Staff Presentation on Forecasting and Conservation Quantification Methods

Committee Workshop on Energy Efficiency and Forecasting

March 11, 2008

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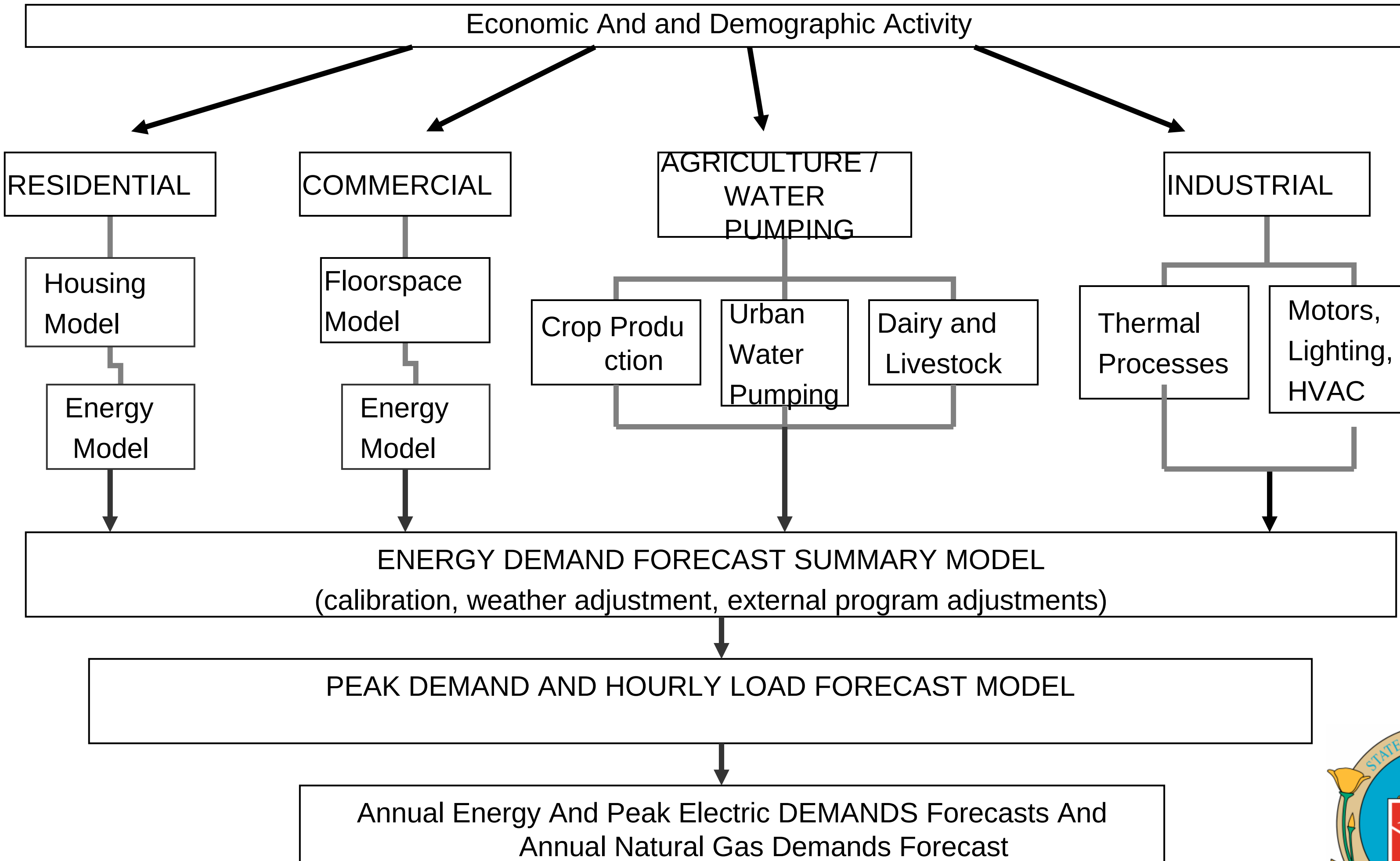
Purpose of staff presentation

- Explanation of staff forecast methods
  - Basic model structure and assumptions
  - How standards and programs are modeled
  - How conservation quantification is done
  - Show the effects of standards and programs on forecast
- Implications for an uncommitted forecast

Staff Forecast Structure



Characteristics of Sector Forecast Models

Sector	Method	Sector Coverage	End-uses Modeled
Residential	End Use Backcast from 1970	Residential electricity and natural gas consumers; 3 housing types	24 appliance and space conditioning categories
Commercial	End Use Backcast from 1975	Electricity and natural gas for 12 building types;	10 equipment and space conditioning categories
Transp., Comm. & Utilities	Trend Analysis	Total electricity and natural gas	None
Street lighting	Trend Analysis	All electricity used for traffic control, street and highway illumination	Streetlights and traffic control devices
Industrial	End Use Forecast	All electricity and natural gas used in the process, extraction, and assembly industries	Motors, thermal processes, lighting, HVAC; process steam, other.
Agriculture	Econometric	All electricity and natural gas used in crop production, livestock, and related commodities	Irrigation pumping, all other
Water Supply	Econometric	Water supply and wastewater agencies	Water supply pumping and treatment for municipal water supply and wastewater

End Use Forecasting

In end use models, demand is measured in terms of end-use energy services. Examples of energy services are the comfort derived from a heated home, the clean dishes from a dishwasher, the illumination from a light fixture.

End-use = a process that uses energy for a particular purpose (i.e. cooking)

Appliance = the specific type of appliance used in that process (i.e. gas stove, electric stove, etc.)

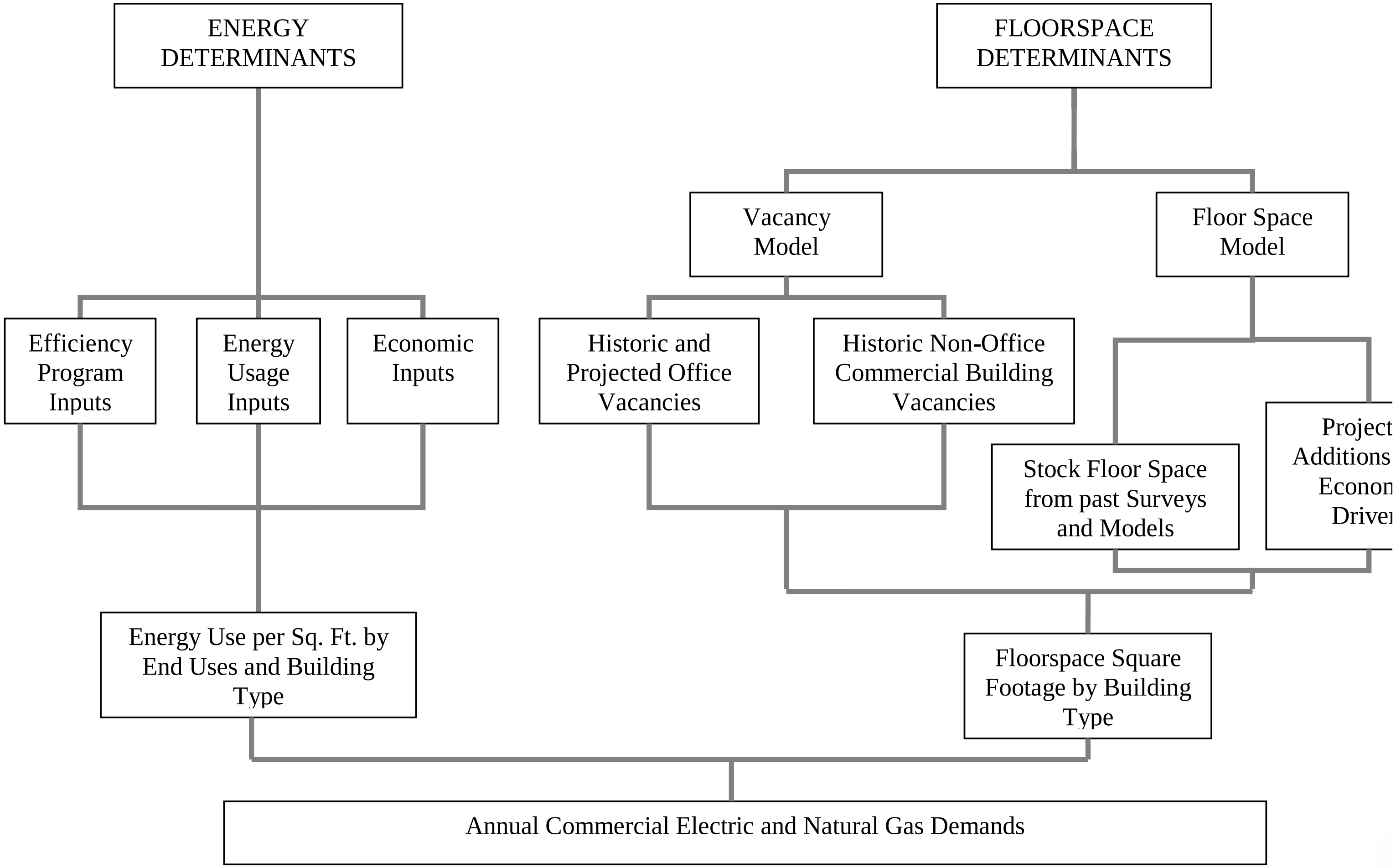
The efficiency of an end use is measured in terms of annual energy use per home, square foot, or economic activity.

Average efficiency is calculated for all equipment of a given end use. “Equipment" or appliance energy use is a *composite* of factors that combine to determine consumption per square foot or household.

Examples:

- Space heating end use efficiency is determined for the composite of heat source, distribution and building shell elements.
- Lighting use per square foot or per home represents the composite effects of the various types and vintages of equipment models

Commercial Forecast Model Structure



Commercial Sector Consumption

Energy use in forecast year "T" for a particular fuel, end use, and building type of vintage year "t" =

End Use Efficiency (U_{Tt}) * Utilization * (% Floorspace Using End Use)

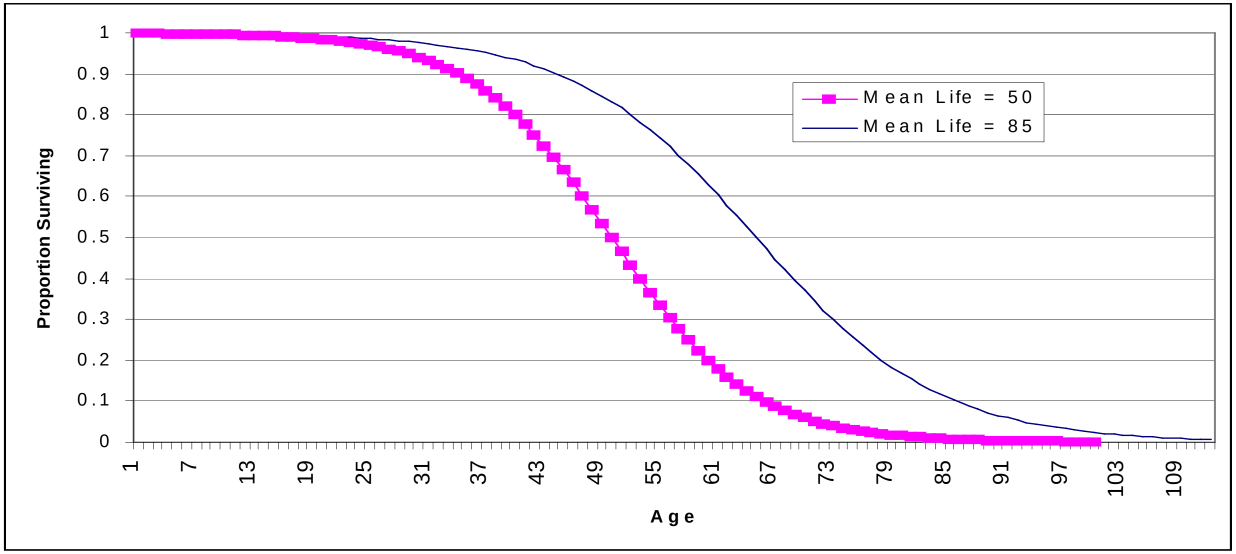
* (New Floorspace + Floorspace Stock remaining in T) *%Occupied

End Use efficiency (U_{Tt}) reflects type and efficiency of energy-using equipment or building. The model keeps track of both building and equipment vintages as well as equipment replacement rates. The efficiency of a particular vintage is a function of:

- price
- the rate of replacement of old equipment
- efficiency levels set by various building and equipment standards.
- assumed rates of compliance with the standards (up to 75%)
- end use efficiency is measured relative to 1977.

Utilization of an end use varies in response to changes in year to year energy prices and utilization elasticity.

Building and Equipment Decay Assumptions



End Use	Mean Equipment Life
Heating	22.3
Cooling	22.3
Ventilation	22.3
Water Heating	11.2
Cooking	22.3
Refrigeration	19.0
Interior Lighting	10.0
Misc.	22.3
Office Equipment	22.3
Exterior Lighting	22.0

	Mean Bldg. Life	Average age of 1964 Stock in 1964 by Climate Zone
Small Office	65	15
Restaurant	65	10
Retail	65	18
Food	65	18
Warehouse	65	20
Refr. Warehouse	65	20
School	85	10
College	85	10
Hospital	85	15
Hotel	65	20
Misc.	85	16
Lrg. Office	65	10

The stock of floorspace or equipment is decayed using a logistic survival function. A shorter life will generally increase savings in the backcast, and reduce savings in the forecast.

Commercial Sector End Use Efficiency

End use efficiency **(U_{Tt})** is a weighted average efficiency of equipment installed in various years within a given building vintage, reflecting the effects of equipment decay, replacement, and the effect of price and equipment standards. For a new building the efficiency under price and equipment standards are compared and only the larger impact is chosen. :

$U_{T,t}$ = Minimum of [U(Price Driven)$_{T,t}$,U(Standard Driven)$_{T,t}$]

Where

U(Price Driven)T,t = $\mathbf{UP_{T-1t'}}$*(1-% Change in Energy Price)* efficiency price elasticity

U(Standards Driven)$_{T,t}$ =

(EUI current year Stds.)/EUI 75 Stds.)*Compliance Rate+UP$_{T,t}$*[1.0-Compliance Rate]

- Compliance starts at 10% in 1st year of a new standard, reaching 75% by 5th year
- Once installed, the equipment efficiency stays constant until it is replaced.
- For an older building, the standards impact is reduced to account for the reduced efficiency of new equipment in an older shell.

Commercial Price Elasticity Assumptions

Commercial Sector Price Elasticities				
	Efficiency		Utilization	
	Elec.	Nat. Gas	Elec.	Nat. Gas
Small Office	0.058	0.093	0.2	0.075
Restaurant	0.058	0.093	0.14	0.075
Retail	0.058	0.093	0.21	0.075
Food	0.058	0.093	0.23	0.075
Warehouse	0.058	0.093	0.12	0.075
Refr. Warehouse	0.058	0.093	0.12	0.075
School	0.058	0.093	0.13	0.075
College	0.058	0.093	0.17	0.075
Hospital	0.058	0.093	0.18	0.075
Hotel	0.058	0.093	0.11	0.075
Misc.	0.058	0.093	0.13	0.075
Lrg. Office	0.058	0.093	0.2	0.075

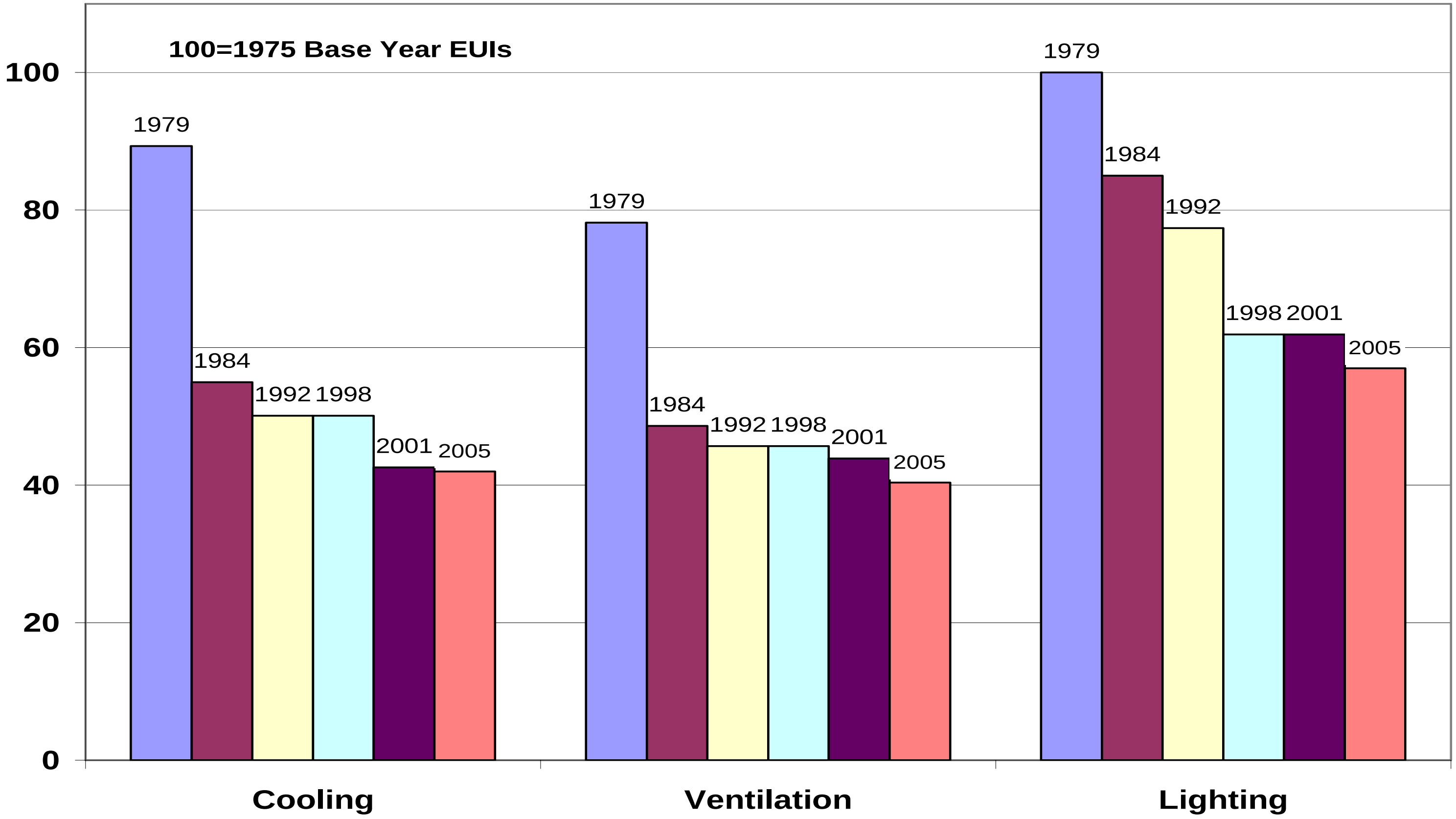
Building and Appliance Standards Impacts

Stds	Cooling	Heating	Fans	Lighting	Water Heating	Ext. Lighting	Refrigeration
1998		NC	NC	Reduction in lighting power density	NC	NC	NC
2001	Reduction in Cooling Equipment Eff .	NC	Reduction in Energy for Lrg. Office & Hosp.	NC	NC	NC	Reduction in Eff.
2005	Duct Insl, Cool Roof, Lighting secondary effect	NC	Reduction in Energy	Reduction in lighting power density	Reduction in Eff.	Reduction	NC

- **Base year end use intensities were developed from building simulations**
- **Impacts for the1998-2005 standards are based on impact analysis done for standards development**
- **Some effects on shell and windows secondary effects on cooling and windows have not been modeled – will be done with incorporation of 2005 commercial end use survey.**

Large Office End Use Intensity

SDG&E Area



Conservation Program Modeling

Program impacts are handled in one of three ways:

1. Some programs have been modeled as part of the commercial sector model. For example, the impacts of a load management audit progam are modeled as followed:

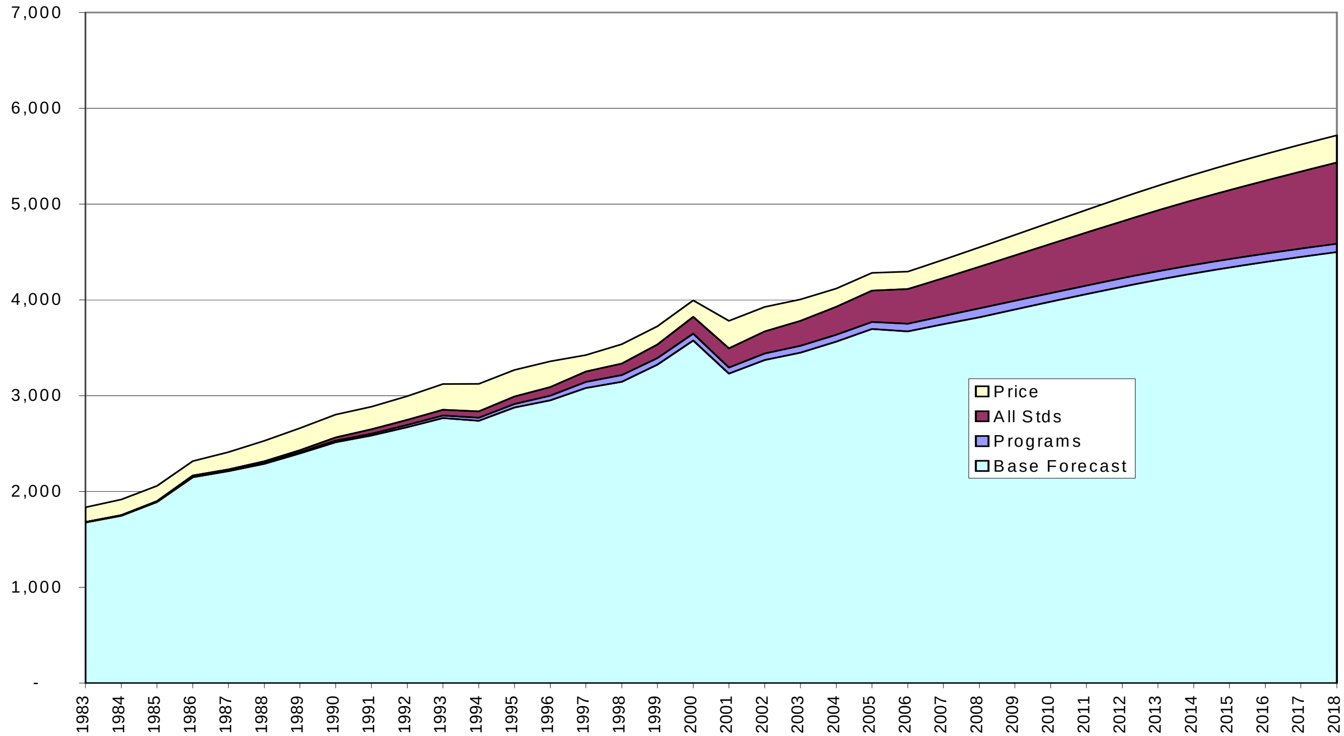
- Quantification is based on initial audit and post-audit reports and other data gathered from the utilities.
- Energy savings per square foot for each end use affected are multiplied by the amount of floor space to be audited in the future to yield annual estimates of gross audit savings.
- Since customers are responding to price levels as well as audits, the gross savings are adjusted to take into account any reduction in energy use from price that would have occurred in the absence of the program. Audited customers are assumed to be representative of average customers and standard short-run price and efficiency elasticities are used.

2. Some programs are modeled externally in the summary model, such as new construction programs to implement measures that exceed Title 24 requirements.

3. Other programs, such as rebates for retrofit activities, are not adjusted for based on staff's assessment that standards and price effects already reflect these impacts.

Conservation Quantification

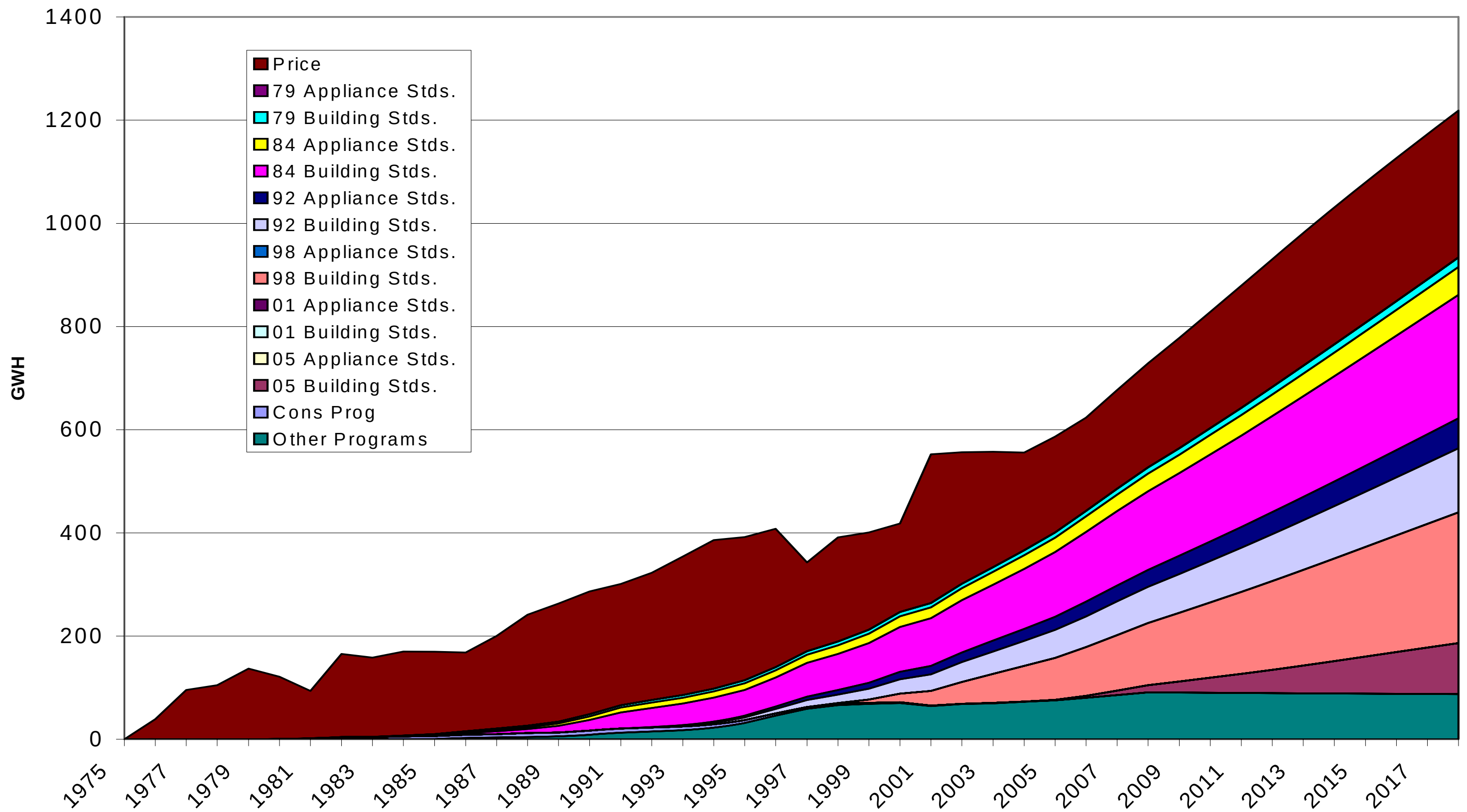
(SDG&E Commercial Sector)



- **To quantify conservation effects in the model, successive iterations of the model are run with prices, standards, and programs removed.**
- **The top line represents consumption with all effects from prices, programs or standards removed.**

Conservation Impacts by Category

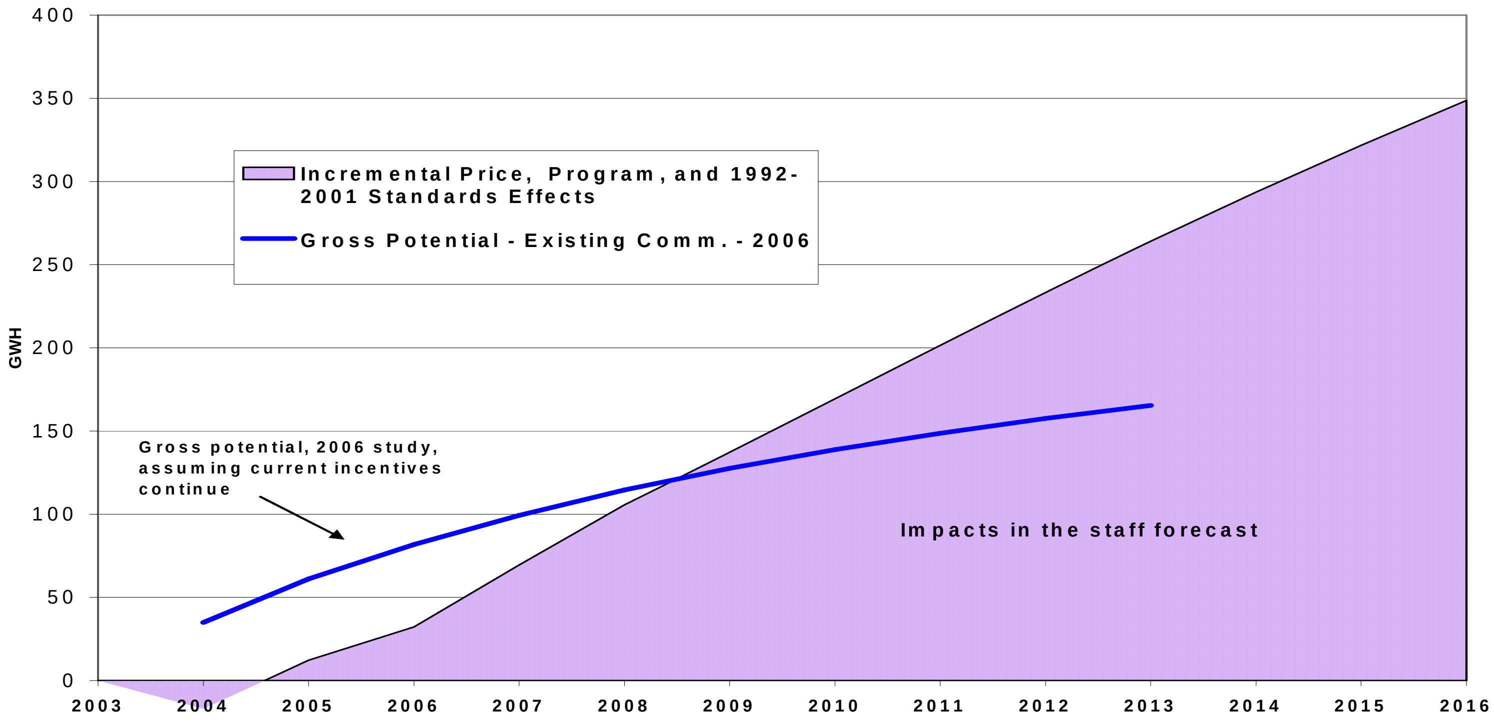
(SDG&E Commercial Sector)



- **The difference between successive iterations of the forecast represent conservation impacts from that program or standard.**

Conservation Impacts on Commercial lighting

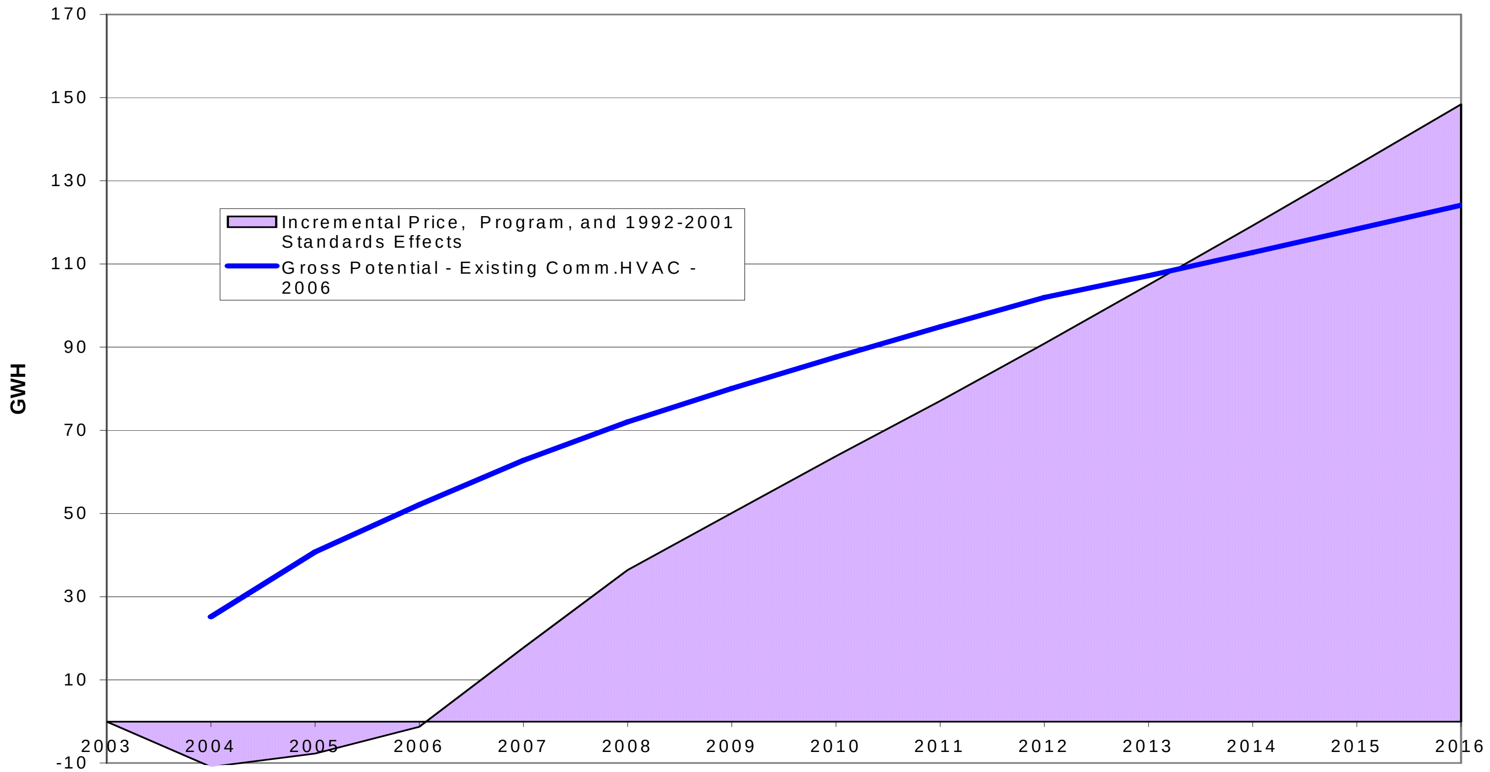
(SDG&E Area)



- Taking the incremental conservation effects from 2003 allows a rough comparison with program plans or potential study scenarios
- By 2010, the impacts in the staff forecast for existing commercial lighting exceed the gross impacts from the current incentives case in the 2006 potential study.

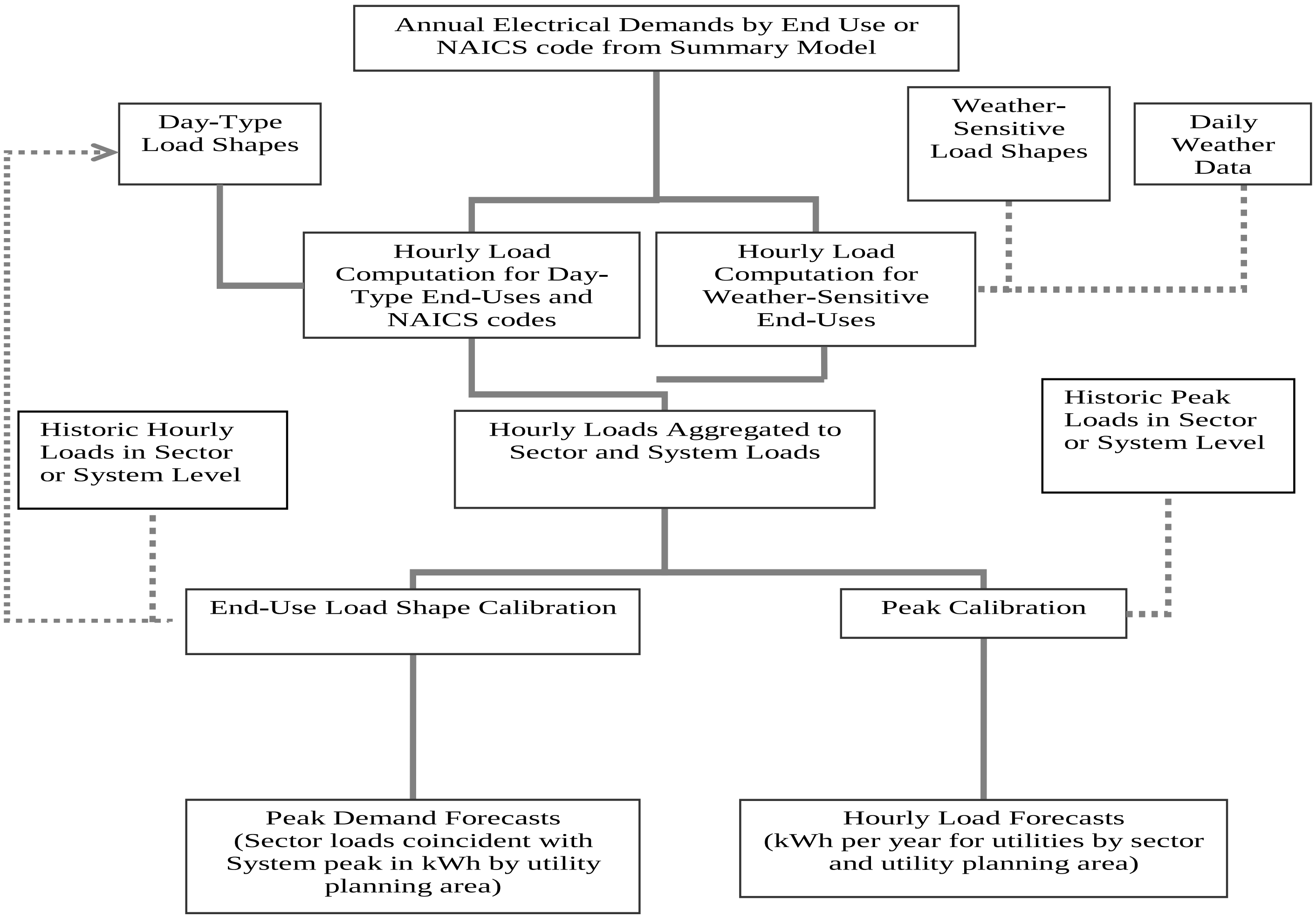
Conservation Impacts on HVAC

(SDG&E Area)



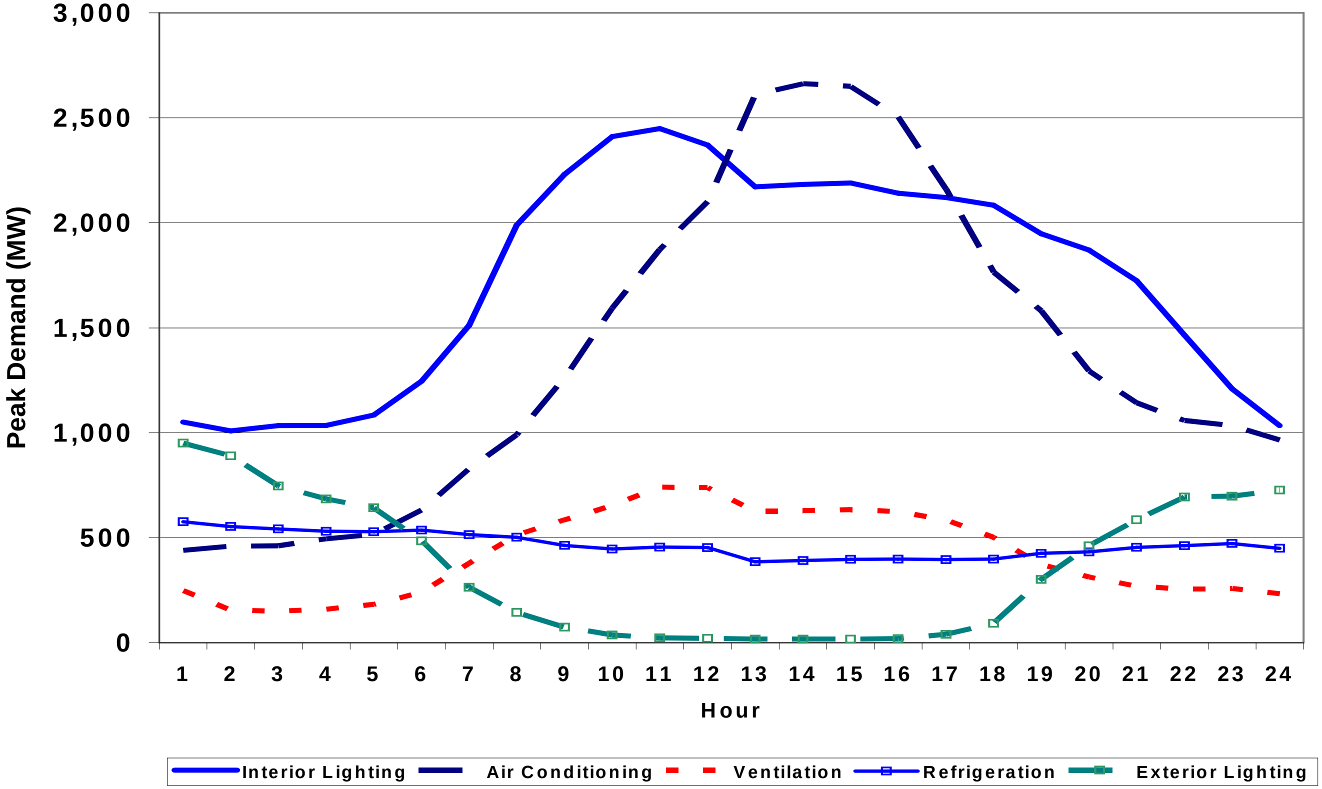
- The impacts in the staff forecast for existing commercial heating, cooling, and ventilation reach the gross impacts from the current incentives case in the 2006 potential study by 2014.

Structure of Hourly and Peak Demand Forecast



Commercial Sector Peak Day Load Shapes

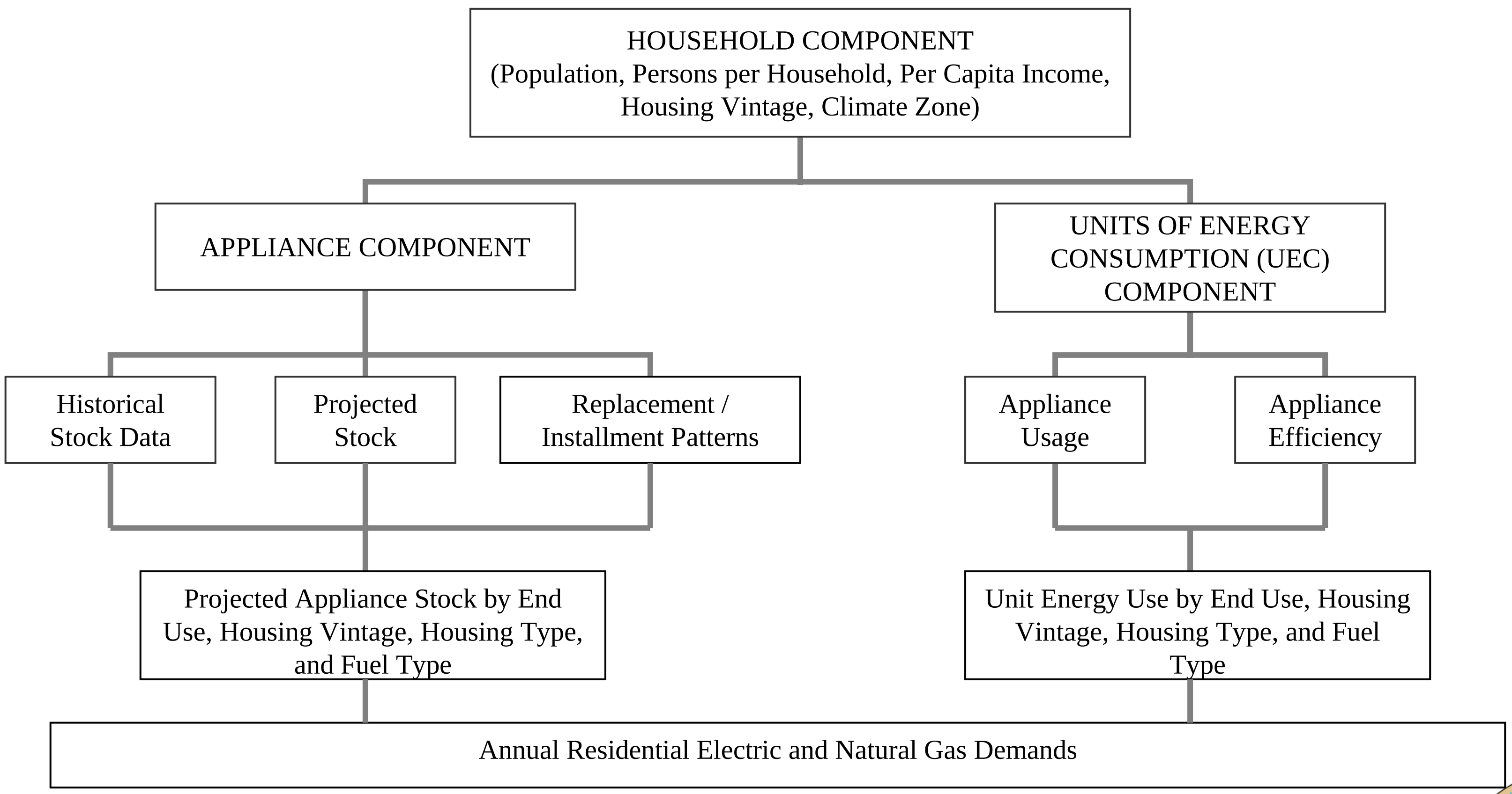
(Major end uses for the SCE Area Peak Day 2003)



- **Conservation impacts in the sector models translate to lower peak demand for that end use.**
- **The impact of programs or standards on system peak will vary depending on the end uses targeted.**

Residential Model Components and Conservation Assumptions

Residential Energy Forecast Model



Residential Model Structure

24 End Use Categories, 3 Household Types, 2 Fuel Types

$$\mathbf{Consumption}_{e,t} = \mathbf{HOUSES}_{t} * \mathbf{ASAT}_{e,t} * \mathbf{UEC}_{e,t}$$

where:

Consumption = end-use consumption

HOUSES = households

ASAT = appliance saturation

UEC = average unit energy consumption for each end-use

e = index of appliance end-uses relevant to a particular fuel type

t = year index.

$\mathbf{HOUSES}_{t} * \mathbf{ASAT}_{e,t}$ = total number of appliances of type e in year t

Households Tracked by Year of Construction

	SMUD Single Family Homes											
	(Forecast year down, construction year across)											
	TOTAL	New Homes										
	HOMES	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1980	202659	5075										
1981	205428	5063	3261									
1982	208393	5050	3253	3464								
1983	214416	4953	3191	3397	10034							
1984	220040	4883	3146	3349	9892	8653						
1985	227802	4797	3090	3290	9718	8501	11633					
1986	235466	4786	3083	3282	9695	8480	11605	8217				
1987	241647	4774	3075	3274	9671	8459	11576	8197	6753			
1988	249856	4761	3067	3265	9644	8435	11544	8174	6734	8896		
1989	260622	4727	3045	3242	9577	8377	11463	8117	6687	8834	12504	
1990	269090	4716	3038	3235	9553	8356	11435	8097	6671	8813	12473	9101

End-Uses (Appliances) Tracked by Year of Purchase

	SMUD Single Family Freezers											
	(Forecast year down, purchase year across)											
	TOTAL	New Appliances										
	FREEZERS	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1980	48436	1811										
1981	48686	1739	1377									
1982	49264	1669	1322	1708								
1983	50559	1602	1269	1640	2749							
1984	51753	1538	1218	1574	2639	2590						
1985	53442	1477	1170	1511	2533	2486	3184					
1986	55099	1418	1123	1451	2432	2387	3057	2898				
1987	56706	1361	1078	1393	2335	2291	2934	2782	2887			
1988	58799	1306	1035	1337	2241	2200	2817	2671	2772	3419		
1989	61507	1254	993	1283	2152	2112	2704	2564	2661	3282	4173	
1990	63381	1204	954	1232	2066	2027	2596	2461	2554	3151	4006	3304

Disaggregation of Appliance Calculation in Year *t*

An appliance saturation is the percentage of households owning a particular appliance. Historic saturations are derived from the 1970 Census and subsequent appliance survey data provided by utilities.

Overall saturations are calculated from the previous year's overall saturation plus the current year marginal saturations (MS).

Marginal saturations (MS) are determined by the percentage of households that buy a new appliance in a given year.

These households comprise four categories of potential markets (PM) for new appliances:

PM1 = homes constructed in the current year
PM2 = Existing homes that as yet do not have the end-use appliance
PM3 = Existing homes with an appliance that failed in the current year
PM4 = Existing homes that replace an operating appliance with a new appliance.

For some end-uses PM3 and PM4 are split into the fuel types of the appliance that existed and the appliance that replaced it. Marginal saturation values, MS1 - MS4, are the saturation values corresponding to the potential markets, PM1 - PM4.

The primary advantage of the potential market approach for marginal saturations is that policy measures that affect only one or two of the potential markets may be modeled directly.

End-Uses affected by appliance standards

Refrigerators (Standard and Frost-Free)
Freezers
Room Air Conditioners
Dishwasher Motors
Dishwasher (water use)
Clothes Washer (water use)
Water Heaters

End-Uses effected by both building and appliance standards

Space Heating (electric and natural gas)

Central Air Conditioning

Water Heating (from measures providing reductions in water use)

Benchmarks for Savings Estimates

Savings estimates in appliances (due to standards and programs) are benchmarked to pre-1978 efficiencies.

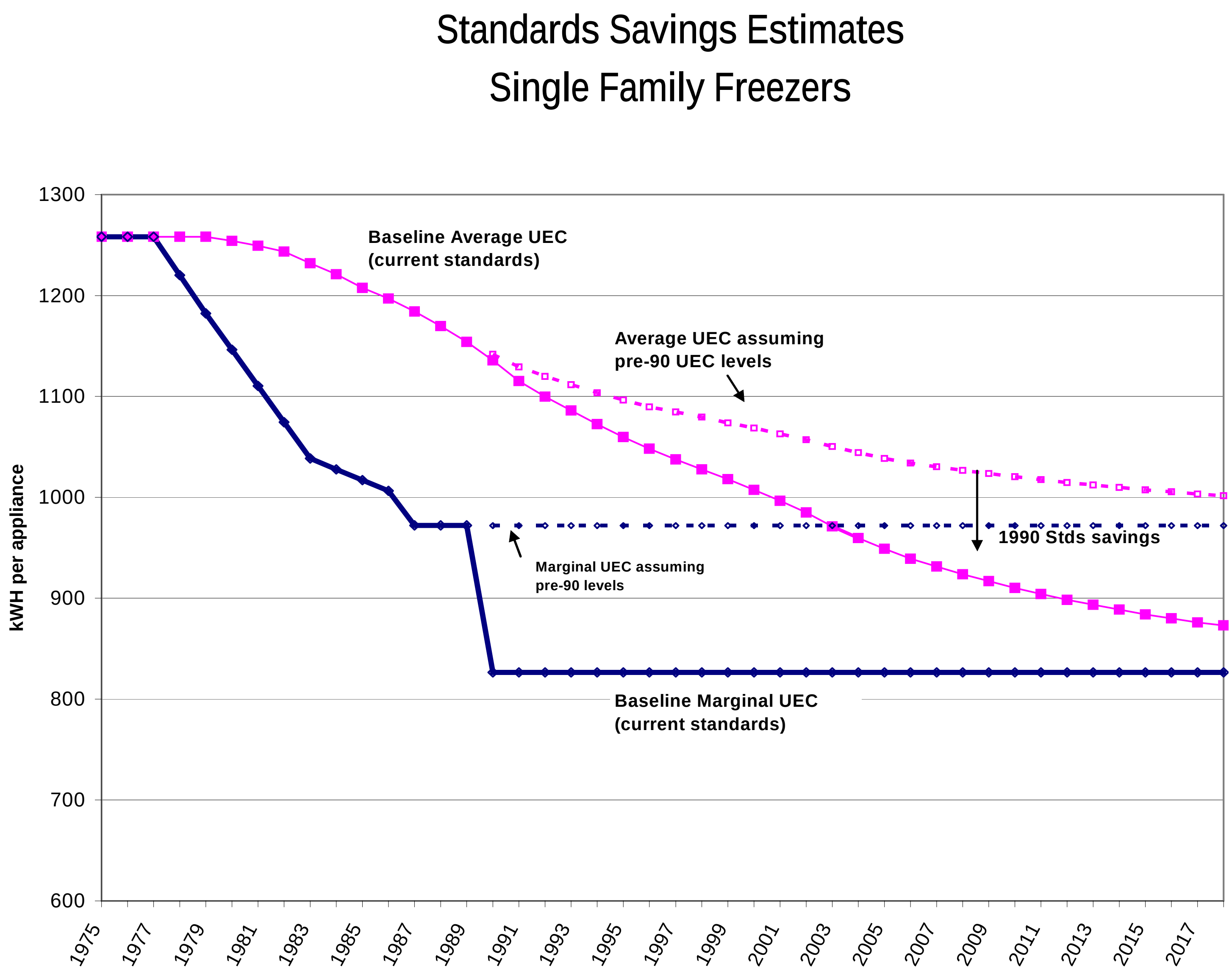
Savings estimates in building shell improvements for heating and cooling are benchmarked to pre-1975 construction practices.

Savings for heating and cooling are a combination of both building shell improvements and appliance improvements.

Use per Appliance Due to Standards

(relative to year shown in yellow)

	year	pre 1960	1970	1978	1980	1983	1987	1990	1992	2001+
frost-free refrigerators	reduction factor	1.200	1.300	1.000	0.880	0.730	0.682	0.652	0.517	0.542
	year	pre 1960	1970	1978	1980	1986	1987	1989	1990	1992+
standard refrigerators	reduction factor	1.100	1.150	1.000	0.940	0.935	0.916	0.916	0.870	0.674
	year	pre 1979	1979	1983	1986	1987	1989	1990+		
freezers	reduction factor	1.000	0.940	0.825	0.800	0.773	0.773	0.652		
	year	pre 1981	1984+							
dish washer motor	reduction factor	1.000	0.900							
	year	pre 1980	1980+							
room A/C	reduction factor	1.000	0.820							
	year	pre 1980	1982	1987	1988	1991	1992	2005	2006+	
central A/C	reduction factor	1.000	0.770	0.770	0.740	0.740	0.672	0.672	0.517	
	year	pre 1981	1981+							
electric space heat	reduction factor	1.000	0.500							
	year	pre 1980	1981	1991	1992+					
gas space heat	reduction factor	1.000	0.900	0.900	0.865					


Standards Savings Estimates
Single Family Freezers
kWH per appliance
1300
1200
1100
1000
900
800
700
600
Baseline Average UEC
(current standards)
Average UEC assuming
pre-90 UEC levels
1990 Stds savings
Marginal UEC assuming
pre-90 levels
Baseline Marginal UEC
(current standards)
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

Retrofit and Building Standards Single Family Insulation Penetration Estimates (PG&E Zone 2 Gas Central Heat)

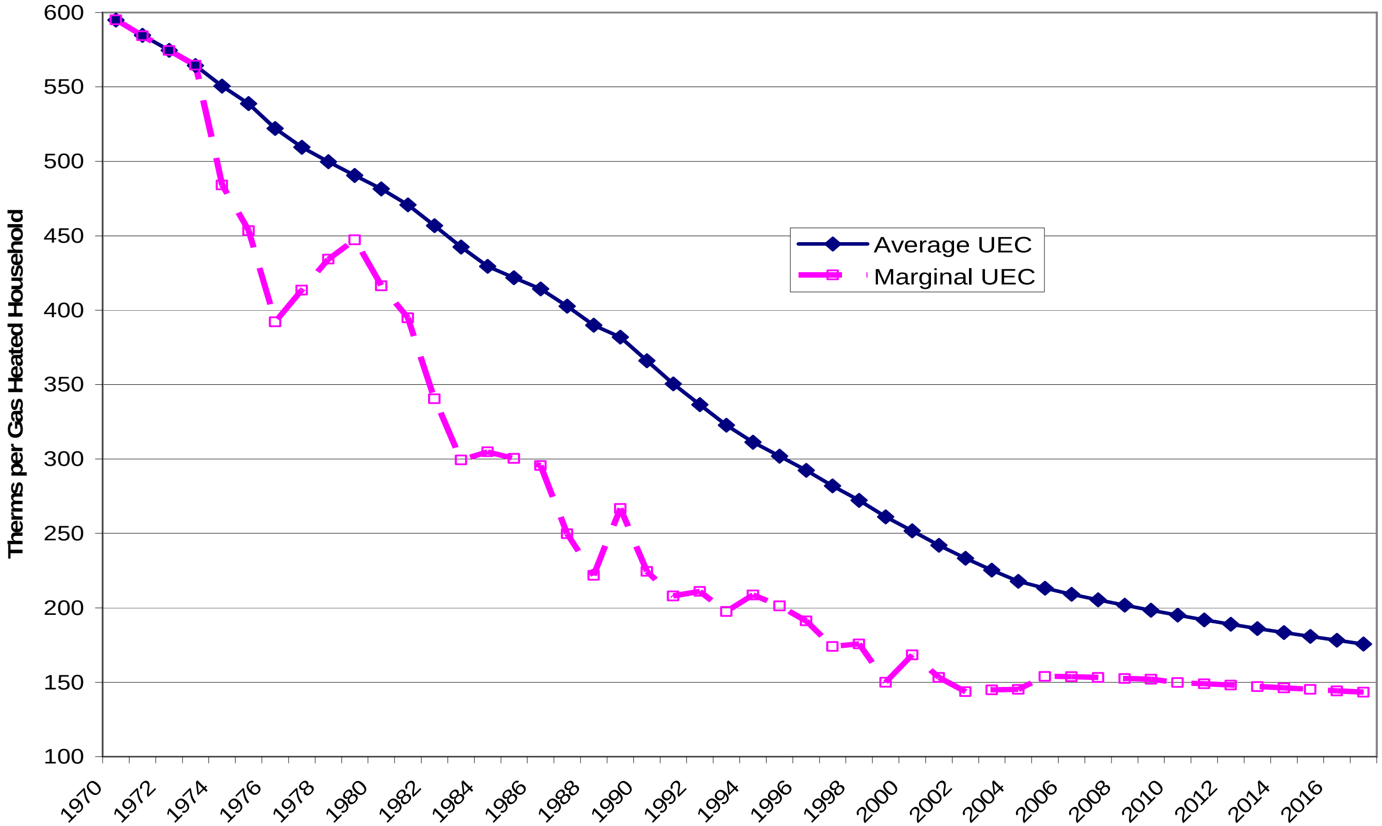
Ceiling Insulation									
	Pre 75 Housing Vintage (existing and retrofit)								
	1975	**1979**	**1983**	**1985**	**1987**	**1990**	**2000**	**2002**	**2018**
PENR0	30%	27%	23%	17%	17%	16%	15%	15%	15%
PENR7	15%	13%	11%	7%	7%	6%	5%	5%	5%
PENR11	25%	24%	23%	18%	18%	17%	16%	16%	15%
PENR19	30%	34%	40%	51%	52%	53%	55%	55%	55%
PENR30	0%	2%	3%	7%	7%	8%	9%	9%	10%
	75-83 Housing Vintage (standards)								
PENR19	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Post 83 Housing Vintage (standards)								
PENR38			100%	100%	100%	100%	100%	100%	100%

Wall Insulation									
	Pre 75 Housing Vintage (existing and retrofit)								
	1975	**1979**	**1983**	**1985**	**1987**	**1990**	**2000**	**2002**	**2018**
PENR0	75%	74%	73%	70%	70%	69%	69%	68%	66%
PENR11	25%	26%	27%	30%	30%	31%	31%	32%	34%
	75-83 Housing Vintage (standards)								
PENR11	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Post 83 Housing Vintage (standards)								
PENR11			25%	25%	25%	25%	25%	25%	25%
PENR19			75%	75%	75%	75%	75%	75%	75%

Reductions in Home Heating Requirements (per square foot) Due to Building Standards

			Housing Vintage				
Forecast Zone	Utility	Region	pre 1975	1975-78	1979-82	1983-92	1993+
1	PG&E	North Coast and Mountain	1.0000	0.800	0.711	0.455	0.423
2	PG&E	Sacramento	1.0000	0.833	0.738	0.478	0.430
3	PG&E	North and South Valley	1.0000	0.833	0.739	0.472	0.425
4	PG&E	East Bay	1.0000	0.833	0.727	0.427	0.410
5	PG&E	San Francisco	1.0000	0.833	0.724	0.412	0.396
6	SMUD	Sacramento	1.0000	0.833	0.753	0.494	0.445
7	SCE	Southern San Joaquin	1.0000	0.833	0.705	0.441	0.396
8	SCE	Coastal LA Basin	1.0000	0.833	0.694	0.468	0.449
9	SCE	Inland LA Basin	1.0000	0.833	0.701	0.490	0.470
10	SCE	Inland Empire	1.0000	0.833	0.713	0.524	0.503
11	LADWP	Coastal LA	1.0000	0.833	0.694	0.483	0.464
12	LADWP	Inland LA	1.0000	0.833	0.689	0.482	0.462
13	SDG&E	San Diego	1.0000	0.833	0.689	0.462	0.444

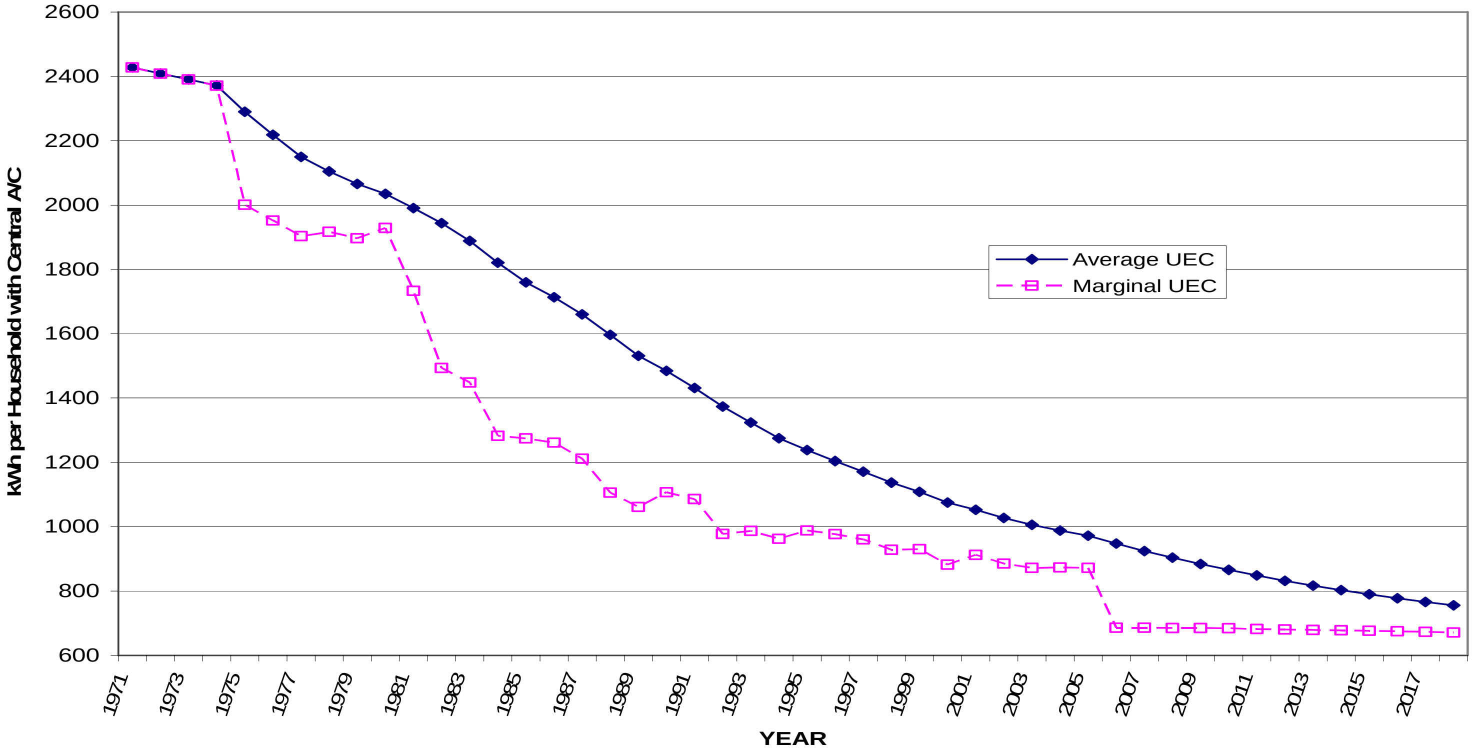
Baseline Annual Average and Marginal Gas Space Heating UECs resulting from Building and Appliance Standards and Building Shell Retrofits (PG&E Forecast Zone 2)



Reductions in Home Cooling Requirements (per square foot) Due to Building Standards

			Housing Vintage				
Forecast Zone	Utility	Region	pre 1975	1975-78	1979-82	1983-92	1993+
1	PG&E	North Coast and Mountain	1.0000	0.909	0.875	0.719	0.719
2	PG&E	Sacramento	1.0000	0.909	0.883	0.689	0.675
3	PG&E	North and South Valley	1.0000	0.909	0.886	0.743	0.728
4	PG&E	East Bay	1.0000	0.909	0.881	0.692	0.685
5	PG&E	San Francisco	1.0000	0.909	0.873	0.740	0.740
6	SMUD	Sacramento	1.0000	0.909	0.851	0.603	0.603
7	SCE	Southern San Joaquin	1.0000	0.909	0.881	0.760	0.745
8	SCE	Coastal LA Basin	1.0000	0.909	0.909	0.809	0.801
9	SCE	Inland LA Basin	1.0000	0.909	0.908	0.812	0.796
10	SCE	Inland Empire	1.0000	0.909	0.894	0.794	0.778
11	LADWP	Coastal LA	1.0000	0.909	0.895	0.759	0.752
12	LADWP	Inland LA	1.0000	0.909	0.898	0.817	0.801
13	SDG&E	San Diego	1.0000	0.909	0.905	0.804	0.804

Baseline Annual Average and Marginal Central A/C UECs resulting from Building and Appliance Standards and Building Shell Retrofits (PG&E Forecast Zone 2)



Measures Affecting Water Heating

Various Iterations of Appliance Standards

Various Iterations of Building Standards regarding water use

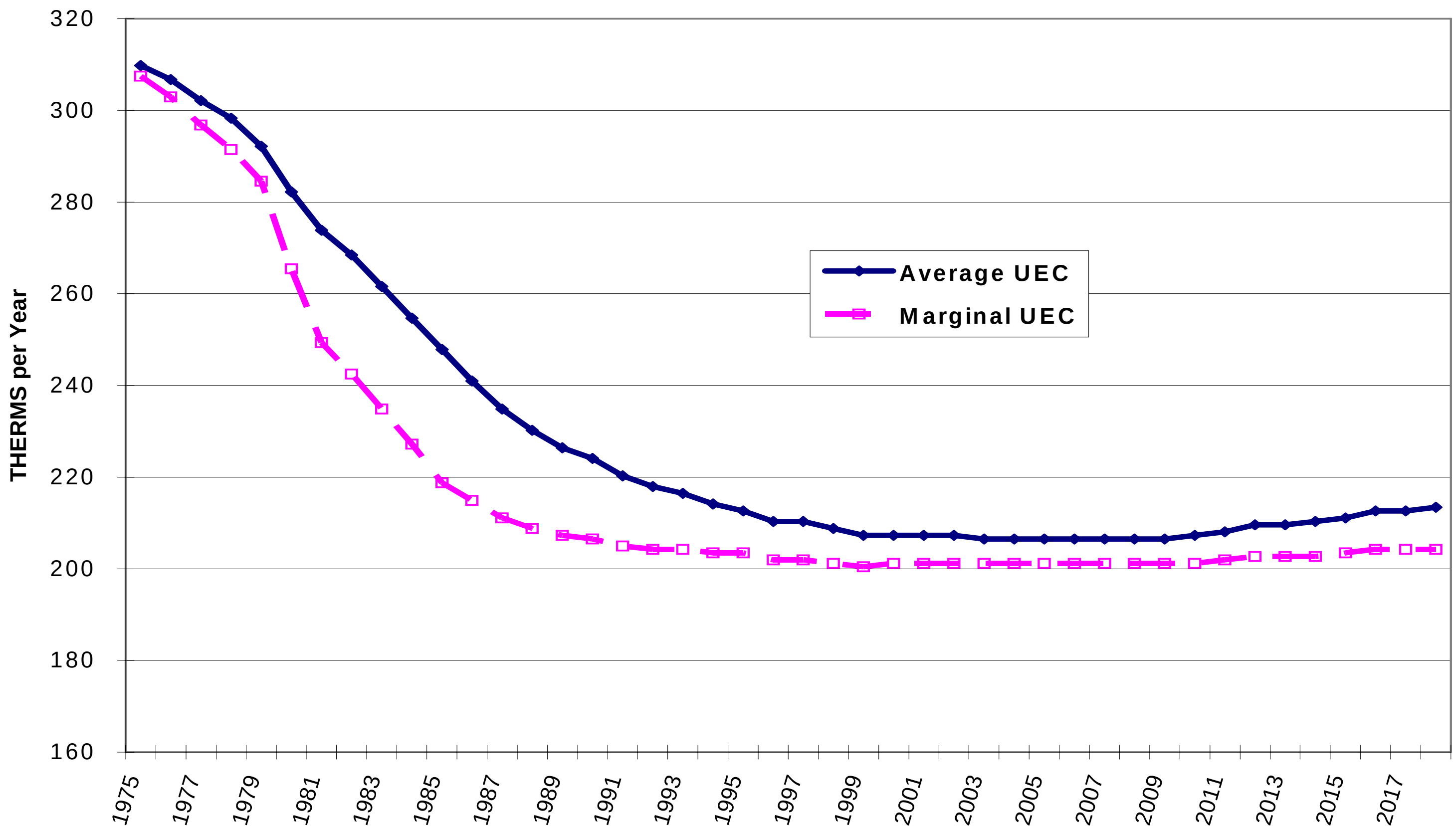
Behavior regarding temperature setting

Retrofit of low flow water devices (i.e. shower-heads)

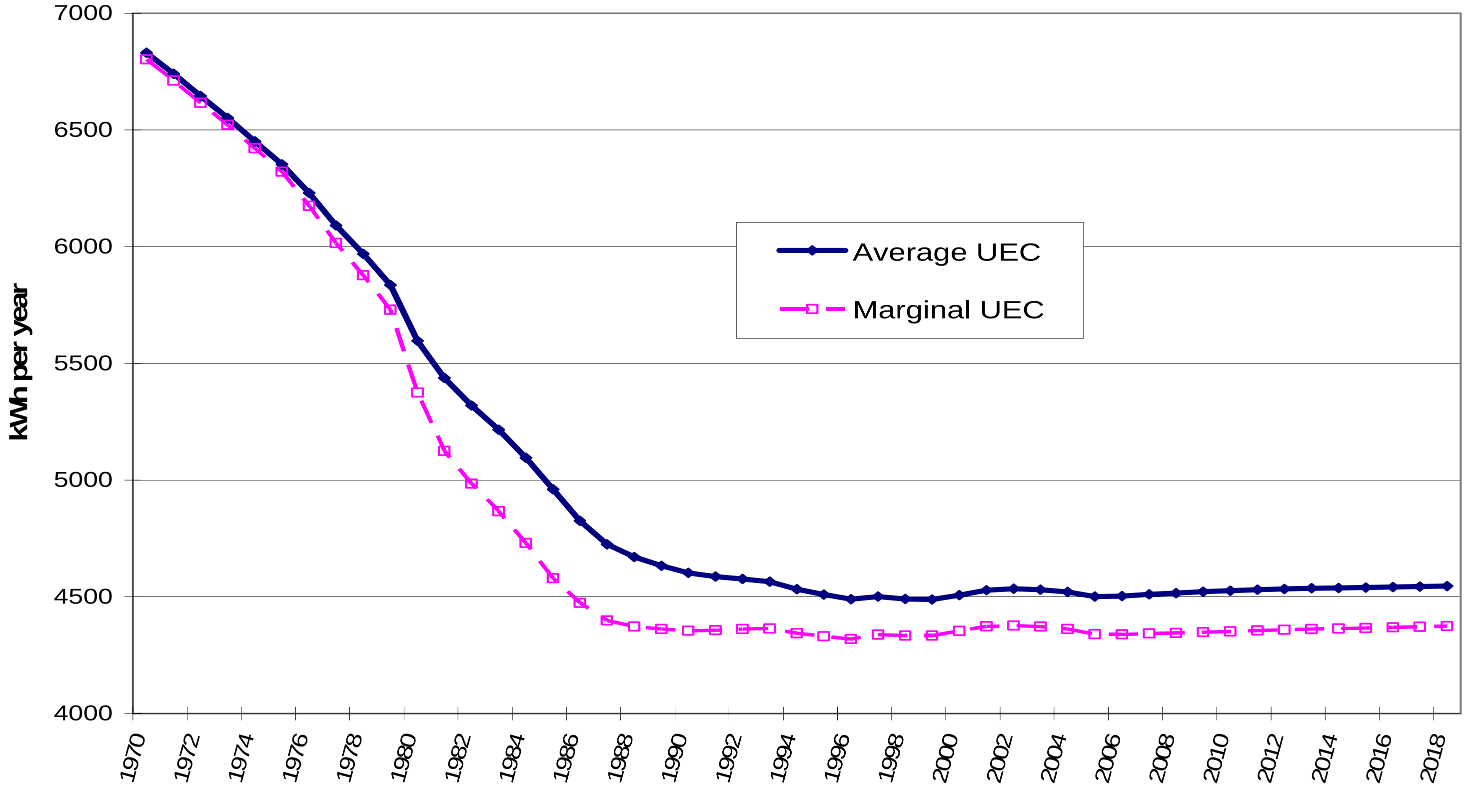
Penetration of cold water clothes washing

Retrofit of water heater blankets

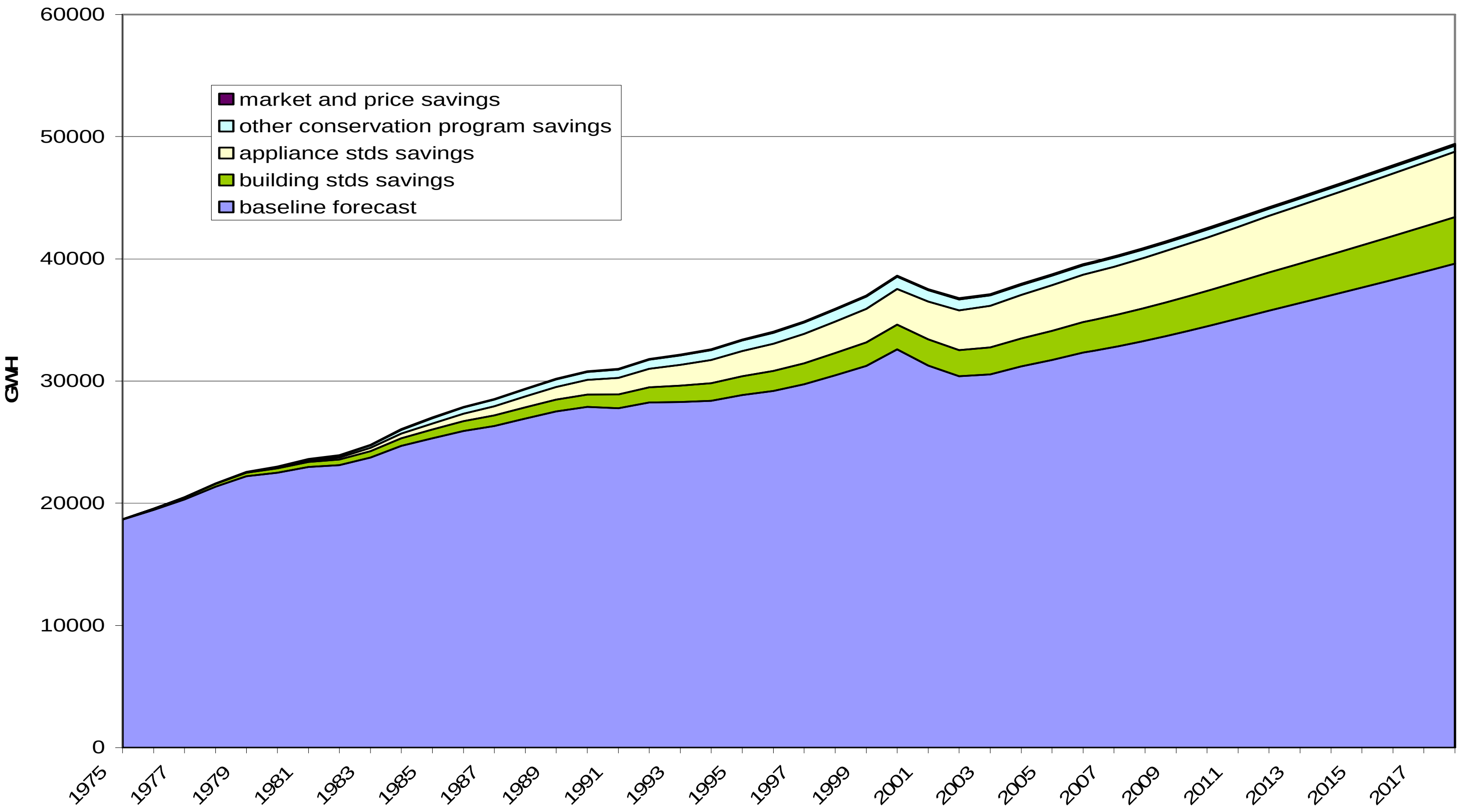
Baseline Annual Average and Marginal Gas Water Heating UEC's resulting from Building and Appliance Standards and Retrofits (PG&E Single Family)



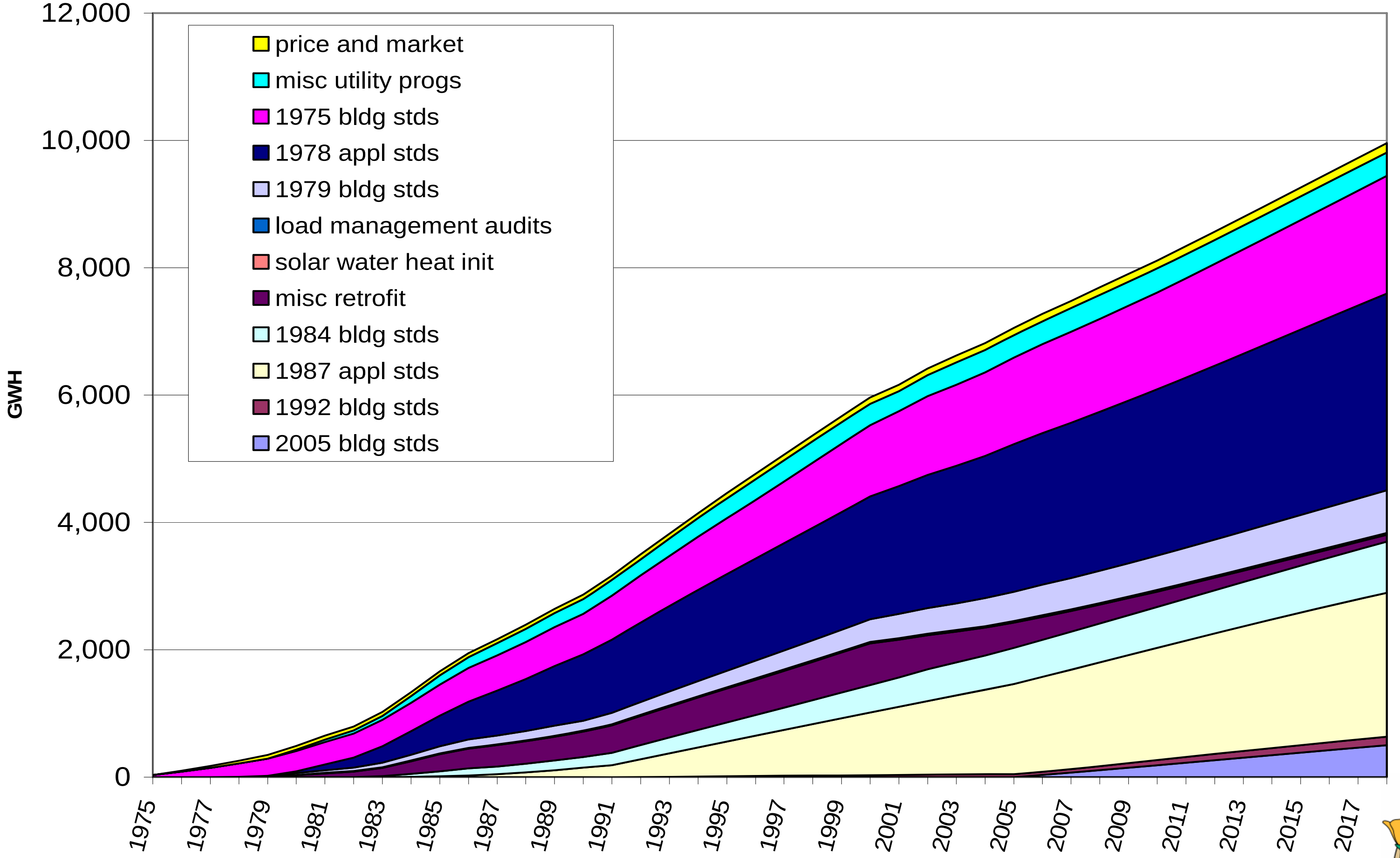
Baseline Annual Average and Marginal Electric Water Heating UEC's resulting from Building and Appliance Standards and Retrofits (PG&E Single Family)



Aggregate Conservation Impacts
PG&E Residential

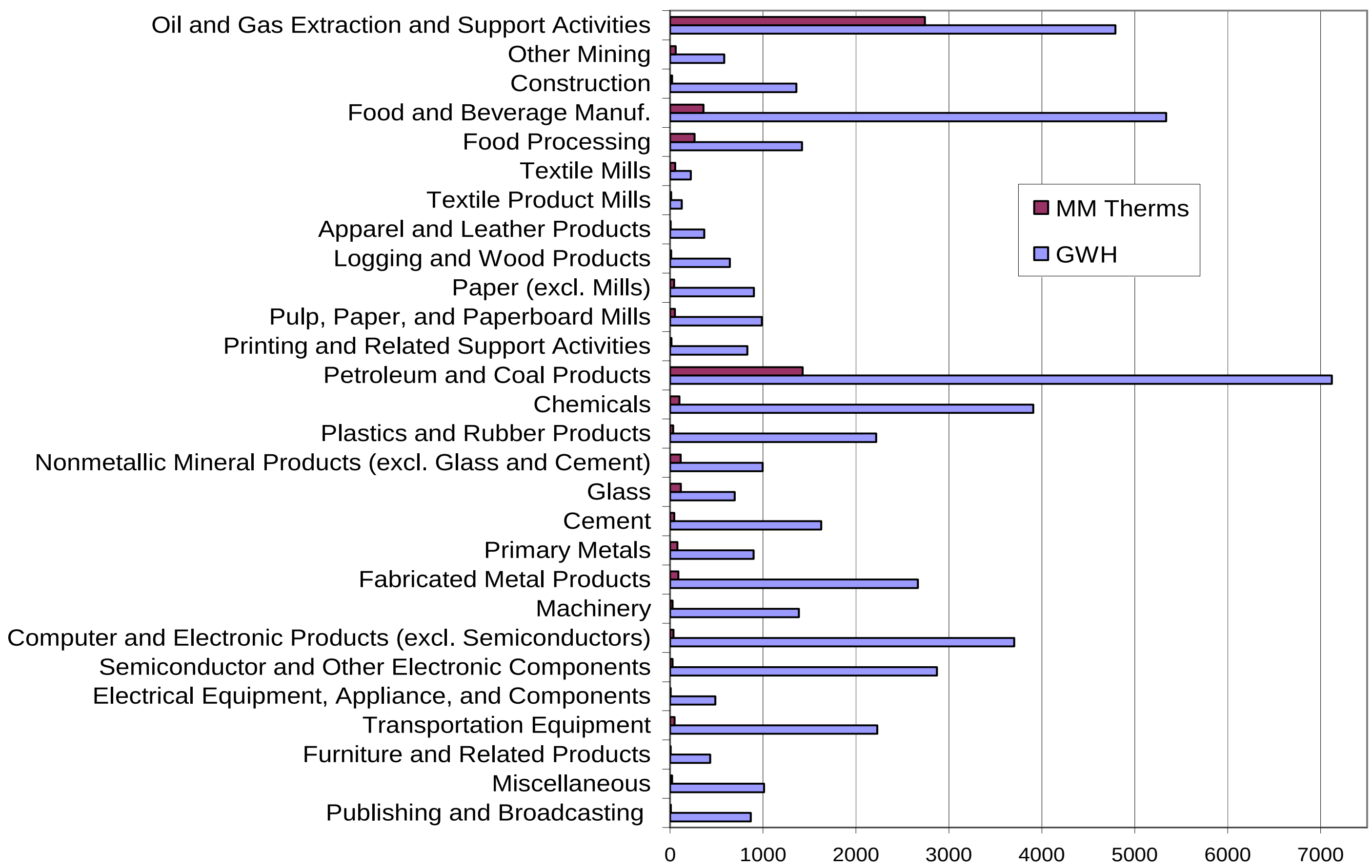


Conservation Impacts by Program
PG&E Residential

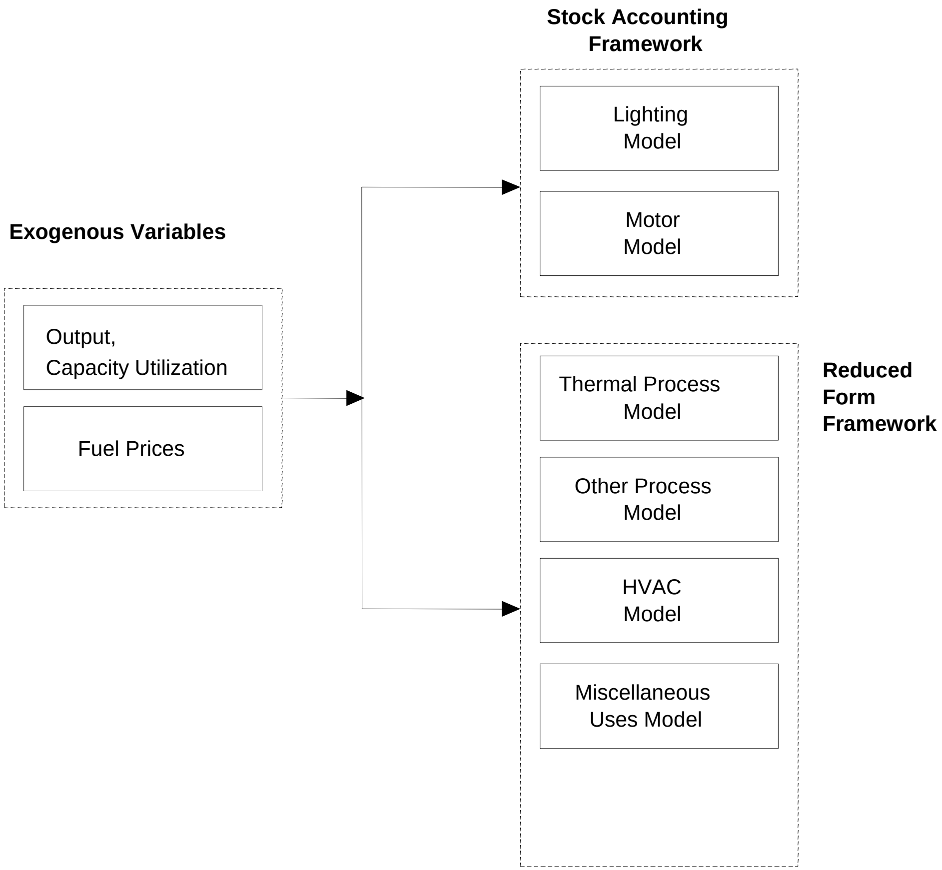


Industrial Sector Forecast Groups

2006 Electricity and Natural Gas Consumption (includes self-generated elec.)



Industrial Sector Forecast Methods



Process End Use Forecast

Annual energy use in an industry for a given thermal use u, equipment option e, and fuel f (gWh or bBtu);

$$ENERGY_{ti,u,e,f} = Output \times PHRti,u \times SHARE_{ti,u,e} \times FRR_{ti,u,e,f}$$

$PHR_{ti,u}$ is the process heat ratio for a given use; or the amount of heat input required to produce a dollar of output (1000 Btu/$). These ratios change over time in response to changes in product mix, the adoption of less energy-intensive processes, and energy prices.

- Structural changes are represented by an exogenously determined growth rate.
- Price elasticity for most industries is -0.20;
- A 3 year moving average of combined electricity and natural gas cost is calculated for each industry, based on their fuel shares.

$SHARE_{ti,u,e}$ = share of the delivered heat required in industry i, for use u, delivered by equipment option e in the year t. These shares change over time in response to adoption of new heating technologies, changes in fuel prices;

FRRu,e,f is the fuel requirement ratio for a specific fuel used by option e (Wh/Btu or Btu/Btu);

Motors Consumption Forecast

Electricity consumption is calculated separately for each industry, motor use, horsepower size category, and motor efficiency option.

Electricity Usage(t) = Output (t) * Horsepower Ratio(t) * 0.746 kW/Hp * Hours(t) * Motor Efficiency Option Market Share * Load Factor / Motor Efficiency

Motor Efficiency Options: Motors are replaced as a result of physical decay or capacity expansion with one of four choices:

1. Standard Efficiency AC Motor
2. High Efficiency AC Motor
3. AC Motor with Electronic ASD controls
4. DC, Synchronous, Single Phase motors

The 3 year net present value of each option is calculated from the installed cost per HP, electricity price, and operating characteristics. A logit function estimates the market share of each option.

Horsepower ratio(t) = HP requirements per output(t-1) * HP ratio growth rate

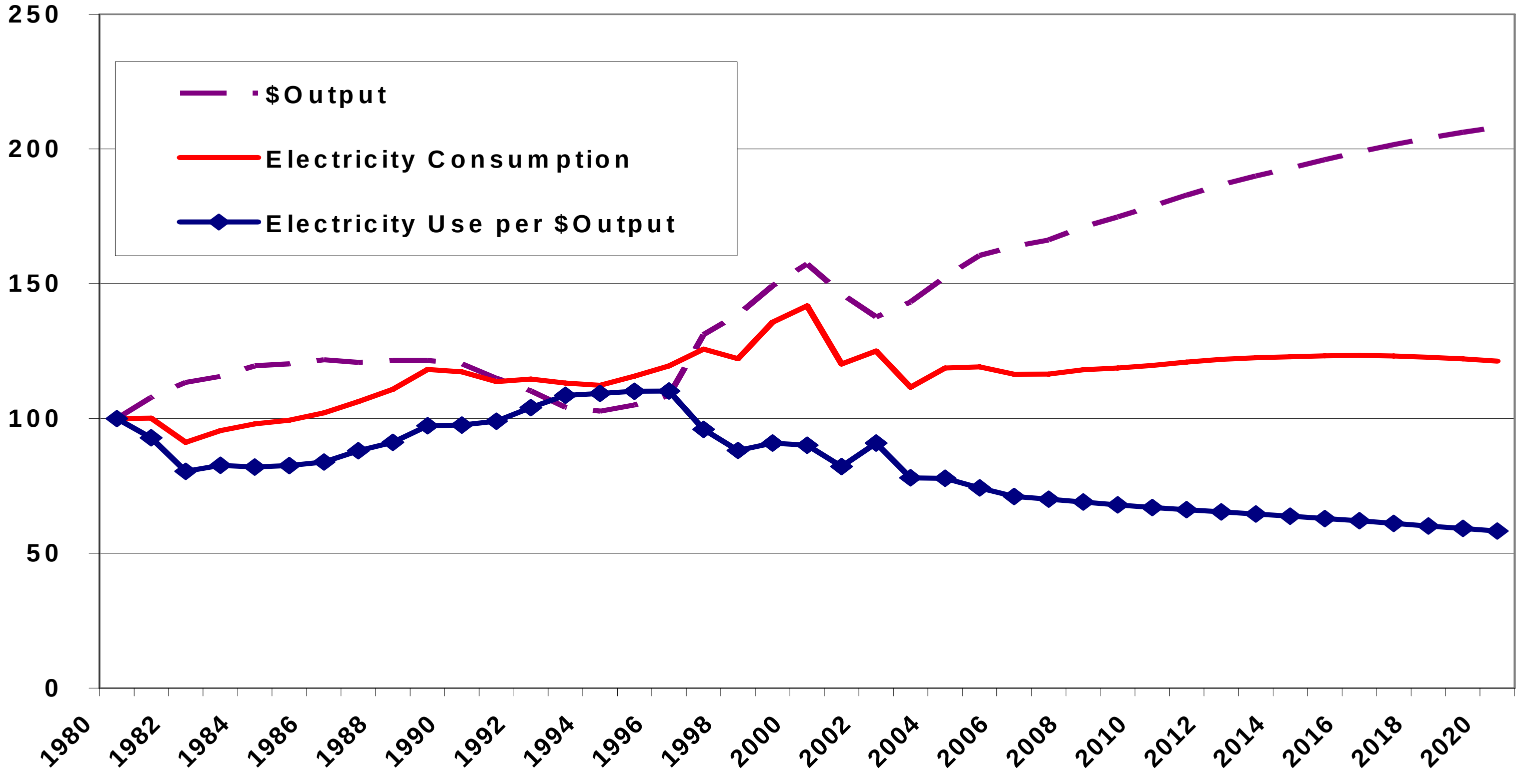
- The HP requirements growth rate represents exogenous changes in energy requires and is estimated from historic trends.

The lighting consumption forecast model follows a similar structure.

Industrial Sector Energy Intensity

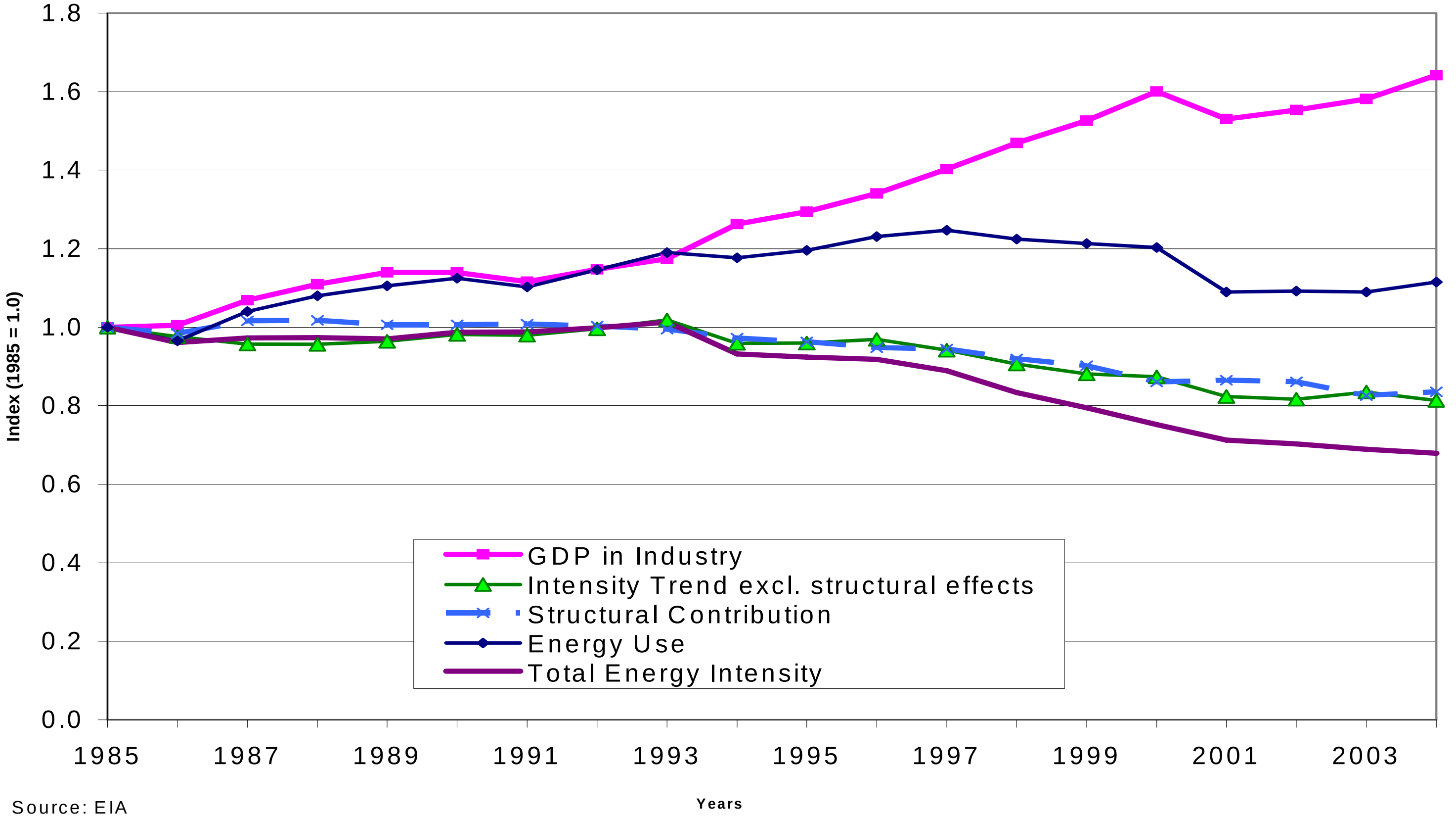
SCE Area Industrial Electricity Consumption

(excl. Petroleum)



Energy intensity is declining, put not all of that decrease can be attributed to efficiency. Structural change from changes in industry mix, product mix, and business methods causes shifts in energy intensity patterns.

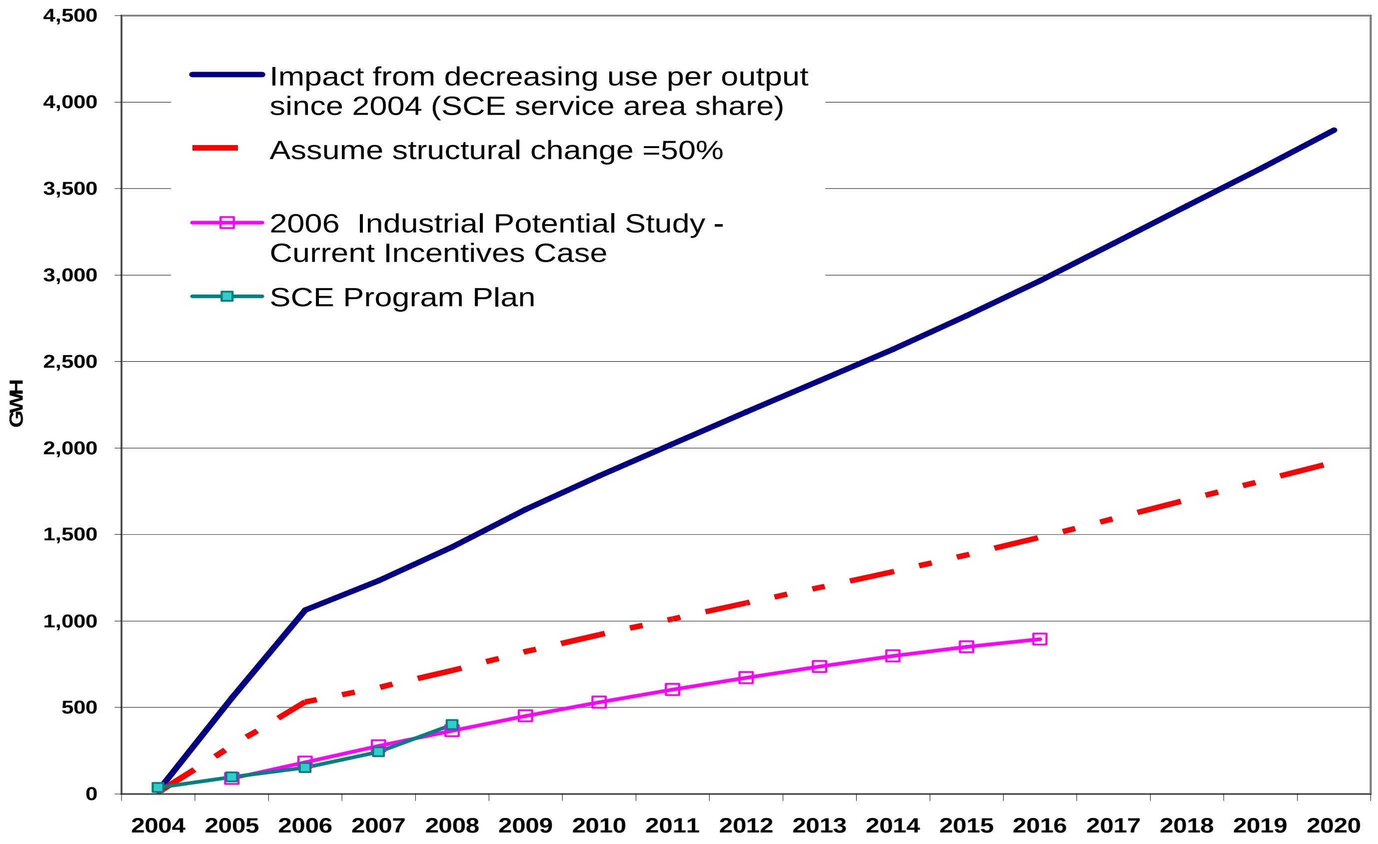
US Industrial Intensity Decomposition



Source: EIA

Many analyses, including EIA's, attempting to decompose US structure versus efficiency find that structural change accounts for about half the decline in intensity.

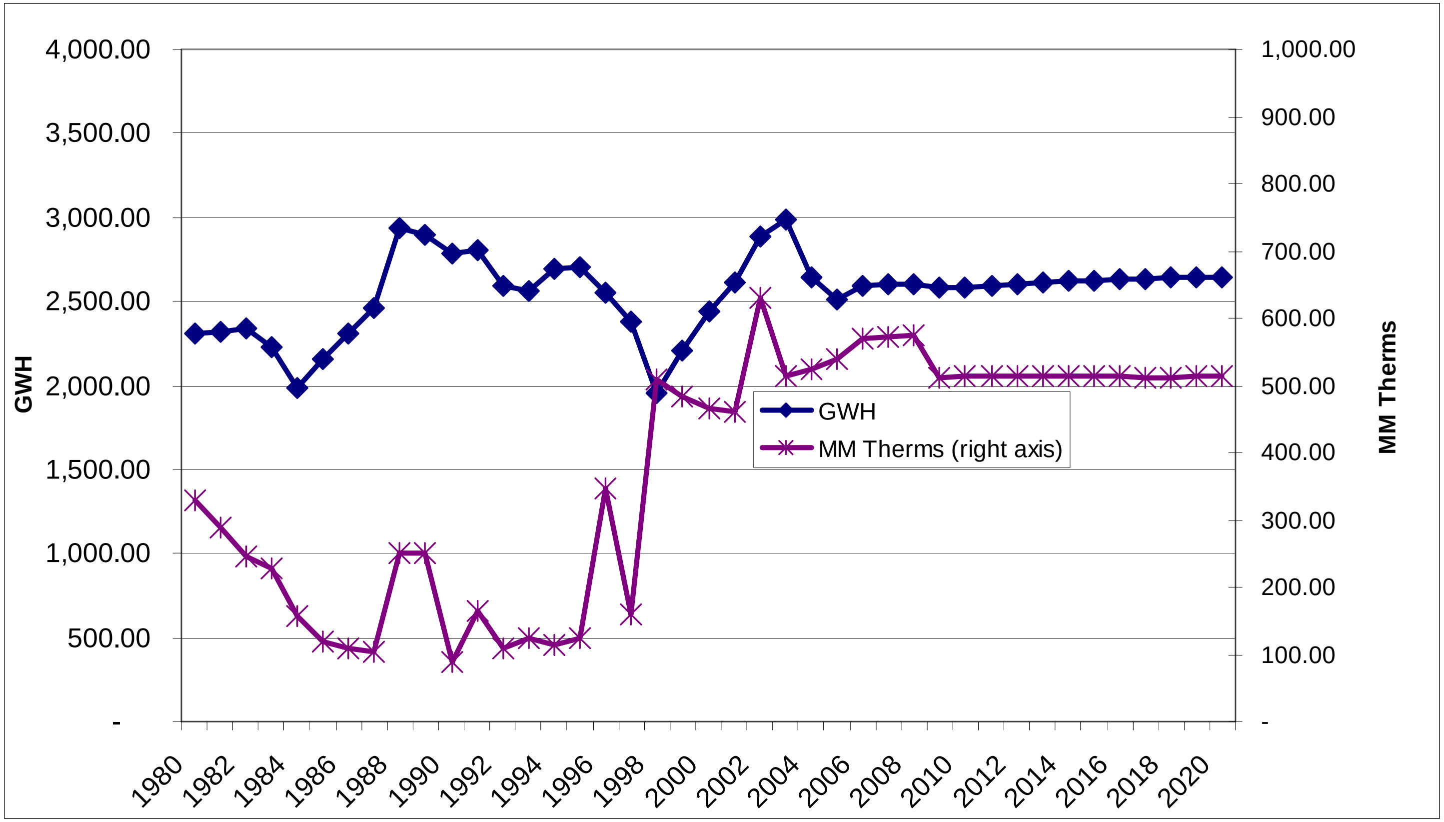
Comparison of SCE Manufacturing Intensity Change with Program Impacts



Overall, the planned energy efficiency impacts are far less than the decrease in energy intensity reflected in the staff forecast.

Comparison of forecast and program assumptions should be done for individual industries and end uses when possible.

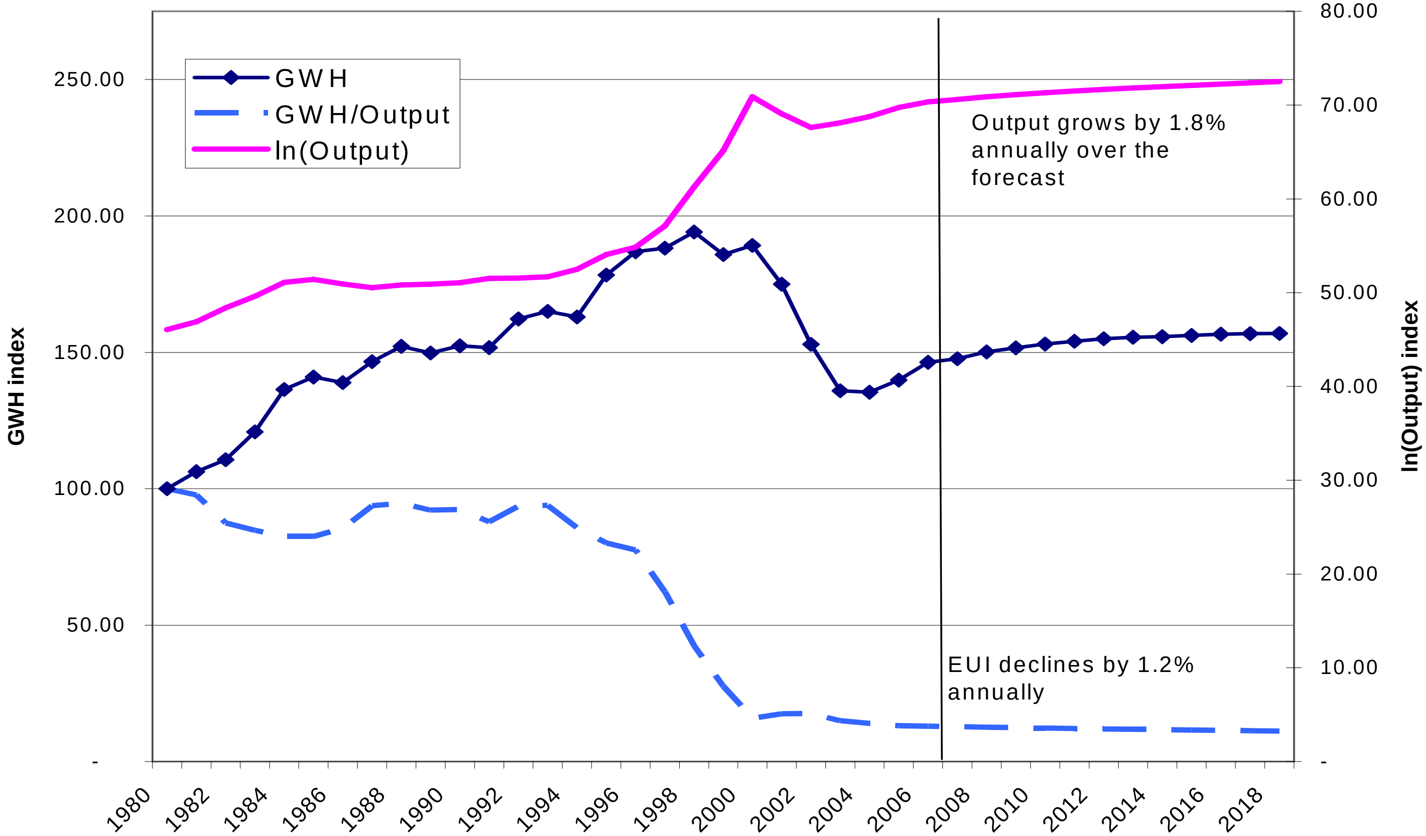
SCE Area Refinery Energy Consumption



Productivity improvement assumptions are specific to each industry

In petroleum refining, consumption is assumed to grow at the same rate as capacity (0.5 % per year). There is no efficiency improvement assumed in the staff forecast.

PG&E Area Semiconductor Electricity Consumption



In this industry, the staff forecast projects a decline in energy intensity reflecting continued improvements in productivity, although at a slower growth rate than history; output growth is slowing.

- **The change in consumption from the decrease in intensity far is roughly twice PG&E's 2006-2008 projected program impacts for the high tech sector.**