastal		6.50	0.28%	0.49%	$0.01	$0.62	2	L
PR6	Inland	"Better, Easier to Use, Residential Sizing Methods "	1.14	0.05%		$0.01	$1.41	2	L
PR6	Transition		0.77	0.03%		$0.02	$1.91	2	L
PR6	Coastal		2.38	0.1%	0.19%	$0.02	$2.24	2	L
S1	Inland	High Performance Windows (U<0.25)	3.16	0.14%		$0.07	$6.46	3	L
S1	Transition		2.18	0.1%		$0.09	$8.74	3	L
S1	Coastal		7.39	0.32%	0.55%	$0.11	$10.28	3	L
H5	Inland	Residential HVAC for Hot-Dry Climates	0.72	0.03%		$0.04	$3.85	4	Special
H5	Transition		0.46	0.02%		$0.06	$5.48	4	Special
H5	Coastal		0.96	0.04%	0.09%	$0.09	$9.24	4	Special
H8	Inland	Residential Gas Absorption Chiller Heat Pumps	0.75	0.03%		$0.06	$6.08	2	Special
H8	Transition		0.48	0.02%		$0.09	$8.72	2	Special
H8	Coastal		1.00	0.04%	0.1%	$0.16	$15.6	2	Special
H16	Inland	High-Efficiency Gas-Fired Rooftop Units	0.22	0.01%		N/A	$8.06	2	Special
H16	Transition		0.21	0.01%		N/A	$7.68	2	Special
H16	Coastal		0.77	0.03%	0.05%	N/A	$7.42	2	Special
H17	Inland	Transpired Solar Collectors for Ventilation Air	0.20	0.01%		N/A	$2.41	3	Special
H17	Transition		0.18	0.01%		N/A	$2.41	3	Special
H17	Coastal		0.52	0.02%	0.04%	N/A	$2.41	3	Special

Measure	Region	Name	2020 Savings Potential (TBtu Source)	% Saved in 2020	Total for Measure	CSE ($/kWh)	CSE ($/MMBtu)	Likelihood of Success Rating	California Priority
H19	Inland	Displacement Ventilation	0.20	0.01%		$0	$0	3	Special
H19	Transition		0.20	0.01%		$0	$0	3	Special
H19	Coastal		0.52	0.02%	0.04%	$0	$0	3	Special
PR5	Inland	Low Energy Use Homes and Zero Energy Houses	3.44	0.15%		$0.12	$12.12	2	Special
PR5	Transition		2.51	0.11%		$0.16	$15.16	2	Special
PR5	Coastal		8.51	0.37%	0.63%	$0.16	$15.66	2	Special
S3b	Inland	Electrochromic Glazing for Commercial Windows	0.04	0%		$0.04	$3.55	3	Special
S3b	Transition		0.04	0%		$0.03	$3.22	3	Special
S3b	Coastal		0.14	0.01%	0.01%	$0.04	$3.54	3	Special
S5	Inland	Residential Cool Color Roofing	1.47	0.06%		$0.04	$4.39	3	Special
S5	Transition		0.94	0.04%		$0.06	$6.25	3	Special
S5	Coastal		1.95	0.09%	0.19%	$0.11	$10.55	3	Special
W4	Inland	Integrated Home Comfort Systems	1.23	0.05%		$0.06	$5.85	2	Special
W4	Transition		0.94	0.04%		$0.07	$6.84	2	Special
W4	Coastal		3.31	0.14%	0.24%	$0.07	$6.8	2	Special
H10b	Inland	Ground Coupled Heat Pumps - Residential	0.52	0.02%		$0.22	$21.73	2	Not
H10b	Transition		0.34	0.01%		$0.31	$30.45	2	Not
H10b	Coastal		0.86	0.04%	0.07%	$0.35	$34.04	2	Not
H14	Inland	Solid State Refrigeration for Heat Pump & Power Generation	0.85	0.04%		$0.34	$33.39	2	Not
H14	Transition		0.56	0.02%		$0.54	$53.11	2	Not
H14	Coastal		1.42	0.06%	0.12%	$0.71	$69.19	2	Not

Measure	Region	Name	2020 Savings Potential (TBtu Source)	% Saved in 2020	Total for Measure	CSE ($/kWh)	CSE ($/MMBtu)	Likelihood of Success Rating	California Priority
P1a	Inland	Residential Micro-CHP Using Fuel Cells	6.40	0.28%		$0.17	$16.47	3	Not
P1a	Transition		3.23	0.14%		$0.16	$15.86	3	Not
P1a	Coastal		2.07	0.09%	0.51%	$0.16	$15.71	3	Not
S2a	Inland	Active Window Insulation	0.59	0.03%		$0.83	$80.85	1	Not
S2a	Transition		0.44	0.02%		$1.18	$115.21	1	Not
S2a	Coastal		0.28	0.01%	0.06%	$1.99	$194.29	1	Not
S4	Inland	Attic Foil Radiant Barriers (Retrofit)†	0.28	0.01%		$0.19	$19.01	2	Not
S4	Transition		0.18	0.01%		$0.28	$27.1	2	Not
S4	Coastal		0.38	0.02%	0.04%	$0.47	$45.7	2	Not
S8	Inland	High Quality Envelope Insulation	0.11	0%		$0.18	$17.56	2	Not
S8	Transition		0.08	0%		$0.24	$23.45	2	Not
S8	Coastal		0.27	0.01%	0.02%	$0.26	$25.75	2	Not
S9	Inland	Engineered Wall Framing	0.09	0%		$0	$0	3	Not
S9	Transition		0.06	0%		$0	$0	3	Not
S9	Coastal		0.21	0.01%	0.02%	$0	$0	3	Not

* Savings estimates may be low, since some climate zones with low population are not included.

†CSE based on installation cost of $0.30/sf for retrofit. Measure is likely to be cost-effective for new construction, where installation costs will be much lower.

For this California analysis, we also replaced the national priority assignments with California-specific values. This included using the California cost-of-saved energy values (see above) and the estimated fraction of 2020 *California* buildings energy that the measure would save. With these California data values and the national Likelihood of Success (Rating) values, we assigned California priority values (see Table B-8, last column). The resulting California-specific priorities differ for many measures from the national values, reflecting California's climate and energy prices.

In general, for any given measure there is a general trend toward lower cost of saved energy as one goes from inland through transitional to coastal climate areas. Of course, climate-driven loads decrease in the same order. The exceptions are themselves interesting. First, to the precision level we used, three measures show zero CSE—commercial ground source heat pumps, displacement ventilation (commercial), and (residential) engineered wall framing. That is, these measures have no incremental cost relative to their displaced counterparts.

Three other measures have the same CSE (within our precision) across all climate areas. These are high efficiency pool and domestic water pumps, commercial-scale micro-CHP (combined heat and power) using fuel cells, and the same using micro-turbines. In the case of pool pumps, we assumed the same annual energy use, implying the same season length in each zone. This may not be completely accurate, but represents the best data available. For the other two technologies, both CHP, the situation is more complex. Within technologies, we assumed the same electricity savings across each zone, but varying incremental gas use, and the values for CSE coincidently seem to coincide.

Five other measures have anomalies, in the sense that CSE does not decrease as climatic intensity decreases. For reasons that may be beyond our analytical resolution, advanced rooftop A/C, active window insulation, electrochromic glazing, and advanced automated building diagnostics (all commercial technologies) are slightly more cost-effective in transition than other zones. On the other hand, residential micro-CHP using fuel cells (not cost-effective) is inverted: It is least expensive in coastal ($0.159/kWh) and most in inland ($0.166/kWh).

For the 33 measures, we find a wide variation in the savings per measure. When we aggregate savings from all climate zones, several measures give savings estimates greater than 20 TBtu of source energy in California in 2020:

- Micro-CHP, whether using fuel cells or micro-turbines (2 measures)
- Aerosol-based duct sealing for the residential sector
- Integrated design process (LEED or 30% better than code)
- Retrocommissioning
- Leak-proof duct fittings

Several other measures would save more than about 10 TBtu:

- High-efficiency pool and residential water supply pumps
- Advanced roof-top packaged air-conditioners
- Ultra-low energy use and zero energy homes and commercial buildings
- Residential micro-CHP using fuel cells
- High performance windows
- Automated commercial window active insulation

The remaining 21 measures would save less than 1 TBtu each in 2020.

About two-thirds of the 99 combinations of measure and climate are cost-effective by our cost criteria. Indeed, Table B-9 shows that 24 of the 33 measures (about two-thirds) are cost-effective in all climate zones considered. Conversely, only six[19] are not cost-effective in *any* climate zone. Only three are cost-effective in some zones.[20]

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[19] These are active window insulation, attic foil radiant barriers, ground-coupled residential heat pumps, high quality envelope insulation, residential micro-CHP using fuel cells, and solid state refrigeration for heat pumps and power generation.

[20] These are "robust" air-conditioning, low energy use homes and zero energy houses, and residential gas absorption chiller heat pumps.

Indeed, almost all measures are either cost-effective in all climate areas, or not cost-effective in any climate area: climate is rarely a key discriminating variable.

Table B-9: Frequency of Measure Cost-Effectiveness by Number of Climate Zones

Cost-Effective	Number of Measures
All climate zones	24
Some climate zones	3
No climate zones	6
N/A (gas only)	2

Note: table uses California energy costs for national study measures.

Table B-10 shows calculated cost of saved energy for each of the measures that are considered cost-effective in some but not all three climate areas. The patterns are logical: measures that reduce climate-related loads or meet cooling needs better are more cost-effective where climate is more intense, and cool roofs have lower value where solar intensity is lower.

Table B-10: Cost of Saved Energy for Measures That Are Cost-Effective in Some But Not All Climate Areas

	CSE, $/kWh		
Measure	Inland	Transitional	Coastal
“Robust” AC	0.064	0.106	0.319
Low Energy Use & Zero Energy Houses	0.124	0.155	0.16
Residential Gas Absorption Heat Pumps	0.062	0.089	0.159

Of the 33 measures, 12 are commercial, seven have both residential and (light) commercial applications, and seven are almost purely residential.

Looking at the data from another perspective, of the cost-effective measures in areas, 18 are coastal, 21 are transitional, and 24 are inland climate zones: where there is greater climate intensity (more heating and cooling load), capital investment in efficiency is warranted.

Finally, our measures include 22 “technologies” and 11 “practices,” a 2:1 ratio. Of course, the distinctions between them are not always clear. As an example, we classify “leakproof duct fittings” as a technology, but the hard tasks of moving toward tighter duct systems include major shifts in practice and consumer expectations or perceptions of value. Even given this caveat, the data suggest that seven of the clearly cost-effective measures are practices and nine are technologies. As in the national study, it is important to note that a higher ratio of “practices” (7 of 11 evaluated, or 64%) is cost effective than of technologies (9 of 20, or 45%, excluding the two gas-only technologies).

Discussion

Table B-11 presents results for the three technologies studied for California, with the compact fluorescents divided into variable (stepped) output and (continuously) dimmable.

Table B-11: Cost of Saved Energy and GWH Saved in 2020, California-Specific Measures.

Measure Name	CSE, $/kWh	CSE, $/MMBtu Source	GWH Saved in 2020
Variable (stepped) output CFLs	-$0.01	-$1.47	1202
Dimmable CFLs	+$0.01	+$0.91	216
Advanced RTU & controls	$0.03	$2.76	1161
Integrated whole-house ventilation	$0.22	$21.73	879

The table suggests that specialty compact fluorescents offer the largest opportunity, both because of their low cost of saved energy and their large savings potential. Within this category, the savings are much larger for dimmable units than for stepped-output bulbs, because there are far more of the former than the latter in houses. Stepped-output bulbs are largely restricted to living-room type floor and table lamps, typically with one bulb per fixture. On the other hand, there are both fixture-mounted and wall-mounted dimming switches, often controlling multiple lamps (such as track lighting and recessed can lighting). Thus, within this category the continuously dimming technology appears to be the more promising option for program development. Of the two cooling technologies (advanced RTU and controls and integrated whole-house ventilation), the advanced RTU is quite cost-effective in all California climate zones, while the demand savings benefits of integrated whole house ventilation would have to be specifically evaluated to make it cost-effective in any zone.

The opportunities for packaged air conditioners for light commercial applications are very attractive. The potential for savings may be larger than what our analyses can capture with very high confidence, since present equipment with present controls may be worse than we assume (Jacobs et al. 2003). Although we include the nominal value of economizers, we may underestimate the value of the controls package in assuring that operators keep the economizers operating. We also may underestimate loads and operating costs from meeting ventilation loads (ASHRAE 62.1). Each of our assumptions is conservative. If they are not true, RTUs actually have higher energy consumption—and larger potential savings from fixing the problems.

The value of night-time ventilation (called “Integrated Whole House Ventilation Systems” in this report), the third technology evaluated, is highly dependent on first cost estimates, taken as $1,200 incremental cost for a residential HVAC system in this analysis. It is likely that the cost would be substantially lower in a new-home production environment characterized by high sales volumes and experienced installers. Thus, this technology may be a more attractive target for new construction programs than for retrofits, at least until it is well established in the marketplace.

For analysis of climate sensitivity, we used California-specific priority values (see Table B-8, last column). The resulting California-specific priorities differ for many measures from the national values, reflecting California’s climate and energy prices (see Table B-12). It is interesting that the distribution of priorities is rather uniform for the California analysis. We identified six each high and medium priorities, eight “special” (new construction, etc.) measures, and four low priorities. In contrast, the national study found fewer very high priority measures and a larger number of measures that were not priorities.

Table B-12. Distribution of Priorities in California and National Studies

Priority	California (total = 33)	National (total = 72)
High	6 (18%)	5–6 (~7%)
Medium	6 (18%)	20–27 (~33%)
Low	4 (12%)	11–14 (~17%)
Special	8 (24%)	10–19 (~20%)
Not	6 (18%)	14–24 (~26%)

Another perspective on priorities for California is shown in Table B-13, expanded from Table 3-3 of the national report.

Table B-13. Measure Priorities Sorted by Cost of Saved Energy ($/kWh)

Measure	Name	Savings Potential (TBtu)	% saved	CSE, $/kWh	CSE, $/MMBtu	Likelihood of Success Rating	Priority
H11	leakproof duct fittings	489	1.03	0	0.40	4	H
PR3	int. design process (30% > code)	620	1.31	0.01	1.20	3	H
A1	1 Watt standby power for home appliances	497	1.05	0.02	1.90	4	H
CA2	advanced HVAC Controls (California only)	1,161	0	0.03	2.80	3	H
H12	aerosol-based duct sealing	443	0.93	0.03	2.50	3	H/M
PR4	retrocommissioning	443	0.93	0.03	2.60	3	H/M
PR1	advanced automated building diagnostics	704	1.48	0.04	4.00	3	H/M
L16	airtight compact fluorescent downlights	393	0.83	-0.01	-1.20	4	M
R1	solid state refrigeration (Cool Chips™)	171	0.36	0	0	3	M
L15	scotopic lighting	154	0.33	0	0	3	M
L14	1-lamp fluorescent fixtures w/ high performance lamps	215	0.45	0.01	0.80	3	M
O1	EZConserve Surveyor software	286	0.6	0.02	1.70	3	M
W3	residential heat pump water heaters	158	0.33	0.02	2.20	3	M
L13	residential CFL portable (plug-in) fixtures	216	0.46	0.03	3.10	3	M
D2	advanced air-conditioning compressors	200	0.42	0.03	2.40	3	M
L11b	commercial LED lighting	176	0.37	0.03	2.90	3	M
H18	CO_2 ventilation control	163	0.34	0.03	2.70	4	M
S1	high performance windows (U<0.25)	144	0.3	0.03	2.70	3	M
L6	low wattage ceramic metal halide lamp	130	0.27	0.03	2.80	3	M
H7	"robust" a/c	278	0.59	0.04	3.80	3	M

Measure	Name	Savings Potential (TBtu)	% saved	CSE, $/kWh	CSE, $/MMBtu	Likelihood of Success Rating	Priority
S5	residential cool color roofing	144	0.3	0.04	3.70	3	M
A2	1 kWh/day refrigerator	140	0.3	0.04	3.90	4	M
H9	adv. cold-climate heat pump/frost-less heat pump	173	0.36	0.05	4.60	3	M
H15	designs for low parasitics, low pressure drops	94	0.2	0	0	4	M/L
D3	advanced HVAC blower motors	112	0.24	0.04	3.80	4	M/L
P2b	commercial micro-CHP using micro-turbines	692	1.46	0.05	5.30	2	M/L
CA1	variable output (stepped) Compact Fluorescents*	12	0	-0.01	-1.50	3	L
H10a	ground-coupled heat pumps	15	0.03	0	0	2	L
D1	advanced appliance & pump motors; CW example	58	0.12	0	0.20	4	L
PR7	bulls-eye building commissioning	47	0.1	0.01	0.60	3	L
PR6	better, easier to use, residential sizing methods	113	0.24	0.01	0.70	2	L
R3	efficient fan options for commercial refrigeration	29	0.06	0.02	1.60	4	L
H13	microchannel heat exchangers	132	0.28	0.02	1.60	2	L
R2	modulating compressor for packaged refrigeration	45	0.09	0.02	2.20	4	L
L3	general service halogen IR lamp	74	0.16	0.03	2.40	2	L
L9	advanced HID lighting	97	0.21	0.05	4.90	2	L
P1b	residential micro-CHP using Stirling engines	201	0.42	0.06	5.50	2	L
P2a	commercial micro-CHP using fuel cells†	767	1.62	0.07	7.40	2	L
PR2	ultra low energy designs & zero energy buildings	199	0.42	0.01	0.60	2	S
H20	advanced condensing boilers (commercial)	23	0.05	0.01	0.60	3	S

Measure	Name	Savings Potential (TBtu)	% saved	CSE, $/kWh	CSE, $/MMBtu	Likelihood of Success Rating	Priority
S2b	active window insulation, commercial	93	0.2	0.02	1.80	2	S
L5	advanced daylighting controls	80	0.17	0.02	2.30	3	S
D4	high-efficiency pool and domestic water pump systems	19	0.04	0.03	3.40	3	S
W4	integrated home comfort systems	43	0.09	0.04	3.80	2	S
H1a	advanced roof-top packaged air conditioners	81	0.17	0.04	3.50	3	S
H1b	advanced roof-top packaged air conditioners	81	0.17	0.06	6.00	3	S
H8	residential gas absorption chiller heat pumps	41	0.09	0.07	6.60	2	S
S8	high quality envelope insulation	15	0.03	0.08	7.80	2	S
S3a	electrochromic glazing for residential windows	3	0.01	0.08	7.80	2	S
H16	high-efficiency gas-fired rooftop units	20	0.04	N/A	3.40	2	S
CA3	integrated whole house ventilation	879	0	0.22	21.70	4	S
S9	engineered wall framing	12	0.03	0	0	3	S/X
H19	displacement ventilation	11	0.02	0	0	3	S/X
CR1	hotel key card system	15	0.03	0.01	1.30	2	S/X
H2a	Cromer Cycle air conditioner — residential	21	0.04	0.03	3.10	3	S/X
L7	hospitality bathroom lighting	28	0.06	0.04	4.00	3	S/X
H5	residential HVAC for hot-dry climates	11	0.02	0.04	4.40	4	S/X
S3b	electrochromic glazing for commercial windows	3	0.01	0.05	4.60	3	S/X
PR5	low energy use homes and zero energy houses	199	0.42	0.07	6.60	2	S/X
H2b	Cromer Cycle air conditioner — commercial	16	0.03	0.07	6.80	3	S/X

Measure	Name	Savings Potential (TBtu)	% saved	CSE, $/kWh	CSE, $/MMBtu	Likelihood of Success Rating	Priority
H17	transpired solar collectors for ventilation air	7	0.02	N/A	2.40	3	S/X
H4	CAC dehumidifiers/free-standing dehumidifiers	5	0.01	0.05	4.40	3	X
L8	universal light dimming control device	97	0.20	0.08	8.10	1	X
L11a	residential LED lighting	229	0.48	0.11	11.30	2	X
H10a	ground-coupled heat pumps (comm.)	43	0.09	0.13	12.60	2	X
H14	solid state refrigeration for heat pumps	106	0.22	0.16	15.60	2	X
S4	attic foil radiant barriers	27	0.06	0.16	16.20	2	X
P1a	residential micro-CHP using fuel cells	171	0.36	0.18	17.40	2	X
L10	hybrid solar lighting	270	0.57	0.27	26.30	2	X
H3	commercial HVAC heat pipes	8	0.02	0.28	27.30	2	X
L4	cost-effective load shed ballast & controller	1	0	0.43	42.90	3	X
H6	UV HVAC disinfection	19	0.04	0.57	56.50	2	X
S2a	active window insulation	41	0.09	0.73	72.20	1	X
W1	residential condensing water heaters	217	0.46	N/A	6.40	2	X
W2	instant gas high-modulating water heaters	127	0.27	N/A	8.30	2	X

Notes: * California-specific savings, from Appendix B, Table B-11.
† Value of waste heat is critical.

Two letters such as “M/L” in the “Priority” column suggest borderline situations, given analytic uncertainties. An “X” in that column indicates that the measure is not a national priority (<0.25% savings forecast, high CSE, low likelihood of success).

This table includes three specific California measures. The percent savings assigned to whole house ventilation is inexact, since we have not attempted to estimate the fraction of the country with consistently large enough diurnal temperature swings to use this strategy.

Of the three technologies specifically analyzed for California, the advanced roof-top unit and controls (CA2) is a high priority on the national list, too. Although variable output compact fluorescent bulbs (CA1) have a very low cost of saved energy, the cumulative potential energy savings in the United States is too low (<0.06%) for them to qualify for even medium priority. Similarly, by the parameters of this study, integrated whole house ventilation (CA3) would not rank as a priority item, because our criteria did not include the value of demand reductions associated with using off-peak cooling. This may, nonetheless, be an important measure for California if judged by time-dependent valuation methods.

The analysis of climate sensitivity has policy implications for California. The first implication is that the potential value of emerging technologies is not terribly dependent on climate, for the relatively small variability considered among coastal, transitional, and inland zones in California. Of 33 technologies and practices considered, 16 were projected to be cost-effective in all climate zones, and 10 were considered too expensive (in cost of saved energy) in all zones. Leaving out two gas-only technologies, only five measures were cost-effective in some climate areas but not in others. From this, we infer that climate is a second-order (less important) variable in screening emerging technologies for California. Further, for four of the five measures with mixed screening results (cost-effective in some but not all zones), the variability in estimated CSE, in the range of $0.005/kWh, is comparable to our estimates of uncertainty in the analysis as a whole.

On the other hand, the variation in estimated savings in 2020 from different measures is very large, more than a factor of 200. This strongly suggests that the most attractive measures are those that combine reasonable cost of saved energy with relatively large (>100 GHW) out-year savings.

Finally, we again see the relatively high importance of "human-ware," the emerging practices that improve efficiency through proper design and sizing, installation, and maintenance. Increasingly, continuing the trajectory of improved efficiency will require investing directly in people and incentives for people, and in showing customers (decision-makers) the economic, comfort, and other values of investments in doing the right jobs the right ways.

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