CHAPTER VII
DETAILED RESULTS FOR VERMONT

A. BASELINE PROJECTIONS

Both project base cases were included in the Vermont analysis of DSM impacts: the Market Potential baseline, in which the average efficiency of new appliances and end uses is allowed to change due to market forces, and the Frozen Efficiency case, interpreted in the Vermont model as a case in which fuel demand varied only with changes in the population and market demand, rather than with changes in appliance efficiencies.

1. *The Market Potential Baseline*

The Market Potential baseline projection was modeled to represent the State's current set of BAU base projections of energy demand. Under the Market Potential case, fuel prices play a significant role in the selection of device efficiencies and in the ultimate fuel demand. Under this case, Vermont projects electricity sales to increase almost 40 percent between 1993 and 2010 at a compound average rate of increase of almost 2.0 percent. Slow economic recovery, coupled with significant increases in the price of electricity expected through 1996, are expected to lead to relatively flat growth in demand over the next several years. Over the longer term, however, strong population growth, coupled with moderate declines in the price of electricity in the State, lead to a relatively strong growth projection.

The principal sector affected by the DSM measures tested for the analysis is the Vermont residential sector. Because natural gas is still only available in a small portion of the State, growth in natural gas is constrained. Residential sales of natural gas are projected to increase about 34 percent through 2010, representing a compound rate of 1.7 percent.

2. *The Frozen Efficiency Baseline*

The Frozen Efficiency baseline used in the energy modeling represents a special case created for this analysis. In effect, this case circumvents the usual market processes that are normally intended to be captured through a model such as ENERGY2020. As such, this scenario in effect interfered with the normal operations of the model as it was designed. Consequently, special features had to be added to the model to enable it to "short circuit" certain functions that normally operate within the model.

Results of the Frozen Efficiency Base Case scenario, however, closely resemble the Market Potential baseline. This was perhaps to be expected, given the fact that real prices in 2010 are projected to vary little from current price levels, despite near-term expected increases in demand discussed above. Under the Frozen Efficiency case, as in the Market Potential case, electricity sales are projected to grow about 40 percent between 1993 and 2010.

Under the Frozen Efficiency case, sales of natural gas show an increase in demand of almost 2 percent relative to the Market Potential baseline. A sensitivity to rising prices under the Market Potential baseline accounts for the difference. In the Frozen Efficiency baseline, as with the Market Potential case, the principal drivers of growth for both electricity and natural gas are the underlying projections of population and economic activity.

B. THE ACTION SCENARIOS

Due to the integrated nature of the economic decisions modeled in the ENERGY2020 model, the two action scenarios, Utility Incentives and Technology Forcing, depend on the baseline assumptions. This differs from the California/District approach, in which the baseline conditions were considered to be essentially stand-alone scenarios, and equally likely futures, and in which such baseline conditions were not part of the decision process (beyond current standards being kept for *all* scenarios). The integrated nature of the Vermont model makes it necessary to always pair the two action cases with a baseline in the tables and discussion that follow.

1. *The Utility Incentives Case*

Under the Utility Incentives case, the Vermont projections of electricity sales show a marked decline from the base cases. As shown in Table VII-1, the Market Potential baseline electricity sales under Utility Incentives for 2010 decline from 7,572 GWh to 7,041 GWh, or roughly a 7 percent drop. Relative to the Frozen Efficiency baseline, the Utility Incentives case showed an even more significant drop in demand, to about 6,900 GWhs relative to the projections of demand equal to 7,570 GWh under the Frozen Efficiency baseline.

The high demand response under the Utility Incentives scenario operating against the Frozen Efficiency baseline versus the Market Potential baseline, upon closer review, appears to be due to the definition of the Frozen Efficiency case as reflected in the modified structure of the model. Under the cases using the Frozen Efficiency baseline, device efficiency levels were selected to be the greater of prior year efficiency levels or the efficiency of the DSM measures. As such, following the first year of DSM, the model always chose the prior year's marginal device efficiency levels. Such a feature probably implied an unrealistically high rate of market transformation from limited term DSM activities. (The rate would likely impress even utility DSM's strongest proponents.) Thus, the results from the Market Potential baseline are probably the most realistic for Vermont.

Projections of demand for natural gas also showed significant declines under the Utility Incentives scenario. With the Market Potential baseline, demand in the year 2010 was projected to fall below the Frozen Efficiency baseline, a result that could be expected to follow from the current projections of rising gas prices in the model.

Table VII-1
Vermont Residential Electricity Sales
under the Utility Incentives Scenario
(GWh/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	5,097	5,097	5,097	5,097
2000	6,201	6,209	5,785	5,782
2010	7,572	7,570	7,041	6,900

Key to column labels for all tables in this chapter:

MP Baseline	= Market Potential baseline
FE Baseline	= Frozen Efficiency baseline
UI	= Utility Incentives scenario
TF	= Technology Forcing scenario

As with electricity, the total residential demand for electricity under the Utility Incentives case using the Market Potential baseline declines from 29.75 MMtherms per year to 26.75 MMtherms per year, as is shown in Table VII-2. Relative to the Frozen Efficiency baseline, the Utility Incentives for natural gas case showed even more significant declines were observed with demand falling from 30.39 to 24.76 MMtherms/year. Again, the stronger DSM response of the Utility Incentives case under the Frozen Efficiency baseline relative to the Market Potential baseline case was not expected, and appears to signal some difficulty with the specifications of the Frozen Efficiency case within the model.

Table VII-2
Vermont Residential Natural Gas Sales
under the Utility Incentives Scenario
(MMtherms/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	21.75	21.75	21.75	21.75
2000	26.08	26.10	24.65	23.55
2010	29.80	30.39	26.75	24.76

Air emissions showed similar patterns of decline under the two scenarios. As shown in Tables VII-3 and VII-4, total NO_x emissions from all energy sources statewide declined under the Market Potential/Utility Incentives case and the Frozen Efficiency/Utility

Incentives case 1.7 percent and 2.5 percent, respectively, while CO_2 emissions declined 2.2 percent and 4.6 percent, respectively, for the year 2010.

Table VII-3
Vermont NO_x Emissions for the Utility Incentives Scenario
(Tons/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	18.13	18.13	18.13	18.13
2000	21.68	21.70	21.44	21.31
2010	23.89	23.96	23.49	23.36

Table VII-4
Vermont CO_2 Emissions for the Utility Incentives Scenario
(Tons/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	6,176	6,176	6,167	6,176
2000	7,470	7,492	7,375	7,296
2010	8,344	8,431	8,158	8,044

2. The Technology Forcing Cases

The Technology Forcing scenario resulted from the addition of a few other technologies being screened into the model. As in the Utility Incentives scenario, most of the savings occurred in the residential sector, since most of the technologies reviewed for the project were in that sector.

Electricity sales reductions under the Technology Forcing cases, relative to the Utility Incentives cases, were quite significant. Using the Market Potential baseline, relative to the Utility Incentives scenario, electricity sales were reduced an additional 4 percent from 7,041 GWh to 6,764 GWh per year. The total reduction was approximately 11 percent from the base projection of 7,572 GWh. Table VII-5 shows these results.

Table VII-5
Vermont Residential Electricity Sales under the Technology Forcing Scenario (GWh/Year)

Year	MP Baseline	FE Baseline	TF vs MP	TF vs FE
1990	5,097	5,097	5,097	5,097
2000	6,201	6,209	5,690	5,764
2010	7,572	7,570	6,764	6,892

Projections of demand for natural gas also showed some decline under the Technology Forcing scenario relative to the Utility Incentives scenario, although these differences were quite small. This was to be expected, since only one additional technology was selected to be included under the Technology Forcing scenario.

Residential demand for natural gas under the Technology Forcing case, relative to the Market Potential baseline, declined from 29.80 MMtherms per year to 26.32 MMtherms per year in 2010. Under the Frozen Efficiency baseline, slightly less significant declines were observed, with demand falling from 30.39 to 26.51 MMtherms/year. The higher demand for natural gas relative to the Utility Incentives case appears to be the result of some fuel switching toward natural gas as a result of the higher electricity prices which result from the more aggressive DSM activities in the electric sector.

Table VII-6
Vermont Residential Natural Gas Sales under the Technology Forcing Scenario (MMtherms/Year)

Year	MP Baseline	FE Baseline	TF vs MP	TF vs FE
1990	21.75	21.75	21.75	21.75
2000	26.08	26.10	24.02	24.44
2010	29.80	30.39	26.32	26.51

Air emissions showed similar patterns of decline under the two scenario with NO_x declining 1.8 percent and 2.5 percent respectively under the market case and the frozen efficiency cases for the year 2010. Carbon dioxide emissions declined 2.4 percent and 4.5 percent, respectively, under the two scenarios in the year 2010; a pattern of decline similar to that experienced under the Utility Incentives scenarios.

Table VII-7
Vermont NO_x Emissions for the Technology Forcing Scenario
(Tons/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	18.13	18.13	18.13	18.13
2000	21.68	21.70	21.36	21.31
2010	23.89	23.96	23.46	23.37

Table VII-8
Vermont CO_2 Emissions for the Technology Forcing Scenario
(Tons/Year)

Year	MP Baseline	FE Baseline	UI vs MP	UI vs FE
1990	6,176	6,176	6,167	6,176
2000	7,470	7,492	7,350	7,300
2010	8,344	8,431	8,147	8,051

C. OVERALL ENERGY DEMAND

Figures VII-1 through VII-4 show the electricity and natural gas demand projections under the two baselines and two action scenarios. As these figures show, overall energy demand for both fuels will rise over the next 17 years, regardless of the amount of DSM activity.

D. SPECIAL PROBLEMS ENCOUNTERED

The Frozen Efficiency baseline was created especially for this project, while the Market Potential baseline represented the pre-existing Vermont forecast of underlying energy demand. As noted earlier, the Frozen Efficiency DSM savings scenarios, as modeled, produced gains in efficiency that were unexpectedly large relative to the Market Potential baseline. The action scenarios run off the Frozen Efficiency baseline implied that marginal device efficiencies could be maintained at high levels created by the initial year DSM stimulus, with no additional DSM activity from the utilities. This would appear to exaggerate the potential for transforming the market through limited-term DSM program activities. Future work on or use of the Frozen Efficiency baseline should attempt to permit the market to return to the marginal efficiencies that would have occurred in the absence of the DSM programs.

Figure VII-1
Vermont Electricity Demand using the Market Potential Baseline

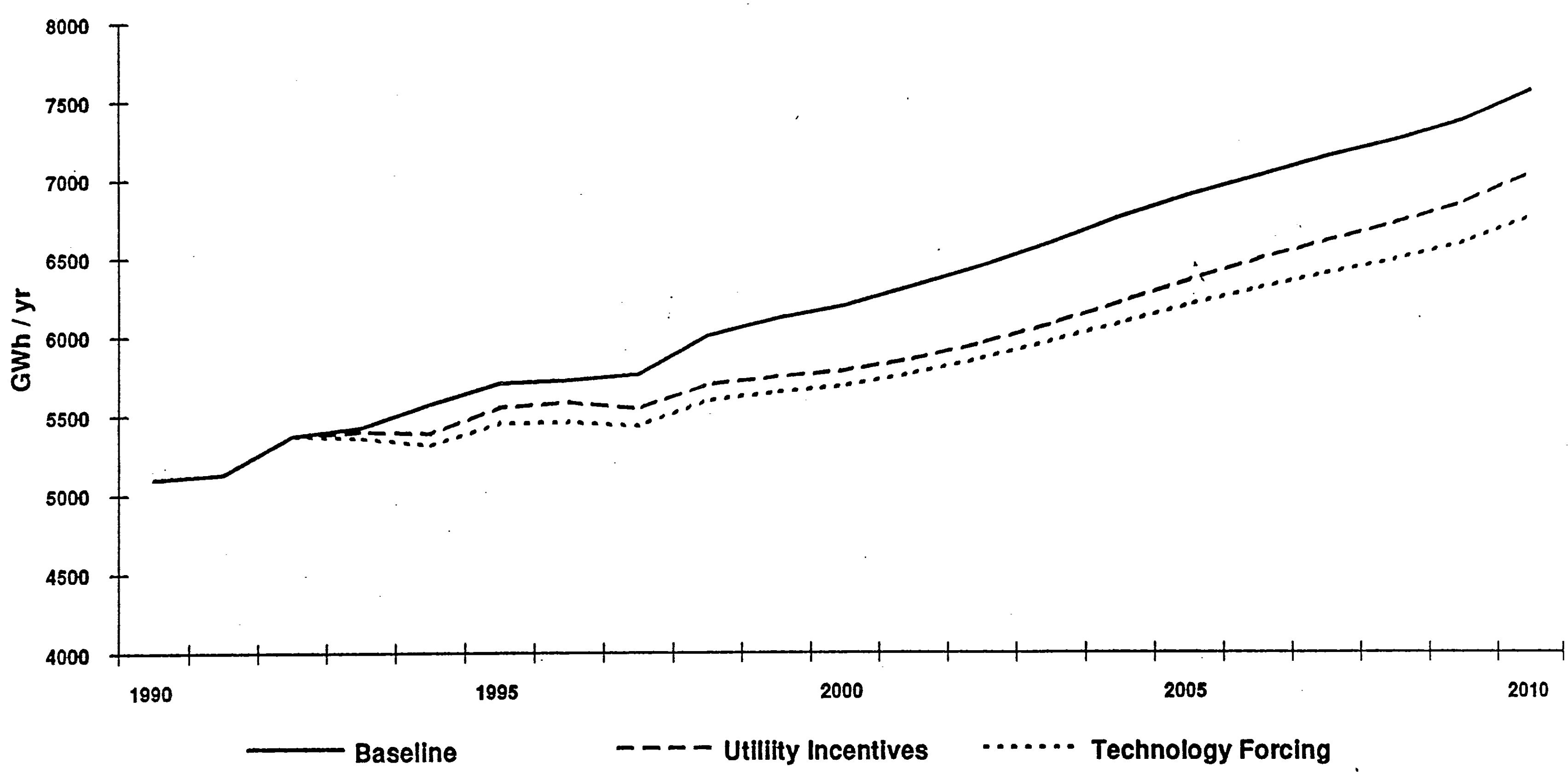


Figure VII-2
Vermont Residential Natural Gas Demand using the
Market Potential Baseline

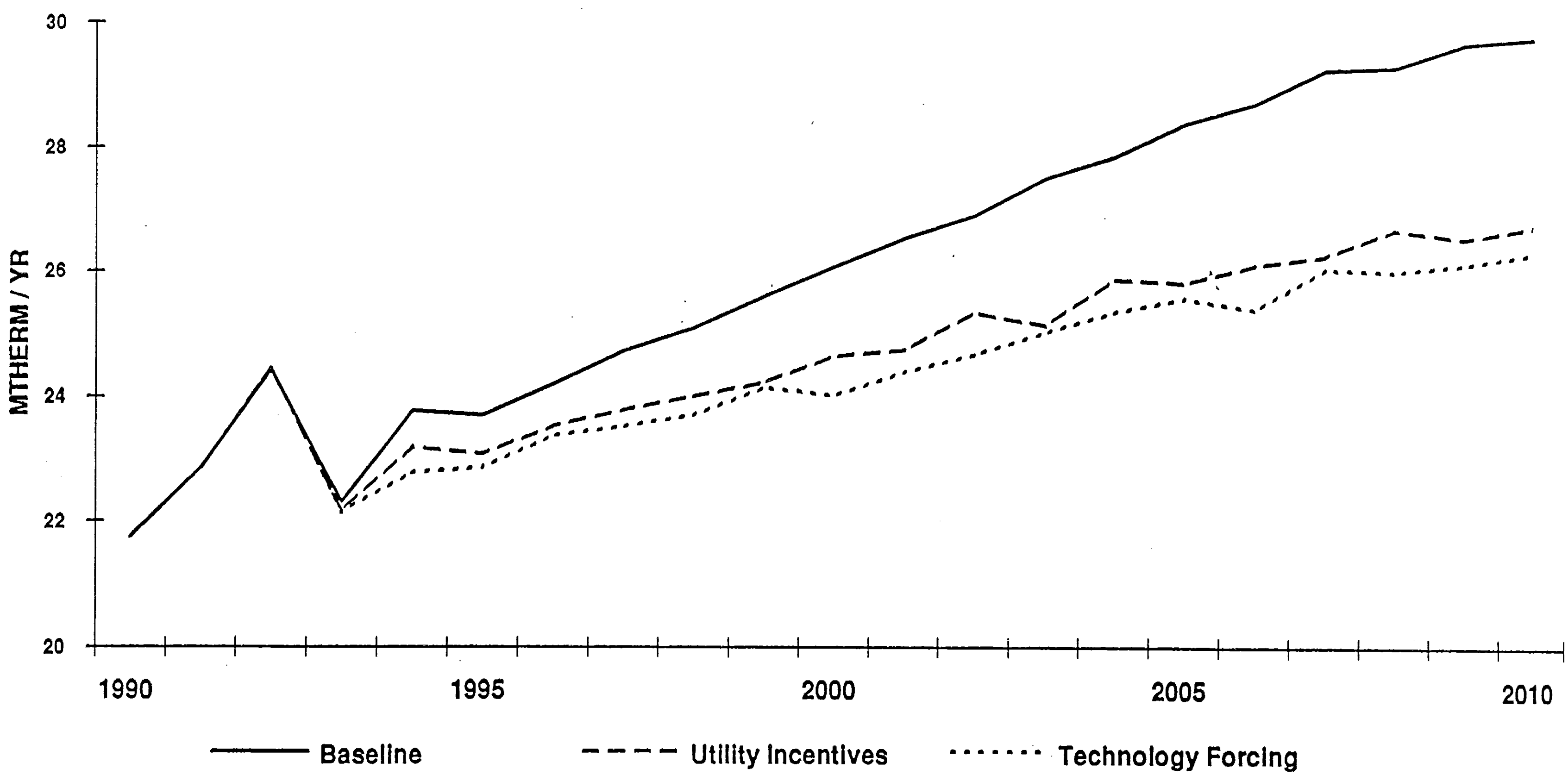


Figure VII-3
Vermont Total Electricity Demand
using the Frozen Efficiency Baseline

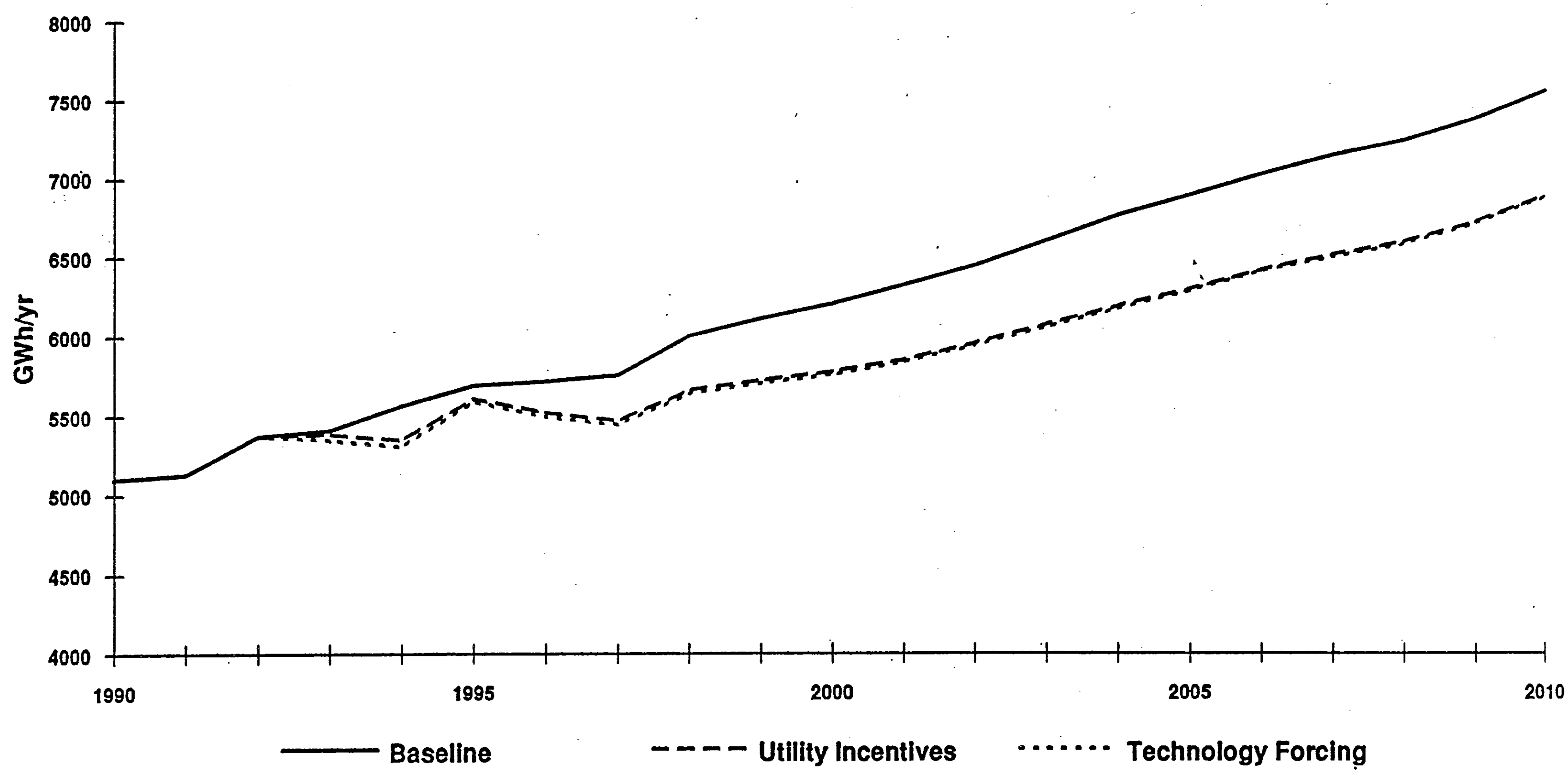
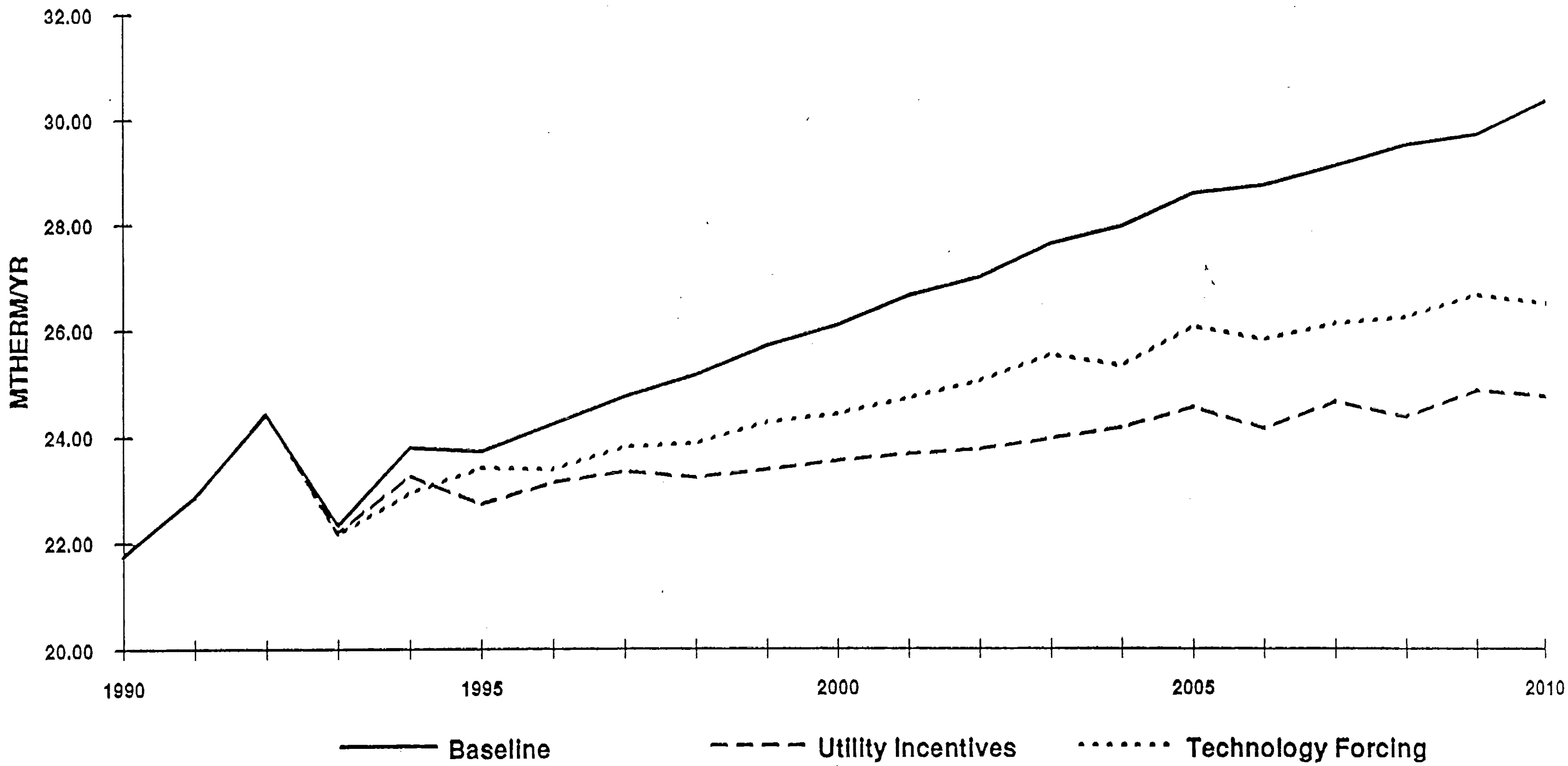


Figure VII-4
Vermont Residential Natural Gas Demand using the Frozen Efficiency Baseline



The Vermont ENERGY2020 model contains significant aggregation in certain sectors. The commercial sector of the model does not separate grocery stores from commercial office complexes or restaurants. Consequently, a review of the technologies that apply to this sector could only be accomplished using aggregated measures across segments of the commercial class. For projects like this one, such aggregation creates some additional work by identifying costs and savings from DSM technologies that are generally specified at a finer level specific to each commercial category. Aggregation may also have the effect of screening in or out (via the TRC test) technologies that might otherwise fail or pass the screen when reviewed in a more desegregated, subclass level. Nevertheless, for a small State like Vermont such enhancements to the model present numerous data problems that are likely to outweigh any gains made by enhancing the model in this manner.

The industrial sector presents problems for modeling DSM due to the somewhat site-specific character of the facilities. Only one DSM measure, high-efficiency motors, was selected in this sector and failed the TRC test, although it is widely recognized that the sector as a whole in Vermont presents great potential for efficiency improvements and that such high-efficiency motors do in fact screen in program design and implementation. Again, aggregations would appear to be creating some difficulties for the model screening procedure.

Capturing the effects of DSM measures when dual end uses are affected (such as space heating and air conditioning in the residential sector) requires special care in both technology screening for incentives and in modeling. The modeling of measures with interactive effects within a particular end-use category presents similar concerns. In the former case, special attention must be given to ensuring that all costs and savings are reflected in the TRC screening and modeling. In the latter, it is necessary to screen each technology as an increment to the technologies that have already been screened into the portfolio of technologies.

ABBREVIATIONS AND ACRONYMS

ACEEE	American Council for an Energy-Efficient Economy
BAU	Business-as-Usual
BDR	Behavioral Discount Rate
BEPS	Building Energy Performance Standards
BGP	Burbank, Glendale, and Pasadena
CAA	Clean Air Act
CDD	cooling degree-day
CEC	California Energy Commission
c/kWh	cents per kilowatt hour
CO	carbon monoxide
CO_2	carbon dioxide
CSC	conservation supply curve
CSE	cost of saved energy
CSP	cost of saved power
DOE	U.S. Department of Energy
DSM	Demand-Side Management
EER	Energy Efficiency Ratio
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESC	energy service class
EUI	energy use intensity
ft^3	cubic feet
GWh	gigawatt hour
HDD	heating degree-day
HVAC	heating, ventilation, and air conditioning
IPM	Integrated Planning Model
LADWP	Los Angeles Department of Water and Power
LBL	Lawrence Berkeley Laboratories
LIEF	Long-Term Industrial Energy Forecasting
LPG	liquid petroleum gas
MAA	measure annual availability
MP	Market Potential Baseline
NAECA	National Appliance Energy Conservation Act of 1987
NERC	National Electric Reliability Council
NO_x	oxides of nitrogen
OTA	Office of Technology Assessment
P	Participant
PUC	Public Utilities Commission
quads	quadrillion Btu
RECS	Residential Energy Consumption Survey
REMI	Regional Economics Model, Inc.
RIM	Rate Impact Measure
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SCG	Southern California Gas Company
SIC	Standard Industrial Classification
SO_x	sulfur oxides

ABBREVIATIONS AND ACRONYMS (continued)

T&D	transmission and distribution
TES	total energy savings
TEU	total energy use
TRC	Total Resource Cost
TSP	total suspended particulates
U	Utility
UEC	unit of energy consumption
VOCs	volatile organic compounds
VSD	variable speed drive
$/kWh	dollars per kilowatt-hour

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APPENDIX A

DISCOUNT RATES USED IN THE ANALYSIS

APPENDIX A
DISCOUNT RATES USED IN THE ANALYSIS

A. DEFINITIONS

The project required assumptions about several types of discount rates which fell into four categories:

- utility discount rates;
- participant (the DSM measure consumer) market rates;
- participant "behavioral" discount rates, reflecting their propensity to participate in DSM/conservation programs; and
- societal discount rates, for prioritizing and selecting among DSM programs using the TRC test.

The definition and treatment of each of these are discussed below.

1. Utility Discount Rates

These rates should reflect expected returns on private capital and are nominally tied to rates of market instruments such as treasury bills, but are assumed to be higher by a fixed amount to reflect presumed project risk. In recent (1992) work using their COMPASS model, SCE used, with apparent California Public Utilities Commission (CPUC) approval, a flat 11.1 percent (nominal) rate for all discount rates, including societal. At current inflation rates, this would be approximately a 7 percent to 8 percent real discount.

For evaluation of Federal legislation involving utility pollution control expenditures, Pechan has typically used 6 percent real discount rates. For instance, 6 percent real was used in work related to regulations promulgated under the Clean Air Act Amendments of 1990 (CAAA) for determining present value of private and government cash flows for electric utility regulatory analysis, with approval from the U.S. Congress' Office of Technology (OTA) and the U.S. Environmental Protection Agency (EPA).

2. Participant's Market Discount Rates

The DSM measure participant's (which could be an individual making decisions about residential measures, or a commercial or industrial energy user) discount rate is based on the consumer's cost of money, considered to be tied roughly to interest rates and savings or short debt instrument yields. In current (12/92) market conditions this could range from a 3 percent money market rate up to 20-plus percent cost of consumer debt, in nominal terms. Some market penetration studies add a factor to the high end of consumer debt rates representing external market inertia, and use this rate for market penetration.

3. Participant's "Behavioral" Discount Rate

Energy-saving market behavior involves decisions which require comparison of the value of current cash versus (possibly somewhat uncertain) future savings. Observation of these choices show that people have a very high "inherent" or "behavioral" discount rate (BDR), especially the low income residential sector, when polled as to their actual indifference level between cash on hand and possible future cash influx (or, equivalently, avoided outflows). The BDR is essentially a numeric result of consumer research, describing consumer behavior, rather than a market interest rate.

Included in the value of BDR are the consumer's market interest rates. In addition, there are components of risk, fear of losing in the transaction, real and surmised transaction hassles, access to information, and the consumer's ability to analyze the merits of the transaction. Observed values of the behavioral discount rate have been found in studies to vary widely across markets, but to be reasonably correlated (at least in the residential sector) with disposable income. For the residential energy using appliance market, the behavioral discount rate has been found to be between 5 percent and 100 percent, with an average in the 20 percent to 25 percent range (nominal). For very low income groups, the rate has been found to be well be over 100 percent, however.

While assumed values of this discount rate are used in some DSM models for estimating long-run market share, and are an option in the COMPASS model, the California DSM model developed for this study opted to use simple payback (in years) instead of a discount rate in its calculations, an essentially similar yet simpler assumption, and according to SCE, more realistic in terms of reflecting actual consumer behavior when selecting energy saving technologies. In essence, simple payback and the BDR are related. A 1-year simple payback would correspond to a 100 percent nominal BDR, for instance.

Due to the difficulties in defining this rate, many utilities are opting to define the BDR in terms of simple payback. In their COMPASS model, used for their DSM filings with the PUC, SCE has adopted this method, developing a simple payback/market share table for each program/market combination, which are used with other market segmentation parameters such as "percent unwilling" to estimate market share.

4. Societal Discount Rate

This is the rate that should be used by regulatory agencies to gauge the relative value of public projects involving long delays in benefits or costs, perhaps bridging generations, compared to current cash outlays such as welfare benefits, road repair, or teacher salary increases.

The societal discount rate has been highly politicized, especially during the energy crisis. Conservatives in general have preferred it to be set relatively high, thus discouraging spending projects involving long payback periods. Advocates of large-scale public projects would prefer it to be set lower, thus increasing the present value of the possible benefits of long-term, capital-intensive projects.

Most academic studies would set the societal discount rate lower than the market (producer's or consumer's) rate, due to complex interactions of government, business, current consumers, and inter-generational liabilities. A major study[1] in 1982 seemed to place the "reasonable range" between 2 percent and 4.6 percent real discount for most public projects.

B. DISCOUNT RATES COMMONLY USED FOR DSM ANALYSIS

The Standard Practice Manual, a joint product of CPUC and CEC, contains guidelines for economic analysis of DSM programs and explicit formulae for testing DSM measures, including the Participant's Test, Utility Test, and the Total Resource Cost/Societal test. It does not give explicit guidelines for what discount rates to use, however, or determine whether different rates can/should be considered for each affected group under the tests. One of the authors of the manual (Don Schwartz, CEC) said that the rates shown in Table A-1 have been used for recent PUC work in California.

Table A-1
Discount Rates Used in Recent California DSM Analysis

Interested Party	Nominal (%)	Real (%)
Participants	20	16
Utility	10.5-12.5	6.5-8.5
Society	7-10	3-6

None of the screening tests of the California Standard Practice Manual (even the Participant's test) is used to model market share in the models investigated for this study. Instead, they are used to help prioritize the measures within utility DSM plans, for which the utilities have applied to recover costs.

C. DISCOUNT RATES SELECTED FOR THE STUDY

After an extensive review of the literature and discussion with several organizations with recent experience in DSM discount rate practice, the rates shown in Table A-2 were selected for the project scenarios.

[1]R. Lind (ed) et al., "Discounting for Time and Risk in Energy Policy," *Resources for the Future*, Washington, DC, 1982.

Table A-2
Study Discount Rates

Scenario	Interested Group	Discount Rates	
		Nominal	Real
Low rates (Utility Incentives and Technology Forcing scenarios)	Participants	14.13	10
	Utility	10.13	6
	Society	6.13	2
High rates (Frozen Efficiency and Market Potential scenarios)	Participants	39.13	35
	Utility	10.13	6
	Society	14.13	10
Mid-range rates (not used)	Participants	24.13	20
	Utility	10.13	6
	Society	7.13	3

Note that the BAU base case was assumed to use a high real discount rate of 10 percent for TRC technology selection, whereas both of the action scenarios used a low 2 percent real social rate. The high 10 percent BAU rate was considered to be the observed current rate used to value future DSM measure societal impact, as expressed by project participants. An initial project goal was to investigate the impact of low social discount rates on DSM/conservation decisions, so both of the other scenarios used a 2 percent real discount rate, which is at the low end of the scale of the Lind discussion of the subject.

The Participant rates were specified for use in the models' market penetration algorithms, if required. The difference between real and nominal rates in the table is a constant 4.13 percent, which is the 1982 to 1991 average inflation rate.

APPENDIX B

TRC CALCULATION METHODOLOGY

APPENDIX B
TOTAL RESOURCE COST CALCULATION METHODOLOGY

The scenarios developed for the project required the screening of technologies using the TRC/societal test. For the Incentives and Technology Forcing scenarios, the TRCs were calculated using a (low) real discount rate of 2 percent. For California, part of the test calculation was performed in the spreadsheet model. This appendix describes in detail how these TRC calculations were performed.

A. BASIC EQUATION FOR TRC CALCULATION

As calculated and used in the analysis, TRC tests are benefit/cost ratios in which the numerator is the annualized sum of the utility and social avoided costs, and the denominator is the annualized sum of all net costs to all parties (participants, non-participants, utilities, and society) of the measure. The costs specifically exclude any transfer costs, like utility buydowns or tax incentives, which are deemed to be only equity transfers. Utility DSM administrative costs are included, however, since the program activities of the utility DSM measures add to total costs in the societal sense.

To ease the modeling burden, the TRCs were developed by calculating all-inclusive multipliers for electrical and natural gas energy savings and electrical peak-load savings, which were then used in the District model spreadsheet to give on-line calculation of the TRC as a quotient of annualized benefits to annualized measure cost, as shown in the following equation:

$$TRC(k) = \frac{xsvkwh(k)*tapvel + xsvld(k)*tapvld + xsvng(k)*tapvng}{\Delta C(k) * crfac(d,ML(k))}$$

$$crfac(d,ML(k)) = \frac{d}{[1-(1+d)^{-ML(k)}]}$$

where:

d	=	real discount rate (2 percent and 10 percent for this study)
ΔC(k)	=	incremental cost of DSM measure k
xsvkwh(k)	=	electricity savings of DSM measure (kWh)
xsvld(k)	=	electricity load savings of DSM measure (MW)

xsvng(k) = natural gas savings of DSM measure (therms)

tapvel = total annualized present value (pv) of avoided cost of electricity including environmental externality costs ($/kWh)

tapvld = total annualized avoided cost of system peak power capacity ($/kW-yr)

tapvng = total annualized avoided cost of natural gas including environmental externalities ($/therm)

crfac(d,ML(k)) = capital recovery factor at real discount rate d for measure life ML(k)

The three multipliers in the numerator of the equation, tapvel, tapvld, and tapvng, were the major parameters used in the District spreadsheet. They represent inclusive annualized effects of energy, load, and externalities. The present value of the benefits (avoided costs) are calculated for an estimate of a planning horizon of utilities, assumed to be 20 years for the project. This is illustrated in the following equations:

$$tapvel = apvel + apvnxel + apvc2el$$

$$tapvng = apvng + apvnxng + apvc2ng$$

where:

apvel = annualized avoided cost of electricity ($/kWh), in which the annualization years are the planning horizon of the utility, assumed to be 20 years

apvnxel = annualized avoided cost of NO_x damage at generating stations ($/kWh)

apvc2el = annualized avoided cost of CO_2 damage at generating stations ($/kWh)

apvng = annualized avoided cost of natural gas ($/therm)

apvnxng = annualized avoided cost of NO_x damage at ng burn sites ($/therm)

apvc2ng = annualized avoided cost of CO_2 damage at ng burn sites ($/therm)

The present value of costs are almost always just the first-year actual out-of-pocket costs, plus administrative overhead if a utility measure is involved; however, if unusual levels of ongoing maintenance is involved, such as in cleaning solar collectors, the cost must include the present value of the net measure O&M, the difference from the base technology's expected O&M.

The avoided cost multipliers used for the California/District are shown in Table B-1 below.

Table B-1
Annualized Avoided Cost Multipliers Used For California/District TRCs

Benefit Multiplier	Units	Real Discount 2%	Real Discount 10%
tapvel	$/kWh	0.065	0.067
tapvld	$/kW	55.650	49.590
tapvng	$/therm	0.483	0.526

Tables B-2 and B-3 show the details of how the multipliers were developed, and the underlying avoided cost and emissions rate data. The methodology employed involved calculation of the present value of 20-year time-series of several key variables, as illustrated in the next section.

B. AVOIDED COST CALCULATIONS

For the TRC calculation, benefits are calculated as avoided costs of production and distribution of electrical energy, peak load power (e.g., delayed construction of generating stations which would otherwise, if not for adoption of the measure, be required to meet expected load), avoided natural gas production and burning, and avoided emissions damage at generating stations and at natural gas burning sites. To estimate these values for the District, 20-year (minimum) time-series of avoided energy and load costs were developed, mostly from publicly available utility PUC filings. SCE developed avoided cost projections for electrical energy and load for 1991 DSM program filings which were adopted for the project. Due to the stringent NO_x regulations which have been recently promulgated for the District, SCE's existing natural gas-burning plants are expected to control to a very low NO_x level, approximately 0.21 lb/MWh by 2005, a fact which dramatically lowers the value of DSM emissions reduction benefit. Natural gas prices were estimated to increase at a real 0.5 percent growth rate.

Avoided emissions benefits may be based either on avoided abatement costs at the source or estimates of damage to health and property. These estimates vary by region and depend on local air quality and political considerations. For instance, in recent published work, California used NO_x damage costs of $24,500 per ton in 1990 dollars, whereas Vermont has used a (wide) range from $250 to $27,500 per ton for its analysis. For the District spreadsheet, only the NO_x and CO_2 values from Table B-4 were used in this analysis.

Table B-2
Annualized Present Value Multipliers for TRC (Societal) Tests

State: CALIFORNIA
Discount rate: 2 percent (real)
1992 dollars, 20-year annualization period

	Units	Value
Electric Energy Effects		
Avoided electricity generation	$ per kWh per year avoided	0.054
Avoided NO_x emissions at generating stations	$ per kWh per year avoided	0.006
Avoided CO_2 emissions at generating stations	$ per kWh per year avoided	0.005
Total kWh effects:	$ per kWh per year avoided	0.065
Electric Load Effects		
Total avoided electric load	$ per kW (at peak) avoided	55.65
Fossil Fuel Burn Effects		
Avoided natural gas burn at end use site	$ per therm not burned	0.299
Avoided natural gas NO_x emissions at end use site	$ per therm not burned	0.133
Avoided natural gas CO_2 emissions at end use site	$ per therm not burned	0.051
Total avoided natural gas effects:	$ per therm not burned	0.483
Assumptions:		
Emissions damage abatement costs ($/ton):	NO_x:26618 CO_2:8.4	
Natural gas emissions (lbs/therm):	NO_x:0.00970 CO_2:11.9	
T&D losses:	7.7 percent	

Table B-3
Annualized Present Value Multipliers for TRC (Societal) Tests

State: CALIFORNIA
Discount rate: 10 percent (real)
1992 dollars, 20-year annualization period

	Units	Value
Electric Energy Effects		
Avoided electricity generation	$ per kWh per year avoided	0.054
Avoided NO_x emissions at generating stations	$ per kWh per year avoided	0.008
Avoided CO_2 emissions at generating stations	$ per kWh per year avoided	0.005
Total kWh effects:	$ per kWh per year avoided	0.067
Electric Load Effects		
Total avoided electric load	$ per kW (at peak) avoided	49.59
Fossil Fuel Burn Effects		
Avoided natural gas burn at end use site	$ per therm not burned	0.324
Avoided natural gas NO_x emissions at end use site	$ per therm not burned	0.145
Avoided natural gas CO_2 emissions at end use site	$ per therm not burned	0.056
Total avoided natural gas effects:	$ per therm not burned	0.526
Assumptions:		
Emissions damage abatement costs ($/ton):	NO_x:26618 CO_2:8.4	
Natural gas emissions (lbs/therm):	NO_x:0.00970 CO_2:11.9	
T&D losses:	7.7 percent	

Table B-4
Avoided Emissions Benefits

Pollutant	$/Ton Avoided (1992 dollars)
NO_x	26,618
SO_2	14,375
PM	9,750
ROG	4,125
CO_2	8.4 (assumed)

Benefits were developed for the project in terms of three types of avoided costs: energy (kWh), load (kW), and emissions ($/ton). Emissions avoided abatement/damage benefits attributed to DSM in the TRC calculations were limited to NO_x and CO_2; the other three pollutants (particulate matter, ROG, and SO_2) are considered to have extremely low avoidance benefit due to the relatively low utility and customer-site emissions rates. Natural gas, kWh, load (kW) and emissions benefits are assumed to occur throughout an assumed 20-year utility planning horizon, and are discounted accordingly, at an assumed 2 percent or 10 percent real rate. Where nominal (inflated) prices are used in the underlying projections of energy or avoided costs, these were deflated to real 1992 dollars using an assumed 4.13 percent inflation rate, prior to discounting in real terms. Table B-5 shows the time-series cost and emissions rate data and the major calculations performed in developing the avoided cost multipliers.

C. SAMPLE TRC CALCULATION

In order to demonstrate the TRC/societal test calculation methodology, a single technology/measure was selected: T-8 lamps and electronic ballasts in the commercial sector, replacing standard fluorescent bulbs, and operating 3,000 hours per year.

Table B-6 shows the baseline data and calculations involved in the TRC/societal test example. As the table shows, measure costs all occur in the first year, and are calculated as an incremental cost to all parties for the new measure. The new fixtures cost $55.50, versus an avoided old cost of $42.50 for the standard fixture, for an incremental cost difference of $13. This was assumed to be bought-down with a 40 percent utility incentive, or 0.4 * 13 = $5.20, plus an assumed first-year (or present value) total utility DSM measure administrative fee of 25 percent of the incentive costs, or $1.30, plus the out-of-pocket remainder from the user of 0.6 * 13= $7.80, resulting in a net incremental cost (to society) of $14.30.

Table B-5
Time-Dimensioned Values Used to Calculate TRC Multipliers

State: CALIFORNIA
Discount rate: 6.13 percent (nominal)
Inflation rate: 4.13 percent (nominal)

	Natural Gas Energy and Emissions					Electric Load		Electrical Energy and Emissions Effects					
	Present value factor	Avg. nat. gas cost ($/therm)	P.V nat. gas cost	P.V nat. gas avd'd no_x	P.V nat. gas avd'd co_2	Summer avd'd load ($/mw)	P.V. avd'd load ($/mw)	Av elec cost $/kwh	P.V. elec cost $/kwh	marginal no_x rate lb/mwh	marginal co_2 rate lb/mwh	P.V. avd'd no_x $/kwh	P.V. avd'd co_2 $/kwh
year	pvfac	avcngdpt	pvng	pvnxng	pvc2ng	ldspk	pvld	avcpkwh	pvavel	nxlbmwh	c2lbmwh	pvnxel	pvc2el
1991	1.000	0.279	0.279	0.129	0.050	0.00	0.00	0.035	0.037	0.91	1073	0.0131	0.0049
1992	1.019	0.292	0.275	0.127	0.049	0.00	0.00	0.034	0.034	0.80	1073	0.0113	0.0048
1993	1.039	0.305	0.271	0.124	0.048	13.57	12.05	0.038	0.037	0.65	1073	0.0090	0.0047
1994	1.059	0.320	0.267	0.122	0.047	36.03	30.14	0.042	0.038	0.66	1073	0.0090	0.0046
1995	1.079	0.334	0.264	0.120	0.046	39.45	31.10	0.045	0.038	0.58	1073	0.0077	0.0045
1996	1.100	0.350	0.260	0.117	0.045	48.12	35.74	0.050	0.040	0.44	1073	0.0058	0.0044
1997	1.121	0.366	0.256	0.115	0.045	80.24	56.15	0.054	0.041	0.29	1073	0.0037	0.0044
1998	1.142	0.383	0.253	0.113	0.044	91.70	60.46	0.054	0.039	0.29	1073	0.0037	0.0043
1999	1.164	0.401	0.249	0.111	0.043	96.41	59.90	0.063	0.042	0.28	1073	0.0035	0.0042
2000	1.187	0.419	0.245	0.109	0.042	101.40	59.36	0.069	0.044	0.27	1073	0.0033	0.0041
2001	1.210	0.439	0.242	0.107	0.041	106.66	58.83	0.075	0.045	0.25	1073	0.0030	0.0040
2002	1.233	0.459	0.239	0.105	0.041	112.17	58.30	0.082	0.046	0.24	1073	0.0028	0.0040
2003	1.256	0.480	0.235	0.103	0.040	117.96	57.77	0.090	0.048	0.23	1073	0.0026	0.0039
2004	1.281	0.502	0.232	0.101	0.039	124.07	57.25	0.097	0.049	0.21	1073	0.0024	0.0038
2005	1.305	0.526	0.229	0.099	0.038	130.49	56.73	0.095	0.045	0.21	1073	0.0023	0.0037
2006	1.330	0.550	0.225	0.097	0.038	137.25	56.23	0.114	0.050	0.21	1073	0.0023	0.0037
2007	1.356	0.576	0.222	0.095	0.037	144.36	55.72	0.123	0.051	0.21	1073	0.0022	0.0036
2008	1.382	0.602	0.219	0.093	0.036	151.84	55.23	0.132	0.052	0.21	1073	0.0022	0.0035
2009	1.408	0.630	0.216	0.092	0.035	159.73	54.74	0.142	0.053	0.21	1073	0.0021	0.0035
2010	1.435	0.659	0.213	0.090	0.035	168.06	54.27	0.153	0.053	0.21	1073	0.0021	0.0034
	tpvfac		tpvng	tpvnxng	tpvc2ng		tpvld		tpvavel			tpvnxel	tpvc2el
Totals:	24.11		4.89	2.17	0.84		909.96		0.884			0.094	0.082
Annualized values, $ per therm, kwh or kw; capital recovery factor =0.0612													
			apvng	apvnxng	apvc2ng		apvld		apvavel			apvnxel	apvc2el
			0.299	0.133	0.051		55.650		0.054			0.006	0.005

NOTES: See text for variable descriptions and equations.

Table B-6
Sample TRC Test Variable Definitions and Results

Description	Value	Comment/formula
Environmental benefit, NO_x, $/ton avoided	26,616	project assumption
Environmental benefit, CO_2, $/ton avoided	8.4	project assumption
Base replacement technology cost, $	42.5	
New technology cost, $	55.5	
Existing life, hours	45,000	
New life, hours	45,000	
Existing efficiency	85	nominal
New efficiency	100	+15% efficiency
Incentive buydown fraction for DSM measure	0.4	
Administrative cost fraction of incentive	0.25	
Incremental cost	14.30	add 25% of 40% utility buydown
Existing total watts	148	
Use per year, hours	3,000	
Existing energy use, kWh/year	444	exwatts*usepy/1000
T&D Losses	0.07	
Savings, energy, kWh/year	71.61	exkwh*(1-exeff/nweff)/(1-tdloss)
Load savings, summer peak (CA), kW	0.0083	71.61 * 966/8355000 (SCE data)
Discount rate (nominal)	0.0613	2 % real
Inflation rate	0.0413	
Technology life, years	15	
Capital recovery factor for technology cost	0.0778	15 years at 2 % real
Annualization period for avoided costs, years	20	
Capital recovery factor for avoided cost	0.0612	20 years at 2 % real
Annualized avd'd cost, load $/kW ($/measure)	55.65	
Annualized avd'd cost, elec energy, $kWh ($/measure)	0.054	
Annualized avd'd NO_x emissions, $/kWh ($/measure)	0.006	
Annualized avd'd CO_2 emissions, $/kWh	0.005	
Total annualized avd'd electricity cost including environmental, $/kWh	0.065	
Annualized total cost ($/measure)	1.11	0.0778 * 14.3
Annualized total benefit ($/measure)	5.12	71.61*0.065 + 55.65*0.0083
TRC/societal benefit/cost ratio	4.61	1.0 or higher is acceptable

NOTES: Measure benefits are based on net generation savings of 71.61 kWh per year electrical energy savings at 0.054 $/kWh avoided for electricity generated, 0.0083 kW of avoided peak load at $55.65 per year per kW avoided, avoided kWh savings of 0.054 $/kWh for electricity, plus 0.006 and 0.005 $/kWh for avoided NO_x and CO_2, or a total annualized benefit of $5.12. The benefit/cost ratio result of 4.61 shows the technology to be highly cost-effective.

APPENDIX C

MARKET PENETRATION, DIFFUSION, AND ADOPTION METHODOLOGY FOR THE CALIFORNIA/DISTRICT REGION

APPENDIX C
MARKET PENETRATION, DIFFUSION, AND ADOPTION METHODOLOGY FOR THE CALIFORNIA/DISTRICT REGION

A. BACKGROUND

This appendix describes the methodology employed in the California/District region spreadsheet model for estimating market penetration of technologies. It was developed as a simplified hybrid of approaches used by several models surveyed for the project. The underlying technology for the market penetration and diffusion S-curve equations, however, are attributable to Lawrence and Lawton (1981)[1]. This methodology may be used as a simple estimating procedure for a region, should more accurate, recent statistical information on the market penetration of energy saving technologies not be available.

In reviewing several DSM market penetration rate reports, it seems clear that most models of market penetration of energy saving technologies, if used without adjustment factors, create optimistically high estimates of a technology's penetration. Residential incentive-oriented DSM programs, like the ones surveyed for this study's residential measures, were reported by EPRI in 1988 to have average annual participation rates of 5.5 percent across the utilities surveyed, with a maximum of 59 percent. However, the median annual rate was much less: half of the programs had annual participation rates of less than 1 percent[2]. Among the data submitted by utilities on DSM markets, there were major problems with defining the term "annual penetration rate." For instance, some utilities included residences which were not feasible for the measure (like homes without access to natural gas service for gas measures) in the candidate universe, which is the denominator, or the rate fraction. Treatment of pre-existing and/or natural saturation levels for measures was also not uniform among the reporting utilities. Even so, the annual rates were generally low, even for measures which seem like clear winners. Behavioral characteristics such as perceived external costs, unforeseen maintenance hassles, and fear of being cheated are not adequately accounted for, as can be seen from the poor market record of the DSM programs. A factor that is widely acknowledged to be highly significant is the degree of personal-contact marketing, such as door-to-door advertising or focused telemarketing, especially if conducted by the utility. The prolific use by modelers of adjustments to the feasible market such as percent unwilling factors inherently acknowledge these difficulties in modeling market behavior.

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[1]K.D. Lawrence and W.H. Lawton, "Applications of Diffusion Model: Some Emperical Results," Chapter 22, *New Product Forecasting*, Lexington, MA, 1981.

[2]L. Berry, "The Market Penetration of Energy-Efficiency Programs," Oak Ridge National Laboratory, DE90-011295, April 1990.

The only information generally available to the policy analyst is the quantifiable elements of the energy-saving technology's cost and efficiency. In the absence of extremely expensive and time-consuming consumer acceptance research, such data represent the only information available to be used to estimate market penetration. Given this uncertainty, and the likelihood that study resources will be constrained, a simple methodology such as the one used here for the California/District will give reasonable results while representing a reasonable, proven starting point toward development of a more accurate system for State or regulatory agency DSM/conservation policy analysis, should resources later become allocated.

B. MARKET PENETRATION AND DIFFUSION METHODOLOGY

Figure C-1 shows the model curves of long-term market share, versus simple payback in years, for three residential measure classes. Figure C-2 shows the model that may be used for all commercial and industrial decisions. The curves give estimates of long-term market share, given a calculation of simple payback, for the user's cash outlay versus energy savings return.

As can be seen from Figure C-1, residential customers are assumed to require a shorter payback for appliances, but will tolerate a much longer payback for space heating and cooling (HVAC) technologies. Other measures, like water heating and lighting, will fall in the "other" category, or between these two sectors in terms of required payback. Commercial and industrial customers are willing to extend the payback to time periods similar to the residential HVAC market decisions, and can be estimated more reliably (according to the literature), so a single curve should suffice to estimate the long-term share, as shown in Figure C-2. The equations for developing the curves are shown in Equation C-1.

Equation C-1: Market Penetration Formula

For $t = 0$ to $t = MX$:

$$y(t) = \frac{y(0)}{(1 + (A*t)^{B})} = \textit{long-term market share,(fraction), for payback } t \textit{ years}$$

where:

$$B = \frac{\ln(\frac{y(0)}{y(P)} - 1) - \ln(\frac{y(0)}{y(1)} - 1)}{\ln(P)}$$

$$A = \exp\left[\frac{\ln(\frac{y(0)}{y(1)} - 1)}{B}\right]$$

For $t = MX$ to $t = MX+1$:

$$y(t) = y(MX) * (MX+1-t)$$

$$t,P,MX \in \textit{years,}$$

$$y(*) \textit{ a dimensionless fraction}$$

Figure C-1 Residential Market Share Curves

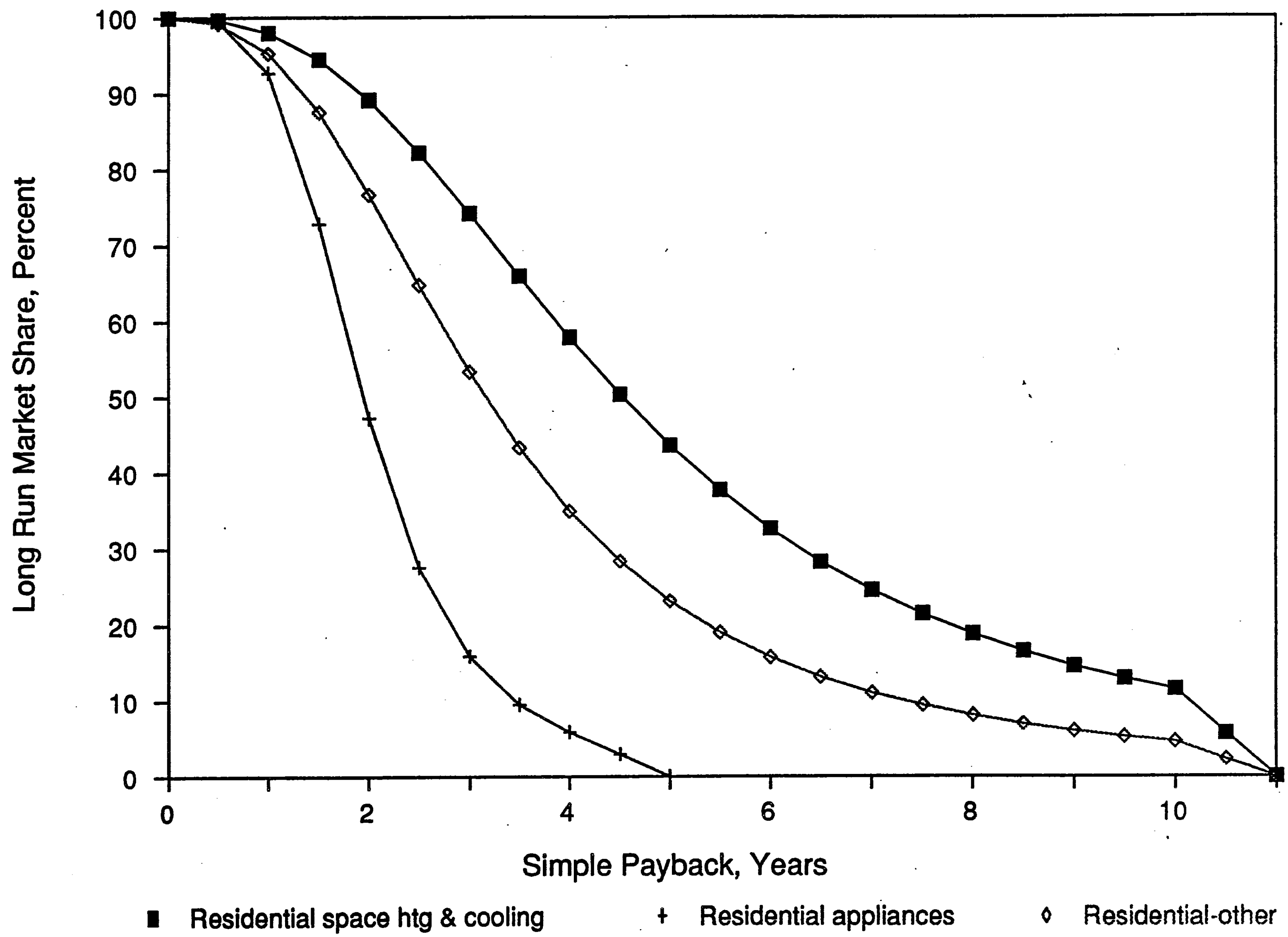
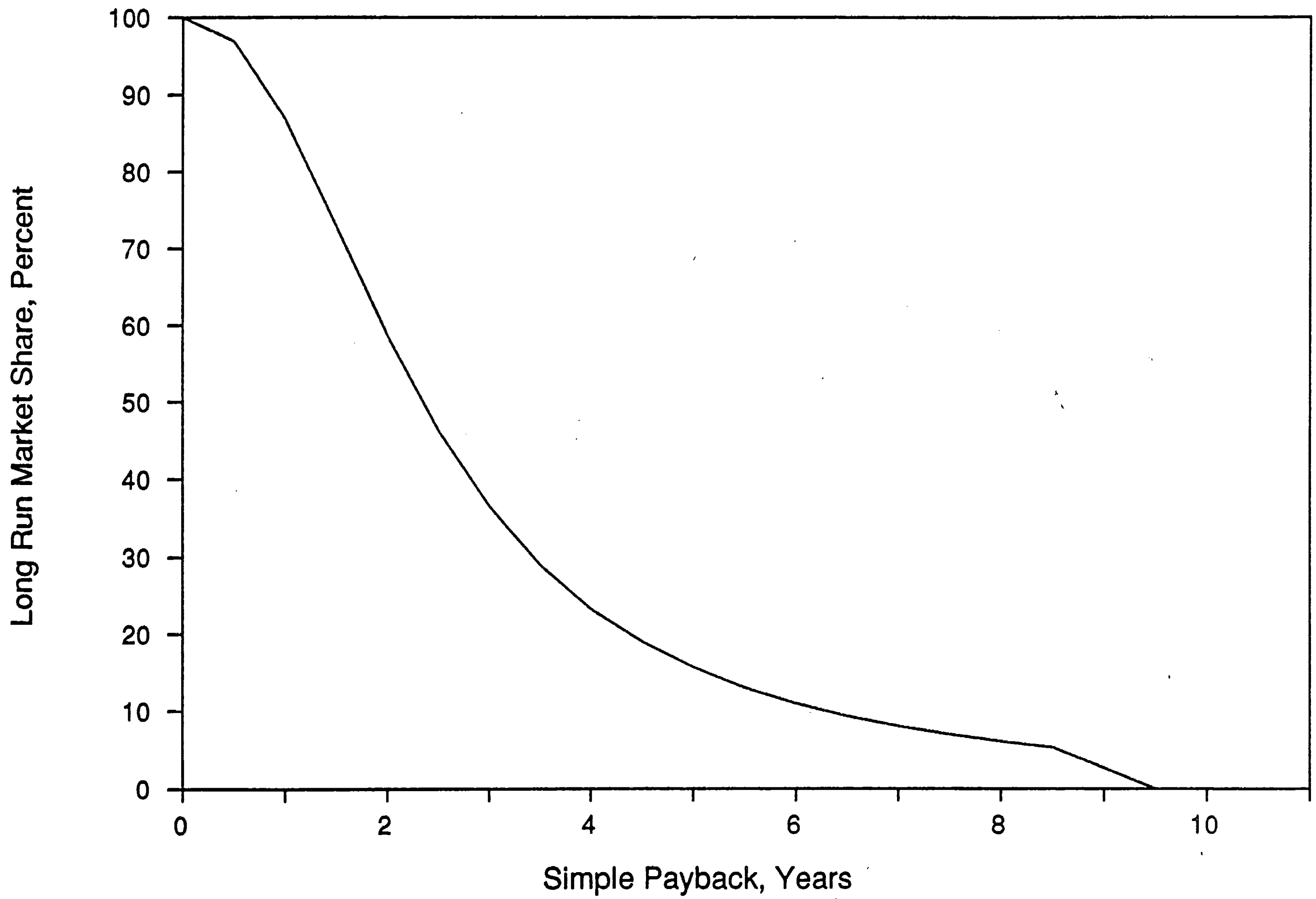


Figure C-2 Commercial/Industrial Market Share Curve



In these equations, y(1), p, y(p), and MX are the major constants. y(1) is the market penetration for a 1-year payback, MX is 1 year less than the maximum payback, in years. p and y(p) represent a "tie point," or observed point on the model curve, where y(p) is the market penetration rate for a payback of p years.

The coefficients for the equations for each of the four curves are shown in Table C-1.

Table C-1
Market Penetration Model Coefficients

Sector	End Use	Market penetration for 1 year payback Y(1)	Tie point payback, years p	Y value of tie point, percent Y(p)	Maximum payback (less 1 year) MX	Value of maximum payback Y(MX)	Equation coefficient A	Equation coefficient B
Commercial & Industrial	All	86.87	5.0	15.66	8.5	5.41	0.4270	2.220
Residential	HVAC	98.00	10.0	11.5	10.0	11.5	0.2208	2.576
Residential	Appliances	92.7	4.0	5.91	4.0	5.91	0.5150	3.834
Residential	All other	95.3	5.0	23.1	10.0	4.67	0.3167	2.6172

In practice, a "percent unwilling" is used as a judgement factor to give a final "reality adjustment" to the results implied by these curves; additionally, a diffusion methodology must accompany the long-term market penetration estimate, as outlined in the next section.

The market equations developed above give only a rough indication of the ultimate market share. They do not indicate how fast the penetration may (will) occur. In the energy-efficient technology market, such penetration rates are typically estimated to be between 5 and 20 years, depending on the novelty, advertising, and consumer payback of the technology. To estimate this rate of market penetration to the ultimate market share, a "diffusion" curve may be used. This could be simply a straight line, achieving the ultimate market share in "x" years. In most of the models reviewed, such as COMPASS, ENERGY2020, and some U.S. Department of Energy (DOE) models, an S-shaped diffusion curve is employed to represent this market inertia, as in Equation C-2. There are two parameters in this equation, S and R, signifying diffusion shape (S) and rate (R). Figures C-3 and C-4 show how the shape of the diffusion curves represented by this equation will change with variations in these parameters. For the California/District analysis, a rate parameter of S = 0.1 was used. R, the rate parameter, was then calculated from long-run market share and MX, which was assumed to be 12 years in all sectors. While not explicitly done for the project, the R and S parameters could have been used for scenario specification purposes, signifying a faster or slower rate of attainment of market penetration, perhaps depending on advertising or other forms of information dissemination. In any case, it must be pointed out that diffusion only affects the near-term years' results. The long-term market share is assumed to be attained after MX years.

Figure C-3 Effects of Shape Parameter "S" on Diffusion Curve

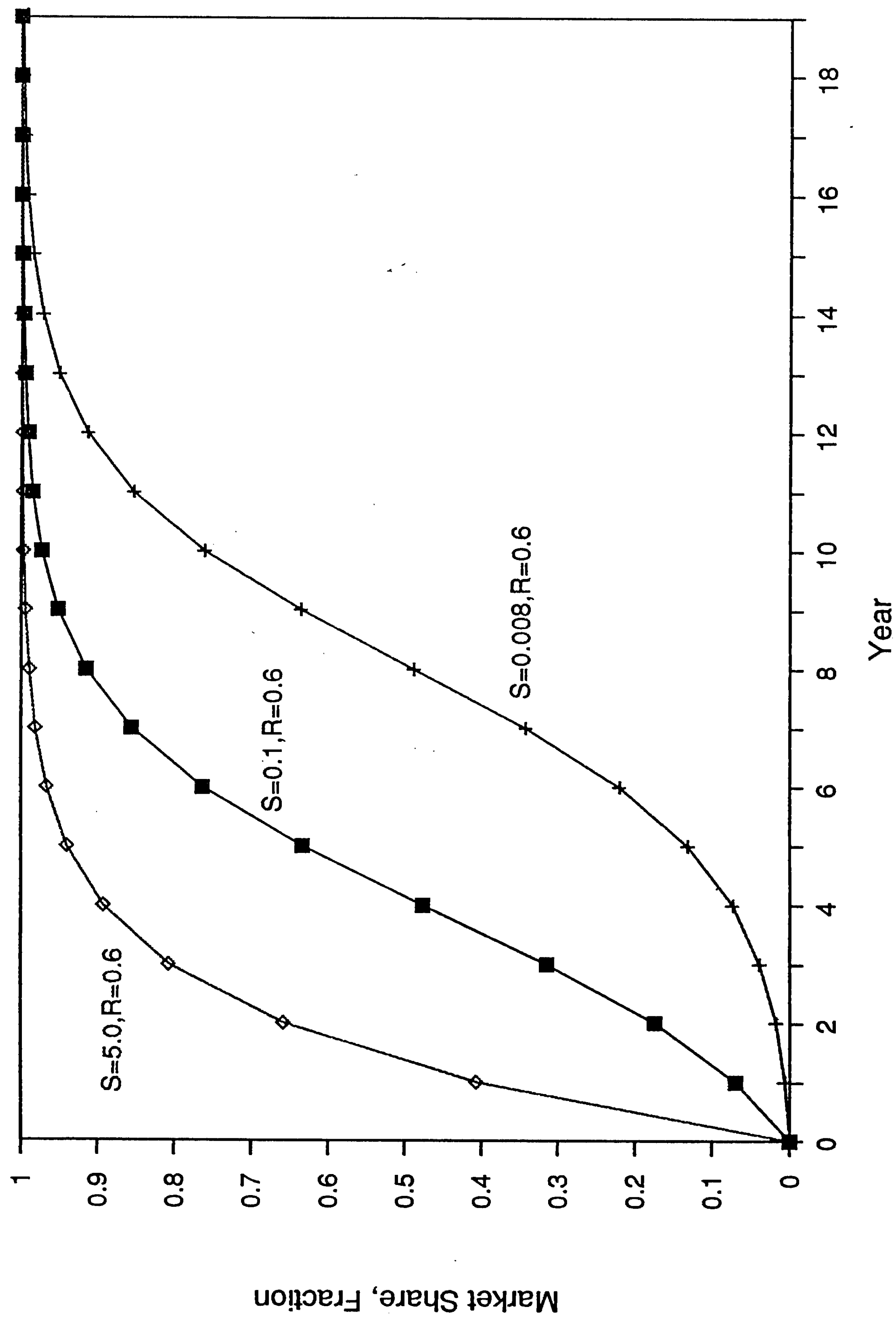
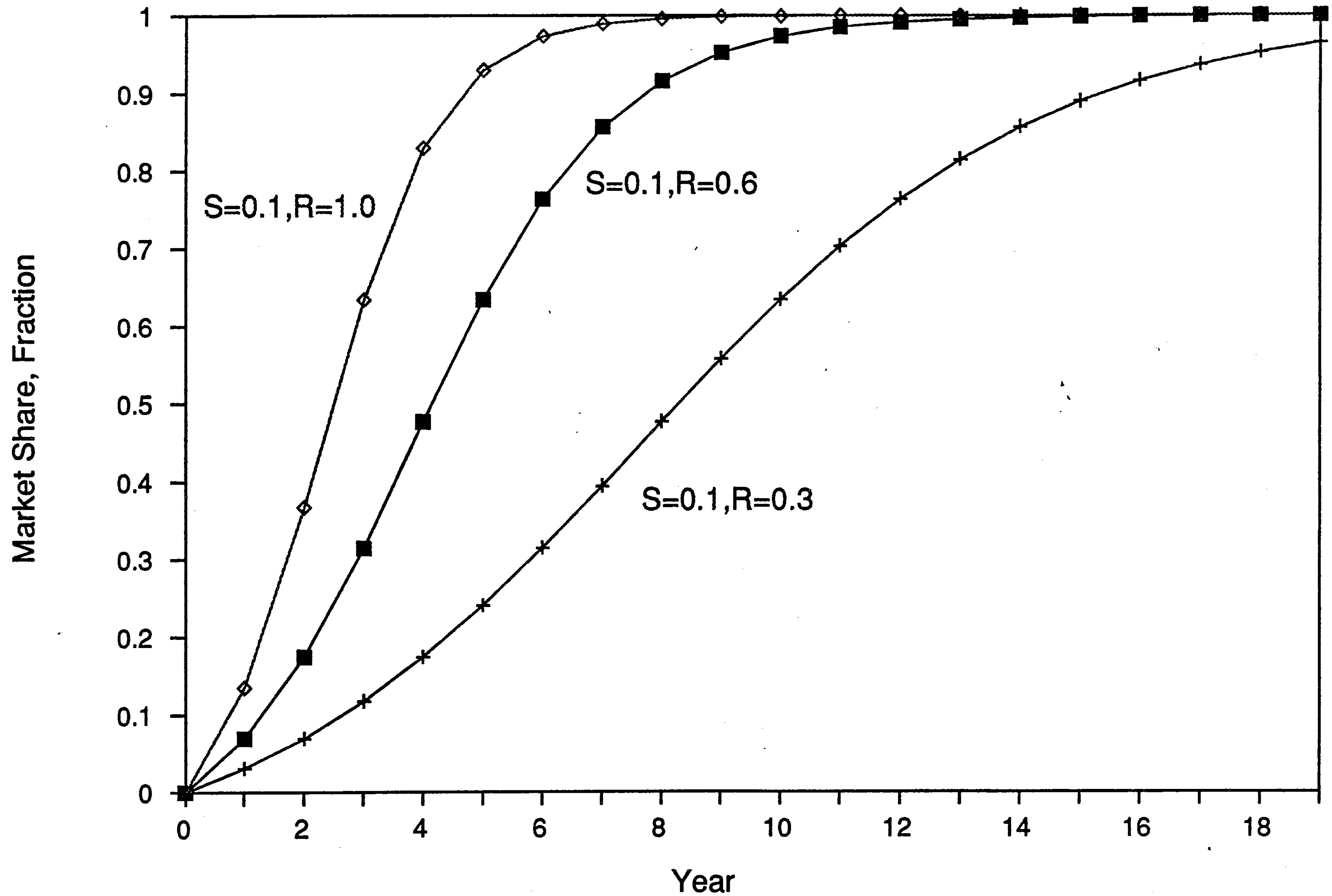


Figure C-4 Effects of Rate Parameter "R" on Diffusion Curve



Equation C-2: Diffusion Formulae

For t = 0 to t = maximum diffusion time:

$$Q(t) = \frac{1 + S}{(1 + (1/S)*e^{-Rt})} - S$$

where:

Q(t) = cumulative fraction adopting the technology by time t

S = curve shape parameter

R = diffusion rate parameter

In practice, the market penetration and diffusion calculations for each technology are made in several steps. For example, assume the technology is an HVAC unit with a simple payback of 2.0 years, years-to-attain is 12, and the diffusion curve shape parameter SS is 0.1. The diffusion vector giving market share by year is calculated by the following steps:

1. Calculate simple payback, SP (assumed to be 2.0 years).

2. Look up long-run market share curve coefficients A and B from table C-1: A = 0.2208 and B = 0.2576, for the example.

3. Calculate LRMS using Equation C-1 with A and B; i.e.

   $LRMS = 1/(1+(A*SP)^B) = 1/(1+(.2208*2)^{2.576}) = .89$

4. Assume diffusion shape parameter is 0.1; calculate RR from MX, the desired years-to-attain, and LRMS, as in Equation C-2; i.e. first calculate the rate parameter RR:

   $RR = -\ln(S*(1-LRMS)/(S+LRMS))/12 = 4.5/12 = 0.375$

5 Calculate the long-run market share vector for years 1 to MX, as in the above equation.

   $Q(t) = (1+SS)/(1+(1/SS)e^{-RR*t}) - SS$

   These calculations lead to the Q(t) values in Table C-2.

Table C-2
Yearly Market Share

t	year	Q(t)
1	1991	0.040
2	1992	0.092
3	1993	0.159
4	1994	0.240
5	1995	0.334
6	1996	0.436
7	1997	0.538
8	1998	0.634
9	1999	0.720
10	2000	0.791
11	2001	0.847
12	2002	0.890
13	2003	0.890
14	2004	0.890
15	2005	0.890

C. CANDIDATE STOCK AND MEASURE ADOPTION

After calculating each technology's long-run market share using its simple payback, represented by its cost and energy savings, and the diffused annual market share, measure adoption rates within the sector/competitive class, and the resulting energy and emissions effects must be finalized. In the spreadsheet model for California, all units are assumed to be is some sense "in the market," no matter how large the payback period nor small the resulting long-run market share. Low probability technologies will change the results very little, and this method in fact is more realistic, since prototype models of new units are often brought to market under special discounts not known to the model.

The supply curve aggregation procedure, in which a technology's costs and benefits are adjusted to be only the incremental values adding to the totality of technologies higher in value on the supply curve, also greatly diminish the likelihood of double-counting.

The yearly market share only affects the candidate stocks that have been exposed to adoption decisions, either in the current year or in prior years. Calculation of these candidate stock levels is the final step of the process.

There are two completely different classes of stock replacement candidates: existing (both for retrofit prior to burnout and replace on burnout (r-o-b); and new (due to absolute stock growth plus replacement of demolished units). In the equations below, these two stock time-series are called CNWDRA(t), for "cumulative new plus demolished unit replacement adoption candidates by year t," and CEXA(t) for "cumulative existing r-o-b and retrofit unit adoption candidates by year t." In general, both of these candidate stock groups grow over time, the existing to cover all of the non-demolished units, and the new to replace the demolished units plus new growth. Figure C-5 shows how this market segmentation for adoption is conceptually processed.

In practice, building stock growth (not including demolition replacement), and the rate of demolished units may be given by the utility data either in terms of rates from a base or explicit data entries. For the SCE existing residential building stock for instance, both the growth and demolished fractions were hand-entered data points, with less growth in near years than later in the period. The r-o-b rate was calculated using what appears to be a standard method: the reciprocal of measure life in years -- 1/ML(k). Instead of adopting individual retrofit (prior-to-burnout) rates, a multiple of the r-o-b rate was applied, considered to be 0.5, or 50 percent of the r-o-b rate for many technologies.

1. Numeric Example of Adoption Procedure

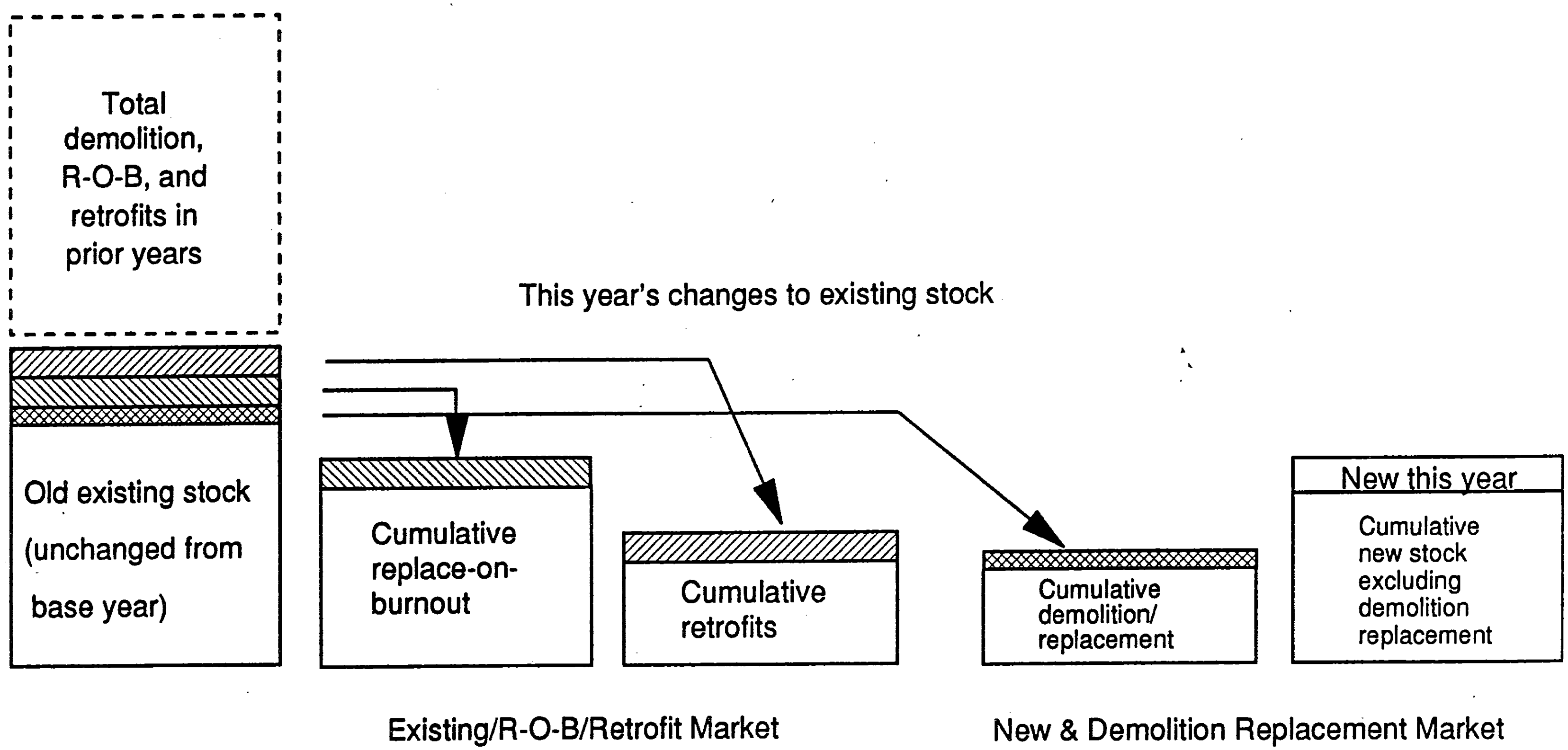
Suppose there are 100,000 initial households considering the purchase/replacement of a technology of life 10 years, subject to the rates of growth, demolition, r-o-b, and retrofit rates, as shown below. (Positive values represent for growth and negative represent decay):

rgr	=	0.027	=	total rate of growth from base year (not including demolition replacement)
rdr	=	-0.015	=	demolition rate, fraction
rrob	=	-0.10	=	-1/life = replace on burnout rate
rrt	=	-0.0626	=	retrofit rate (which may be expressed as a fraction of r-o-b rate instead, as in the model).

Figure C-6 shows the two cumulative stock growth sums CNWDRA and CEXA for the growth/decay/retrofit/r-o-b factors above. These totals may be multiplied by "adjusted" UEC, for applicability, feasibility, and number of units and the yearly market share fraction YMS(t) to give net adoption (and/or savings) in energy units, as is done in the model.

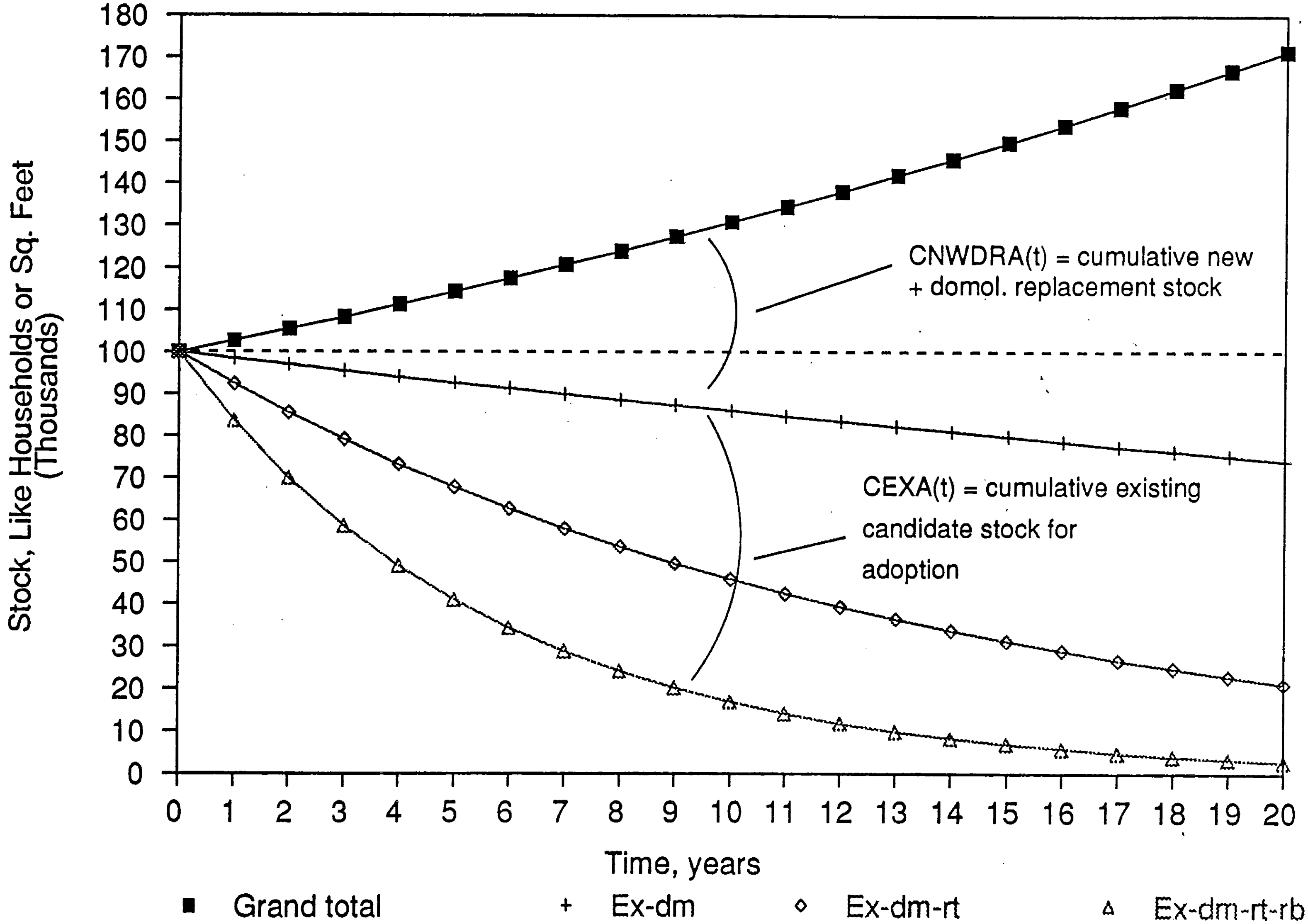
If all of the growth factors were exponential, instead of being table look-up fractions, the equations would be as shown in Equation C-3.

Figure C-5 Market Segmentation for Adoption Procedure



E. H. Pechan & Associates, Inc.

Figure C-6 Candidate Stock for Adoption



Equation C-3: Cumulative New and Demolition Replacement Candidates

(Note: This includes all new units, including coverage for both growth and replacement of demolished units.)

$$CNWDRA(t) = X(0) * (e^{(rgr * t)} - e^{(rdr * t)})$$

Where X(0) is the beginning year existing stock. This calculation is done in the model by subtracting the undemolished existing units from the grand total stock with growth to give the "new" cumulative candidate adopters.

Equation C-4: Cumulative Existing Adopters

(These are the cumulative old existing stock, excluding demolished units, which are assumed to have been retrofitted or replaced on burnout at time t.)

$$CEX(t) = X(0) * e^{(rdr * t)} - X(0) * e^{(rdr+rrob+rrt)*t}$$

$$= X(0) * e^{(rdr * t)} * (1 - e^{(rrob+rrt)*t})$$

In this case, the "base" is X(0) * e^{rdr*t}, which is the undemolished old existing stock, upon which the rrob and rrt decay rates are applied.

For the 100,000 initial households of the example, the cumulative adoption candidates after 13 years would be:

CNWDRA(13)	$= 100000 * (e^{.027*13} - e^{-.015*13})$		
	= 100000 * (1.42048 - .8228)	=	59,768 new households
CEXA	$= 100000*e^{-.015*13}*(1-e^{(-.1-.0626)*13})$		
	= 100000*.8228 *(1 - .12078)	=	72,342 existing adopters through r-o-b or retrofit

APPENDIX D

DSM MODEL ASSESSMENT

APPENDIX D
DSM MODEL ASSESSMENT

A. OVERVIEW

This appendix outlines an assessment of currently available DSM modeling systems acquired and investigated by Pechan as an interim milestone of the project. The models vary widely in coverage, purpose, and development resources, ranging from well-documented commercial software packages to spreadsheet fragments.

The final decision on which modeling systems to use for the project (ENERGY2020 for Vermont and a new spreadsheet model for SCAQMD) was made largely on the basis of project resources and system and/or data availability. It should therefore be noted that these choices should not be taken as a recommendation by Pechan or project staff as to the approach to be taken on future DSM analyses which might have different goals and/or resources.

Table D-1 describes some of the relevant information on system structure, ownership, language, and resources for each of the systems investigated. The sections that follow contain information and commentary on the structure and applicability of these systems to DSM/conservation policy analysis for States and regional regulatory agencies.

In addition to the systems in Table D-1, several other DSM systems were available but were not investigated for the project due to lack of resources or difficulty in accessing information on them. These include the following systems:

- The Northeast Region Demand-Side Management Data Exchange (NORDAX) collection of DSM data bases and programs -- Since Synergic Resources Corporation (SRC) was the technical consultant on the NORDAX system development, the COMPASS model may be considered to include the technology of the NORDAX system, possibly in a more up-to-date format.

- XENERGY Corporation DSM/Assyst programs and data bases -- While some DSM data files developed by XENERGY were made available to the project by SCE, no documentation or prototype copies of DSM/Assyst were obtained in time for in-depth assessment.

- The Electric Power Research Institute (EPRI) DSM programs and data bases, for the residential (REEPS), commercial (COMMEND), and industrial (INDEPTH/ERG) sectors.

Table D-1
DSM Models Investigated

System	Contact	Hardware, Language, and/or Structure
California Energy Commission (CEC) DSM analysis system (spreadsheet fragments).	Michael Messenger California Energy Commission Sacramento, CA 916-654-1563	EXCEL
COMPASS	Synergic Resources Corporation Bala Cynwyd, PA Dilip LeMaye,President 215-667-2160	IBM PC-based. Source code is not provided and unknown.
DOE Market Penetration Models for Renewable Fuels (for Geothermal Heat Pumps, Residential Rooftop Photovoltaics, and Active and Passive Solar Technologies).	(by SAIC, Inc) Todd Burski, DOE/EIA 202-586-2313	IBM PC-based in Lotus 1-2-3, Release 3.0
ENERGY2020	Systematic Solutions, Inc. Vandalia, OH Dr. Jeff Amlin, President 513-890-0527 or Policy Analysis Corporation Dr. George Backus, President 612-257-5609	IBM PC-based. Requires the PROMULA language compiler (about $1495 in 12/92).
San Diego Gas and Electric Company's DSM system	Rob Rubin SDG&E, San Diego, CA 619-696-4822, or Fred Siebold Regional Economic Research, Inc. San Diego, CA 619-481-0081	Mainframe SAS
EPA Region IV (Atlanta) CO_2 Emission Reduction Scenario Generator (DSM emissions model)	Cory Berish EPA Region IV, Atlanta, GA 404-347-7109, or Jeffrey S. Tiller, President Southface Energy Institute Atlanta, GA 404-525-7657	IBM PC-based, Lotus 1-2-3

B. DESCRIPTION OF MODELS INVESTIGATED

1. *ENERGY2020*

a. *History*

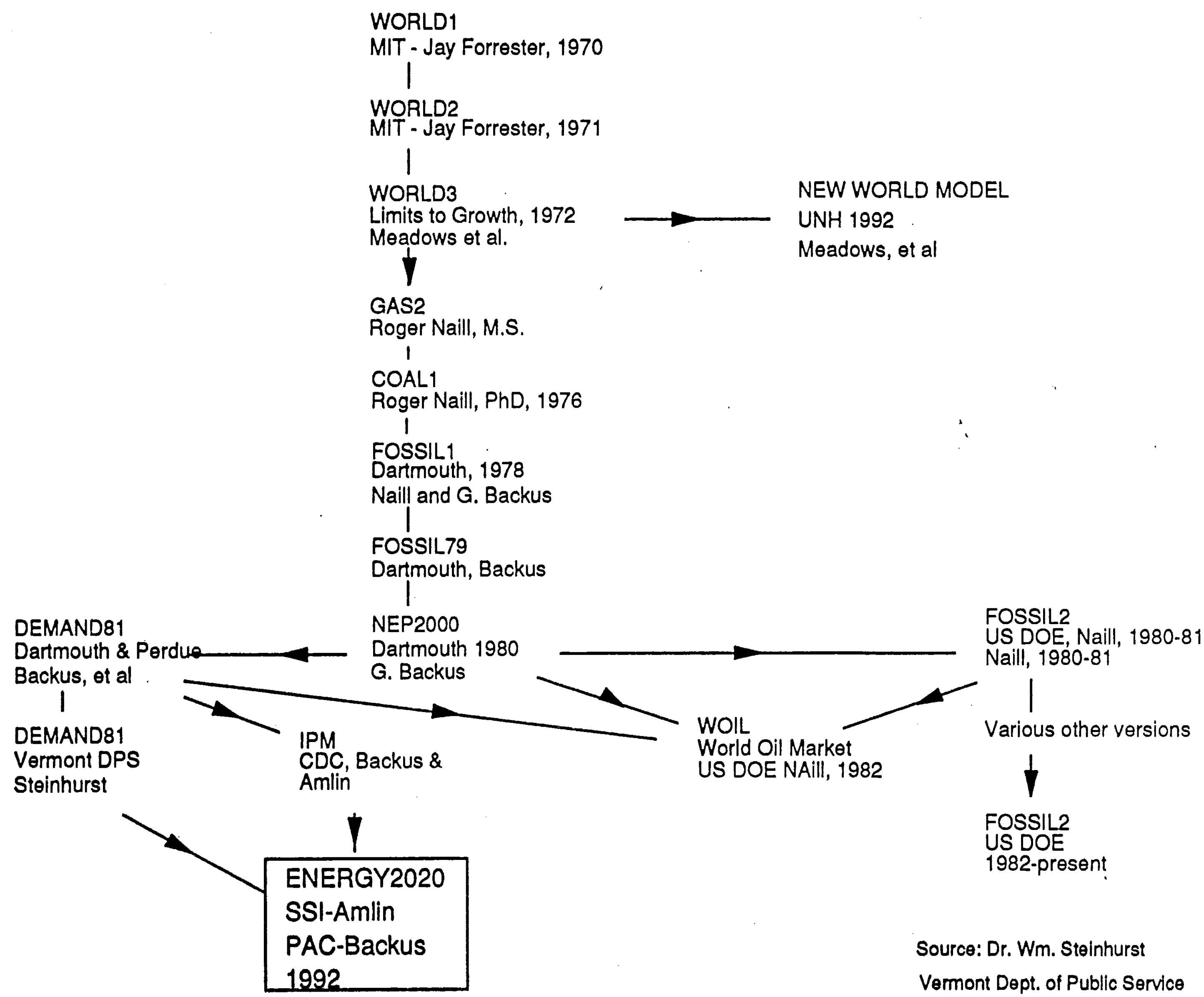
ENERGY2020 is a relatively large, full supply/demand/conversion energy and environmental simulation system. It is a version of an active collection of similar systems which evolved from work at Massachusetts Institute of Technology (MIT) and Dartmouth that was done in the early 1970s. While in strictly legal terms useable copies of it are in the public domain (Vermont was given verbal approval by its authors to send a copy of the model to Pechan without a contract, for instance), we would define it to be "quasi-proprietary," since the model is so massive and complicated that the services of a knowledgeable modeler will be required to effectively load data and calibrate it for specific regional policy analysis.

The grandparent model of ENERGY2020 was developed for a global population, economic, agriculture, and pollution impact study conducted at MIT between 1970 and 1972. The study provided a year-by-year simulation of market/population/economic conditions and behavior using an algorithm which was based on solving a set of differential equations defining the market in systems terms. To expedite the modeling effort, MIT developed DYNAMO, a software language used for such systems-dynamic models.

During the energy crisis of 1973, the systems-dynamic methodology was employed at Dartmouth College to develop an energy market simulation known as FOSSIL1. The third major expansion of its development took place in 1980 and 1981 in DOE's Office of Policy, Planning, and Analysis under Dr. Roger Naill. Dr. Naill was one of the original developers of FOSSIL1 at Dartmouth, where it was called FOSSIL2. FOSSIL's essential structure has since been used to develop several other models. Figure D-1 shows a genealogy of the various predecessors and parallel transformations, as best we know them.

ENERGY2020 is currently marketed by Systematic Solutions, Inc. (SSI) of Vandalia, Ohio, by Dr. Jeff Amlin, president of SSI, and by a colleague company, Policy Analysis Corporation of Minnesota, run by Dr. George Backus. In contrast to FOSSIL2, which concentrated on oil and gas supply and demand issues, ENERGY2020 has been expanded in the utility area. In particular, a detailed DSM planning module has been recently included. It has been used by the Illinois Department of Energy and Natural Resources to complete a required utility planning report, by the State of Massachusetts Executive Office of Energy Resources for an integrated energy plan, and by Vermont's Department of Public Service (VDPS) for an impact analysis of a major gas pipeline proposal. The model has been widely disseminated to research organizations, universities, electric utilities, State and Federal energy agencies, and public utility commissions. SSI claims that ENERGY2020 represents the results of over 250 experience-years of model development, testing, and use, at a total cost across all developers and predecessor systems of over $15 million.

Figure D-1 ENERGY2020 Development History



Source: Dr. Wm. Steinhurst
Vermont Dept. of Public Service

b. *Cost and Availability*

ENERGY2020 can be obtained from SSI with a minimal generic data base for a specific utility and/or a State for as little as $20,000, which covers mainly consulting fees and the PROMULA software (about $1,500) needed to compile it on a personal computer. To perform an individual study, however, a macroeconomic forecast such as those sold by DRI, Wharton, or Chase Econometrics would need to be provided for each scenario, adding between $4,000 and $20,000 to the effort. SSI advises users to purchase a model which is similar to the DRI models, called REMI, for the macroeconomic analysis, from Regional Economic Modeling, Inc., at a cost of about $15,000. Thus, the cost of a minimal system capable of generating a forecast for a small State or utility is in the $30,000 to $40,000 range.

Realistically, however, the investment relative to the learning curve for in-house analysts, for tailoring the model to the actual needs of the organization, obtaining primary data and "scrubbing" secondary model-oriented data files, and setting up and using the model for an initial study would add significantly to the costs. For a DSM/conservation model for the entire State of California, for instance, it is probable that 1.0 to 2.0 person-years of analyst time would be required, probably increasing the total cost to the $100,000 to $150,000 range.

c. *Vermont DPS Version of ENERGY2020*

The VDPS version of the ENERGY2020 model is used periodically in combination with the REMI macroeconomic model to perform energy/environmental policy analysis. It was first used in 1988 and 1989 to support a substantial study of the effects of a proposed Canadian natural gas pipeline on Vermont energy costs, utility rates, and pollution, including greenhouse gases. It later became the major integrating framework used to generate the Vermont Comprehensive Energy Plan of January 1991, a massive energy policy analysis effort. Jeff Amlin and George Backus, the authors of the ENERGY2020 model, were under contract to VDPS for both these studies, as was George Treyz and staff of Regional Economic Modeling, Inc., to assist with running a companion version of the REMI macroeconomic model tailored for Vermont.

The Vermont Comprehensive Energy Plan used a top-down control target of a reduction of global warming gases by 10 percent, and a reduction in per-capita consumption of nonrenewable (mostly fossil) energy of 20 percent by the year 2000, using ENERGY2020. Both voluntary and mandatory policies were modeled, affecting all major end-use energy consuming sectors. Policies were developed for electric and gas utilities which required least-cost integrated planning (LCIP), essentially adding DSM/conservation to the list of utility supply-side alternatives, and re-defining energy demand as demand for energy services, presumed to be clean, efficient, and to the extent possible, renewable, taking into account full (but discounted) societal cost of emissions and other impacts. In addition to utility programs, vehicle fuel economy tax/rebate policies, solar incentives, fuel taxes, and speed limits were all investigated. While the list of policies for the study included intense utility DSM and building and appliance efficiency improvement, the DSM efforts were not the central focus of the analysis. However, the methodology for inclusion of DSM as a substantial supply alternative, and the data base and modeling parameters necessary to accommodate them, existed in the VDPS version of ENERGY2020 prior to this current project.

d. Southern California Edison's Version of ENERGY2020

Pechan was informed by ENERGY2020's developers that SCE had a working version of the system. To assess whether this version might be employed for the project, Pechan inquired of the status of the model at SCE. The model was traced to the rate and revenue division, under Mr. Carl Silsby. We found that while they had used the model 5 or 6 years ago for rate/revenue study in a joint effort with PACE (a consulting firm), they have not used it much since then. It was used only for rate/revenue projection work, and was never set up to do DSM or environmental impact studies. They currently use the ELFIN model for most of their rate forecasting, which employs the Delreaux-Booth convoluted integral load-curve filling algorithm, and is similar to the PROMOD model used by many utilities for production costing, system planning, and rate/revenue forecasting. For DSM program investigation, SCE uses the COMPASS model, which is discussed below.

SCE's production experience with ENERGY2020 was not very good. They found that the PROMULA language compiler/linkage editor in which the current production version of ENERGY2020 is written to be cumbersome, having space (memory) problems on their PCs. Load modules were limited to 640 Kilobytes of memory, causing memory "overlap" problems which have never been completely resolved. SCE continues to send staff to the ENERGY2020 user's conferences, however, so there is some residual interest in keeping it partially alive there.

2. The COMPASS Model

a. Overview of COMPASS

The Comprehensive Market Planning and Analysis System (COMPASS) is a PC-based decision analysis system developed and marketed specifically to assist utilities in planning their DSM programs. It provides a convenient repository for data on current and candidate DSM technologies and programs, contains the structure for development of a data base containing relevant data on the utility's service area, properly segmented for market research, has algorithms for DSM technology market penetration estimation, and complete DSM plan impact analysis and reporting. It generates numerous reports formatted in a style commonly used for DSM plan submissions to government agencies, including standard practice benefit/cost screening tests such as the TRC test with a social discount rate, often required by public utility commissions. An adjunct of the TRC testing is an environmental impact analysis, including both end-use location and energy supply emissions impacts.

COMPASS uses a data intensive, measure-specific analytic technique, often now described as a bottom-up approach to DSM program planning. It allows the user to generate many different "what-if" candidate DSM plans, and then calculate total cost to all sectors (participant, utility, ratepayers, etc.). It must be used in conjunction with a utility's resource planning model to establish marginal and average avoided costs, energy, load, and rate impacts. Although linkages are provided to resource-planning models such as PROMOD so that, for instance, the DSM energy and load demand savings might be passed to the planning model to recalculate resources and thus avoided costs, this type of iterative procedure is installation-specific, and not automatic.

The standard practice benefit/cost tests, such as TRC/Societal, Participant, Utility, and Rate Impact tests, are built into COMPASS. They do not generally screen the list of programs, however. The user must select the programs to be included in the DSM plan. Then, COMPASS calculates the total combined effects of the total DSM plan. A major problem of using this bottom-up approach is the danger of overestimating DSM reductions when multiple measures are applied to the same end-use energy sector, as is usually the case. For instance, residential heating measures like double-pane windows and high-efficiency heat pumps are not linearly additive: 1 Btu saved with double-pane windows alone plus 1 Btu saved with an efficient heat pump alone might only be 1.8 Btu saved if both technologies are selected by the household. The algorithmic methodology for dealing with the nonadditive nature of efficiency programs was not documented, and is expected to be very costly and difficult to address in any defensible manner. One source said that these effects were generally incorporated off-line as adjustments to efficiency once a combined package of efficient programs was defined for a particular market segment.

b. SCE's Version of COMPASS

SCE's version of COMPASS is being used and further developed in their Energy Efficiency and Market Services Division under Mr. Frank Schultz. Ms. Andrea Horwatt, one of the primary development analysts and users of the system, assisted in our review of their DSM modeling. SCE is currently expanding their version of COMPASS to be SCE's principal DSM planning analysis tool and to include comprehensive DSM/environmental impact analysis capabilities. The data base contains about 56 technologies in over 100 market segments, for a total of about 3,500 technology/segment combinations. In the SCE model's commercial sector, there are 14 building types, 4 weather zones, and base stock existing/new designation, or 112 market segments.

SCE originally agreed to use its COMPASS model to investigate scenarios for the project for California. However, all effort expended by them was to have been on a *pro-bono* basis, and resources originally allocated were not available in time to participate.

3. California Energy Commission DSM Spreadsheet

The methodology used at CEC (Michael Messenger et al.) for calculating DSM impacts in their 1991 Global Climate Change study was essentially a spreadsheet data analysis. A copy of the code was obtained and analyzed for the project, consisting of Lotus 1-2-3 spreadsheets and macros, mimicking much of the COMPASS approach, but with reduced form data bases, and simpler estimates of market penetration targets and maximum annual rates of change. The modeling activity was only performed on the residential sector for SCE's service territory. It arranged 15 technologies into five "packages" which were selected by the households according to pre-set yearly percentages. Each package was given a maximum achievable market penetration rate over the 1990 to 2010 time frame, and a maximum annual rate of change in penetration (15 percent per year). Households were segmented by existing/new and "primary gas heat/primary electric heat." The spreadsheet did not use market-penetration methods based on economic choice like simple payback, benefit/cost ratio, or minimum acceptable internal rate of return. Instead, market penetration estimates were made for each of the packages and the maximum penetration was simply extrapolated as a scenario input. Thus, one of the more interesting aspects of other DSM models -- their market penetration and adoption response algorithms -- were not incorporated into the CEC work.

A major drawback of the spreadsheet approach, apparent in the CEC material, is that the format does not easily lend itself to documentation, although the programs were delivered to us at our request with no expectation of any accompanying documentation. Many of the assumptions are essentially locked into the spreadsheet as fixed parameters or formulae, without explanatory comments. Unless the modeling assumptions are specifically addressed in the study, the rationale for the assumptions will be lost unless the original author is available and remembers what was done during the analysis. In general, however, the impression of the CEC work is one of thoroughness within the constraints of a very complex market penetration environment, with complicated programmatic/fuel overlap.

4. DOE Renewable Fuel Technology Models

As part of our review of current methodologies, we investigated the availability of DSM/conservation-oriented models at DOE's Energy Information Administration (EIA), to see if any might be augmented and/or converted for use in the project. We found that there is no generalized, national integrating framework for DSM/conservation at DOE. However, there were listed in their literature three relatively small models, developed under contract to EIA by Science Applications International Corporation (SAIC) and delivered in October 1991, for three renewable fuels technologies: residential roof-top photovoltaics, active and passive solar systems, and geothermal heat pump systems. These were acquired and reviewed by Pechan for the current project.

The three models were almost identical in structure, being spreadsheet models in Lotus 1-2-3 release 3.0 format, using relatively complex macros interlinking files, and producing forecasts for scenarios used in DOE's most recent *Annual Energy Outlook*. In structure, these models are similar to the methodology used by CEC, except that they estimate only the *economic potential* as a stand-alone system for each of the technologies -- the results were not integrated or packaged with other technologies. Essentially, they are market penetration models, which act on DOE region-level data files to generate regional impact information. The models use simple payback/penetration tables for market penetration estimation similar to the COMPASS market penetration methodology. While the algorithms might be useful at some point to develop individual technology market penetration sub-models for a larger effort, they do not offer the integrated framework needed for analyzing complex DSM/Conservation policies which were required for the current project.

5. EPA-Region IV/Southface Energy Institute (EPA/SEI) Models

These are three relatively simple Lotus 1-2-3 models, one each for Residential, Commercial, Industrial, and Transportation sectors, were developed during 1992 by EPA's Region IV office, contracting with Southface Energy Institute (also of Atlanta) to investigate the DSM effects on CO_2 emissions in the Region IV area. The system is based on State-level data on energy using technology stocks (including building insulation and HVAC status), energy consumption, and conservation data from publicly available sources. The systems have several good features: (1) built-in graphics and tables, (2) ease of access to data sources, and (3) simplicity in terms of technologies, algorithms, and definitions. Insofar as the models calculate changes to accepted forecasts of energy consumption, proper calibration may be assumed to be correct, in terms of Commerce and DOE estimates, for States or aggregation of State-level results.

At their current stage of development, the EPA/SEI models would best serve a large State, or an agency like EPA's district office, at a higher level of aggregation than States, to derive control totals for broad DSM/conservation efforts. They are much too aggregated for a utility DSM analysis, and may not capture the detail needed for a small regulatory service area like SCAQMD, especially for projects involving detailed emphasis on technologies, such as golden carrot policies. The methodology and structure are simple and easy to expand, however, so they represent a good modeling resource.

6. San Diego Gas and Electric Company DSM Analysis System

San Diego Gas and Electric Company (SDG&E) has developed a comprehensive mainframe-based DSM analysis system, which they claim fulfills their DSM analysis requirements better than a packaged system like COMPASS. The system was developed by Regional Economic Research, Inc., (RER) of San Diego, which is the repository for much of the EPRI DSM-related software and data analysis packages (e.g., COMMEND).

In algorithmic structure and coverage, the SDG&E/RER system is similar to COMPASS. However, being written in the Statistical Analysis System (SAS) on the mainframe allows for somewhat easier access to SDG&E data related to DSM analysis, such as integrated planning systems (for load impacts and avoided cost data, while providing a generally flexible modeling environment. As in COMPASS, market penetration is calculated from S-curves that are derived from relative attractiveness factors for the technology within a given competition class and is further delineated by the type of decision (pre- or post-failure replacement of existing equipment, or new construction), an awareness factor for the technology, the technology's current saturation, base technology life and retirement rate, building stock demolition turnover, and growth rates. The flexibility of having a system written in a standard data base management language like SAS, with source code available to the ongoing operators of the system, is a great benefit over the COMPASS approach, in which the model source code is not transmitted to the user. As a case in point, at the end of 1992, SCE was considering contracting for development of an open-ended system to replace COMPASS, citing this inflexibility as on of the main reasons for their desire to change.

Whereas Mr. Rob Rubin of SDG&E and the developer, Mr. Fred Siebold of RER, were interviewed about the status and content of the RER system, the model was not acquired and run as part of our assessment (unlike the other models were). Mr. Siebold indicated that the model software and data base technology may be customized and installed for other client use on a consulting-fee basis. No cost information was obtained, since the customizing could be open-ended.

The SAS system in which the SDG&E model was written is available on PCs, and simple programs operating on small data bases may be used almost interchangeably with mainframe SAS. However, if the programs and/or data files are large on the mainframe, or the data file refreshing cycles are relatively short, PC conversion may not be cost-effective.

C. SUMMARY/CAVEATS

With their relatively low front-end software cost, in the range of $15,000 to $30,000, off-the-shelf proprietary models like ENERGY2020 or COMPASS appear to offer an attractive alternative to internal development of DSM analysis systems. However, they provide only the partial framework for the analysis. They cannot be instantly used by the buyer for any coherent analytic effort, and it always remains incumbent on the user to develop the data base defining the market(s) of interest, to establish scenario guidelines for the modeling effort, and to add emissions impact and internal avoided cost estimates. The model software itself, whether purchased from a vendor or developed internally will be relatively cheap -- only 20 percent to 25 percent of our estimate of total project costs for reasonably complex markets. The remaining cost is taken up in data development, software modification, calibration, and testing.

Given this fact, it would appear to be most cost/beneficial to let data development requirements initially lead the DSM modeling effort, while having a conceptual design in mind for model development and/or outright purchase of an off-the-shelf software system, as a DSM oriented data base becomes established. For an electric utility, the market data base probably already exists in various forms, and will need only to be augmented with technology data and model parameters and segmented appropriately to handle modeling analysis.

APPENDIX E

CALIFORNIA/DISTRICT DSM MODEL MEASURES

Table E-1
California/District DSM Model Measures

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
Residential Sector				
101	EX,NW	**Superefficient CAC (VSD, SEER=16.9)**	Central air conditioner with variable-speed drive (VSD) unit, currently available from the TRANE Corporation and others. Utilizes electronic motor controls to achieve a SEER of 16.9. Relatively expensive with long payback, but offers greater comfort, reduced temperature differentials and quieter operation, which may increase saturation at the upper end of the market.	CEC, 1989, Trane Corp, 1990, XENERGY, Inc. 1992
102	EX,NW	**Indirect/Direct Evaporative Cooling**	An indirect evaporative cooler which uses a first-stage evaporative cooling cycle to pre-cool air within a heat exchanger. The pre-cooled air is evaporatively cooled in a second stage to further lower the temperature. Can supply 67°F air with an inlet dry-bulb temperature of 101°F. Manufacturer reported efficiency are as high as 47.8 percent, which translates to only 17 percent of annual cooling energy from a standard AC unit. This type of cooling technology has a great deal of potential in areas of low relative humidity.	Manufacturer literature and XENERGY, Inc. communication with Vari-Cool; Huang, 1992.
103	EX,NW	**Duct Leakage**	Recent studies have indicated that duct leakage in forced air heating and cooling systems is one of the largest energy consumers in typical California residences. Additional work is under way to characterize the problem and devise strategies for programs to solve the problem. Many duct systems have loose connections which provide major leaks. Many return systems use plenums rather than ducts and have large leaks to the outdoors. The solution to the problem will involve a test to determine the magnitude of the leaks, and perhaps a procedure to fix common problems, although in new construction identifying the problem may be sufficient. Many programs in this area have used blower doors as a diagnostic tool.	Procter and Pernick, 1992.
104		**AC Maintenance**	This measure involves diagnostic and repair services for existing central air conditioners to improve their efficiency. Inspection and service of CAC systems involves checking the refrigerant level, cleaning the coils, cleaning the blower, and cleaning or replacing filters.	Procter and Pernick, 1992.

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
105	EX,NW	**Improved CAC (SEER=11.9)**	The high-efficiency central air conditioner (CAC) utilizes increased outdoor and indoor coil area and a more efficient motor to raise the SEER to 11.9, several points higher than the 1993 National Appliance Standards requirement. These units and even some more efficient units are commercially available.	LBL, 1990; CCIG, 1992
106	EX,NW	**Improved CAC (SEER=12.4)**	Same as aa.9 SEER unit above, but raises SEER to 12.4.	LBL, 1990; CCIG, 1992
108	EX,NW	**Vegetation/Tree Planting**	Recent studies by LBL have suggested that significant cooling savings can be obtained via strategic vegetation and tree planting around conditioned dwellings.	Akbari, 1992
109	EX,NW	**Evaporative Pre-Cooler**	An evaporative pre-cooler utilizes the latent heat absorbed by evaporating water to pre-cool the air entering an evaporator coil. Especially efficient in hot, dry areas.	Xenergy estimates
110	EX,NW	**Whole house fans**	Whole house fans are installed between the living space and the attic, to move cool air through the living space and into the attic, forcing hotter air out of attic vent spaces. Especially useful in late afternoon/early evening periods.	Fowler, 1989 and CEC, 1989a
111	EX,NW	**Window Film**	A film applied to south, west, and east windows to reduce solar transmission from 0.97 to approximately 0.5. Commercially available at most retail hardware stores.	CEC, 1991
111	NW	**Tinted Glass**	For new construction, tinted glass on the south, west, and east windows. Based on CEC's CALPASS model runs for sensitivity analysis for the residential Title 24 (1992 California energy use regulation) standards.	CEC, 1991
112	EX,NW	**Sunscreens**	Shade screens are similar to conventional screens except that they utilize a series of tiny louvers rather than a mesh. They permit air and a reduced amount of light and heat to pass through to the window. For new construction, the measure specifies that sunscreens be installed on the south, west, and east windows. Based on CEC's CALPASS runs for sensitivity analysis for residential Title 24 standards.	CEC, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
113	EX,NW	**Light-Colored Roof**	Recent research by LBL and others has indicated that changing the albedo of building surfaces exposed to direct insolation can reduce air conditioning requirements. This measure involves reduction of roof absorption from a base assumption of 0.5 to a value of 0.2 resulting from lighter colored roofing materials.	Building simulations, for Edison, Akbari, 1992
121	EX,NW	**Ceiling Insulation-CAC**	In existing construction, an upgrade of previously uninsulated ceilings to R-19. In new construction, an upgrade from R-19 & 30 to R-60. Based on CEC's CALPASS runs for sensitivty analysis for residential Title 24 standards.	CEC, 1991
131	EX,NW	**Wall Insulation-CAC**	In existing construction, an upgrade of previously uninsulated walls to R-11. In new construction, an upgrade from R-11 to R-19. Based on CEC's CALPASS runs for sensitivity analysis for residential Title 24 standards.	CEC, 1991
141	EX,NW	**Improved Room AC (SEER=10.2)**	High-efficiency room air conditioners with an EER of 10.2 are commercially available from Friedrich, Carrier, General Electric and several others. This higher efficiency is made possible by increasing condenser and evaporator area, and using a more efficient fan motor and compressor.	LBL, 1990 and ACEEE, 1990
142	EX,NW	**Improved Room AC (SEER=12)**	High-efficiency room air conditioners with an EER of 12 have limited availability. Again, this increased efficiency is made possible by increasing condenser and evaporator area, and using a more efficient fan motor and compressor.	ACEEE, 1991
201	EX	**Base Electric Heat to Heat Pump**	The heat pump operating in heating mode uses electricity and extracts latent heat from outside air, resulting in overall system efficiency higher than that from a conventional electric resistance heater. The heat pump used for this measure has an HSPF of 8.0.	LBL, 1990; CEC, 1989a; and ACEEE, 1990
401	EX,NW	**High-Efficiency Manual-Defrost Refrigerator**	Refrigerator/freezer using conventional technologies such as efficient fans, 2" of door and 3" of side foam insulation and a high-efficiency compressor. The UEC in the model is for a 16.8 ft^3 adjusted volume (AV) refrigerator.	LBL, 1990
402	EX,NW	**Near-Term Manual Refrigerator**	The same as just above with a 5.3 EER compressor and condenser anti-sweat heaters.	LBL, 1990

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
411	EX,NW	**High-Efficiency Auto-Defrost Refrigerator**	Advanced auto-defrost unit using conventional technologies such as efficient fans, 2" of door and 3" of side foam insulation and a high-efficiency compressor. The UEC in the model is for a 20.8 ft^3 (AV) refrigerator.	LBL, 1990
412	EX,NW	**Near-Term Freezer**	A 25.1 ft^3 (AV) upright, manual defrost unit with a 5.1 EER compressor and 2 inches of door insulation.	LBL, 1990
413	EX,NW	**High-Efficiency Freezer**	The same as just above with evacuated panels.	LBL, 1990
501	EX,NW	**Induction Stovetop**	An electric range that uses induction heating.	Competitek, 1990
502	EX,NW	**Cook Top Reflector Pans**	Improved reflectors for electric ranges.	Competitek, 1990
503	EX,NW	**High-Efficiency Oven**	This measure includes added insulation, improved seals, and reduced mass.	Competitek, 1990
601	EX,NW	**Solar Water Heater**	This technology's efficiency and cost-competitiveness will vary a great deal, depending on the climate, installation, and performance. The unit found most effective for residential and small commercial applications is the Geyser Pump rooftop collector, a passive collector/heat exchanger.	Sage Advance Corporation, 1991
602	EX,NW	**DHW Tank Wrap**	A tank wrap is a simple 2"-4" fiberglass insulation blanket that wraps around a standard gas or electric water heater, installed as a retrofit.	XENERGY estimates
603	EX	**Low-Flow Showerhead**	Many households are still equipped with shower heads using from 4 to 8 gallons per minute. Low-flow shower heads can significantly reduce hot water use proportionately, for a nominal cost. There are obvious quality-of-life and political/philosophical issues to be addressed here. Attention must be paid to choosing a shower head designed for quality low flow, rather than simply installing flow restrictors that may decrease the quality of the stream. Some units on the market that offer even lower flow rates of 0.5 to 1 gpm.	LBL, 1988c
604	EX,NW	**Heat Pump Water Heater**	A heat pump water heater uses standard heat pump technology to transfer ambient heat from air to a water storage tank, similar in construction to space conditioning heat pumps. The unit described has an energy factor (EF) of 2.0.	LBL, 1990

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
605	EX,NW	**Hot Water Saver**	A hot water saver is a storage device that draws standing hot water out of a pipe over a preset period of time (about 30-40 minutes). Removing hot water from a long pipe run reduces line loss associated with most hot water systems. The device is attached to the hot water heater at the cold water input side. Another set of mixing/return valves is added at a point farthest from the heater.	
621	EX,NW	**High-Efficiency Dishwasher**	This dishwasher includes improved food filter, motor, and fill control.	LBL, 1990
641	EX,NW	**High-Efficiency Clothes Washer-Vertical Axis**	Front loading washers use substantially less hot water per load and thus drastically reduce the total energy required for washing. These machines are also easier on clothes and use less detergent. They are popular in Europe and commercially available in the U.S., where they retail for approximately $150 more than top loaders.	LBL, 1990
642	EX,NW	**Hi Eff Clothes Washer-Horizontal Axis**	This technology relies on thermostatic valves, improved motor, elimination of a warm rinse cycle and a plastic tub to reduce energy consumption. These improvements are all made on a standard top mount machine.	LBL, 1990
701	EX,NW	**Heat Pump Dryer**	Although heat pump dryers have been produced and shown to offer more desirable features, they are not commercially available as of end of 1992. A heat pump dryer operates a standard heat pump to heat incoming dry air and then condenses the water out of the hot moist exiting air by recirculating it over the condenser coils.	ACEEE, 1986a
702	EX,NW	**Microwave Dryer**	An emerging technology that uses microwave technology to dry clothes.	ACEEE, 1986a
801	EX,NW	**Compact Fluorescent**	Measure savings are from changing a 75-watt incandescent bulb to an 18-watt fluorescent integral lamp which screws into the normal lamp socket. Included in the O&M cost are the net present value of the future incandescents that would have been changed over due to the differing measure lives. The average case assumes lamps operate 3 hours per day.	XENERGY estimates
901	EX,NW	**Two-Speed Pool Pump**	A two-speed swimming pool pump that obtains efficiency savings by operating at a lower speed than conventional pool pumps.	XENERGY estimates

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
Commercial Sector				
Commercial Cooling (Space CAC and Product Chillers)				
101	EX,NW	**High-Efficiency Centrifugal Chiller**	An efficiency upgrade from the base unit with a COP of 5.3 (above Title 24 minimum COP of 4.1) to high-efficiency unit with a COP of 6.5. Costs were calculated assuming a 150-300 ton capacity range.	XENERGY and Chiller Manufacturers, 1991
102	EX,NW	**Base Centrifugal Chiller to Variable Speed Drive (VSD) High-Efficiency Chiller**	Efficiency upgrade from base unit with a COP of 5.3 to a high-efficiency unit (COP 6.5) incorporating electronic controls add an additional 12% savings during periods when the unit is normally partially loaded. Costs were calculated assuming a 150-300 ton range.	XENERGY and York, 1990
103	EX	**Window Film-Chiller**	Advanced window films can be used to reduce the thermal load of south and west facing windows significantly. North windows can make use of films that reflect radiant heat back into a space while providing uniform window color. This measure applies to the fraction of cooling load with central chillers.	XENERGY, 1991, DOE 2.1D simulations
103	NW	**High-Performance Tinted Glass-Chiller**	The California Title 24 minimum window tinting for new commercial buildings is approximately SC=0.67 shading coefficient. This window has an extremely low shading coefficient of SC=0.26 and a concomitantly low visible light transmittance of 0.05. Although cooling savings are maximized with this measure, customer and community acceptance has been divided (some cities prohibit highly reflective glass).	CEC, 1991 and XENERGY and BSG DOE 2.1D
104	EX,NW	**Variable-Speed Drive (VSD) for Cooling Tower**	Using VSD electronic controls to reduce speeds of cooling tower motors proportionate to demand can significantly lower tower fan energy consumption.	XENERGY, 1991
105	EX,NW	**Two-Speed Cooling Tower**	A cooling tower with high and low speeds is a less expensive way to achieve energy savings similar to the VSD controls.	XENERGY, 1991
105	EX,NW	**Cooling Maintenance-Chiller**	Periodic maintenance of an air conditioning system includes cleaning evaporator and condenser coils, maintaining proper refrigerant levels and checking for leaks, replacing filters, and straightening condenser fins.	XENERGY, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
107	EX	**Economizer-Chiller**	Air economizers reduce cooling energy usage in commercial buildings which experience cooling loads even during cold and mild weather due to solar and internal loads by supplying cool outside air rather than warmer room air in place of or to augment mechanical cooling. Since economizers are required by Title 24 standards for new construction, this measure is only applicable to existing systems without economizers.	XENERGY, 1991; Taylor, 1991
108	EX,NW	**Chilled Water Reset-Chiller**	The higher the chilled water temperature, the higher the coefficient of performance of the chiller. Thus, there is potential to save energy by increasing the chilled water temperature as the cooling decreases to maintain constant return water temperature. In most chillers, capacity is controlled by sensing the temperature of water leaving the chiller and modulating the refrigerating capacity of the compressor accordingly. As the load drops, the sensor detects colder supply water temperature and lowers the chiller's capacity to maintain constant supply water temperature. To apply chilled water reset, the supply temperature set point should increase as the load decreases.	XENERGY, 1991
109	EX,NW	**Energy Management System-Chiller**	An energy management system (EMS) is a computer-based system used for automatic monitoring and control of building energy systems. An EMS can be programmed for setforward and setback, equipment shutoff, etc. Because the EMS utilizes direct digital controls (DDC), control functions are greatly simplified compared with pneumatic controls.	XENERGY, 1991.
110	NW	**Medium-Performance Tinted Glass-Chiller**	The Title 24 minimum window tinting for new commercial buildings is approximately SC=0.67. This window has a fairly low shading coefficient of SC=0.44 but maintains a reasonable visible light transmittance of 0.33.	CEC, 1991 and XENERGY and BSG DOE 2.1D simulations
111	NW	**Medium Performance Low-E Glass-Chiller**	The Title 24 minimum window tinting for new commercial buildings is approximately SC=0.67. This window has a very low shading coefficient of SC=0.29 and still maintains a reasonable visible light transmittance of 0.28. This glass maximizes cooling savings and still allows the penetration of daylight. However, the incremental cost is still quite high.	CEC, 1991 and XENERGY and BSG DOE 21.D simulations

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
151	EX,NW	**High-Efficiency DX Air conditioning**	Using higher efficiency motors and larger coil areas, EER ratios can be improved from 8.5 to 11. High-efficiency DX units currently have limited availability as the market is extremely first-cost driven.	XENERGY and ARI Listings, 1991
152	EX,NW	**Evaporative Pre-Cooler-DX**	An evaporative pre-cooler utilizes the latent heat absorbed by evaporating water to pre-cool the air entering an evaporator coil. It is especially efficient in hot, dry areas.	XENERGY estimates
152	EX	**Window Film-DX**	Advanced window films can be used to reduce the thermal load of south and west facing windows significantly. North windows can make use of films that reflect radiant heat back into a space while providing uniform window color. This measure applies to the fraction of cooling load with air-cooled DX systems.	XENERGY, 1991; DOE 2.1D simulations

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
154	EX,NW	**Air-Cooled to Water Cooled DX**	Refrigeration systems must reject the heat absorbed in the cooling process as well as compressor heat. The closer the temperature of the condenser is to the evaporator, the more efficient the cooling system. Water or evaporatively cooled systems can achieve lower condensing temperatures than air cooled systems since the driving force is ambient wet-bulb temperature which is always lower than ambient dry-bulb temperature. While any refrigeration system may be water or evaporatively cooled, by far the most common systems where water-cooled condensers are an option versus air-cooled condensers are for chillers less than about 200 tons. Above that range, very few chillers are air-cooled, since it is usually cheaper to use water-cooled condensers and less space is required. Only very built-up DX systems are water-cooled; DX systems are usually air-cooled or evaporatively cooled. Packaged DX systems are almost entirely air-cooled with no factory option for evaporative condensers, although it is possible to field modify larger sizes to be evaporatively cooled. Some semi-custom packages (e.g. Mammoth) can be built with evaporative condensers. Built-up DX systems are almost always evaporatively cooled, since this is usually less expensive than air-cooled. This measure is included to indicate the potential available from conversion of air-cooled systems. However, the costs of such conversions are extremely uncertain; no hard cost data is available. In addition, water-cooled systems require added maintenance over air-cooled systems.	XENERGY, 1991; Taylor, 1991
155	EX,NW	**Base DX (Direct Expansion) AC to Indirect Evaporative Cooling**	An indirect evaporative cooler uses a first-stage evaporative cooling cycle to pre-cool air within a heat exchanger. The pre-cooled air is cooled evaporatively in a second stage directly to lower the temperature further. This type of cooler can supply 67°F air with an inlet dry-bulb temperature of 101°F. Manufacturer-reported energy efficiency ratios are as high as 47.8, which translates to only 17% of the annual cooling energy from a standard DX unit. This type of cooling technology has a great deal of potential. The slight added humidity and added maintenance may prove undesirable in certain cases, however.	Manufacturer literature and personal communication, Vari-Cool, 1990; Huang, 1992

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
156	EX,NW	**Indirect Evaporative Cooling with DX Backup**	This is the same as the preceding measure except that the existing DX system is kept as a backup for use during humid and peak cooling periods.	Manufacturer literature and personal communication, Vari-Cool, 1990; Huang, 1992
157	EX	**Economizer-DX**	Air economizers reduce cooling energy usage in commercial building which experience cooling loads even during cold and mild weather due to solar and internal loads by supplying cool outside air rather than warmer room air in place of or to augment mechanical cooling. Since economizers are required by Title 24 Energy Standards for new construction, this measure is only applicable to existing systems without economizers.	XENERGY, 1991; Taylor, 1991
158	EX,NW	**Energy Management System-DX**	An energy management system (EMS) is a computer-based system used for automatic monitoring and control of building energy systems. An EMS can be programmed for setforward and setback, equipment shutoff, etc. Because the EMS utilizes direct digital controls (DDC), control functions are greatly simplified compared with pneumatic controls.	XENERGY, 1991
159	EX,NW	**Cooling Maintenance-DX**	Periodic maintenance of an air conditioning system includes cleaning evaporator and condenser coils, maintaining proper refrigerant levels, checking for leaks, replacing filters, and straightening condenser fins.	XENERGY, 1991
160	NW	**Medium Performance Tinted Glass-DX**	The Title 24 minimum window tinting for new commercial buildings is approximately SC=0.67. This window has a fairly low shading coefficient of SC=0.44 but maintains a reasonable visible light transmittance of 0.33.	CEC, 1991 and XENERGY and BSG DOE 2.1D simulations
161	NW	**Medium Performance Low-E Glass-DX**	The Title 24 minimum window tinting for new commercial buildings is approximately SC=0.67. This window has a very low shading coefficient of SC=0.29 and still maintains a reasonable visible light transmittance of 0.28. This glass maximizes cooling savings and still allows the penetration of daylight. However, the incremental cost is still quite high.	CEC, 1991 and XENERGY and BSG DOE 2.1D simulations.

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
Commercial/Industrial Electric Heating				
201	EX	**Air-to-Air Heat Pump-ROB**	Replacement upon burnout of existing electric resistance heating systems that are cross-saturated with DX air conditioning. Prototype replacement is for a 10-ton unit with COP of 2.5.	
Commercial/Industrial Lighting				
301	EX	**4-F40 to 4-F32T8/Elect-ROB**	This measures compares the incremental costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with an electronic ballast and all 34-watt lamps with 4 four-foot, 32-watt T8 lamps, and 1 electronic ballast.	XENERGY, 1991
302	EX,NW	**F40 Fixture to 2-T87 w/electronic ballast & Specular Reflectors-ROB**	This measures compares the incremental costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with 2 four-foot, 32-watt T8 lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. The measure may reduce light levels slightly; however, it is a very common retrofit for many facilities. Costs are calculated on ballast life of roughly 20 years. The reflector may have some residual value at the end of this period which is not included.	XENERGY, 1991
303	EX	**4-F40/ES to 4-F34/Elect - ROB**	This measures compares the incremental costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with an electronic ballast and all 34-watt lamps. The measure life is for the approximate life of the ballast which is about 50,000 hours. Electronic ballasts operate at a higher frequency, thus eliminating the undesirable flicker of conventional core/coil ballasts.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
304	EX	**F40 fixture to 3-F34/Elec & Specular Reflectors-ROB**	This measure compares the incremental costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp with 3 four-foot, 34-watt lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. This measure may reduce light levels slightly; however, it is a very common retrofit for many facilities. Costs are calculated on ballast life of roughly 20 years. The reflector may have some residual value at the end of this period which is not included. In new construction, the only difference is the existing base case system, which consists of three lamps and two energy-savings ballasts.	Xenergy, 1991
305	EX,NW	**F40 fixture to 2-F34/Elec & Specular Reflectors-ROB**	This measures compares the incremental costs of replacing an existing construction base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp with 2 four-foot, 34-watt lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. May reduce light levels slightly, although it is a common retrofit. Costs are calculated on ballast life of 20 years. The residual reflector value is considered zero. In new construction, the only difference is the existing base case system, which consists of three 40-watt lamps and two energy-savings ballasts.	Xenergy, 1991
306	NW	**3-F40 fixture to T8 w/electronic ballast**	Standard 3-lamp fixture for new construction replaced with F32, T8 lamps and electronic ballast. F32, T8 lamps are slightly smaller in diameter and produce about 5% more light than regular F32 lamps.	Xenergy, 1991
306	EX	**4-F40 to 4-F32T8/Elect-RET**	This measures compares the retrofit costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with an electronic ballast and all 34-watt lamps with 4 four-foot, 32-watt T8 lamps, and 1 electronic ballast.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
307	EX	**F40 fixture to 2-T8 w/electronic ballast & Specular Reflectors-RET**	This measures compares the retrofit costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with 2 four-foot, 32-watt T8 lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. May reduce light levels slightly. A very common retrofit. Costs are calculated on ballast life of 20 years. Residual reflector value considered zero.	Xenergy, 1991
308	EX	**F40 fixture to 3-F34/elec & Specular Reflectors-RET**	This measures compares the retrofit costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp with 3 four-foot, 34-watt lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. May reduce light levels slightly, although it is a common retrofit. Costs are calculated on ballast life of 20 years. Residual reflector value considered zero. In new construction, the only difference is the existing base case system, which consists of three lamps and two energy-savings ballasts.	Xenergy, 1991
309	EX	**F40 fixture to 2-F34/Elec & Specular Reflectors-RET**	This measures compares the retrofit of replacing an existing construction base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot, 34-watt lamps, 1 electronic ballast, and a specular reflector. Labor costs include fastening reflectors, moving lamp mounts, installing ballasts and all associated engineering work. May reduce light levels slightly, although it is a common retrofit. Costs calculated on ballast life of roughly 20 years. The reflector may have some residual value at the end of his period which is not included. In new construction, the only difference is the existing base case system, which consists of three 40-watt lamps and two energy-savings ballasts.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
310	EX,NW	**Occupancy Sensor-4' Fixtures**	An occupancy sensor uses ultrasonic or infra-red waves to sense motion in a room. Upon detection, lights are switched on for a preset amount of time. These controls prevent unused lights from remaining on longer than necessary.	Xenergy, 1991; personal conversation with Andy Chandler-Watt Watcher, 1990
311	EX,NW	**Stepped Photocell Dimming-4' Fixtures**	Photocell controls are used to dim electric lights (via binary switching) in perimeter offices as more daylight becomes available during the day. Cost and savings are per fixture. This measure will not apply to all cases (i.e., internal and windowless offices). The applicability factor has been adjusted accordingly.	Xenergy, 1991
312	EX	**4-F40/ES to 4-F34/Elect -RET**	This measure compares the retrofit costs of replacing a base case fixture that includes a mix of one standard and one energy-saving ballast and 4 four-foot tubes comprised of three 40-watt lamps and one 34-watt lamp, with an electronic ballast and all 34-watt lamps. The measure life is for the approximate life of the ballast, which is about 50,000 hours. Electronic ballasts operate at a higher frequency, thus eliminating the undesirable flicker of conventional core/coil ballasts.	Xenergy, 1991
321	EX,NW	**2-F96T12/ES to Electronic Ballast-ROB**	This measure compares the incremental cost effectiveness of replacing an energy-saving ballast and eight-foot, 75-watt lamps with an electronic ballast.	Xenergy, 1991
322	EX,NW	**2-F96T12 to Energy Saving (ES) lamps & Electronic Ballast -ROB**	This measure compares the incremental cost effectiveness of replacing two standard 75-watt, eight-foot fluorescent lamps and energy-saving ballast with two energy-saving, 60-watt lamps and an electronic ballast. Provides slightly decreased light levels; however, it has been considered acceptable in many applications.	Xenergy, 1991
323	EX,NW	**8' Specular Reflectors Package-ROB**	This measure includes replacing 2 eight-foot, 75-watt lamps and an energy-saver ballast with one 75-watt lamp, one half an electronic ballast (tandem wired - 1 per 2 fixtures) and an eight-foot specular reflector. This layout will deliver roughly equivalent amounts of light with less glare.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
324	EX	**2-F96T12/ES to Electronic Ballast-RET**	This measure compares the retrofit cost effectiveness off replacing an energy-saving ballast and eight-foot, 75-watt lamps with an electronic ballast.	Xenergy, 1991
325	EX	**2-F96T12 to Energy Saving (ES) lamps & Electronic Ballast-RET**	This measure compares the retrofit cost effectiveness of replacing two standard 75-watt, eight-foot fluorescent lamps and energy-saving ballast with two energy-saving, 60-watt lamps and an electronic ballast. Provides slightly decreased light levels; however, it is acceptable in many applications.	Xenergy, 1991
326	EX	**8' Specular Reflectors Package-RET**	This measure compares the retrofit cost effectiveness of replacing 2 eight-foot, 75-watt lamps and an energy-saver ballast with one 75-watt lamp, one half an electronic ballast (tandem wired - 1 per 2 fixtures) and an eight-foot specular reflector. This layout will deliver roughly equivalent amounts of light with less glare.	Xenergy, 1991
327	EX	**Occupancy Sensor 8' Fixtures**	An occupancy sensor using ultrasonic or infra-red waves to sense motion in a room. Upon detection, lights are switched on for a preset amount of time. These controls prevent unused lights from remaining on longer than necessary.	Xenergy, 1991; personal conversation with Andy Chandler-Watt Watcher, 1990
328	EX	**Stepped Photocell Dimming-8' Fixtures**	Photocell controls are used to dim electric lights (via binary switching) in perimeter offices as more daylight becomes available during the day. Cost and savings are per fixture. This measure will not apply to all cases (i.e., internal and windowless offices). The applicability factor (in the DSM model) has been adjusted accordingly.	Xenergy, 1991
341	EX,NW	**60-Watt incandescent to 13-watt compact fluorescent**	The lifetime measure cost includes the present value of the avoided replacement costs of existing lamps and labor to replace them, due to differences in expected life of the measure versus base lamps.	Xenergy, 1991
351	EX,NW	**75-watt incandescent to 18-watt compact fluorescent**	The lifetime measure cost includes the present value of the avoided replacement costs of existing lamps and labor to replace them.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
361	EX,NW	**100-watt PAR incandescent to 28-watt compact fluorescent w/reflector**	This replacement is especially effective in recessed or "can lighting." The lifetime measure cost includes the present value of the avoided replacement costs of existing lamps and labor to replace them.	Xenergy, 1991
371 23	EX,NW	**150-watt incandescent PAR to 90-watt halogen PAR-ROB**	Replacing a 150-watt incandescent PAR lamp with a 90-watt halogen reduces energy use and provides a better quality, whiter light.	Xenergy, 1990.
Commercial Refrigeration: Head Pressure Measures				
401	EX,NW	**Oversize Evaporator Condenser**	Self-explanatory	Xenergy, 1991; EPRI, 1989
402	EX	**Balanced Port Expansion Valve**	Balanced port expansion valves have the ability to throttle refrigerant flow over a large inlet pressure range, whereas a standard, thermostatic expansion valve can operate only over a more limited range. Minimum head pressure or condensing temperature of a refrigeration system employing thermostatic expansion valves must be kept at a near fixed value, typically around 90 to 95°F. With balanced port expansion valves, condensing temperatures are able to float down to temperatures of 70°F or even lower, e.g., 60°F or, at times, even 45°F. Balanced port expansion valves are an alternative to electronic expansion valves.	Xenergy, 1991; EPRI, 1989
403	EX	**Electronic Expansion Valves**	Electronic expansion valves allow the operation of floating or very low head pressure control. Where the balanced port valve is mechanically actuated, the electronic valve is electronically actuated. This allows for smoother regulation of superheat, therefore maintaining a more constant display case discharge air temperature. A drawback with electronic expansion valves is their installation cost, which is two or three times that of balanced port valves to install because of all the necessary wiring. Electronic expansion valves are an alternative to balanced port expansion valves.	Xenergy, 1991; EPRI, 1989

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
Commercial Refrigeration: Subcoolers		(Subcooling refers to the cooling of liquid refrigerant below the saturation temperature. Subcooling increases refrigeration capacity as well as preventing the formation of flash gas).		
404	EX,NW	**Ambient Sub-Coolers**	The ambient subcooler is a heat exchanger located within or outside the system condenser, at the air entry side. It has the ability to reduce liquid refrigerant temperature anywhere from 5 to 15°F by heating rejection to the ambient environment. Ambient subcoolers are an alternative to remote evaporative subcoolers.	Xenergy, 1991; EPRI, 1989
405	EX,NW	**Low-Temp External Liquid Suction**	Often, the liquid and suction piping in a display case is soldered together in order to create liquid-to-suction heat transfer. The purpose of this heat exchange is to take full advantage of the potential of the suction gas exiting the display case to absorb heat from the liquid refrigerant flowing to the display cases. This increases the refrigeration effect or capacity of the refrigerant and negates the heat gain to the suction gas from the ambient. For more efficient liquid-to-suction heat transfer, heat exchangers are offered to accomplish the same task as the soldering of the liquid and suction lines. These heat exchangers are simple tube-in-tube designs, typically called external liquid-suction heat exchangers, which may be attached to most display cases. The term external signifies that these exchangers are attached outside of the display case, whereas the soldering of the refrigerant piping is done in the display case. External liquid-suction heat exchangers are an alternative to mechanical subcoolers.	Xenergy, 1991; EPRI, 1989
406	EX,NW	**Medium-Temp External Liquid Suction**	Same as above for medium temperature applications.	Xenergy, 1991; EPRI, 1989

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
407	EX	**Low-Temp Mechanical Sub Cooling**	Mechanical subcoolers can achieve further (i.e., beyond ambient) subcooling of the liquid refrigerant. They are more common than ambient subcoolers for retrofit installations since these units do not need to be attached to the condenser and are smaller and much simpler to install in retrofit applications. They are also more effective for reducing liquid temperature; with mechanical subcooling, drops in liquid temperature of up to 50°F can be realized. Mechanical subcoolers are an alternative to external liquid suction heat exchanger.	Xenergy, 1991; EPRI, 1989
408	EX,NW	**Medium-Temp Mechanical Subcooling**	Same as above for medium temperature applications.	Xenergy, 1991; EPRI, 1989
Commercial Refrigeration: Compressor and Defrost Measures (This category includes change-out of compressors and display case evaporator defrosting. Compressors and defrost measures are grouped since the defrost techniques presented are coupled with the compressor system.)				
410	EX	**High Efficiency Stand-alone Compressors**	High efficiency compressors may be defined as compressors which offer significant improvement in efficiency over what is already in place. Typically, a compressor yielding about a 10 percent improvement in the compressor energy efficiency ratio (EER) in a change-out is considered high efficiency. High efficiency compressors are offered in models greater than 5 horsepower, which typically accounts for about 50 percent of total installed horsepower in a stand-alone supermarket refrigeration system.	Xenergy, 1991; EPRI, 1989
411	EX,NW	**High Efficiency Multiplex**	Even though 95 percent of supermarkets use multiple compressor racks, not all compressors on those racks are high efficiency. Same as above for medium temperature applications.	Xenergy, 1991; EPRI, 1989

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
412	EX	**Single Variable Speed Compressor for Multiplex Rack**	In an attempt to further improve the capacity matching of a multiplex compressor rack, the rack may be equipped with a variable speed compressor. The compressor speed is varied by the use of a frequency inverter. Generally, the smallest compressor on the rack is equipped with an inverter, since this compressor cycles the most in order to meet the variable load imposed on the rack. This is the most common application of a variable speed compressor in supermarket refrigeration. A frequency inverter is a device which receives electric current at the standard AC frequency. The current received is changed to DC, then reduced to the desired frequency and converted to the required AC, yielding a reduced compressor speed. Using one variable speed compressor per rack is an alternative to the full variable speed rack.	Xenergy, 1991; EPRI, 1989
413	EX,NW	**Full Variable Speed Multiplex Compressor Rack**	Another approach to applying variable speed compressor technology to supermarket refrigeration is to equip an entire refrigeration rack with variable speed compressors. Though the energy savings are greater when all compressors are variable speed, the high cost of inverters does not make this type of configuration cost-effective. Using a full rack of variable speed compressors is an alternative to using only one per rack.	Xenergy, 1991; EPRI, 1989

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
414	EX	**Hot Gas Defrost Multiplex**	During operation of an evaporator coil at temperatures below 32°F, moisture from the air flowing through the coil accumulates on the coil as frost. The frost eventually builds to a point where the airflow is obstructed enough to hinder refrigeration of the display case. Typically, one to four times throughout the day, this frost formation on the coil must be removed. The evaporator coils may be defrosted by shutting off the flow of refrigerant to the evaporator and allowing the air circulating through the display case to warm up and melt the frost off the coil. The defrosting process may be hastened by the use of electric resistance heaters installed within the air flow route. Electric resistance heaters are generally used in low temperature refrigerated cases and walk-in boxes. Hot gas defrost is an efficient alternative to electric resistance defrost. The hot discharge gas of the compressor passes through a tube-in-tube heat exchanger where it evaporates liquid from the defrosting evaporators. This discharge gas is cooled somewhat, then proceeds to the evaporator where it condenses, melting the frost off the coils. This liquid then proceeds to the heat exchanger, where it evaporates. The superheated gas then proceeds to the compressor.	Xenergy, 1991; EPRI. 1989
415	EX	**Hot Gas Defrost Stand-alone**	Same as above for stand-alone applications.	Xenergy, 1991; EPRI, 1989
Commercial Display Case Measures				
418	EX,NW	**High Efficiency Display Case Fan Motors**	High efficiency display case fan motors available on the market consume about half the energy of standard display case motors. These motors are easily replaced in retrofit installations, but may also be installed during assembly of the display case before its installation.	Xenergy, 1991, EPRI, 1989
419	EX,NW	**Anti-Sweat Heater Controls**	The purpose of an anti-sweat (or anti-condensate) heater is to prevent build-up of condensate and frost on the inside door of a reach-in display case. Typically, anti-sweat heaters are used on doors of frozen food reach-ins.	Xenergy, 1991; EPRI, 1989

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
420	EX	**Doors for Reach-In Display Cases-Low Temp**	Very low and low temperature reach-n cases are now manufactured with doors attached. Of medium-temperature applications, dairy cases experience the greatest load per foot of display case and doors are not standard equipment. Adding doors to these cases would reduce the sensible and latent loads realized by the evaporator, and subsequently, the compressors. Though not common, doors may be added to medium temperature cases at the factory. Reach-in doors are an alternative to vinyl strip curtains.	Xenergy, 1991; EPRI, 1989
421	EX,NW	**Doors for Reach-In Display Cases-Medium Temp**	Same as above for medium temperature applications.	Xenergy, 1991; EPRI, 1989
422	EX,NW	**Vinyl Strip Curtains for Display Cases**	Vinyl strip curtains for medium temperature display cases of various types offer the same type of benefit as doors on reach-ins, though not the same magnitude of energy savings. Unfortunately, the aesthetics and convenience of this enhancement are far from attractive and thus are not favored by many supermarkets, according to the leading supermarket refrigeration manufacturer-contractor. Vinyl strip curtains are an alternative to reach-in doors.	Xenergy, 1991; EPRI, 1989
423	EX,NW	**Vinyl Strip Curtains for Walk-In Coolers**	Vinyl strip curtains, commonly used on low temperature walk in coolers can also improve the efficiency of medium temperature walk in coolers.	Xenergy, 1991; EPRI 1989
Commercial/Industrial Ventilation				
502	EX,NW	**Energy Efficient Motors for Ventilation**	High efficiency motors make use of tighter windings, lower bearing tolerances, more advanced lubricants and improved design to reduce energy consumption. These motors can easily replace most existing lower efficiency motors.	Xenergy, 1991
503	EX,NW	**VSD Motor with VIV Base**	This measure is a variable speed drive motor replacing a standard motor in an HVAC system that already has variable inlet vane controls.	Xenergy, 1991
504	EX,NW	**Motor On/Off Controls (EMS)**	This measure represents costs and savings from optimized motor run time as might be accomplished via an EMS system, or in smaller applications, by timeclocks.	Xenergy, 1991

Table E-1 (continued)

ID	Existing (EX) or New (NW)	Measure Label	Measure Description	Reference
All Sectors: Miscellaneous				
801	EX,NW	**Base Copier to Standby Copier**	This measure is a copier with a power saver control mode during idle periods. Since restart times may last a few minutes, customer acceptance may be lower.	Competitek, 1990
802	EX,NW	**Base PC to Laptop Technology**	This measure represents the incremental costs and energy savings of laptop compared with standard PCs.	Competitek, 1990

APPENDIX F

GLOSSARY OF DSM-RELATED TERMS AND ACRONYMS

APPENDIX F
GLOSSARY OF DSM-RELATED TERMS AND ACRONYMS

The definitions below are arranged by general supply curve energy service class.

A. GENERAL DSM TERMS

AHAM	Association of Home Appliance Manufacturers
ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BSR	Board of Standards Review of ANSI
CFR	*Code of Federal Regulations*
HVAC	Heating, Ventilating and Air Conditioning

1. Load (Electric Power Measure)

In reference to electricity, "load" refers to the instantaneous rate of energy use, often called "power," expressed in watts. The electric load of a common household clothes iron is about 1 kW, for instance, which uses electricity at 10 times the rate of a 100 W incandescent bulb. Electric load impacts are an important part of conservation analysis, since monetary benefits in terms of delayed plant startup time may be applied to measures conserving energy used during major "peak-load" periods, like space conditioning during August afternoons in the South or winter mornings in the North.

2. Load (Energy Consumption Measure)

While care must be taken to distinguish this interpretation of the term load from the electric power measurement discussed above, energy conservation analysts use the term load in reference to the net energy requirements for an enduse activity, expressed in Btu, therms, or kWh per year or season. It is usually prefaced by a phrase defining the enduse category (e.g., "heating load," "cooling load," or "water heating load"). For example, the heating load for a gas space heating was reported as about 296 therms in one utility's service area, which, given that the average efficiency of gas heaters in the area was 63 percent, resulted in consumption at the meter (the UEC, as defined below) of gas space heating in the area of 470 therms per year (= 296/0.63).

3. UEC (Unit Energy Consumption)

An energy conservation modeling term, probably with roots in Oak Ridge, Lawrence Berkeley Laboratories and/or EPRI energy conservation modeling activities. Whereas no explicit definition was found in the literature, UEC is, from context, the average annual energy use of a *specific* energy service class defined by end-use sector (residential, commercial, or industrial), energy utilization classification (e.g. water heating or space heating), and geographic/climate-zone (e.g., Southern California/coastal) considerations. Also, the implication from contextual usage is that UEC means energy use at the customer's meter, i.e., not including utility primary supply or distribution losses, but including efficiency losses downstream of the meter. For example, one California utility claimed in a recent DSM filing that the UEC of gas water heaters in their service area is 210 therms per year, but after losses of 50 percent, water heating load was only 105 therms per year.

4. EUI (Energy Utilization Intensity)

Another modeling term related to UEC and not well defined in the literature where it has also been termed "energy use intensity" or "energy utilization index." From context, EUIs are energy use rate parameters used especially in commercial and industrial sector conservation analysis, to allow estimation of the total annual usage (i.e., the UEC) for a specific energy service class, given data on building square footage. For example, a report for a California utility found that the initial cooling EUI for medium-sized offices in their service area was 5.47 kWh per square foot per year, but that the variation was between 2.85 kWh/ft^2 and 7.45 kWh/ft^2 due to changes in climate zone and base technology[1].

B. TERMS RELATED TO APPLIANCES

1. Adjusted Volume (AV)

A volume measure used for standards calculations for refrigerator-freezer annual energy consumption. AV is calculated as follows:

$$AV = FVF * (\text{freezer volume, ft}^3) + (\text{refrigerator volume, ft}^3)$$

where FVF is freezer volume factor, commonly 1.63. A refrigerator-freezer with a 15 cubic foot food space and a 5 cubic foot freezer would have an adjusted volume of 5 * 1.63 + 15 = 23.15 cubic feet.

2. Freezer

A cabinet designed as a unit for the freezing and storage of food at temperatures of 32°F or below and having a source of refrigeration requiring energy input.

[1]SDG&E Technology Load Study Final Report, XENERGY, Inc. May, 1992, p 2.23.

3. *Freezer Volume Factor (FVF)*

The multiplier for freezer volume to add to refrigerated volume in calculating the NAECA standard energy usage is the freezer volume factor. FVF is 1.44 for refrigerators, 1.63 for refrigerator-freezers, and 1.73 for freezers.

4. *Refrigerator*

A cabinet designed for the refrigerated storage of food at temperatures above 32°F, having a source of refrigeration requiring energy input. It may include a compartment for freezing and storage of food at temperatures below 32°F, but does not provide a separate low temperature compartment designed for freezing and storage of food at temperatures below 8°F.

5. *Refrigerator-Freezer*

A cabinet which requires the use of energy input for its functions, consisting of two or more compartments, at least one of which is designed for the refrigeration and storage of foods at temperatures above 32°F, and with at least one compartment designed for the freezing and storage of food at temperatures below 8°F which may be adjusted by the user to a temperature of 0°F or below.

C. TERMS RELATED TO SPACE CONDITIONING

1. *Air Conditioner*

One or more factory made assemblies which include an evaporator or cooling coil and an electrically driven compressor and condenser combination; it may also include a heating function.

2. *Annual Fuel Utilization Efficiency (AFUE)*

An efficiency measure applied to fossil fuel-fired heating devices. AFUE is the fraction of the energy content of the incoming fuel consumed by the device which is converted into useful heating of the space (as opposed to being lost "up the stack" or used as motive power for the device). A typical value for a gas central heating system is 0.76, or 76 percent.

3. *Central Air Conditioner*

An air conditioner that is not a room air conditioner.

4. *Central Air Conditioning Heat Pump*

A central air conditioner that is capable of heating by refrigeration and that may or may not include a capability for cooling.

5. Coefficient of Performance (COP)

For heat pumps, COP is the ratio of the rate of useful heat delivered to or extracted from the conditioned space by the complete heat pump unit, exclusive of any auxiliary heating functions, to the corresponding rate of energy input. COP is measured in consistent units such as Btus, with kWh converted to Btus at the rate of 3.412 Btu per watt-hour, as tested under specified operating conditions. COP is dimensionless. Typical values fall in the range of 2.5 to 3.0, which would be equivalent to overall efficiency of 250 to 300 percent. If a heat pump's EER (or SEER) is known, then COP is EER (or SEER) divided by 3.412.

6. Energy Efficiency Ratio (EER -- of air conditioners)

EER is a measure of the cooling performance of room air conditioners; it is sometimes applied to heat pumps while operating in cooling mode. EER is the cooling capacity of the unit in Btus removed from the conditioned space per hour, per watt-hour of electricity consumed in the process, measured under regulated test conditions. Typical values are 7.0 to 9.0 Btus per watt-hour. EER multiplied by 100 and divided by 3.412 gives the overall energy conversion efficiency -- e.g. EER 8.0 implies 8 * 100/3.412 = 235 percent efficiency.

7. Heating Seasonal Performance Factor (HSPF -- of heat pumps)

Heating Seasonal Performance Factor. A measure of the seasonal heating performance of heat pumps, HSPF is the total heating output of a heat pump (in Btus) during its normal heating period, divided by the total electrical energy input (in watt-hours) for the same period. HSPF incorporates performance measures for varying outdoor temperature, losses due to cycling and defrosting, and auxiliary resistance heat requirements. Units are Btus per watt-hour. Typical values are 7.0 to 9.0 Btus per watt-hour.

8. Integrated Part Load Value (IPLV -- of air conditioners)

IPLV is a measure of part-load efficiency for the cooling mode of certain types of HVAC, similar to SEER, which is defined and referenced in ARI and ASHRAE standards, and in 10 CFR 400-499 air conditioning regulation documentation. Compliance with minimum efficiency standards for these selected equipment types include compliance both with the full-load requirements and the specified IPLV part-load minimum. For example, in 10 CFR 435.108, minimum efficiency for the cooling mode of air cooled unitary air conditioners and heat pump of $\geq$ 65,000 and < 135,000 Btu/hour capacity is stated as 8.9 EER and 8.3 IPLV.

9. Room Air Conditioner

A room air conditioner is a factory encased air conditioner designed as a unit for mounting in a window or through a wall, or as a console. It is designed for delivery of conditioned air to an enclosed space without ducts.

10. Seasonal Efficiency (Gas Heaters)

Seasonal efficiency (SE), of gas fan-type central furnaces, defined in California appliance efficiency regulations, by the equation below:

$$SE = \frac{[\text{auxiliary gas consumption (Btu/yr)} * AFUE + \text{electrical energy consumption (kWh)}] * 3412 \text{ Btu/kWh}}{[\text{total auxiliary annual gas use Btu/yr} + \text{electricial energy use (kWh)}] * 10236 \text{ Btu/kWh}}$$

11. Seasonal Energy Efficiency Ratio (SEER -- of air conditioners)

An efficiency measure for air conditioners which is similar to EER, but incorporates performance tests under varying outdoor temperatures, humidity, and losses due to cycling times. SEER (like EER) is the number of Btus of heat removed from the conditioned space per watt-hour of electrical energy input. Typical values are 9.0 to 12.0 Btus per watt-hour.

D. WATER HEATING RELATED TERMS

1. Cut-In

The time or water temperature at which a water heater's thermostat has acted to increase the energy or fuel input to the heating elements, compressor, or burner, to elevate the water temperature.

2. Cut-Out

The time or water temperature at which a water heater's thermostat has acted to decrease the energy input to the heating elements, compressor or burner to a minimum.

3. Energy Factor

Defined in 10 CFR 430, Subpart B, Appendix E. A laboratory measure of actual daily cycle water heater efficiency, performed using six test draws of hot water totaling 64.3 gallons over a 24-hour period, raising the water 77°F (from 58° to 135°).

4. Recovery Efficiency

The ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater.

5. Standby

The time period during which water is not being withdrawn from the water heater.

6. Standby Loss

(For storage type water heaters only.) Standby Loss measures the losses from the stored hot water to the immediate space surrounding the storage tank. It may be expressed as a percent lost per hour, or, less commonly, in watts per hour per square foot of storage tank surface area.

7. Thermal Efficiency (of gas water heaters)

The percentage of heat from the combustion of gas which is transferred to the water as measured under regulated test conditions. For instance, the California standard for large gas water heaters is a minimum 76 percent thermal efficiency.

E. TERMS RELATED TO BUILDING SHELL INTEGRITY AND INSULATION

1. R-Value

Also called "thermal resistance," the R-value of a material (insulation or building component) is a measure of the resistance of the material to heat flow through it, given a temperature difference between two of the material's surfaces. The higher the R-value of insulation, for instance, the better it will reduce the flow of thermal energy. Most R-11 wall insulation will just fit into a frame wall with 2' x 4' studs, whereas, R-38 insulation, being 10" to 18" thick depending on the material, could not be retrofitted to old frame houses unless the walls were to be completely modified. R-value is the reciprocal of thermal conductance, or 1/U. Units are (hour - sq. ft. - degree F) per Btu.

2. U-Value

Thermal Conductivity is a measure of the ability of a body to conduct heat, measuring the time rate of heat flow through the body induced by a unit temperature difference between the body's surfaces. The reciprocal of R-value, or thermal resistance. Units are Btu per (ft^3 - hour - degree F).

APPENDIX G

LONG-TERM INDUSTRIAL ENERGY FORECASTING MODEL DESCRIPTION

ACKNOWLEDGEMENTS

This material was excerpted from the following sources with permission from Marc Ross, the primary author.

1. Ross, M.H., and R. Huang, "A Model for Long-Term Industrial Energy Forecasting (LIEF)," Lawrence Berkeley Laboratories, LBL31861, February 1992.

2. Ross, M.H., P. Thimmapuram, R.E. Fisher, and W. Maciorowski, "Long-Term Industrial Energy Forecasting (LIEF) Model (18 Sector Version)," Argonne National Laboratory, March 1993.

APPENDIX G
LONG-TERM INDUSTRIAL ENERGY FORECASTING MODEL DESCRIPTION

A. BACKGROUND

The Long-Term Industrial Energy Forecasting (LIEF) model described in this appendix was used to forecast industrial sector DSM results for the California/District region. The model was created by Marc Ross at the Physics Department of the University of Michigan and was developed in collaboration with the Energy Analysis Program at the Lawrence Berkeley Laboratory. The purpose of this appendix is to establish the content and structural validity of the model, and to provide estimates for the model's parameters. The model is intended to provide decision makers with a relatively simple, yet credible tool to forecast the impacts of policies which affect long-term energy demand in the manufacturing sector. Particular strengths of this model are its relative simplicity which facilitates both ease of use and understanding of results, and the inclusion of relevant causal relationships which provide useful policy handles.

The modeling approach employed by LIEF is intermediate between top-down econometric modeling and bottom-up technology models such as those developed for the residential and commercial sectors of the District. It relies on the simple concept that trends in aggregate energy demand are dependent upon the following factors: (1) trends in *total production*; (2) *sectoral or structural shift*, that is, changes in the mix of industrial output from energy-intensive to energy non-intensive sectors; and (3) changes in *real energy intensity* due to technical change and energy-price effects as measured by the amount of energy used per unit of manufacturing output (kBtu per constant dollars of output). The manufacturing sector is first disaggregated according to their historic output growth rates, energy intensities, and recycling opportunities. Exogenous, macroeconomic forecasts of individual subsector growth rates and energy prices can then be combined with endogenous forecasts of real energy intensity trends to yield forecasts of overall energy demand.

Proper description of production activities is a key to reasonable forecasting of industrial energy use. Sectoral shifts and changes in real energy intensity can only be properly characterized if careful attention is paid to *sectoral disaggregation* as well as to *data series*. It is often more important to the forecast than the description of efficiency improvement. Disaggregation into 2-digit Standard Industrial Classifications (SICs) is not satisfactory for long-term forecasting, or for energy-intensive industries or energy non-intensive industries.

B. LIEF'S "HYBRID" APPROACH

LIEF uses a hybrid approach to identifying conservation and technical (fundamental process) change. The approach is basically a statistical one, but *a priori* engineering judgment enters to identify parameters and to cast the energy conservation relationship explicitly between energy and capital. For this reason, LIEF's approach may be termed a hybrid. Exogenous forecasts of individual subsector growth rates and energy prices are combined with endogenous forecasts of real energy intensity trends to yield forecasts of overall energy demand. For manufacturing subsector i, energy form j, and year t, energy intensity is calculated as follows:

$$EI_{ij}(t) = \frac{E_{ij}(t)}{Q_i(t)}$$

where:

$Q_i(t)$	=	a measure of the annual production in subsector i
$E_{ij}(t)$	=	the annual energy consumption of energy from j

For the historical estimation of parameters, $Q_i(t)$ is real gross output from the Bureau of Labor Statistics, and $E_{ij}(t)$ is taken from the National Energy Accounts.

Figure G-1 shows the major data flows and highlights the key transformations performed by LIEF. Figure G-2 shows the model's dynamic structure, and Table G-1 shows the key model equations.

C. IMPORTANCE OF SECTOR DEFINITIONS

Declining output share of the basic materials industries has characterized product mix in recent decades. These industries are primary metals; chemicals; petroleum refining; stone, clay, and glass; and pulp and paper. The tonnage of basic materials produced (and consumed) is growing more slowly than manufacturing as a whole. These industries are roughly 10 times as energy intensive as the remainder of manufacturing. Sectoral shift away from the basic-materials industries has been of comparable importance to real efficiency improvements in explaining the historical decline in total energy intensity.

There are several explanations for the declining role of basic materials:

- increased energy prices,
- cyclical effects,
- international competition, and
- reduced material intensity for more basic reasons.

The premise underlying the fourth explanation is that as the gross national product (GNP) rises in advanced industrial economies, basic materials become relatively less

Figure G-1
Industrial Energy Demand Forecasting Using LIEF

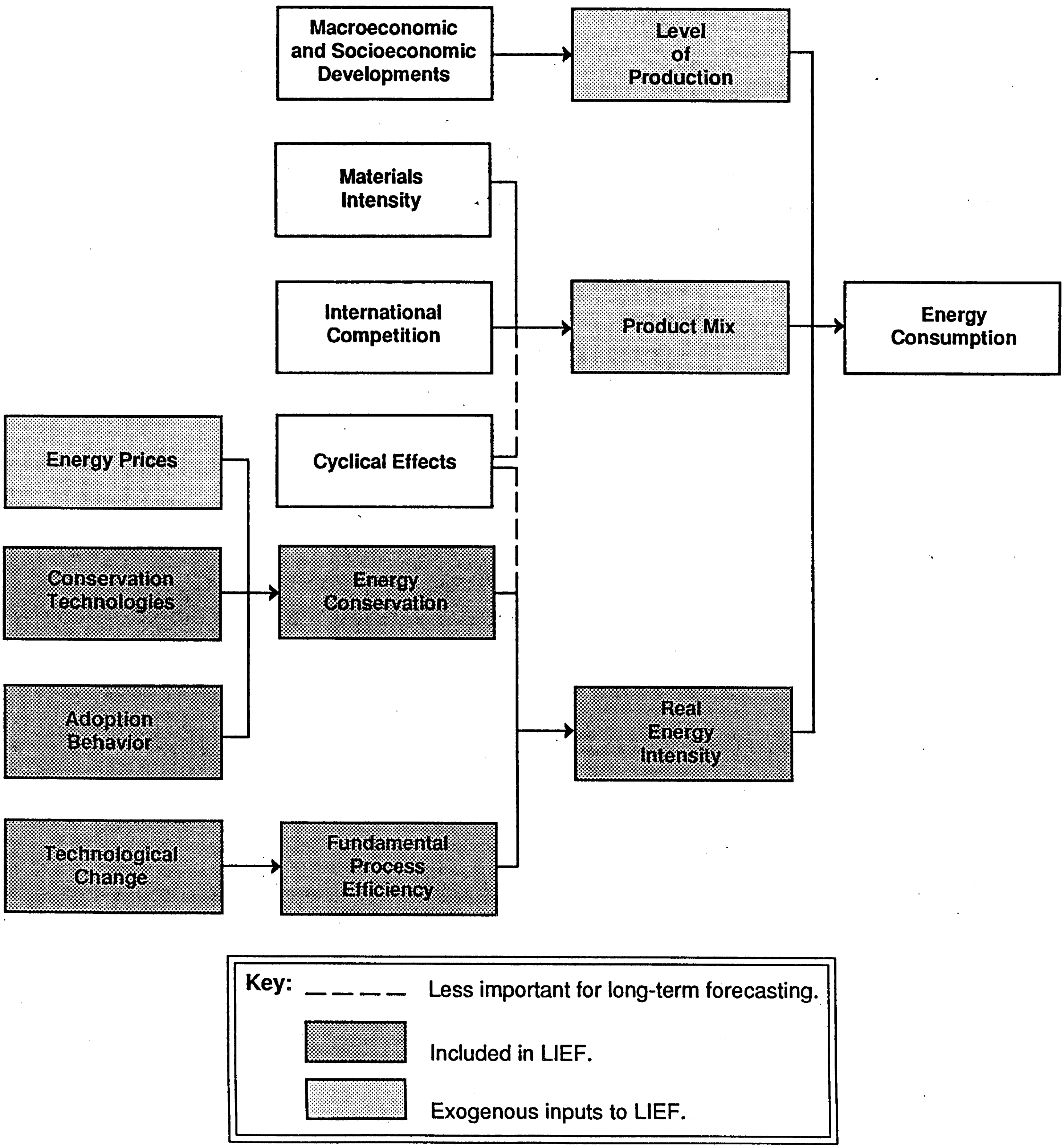
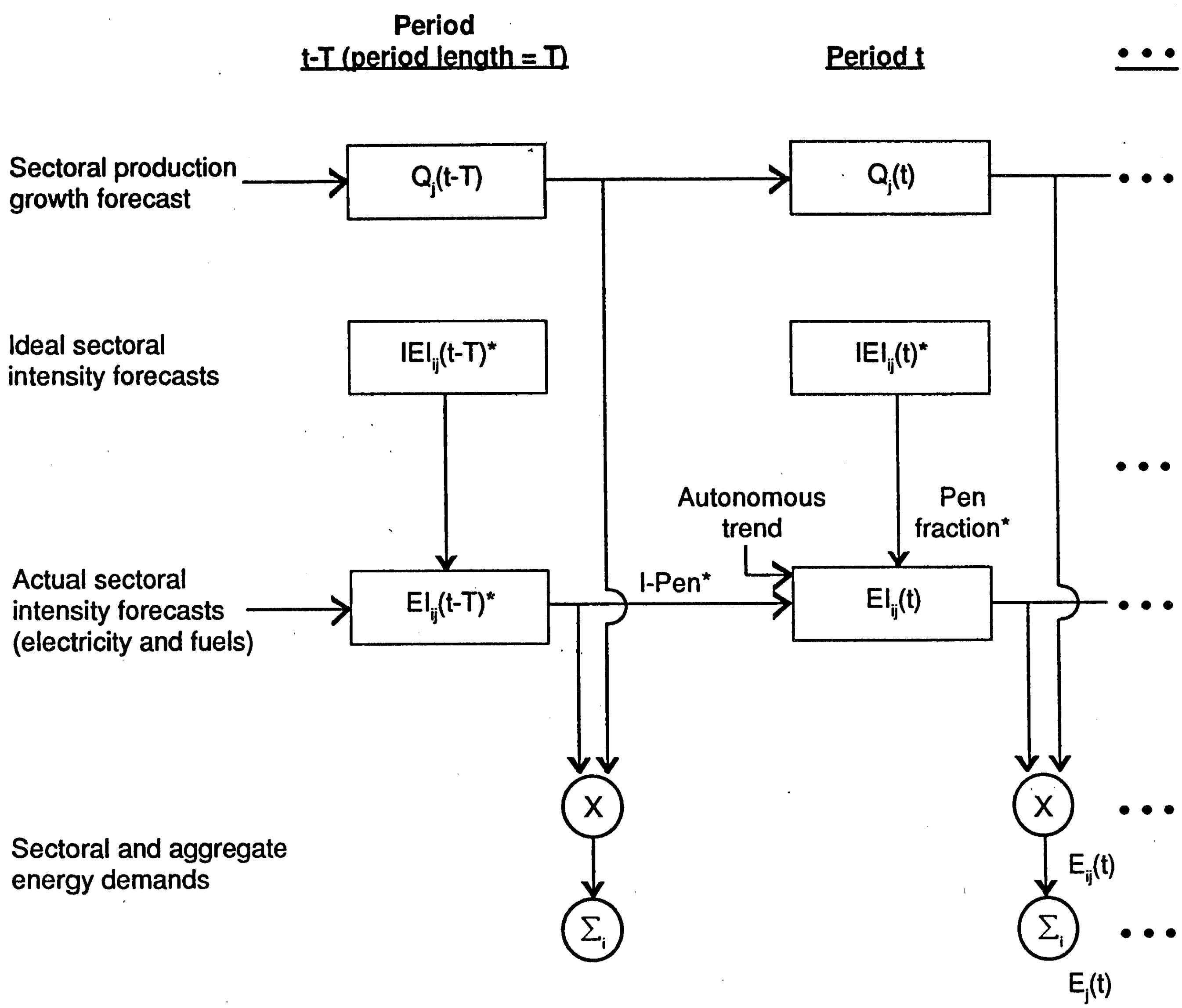


Table G-1
LIEF 18-Sector Model for U.S. Industry

Low-Material-Intensive Manufacturing (Sectors 1 and 2)	
*Sector 1:	General mature manufacturing
*Sector 2:	Fast-growing manufacturing
Energy-Intensive Manufacturing Process Sectors (Sectors 3-12)	
*Sector 3:	Pulp and paper mills
Sector 4:	Industrial inorganic chemicals
Sector 5:	Industrial organic chemicals
*Sector 6:	Petroleum refining
Sector 7:	Glass and glass products
*Sector 8:	Cement
*Sector 9:	Stone and clay products
*Sector 10:	Iron and steel
Sector 11:	Primary aluminum
Sector 12:	Nonferrous metals (excluding primary aluminum)
Nonmanufacturing Industries (Sectors 13-16)	
*Sector 13:	Agriculture and Water Pumping
*Sector 14:	Mining (excluding oil and gas)
*Sector 15:	Oil and gas extraction
*Sector 16:	Construction
Other Manufacturing Energy Use (Sectors 17 and 18)	
Sector 17:	Feedstocks
Sector 18:	Uranium enrichment

NOTES: *Only these 11 sectors were used for the California/District model.

Figure G-2
Dynamic Structure of the LIEF Model
(Simplified)



NOTES: Ideal energy intensities depend on prices and the capital recovery factor (CRF). Actual energy intensities are described by a partial adjustment process with the ideal intensity technologies penetrating at a specified fraction, Pen(t), each period. Energy intensities are scaled by an autonomous time trend.

important. This dematerialization is associated with the saturation of heavy products (high weight-dollar value), innovative products characterized by low weight/dollar value, competition among materials, and technological advances that reduce the use of material in standard applications.

Long-term energy demand will be profoundly impacted by whichever theory characterizes the future. If cyclical effects and international competition are dominant, then the shift away from energy-intensive industries could be transitory. On the other hand, if high-technology products with relatively low materials content continue to dominate industrial growth, then energy demand in the long-term will be diminished.

The impact of sectoral shifts and changing process energy intensities can be adequately characterized only if careful attention is paid to sectoral disaggregation. The choice of disaggregation can be more important to a forecast than the description of efficiency improvement. Ross and his colleagues have found that disaggregation into 2-digit SICs is not satisfactory for long-term forecasting, or for energy-intensive industries or energy non-intensive industries.

The problem is not that there are too few 2-digit sectors, but that they are poorly aggregated for energy analysis. Some energy-intensive 2-digit industries, especially chemicals and allied products (SIC 28), contain a heterogeneous mix of highly energy-intensive and energy non-intensive sectors with quite different growth rates. Also, some energy non-intensive 2-digit sectors, such as non-electrical machinery (SIC 35), contain a heterogeneous mix of very fast-growing sectors, along with slow-growing sectors of low, but greater, energy intensity. According to some forecasts, electricity consumption in light-industry sectors, such as SIC 35, could become huge. Therefore, for long-term forecasts, it is as important to disaggregate the fast-growing sectors as it is the basic-materials sectors.

The current version of LIEF organizes industry into 18 sectors, as shown in Table G-1. These sectors include mature, as well as fast-growing low-intensity, manufacturing process sectors, 10 energy-intensive manufacturing process sectors, 4 non-manufacturing sectors, a feedstock sector, and a uranium enrichment sector.

D. REAL ENERGY INTENSITY FORECASTING APPROACH

The fuel intensities of various manufacturing processes fell an average of about 1.2 percent per year before the early 1970s, and fell even more quickly afterwards. Before the 1970s, electricity intensities increased by about 1.8 percent per year in most industries at the 2-digit SIC level; after 1973, these intensities decreased. These trends can be explained by two main developments:

- steady evolution of fundamental process efficiency, and
- steps taken by manufacturing to reduce energy consumption in response to the 1973 and 1979 energy price shocks (conservation and "housekeeping" measures).

1. Fundamental Process Efficiency

Substantial evidence suggests that general progress in production technology tends to reduce all factor inputs, including energy, although there is a tendency for new applications of electricity. This "neutrality" of productivity improvement based on fundamental process change has been discussed.

2. Conservation and Housekeeping Measures

Conservation refers here to investments for which a critical rationale is energy cost reduction. Housekeeping measures are operational changes in response to energy prices. Starting about 1973, industry made major additional efforts of both kinds.

Investment projects differ widely in the importance of energy prices in the entire identification and decision making process leading to project implementation. As a convenient approximation to this distribution of projects, we put each project into either one of two categories: projects where energy price is a primary consideration and projects where it is a minor consideration. Observation of actual project selection procedures and their dependence on project size and project category (i.e., strategic, mandatory, discretionary) suggests that this approximation may be satisfactory, although many of the most desirable small projects have multiple benefits, including energy cost reduction. Even with the latter type of project, in many cases the energy benefits are calculated, while important co-benefits are hard to estimate credibly. The role played by these co-benefits may be to raise the priority given to the project while not affecting the economic analysis as such.

Electrification, primarily new applications of electricity, refers here to projects motivated by process and product improvement rather than by energy costs. For example, empirical evidence suggests that the price of electricity did not affect the adoption of electric-arc furnaces. The conclusion appears to be even stronger for examples in less energy-intensive sectors.

Unlike electrification, fuel substitution refers here to cases where energy prices are a prime consideration in the choice between electricity and fuel. Examples of such cases include motors versus fuel-driven prime movers and high-temperature electric versus fuel furnaces, where the production process is essentially the same.

This analysis does not consider switching among fossil fuels. Such fuel switching is not as important as one might think, since natural gas already dominates fossil fuel consumption for heat and power in almost all manufacturing sectors. Petroleum products are used in sectors where they are critical to the process, such as in feedstocks, at sites unconnected to gas lines, and where they are by-products. Much coal use is process related, as in iron and steel.

Energy intensity forecasting in LIEF rests on the hierarchy of industrial decision making discussed above:

- the choice of fundamental production processes, which is autonomous in the sense that it is not sensitive to energy prices; and

- the choice of energy-related technologies, including some process changes, which is sensitive to energy prices.

For long-term forecasts, it is assumed that operational decisions, as separate from process choices, are not important.

LIEF characterizes energy-price-independent decisions on process technology as a simple time trend in energy intensity (Table G-2). The autonomous trend parameters, B_{ij}, dictate the annual rates at which electricity and fossil fuel intensities change, and the parameter BPR represents the time it takes for the trend to go to zero, of the order of 100 years.

For the choice of energy-related technology, the conservation supply curve (CSC) is adopted as the basic analytical tool. Conservation supply curves can be derived from engineering-economic descriptions of conservation opportunities. This engineering perspective is shown in Figure G-3. The CSC specifies the energy conservation potential as a function of marginal capital cost, analogous to an energy supply curve. The Y-axis is the marginal capital cost of a project, as illustrated in Figure G-4. The X-axis is the cumulative energy savings (over all projects), either as an absolute annual rate (e.g., kWh/yr) or as a percentage. Alternatively, analysts often convert the project's capital costs into a stream of annual payments divided by the annual energy savings, so that the Y-axis is in the same units as the energy price. The use of CSCs in a model introduces variables besides price that provide useful policy analysis handles.

The derivation of the conservation supply curve from an economic perspective is shown in Figure G-5. Part (a) of this figure shows total capital expenditures versus total energy savings per year. Part (b), the CSC, depicts the marginal capital cost as a function of energy savings per year. The CSC yields the capital expenditures required to save an additional unit of energy, given an existing level of energy savings, E_o-E. The CSC rises because conservation opportunities should be taken in order, with the least cost first, and at high levels of existing energy savings it becomes more costly to save an additional unit of energy.

While development of highly detailed CSCs is common practice for the residential and commercial sectors, severe data problems face the construction of CSCs for industry. The CSCs constructed by using the engineering, or bottom-up, approach are lists of identified conservation projects, ordered in terms of increasing cost. Some energy forecasting models with broad industrial coverage are essentially based on this approach. However, the vast heterogeneity of the industrial sector, the often proprietary nature of industrial process technology, frequent confidentiality problems with publicly acquired information, and the lack of experience at high energy prices create severe data problems, particularly for cost information. Consequently, adequate CSCs constructed from the bottom up are often limited to a few specific processes or plants. Examples include a conservation plan for a particular refinery and a study of an integrated steel mill.

The CSCs constructed by analogy extend the applicability of CSCs developed for specific industries or plants to analogous facilities. In this way, broader sector coverage can be obtained. In our opinion, this is a practical approach for constructing adequate CSCs for the entire manufacturing sector.

Table G-2
Overview of LIEF Model Equations

Total Industrial Electricity or Fuel Demand –

$$E_j(t) = \sum EI_{ij}(t)\ Q_i(t)$$

where:

i	=	manufacturing sector
j	=	energy type (only two types are incorporated in the present version: fossil fuel and electricity)
$E_j(t)$	=	total demand for energy type j
$EI_{ij}(t)$	=	energy intensity of sector i for energy type j
$Q_i(t)$	=	production in sector i

Electricity and Fuel Intensities by Sector –

$$EI_{ij}(t) = (1 - Pen)\ EI_{ij}(t-T)\ \exp\ (-B_{ij}(t)T)\ +\ PenIEI_{ij}(t)$$

where:

Pen	=	penetration rate for period T of cost-effective, energy-price-sensitive conservation
IEI_{ij}	=	ideal energy intensity from conservation supply curve for sector i and energy type j
$B_{ij}(t)$	=	declining autonomous trend rate
T	=	length of one period for which forecasts are made

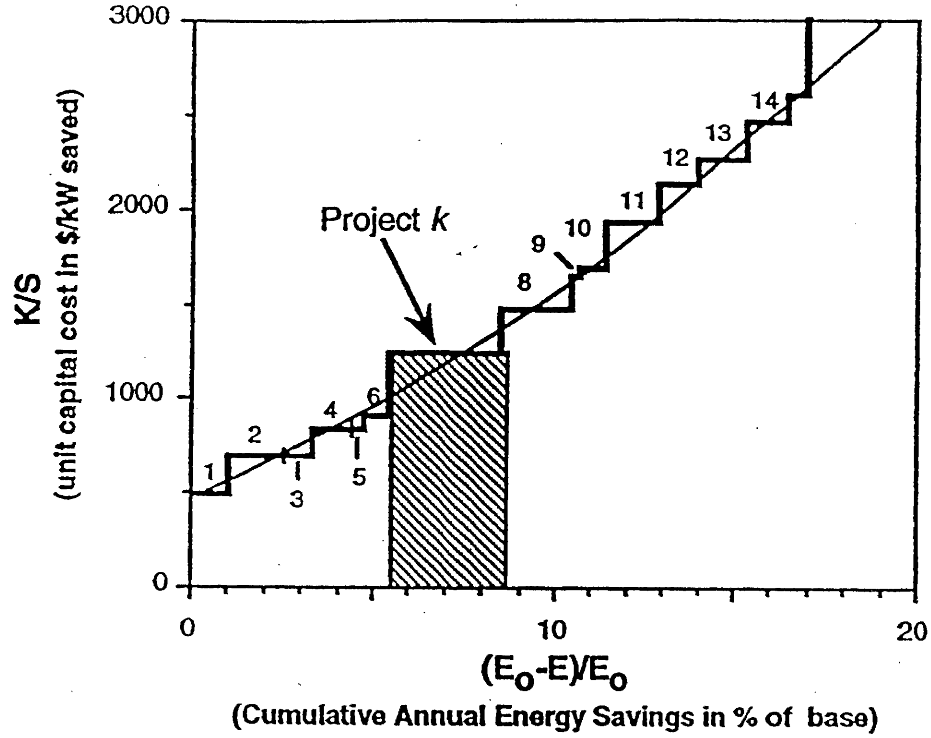
Smoothed Conservation Supply Curve or Ideal Energy Intensity –

$$IEI_{ij}(t) = IEI_{ij}(t_o) \left[\frac{EP_{ij}(t)/CRF(t-T)}{P_{ij}(t_o)/CRF(t_o)} \right]^{-A_{ij}} \exp\ (-\sum\ B_{ij}(t')\ T)$$

where:

A_{ij}	=	CSC price elasticity
CRF	=	capital recovery factor
$B_{ij}(t)$	=	autonomous trend
$EP_{ij}(t)$	=	expected price of energy type j relevant to conservation at time t
$P_{ij}(t_o)$	=	price of energy type j in base year t_o

Figure G-3
Conservation Supply Curve

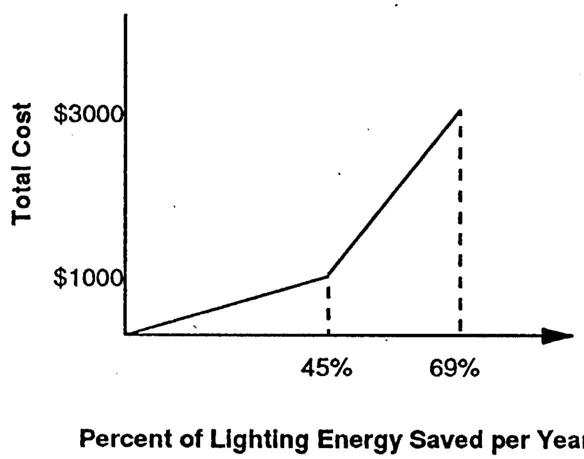


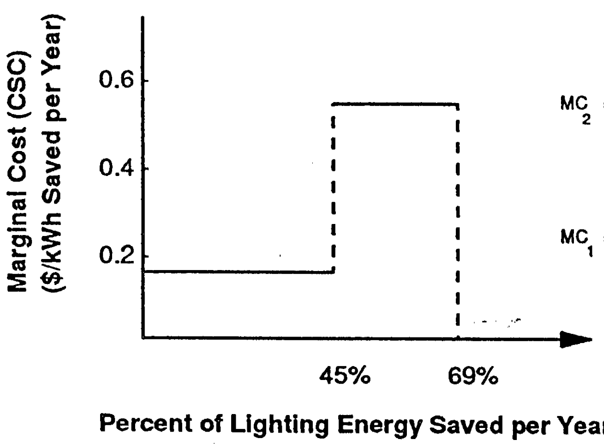
Note: Numbers on curve correspond to hypothetical project number.

Figure G-4
Example of Marginal Costs of Conservation Projects

	Costs per Bulb ($)	Energy Savings (kWh/yr) Percent Reduction	Total Cost of Measure in $ (Assuming Replacement of 100 Bulbs)*
HiEFF	10	45	1,000
VHiEFF	30	69	3,000

NOTES: *Considers two types of lighting: high-efficiency and very high-efficiency. Base energy use is 150 kWh/yr per bulb.

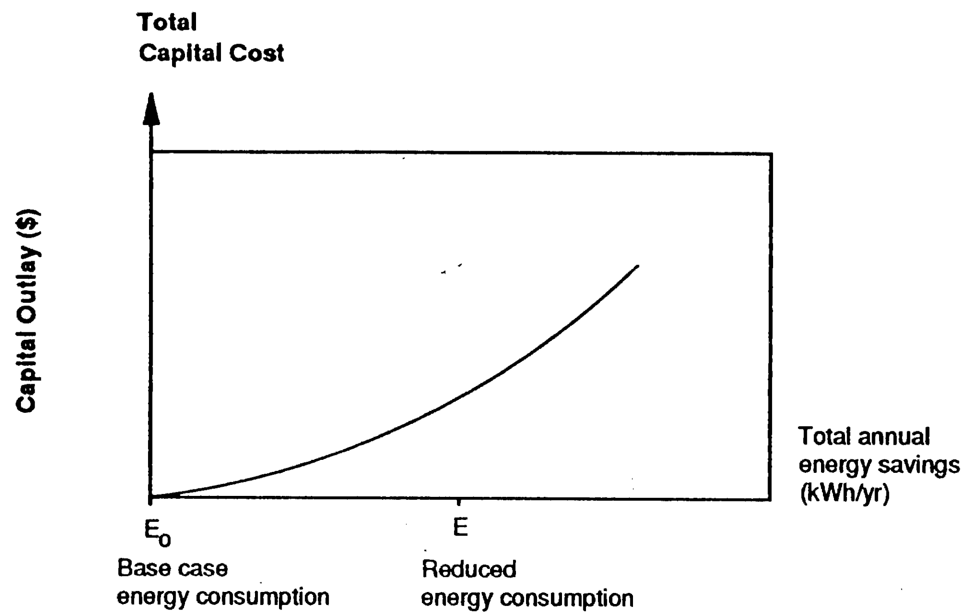




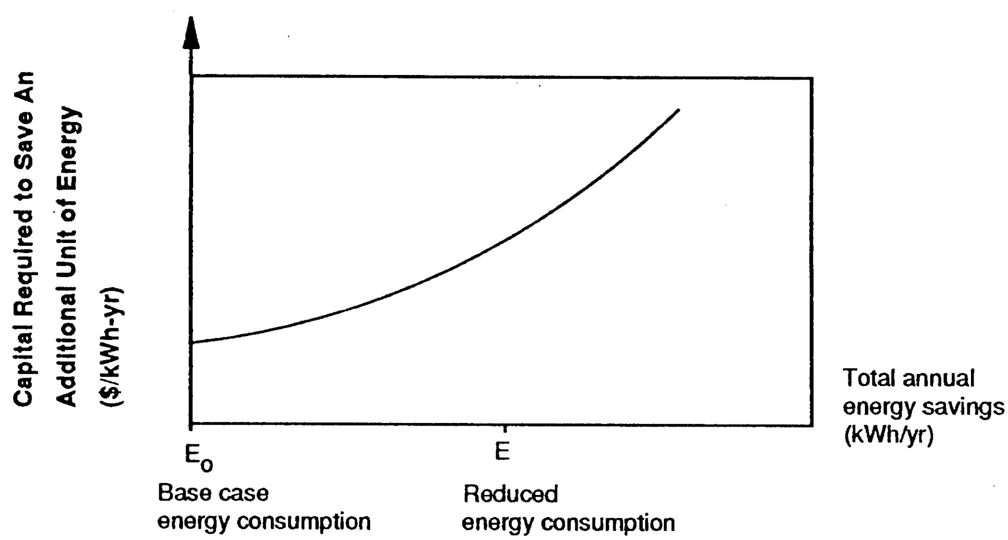
$$MC_2 = \frac{\$30 - \$10}{(69\% - 45\%) * E_0/\text{bulb}} = 0.56 \text{ \$/kWh-yr}$$

$$MC_1 = \frac{\$10}{(45\%) * E_0/\text{Bulb}} = 0.15 \text{ \$/kWh-y}$$

Figure G-5
Conservation Supply Curve Economic Perspective



(a) Capital expenditure as a function of energy saved per year



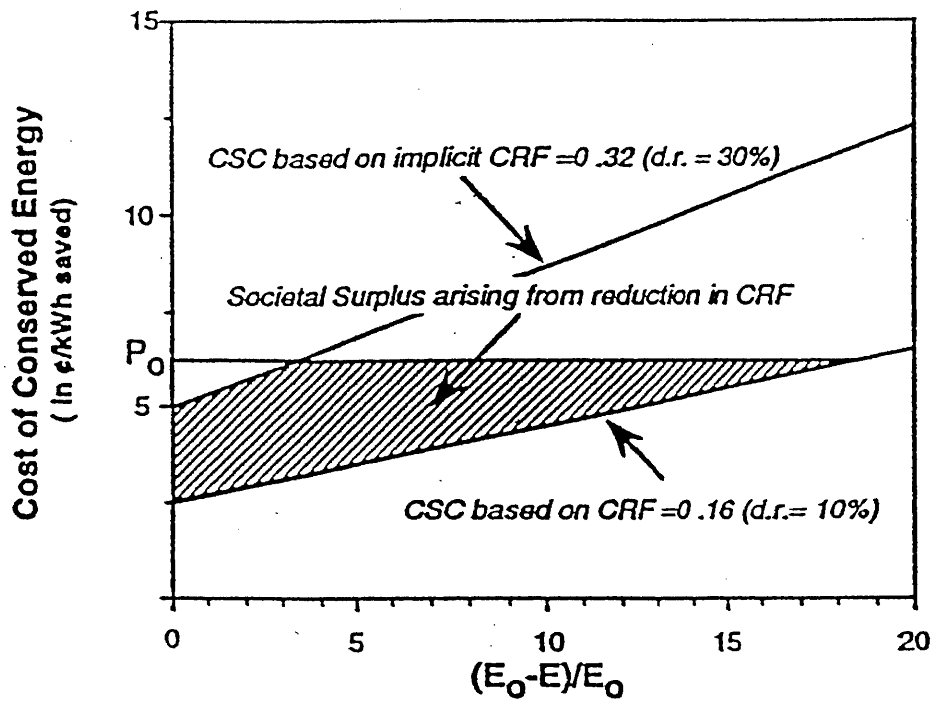
(b) Conservation supply curve (slope of capital outlay curve above)

LIEF characterizes the conservation opportunities through two parameters, A_{ij} and $Gap0_{ij}$, which roughly correspond to the slope and intercept of the CSC, respectively. Statistical analysis of historical data and engineering case studies are used to estimate CSC parameters for each sector and fuel type without specifying the technologies. This method is less detailed than the approaches just discussed. Detailed information is not as relevant for long-term forecasting, however.

In LIEF, a firm finds a conservation project cost-effective if the annualized cost of the measure is less than the energy cost avoided. The project's capital costs are annualized by using the firms *implicit* discount rates as expressed in the capital recovery factor (CRF). A project's attractiveness is then directly proportional to the energy price expected and inversely proportional to the implicit CRF. Energy prices and the CRF determine the "ideal energy intensity," that is, the energy intensity if all firms immediately adopted the most cost-effective projects (while retaining their implicit CRF). Raising price expectations or lowering implicit CRFs increases the ideal level of conservation (Figure G-6). Figure G-6 shows that extent of conservation that is economic at a given price of energy and at a CRF. The last unit of energy saved that is economic satisfies the condition that the annualized cost of conserving the energy equals the price of purchasing the energy.

The penetration rate, pen(t), is a measure of the rate at which industry adopts conservation projects. Firms do not immediately adopt all cost-effective projects for several reasons, such as lack of capital, other business concerns (opportunity costs), or scheduling of production. Also, firms may simply be unaware of conservation opportunities, including new opportunities. An increase in penetration reflects a higher priority given to energy conservation by industry and better dissemination of information.

Figure G-6
Dependence of Conservation Supply Curve on Capital Recovery Factor



(Cumulative Annual Energy Savings in % of base)

Note: CCE calculated assuming project life = 10 yrs