Long-Term Potential for Energy Efficiency in California Buildings and Industry

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Background

- **The use of electricity and natural gas by California's commercial, residential, and manufacturing sectors accounts for a significant fraction of the state's energy demand and greenhouse gas (GHG) emissions**

Sector	Estimates for 2004					
	Electricity Use		Natural Gas Use		GHG Emissions (due to electricity and natural gas use)	
	GWh	% of CA Total	MTh	% of CA Total	MMTCO2e	% of CA Gross Emissions
Residential buildings	84,794	31%	5,150	21%	67	14%
Commercial buildings	99,362	37%	1,960	8%	57	12%
Manufacturing	44,061	16%	3,145	13%	46	9%
Total (above 3 sectors)	**228,217**	**84%**	**10,255**	**42%**	**170**	**35%**
Total for all of CA sectors	271,994		24,200		484	

Sources: California Energy Consumption Database (http://www.ecdms.energy.ca.gov/), U.S. DOE EIA Natural Gas Navigator, and California Air Resource Board, Greenhouse Gas Inventory Data - 1990 to 2004 (http://www.arb.ca.gov/cc/inventory/data/data.htm).

- **Energy efficiency improvements to California buildings and industrial facilities are critical toward reducing state energy demand and achieving the GHG reduction goals of Executive Order S-3-05**

Project goals

- **To develop an analytical framework for estimating the potential electricity and natural gas savings associated with efficiency improvements in California's industrial, residential and commercial sectors over the long-term (i.e., through 2050) that considers:**
  - **Structural changes in California (e.g., changes to housing stock and industrial output)**
  - **End use technology changes (e.g., efficiency improvements) and uptake**
  - **Changes in end use service demand**
  - **Future technology and energy costs**

- **To strike a balance between modeling detail, available resources, and inherent (and significant) uncertainties associated with long-term projections**
  - **Focus on key end uses**
  - **Cumulative changes (2025 and 2050) versus year-by-year granularity**

- **To explicitly address data and modeling uncertainties to improve the robustness of decision making**

- **To provide scenario-based results that can serve as useful inputs to other state energy and econometric models for policy evaluation (e.g., supply curves)**

Previous work and project team

- **Previous PIER and CEC projects have played an important role in developing the methods and data sources leveraged in this project, including:**
  - **Long-term residential electric efficiency study (Itron 2007)**
  - **California Energy Balances (LBNL ongoing)**
  - **Emerging energy-efficient industrial technologies (ACEEE, LBNL ongoing)**
  - **GHG Mitigation Supply Curves for In-State Resources (Itron 2003)**
  - **Database for Energy Efficient Resources (DEER)**

- **California IOU potential studies for buildings and industry**

- **Project team:**
  - **Project leadership, industrial analysis, and scenario development:**
    - **Lawrence Berkeley National Laboratory (Eric Masanet, Alan Sanstad)**
  - **Commercial and residential building analysis:**
    - **Itron, Inc. (Mike Rufo, Mike Ting, Alan North)**
  - **Industrial analysis**
    - **Ecofys (Ernst Worrell)**

Research plan

- Literature review to identify available data and possible long-term modeling approaches
- Identification of appropriate energy demand drivers for California buildings and industry
- Development of a technology-rich, bottom-up analytical framework for assessing potential energy savings through 2025
- Development of a long-term analysis framework (2025 – 2050) that:
  - explores technology development trends and technological limits at the end use level (e.g., lighting, steam, cooling)
  - identifies plausible long-term structural, economic, and regulatory scenarios affecting energy prices and energy demand drivers in the state
- Integration of analysis frameworks and generation of scenario-based results over the entire analysis period (i.e., through 2050)

General modeling approach

- **Energy demand drivers based on historical correlation analyses and available (exogenous) forecast data:**
  - **Residential: number of housing units by building type**
  - **Commercial: square feet by building type**
  - **Industrial: valued added/industry GSP (real dollars)**

- **Focus on modeling of end use energy intensity to provide flexibility for detailed bottom-up technology models (2025) and the exploration of technological evolution and limits (2050):**
  - **Residential: energy consumption by end use and building type (energy/household)**
  - **Commercial end uses: energy intensity by end use and building type (energy/ft^2)**
  - **Industrial end uses: energy intensity by end use and sub-sector (energy/$)**

- **Development of plausible future scenarios for key modeling parameters**

- **Technological change modeled using base year technology penetrations and scenario-driven efficiency improvement and adoption rates**

Modeling detail: buildings

Sector	• Residential	• Commercial
Geographic region	• 16 standards climate zones	• Statewide
Building type	• Single-family dwelling • Multi-family dwelling	• College • Food Store • Health • Large Office • Lodging • Miscellaneous • Refrigerated Warehouse • Restaurant • Retail • School • Small Office • Unrefrigerated Warehouse
Building vintage	• Existing construction • New construction	• Existing construction • New construction
End use	• Space Cooling • Space Heating • Furnace Fan • Water Heating • Cooking • Refrigerator • Freezer • Clothes Dryer • Lighting • Pool Pump • Miscellaneous	• Space Cooling • Space Heating • Ventilation • Water Heating • Commercial Cooking • Refrigeration • Exterior Lighting • Interior Lighting • Office Equipment • Miscellaneous

Modeling detail: industrial

Focus on end uses of greatest significance in California:

- **Modeling of cross cutting technologies for all industrial sub-sectors:**
  - Electricity (82% of total use)
    - Motors (52%)
      - Drives (19%)
      - Pumps (18%)
      - Compressed air (9%)
      - Fans (8%)
    - HVAC (12%)
    - Refrigeration (9%)
    - Lighting (8%)
  - Natural gas (48% of total use)
    - Steam systems (26%)
    - CHP (10%)
    - HVAC (8%)
- **Modeling of process heating technologies for the most important industrial sub-sectors:**
  - Electricity (9% of total use) (food, refineries, plastics, glass, metals, electronics)
  - Natural gas (48% of total use) (food, refineries, chemicals, cement, glass, metals)

Treatment of uncertainty

- **Uncertainties are inherent in any modeling effort, but they are a critical concern in this project given its long-term analysis period and the current rapidly changing regulatory and market landscapes related to GHG emissions mitigation in California**

- **Uncertainties are made (more) explicit by:**

  - **Developing realistic ranges for key modeling variables (e.g., technology penetrations and energy savings) rather than point estimates**

  - **Developing plausible future scenarios for structural, economic, and policy conditions rather than deterministic projections (e.g., business as usual energy demand)**

- **Focus on providing insights to support robust decisions**

2025 scenario analysis example: technical potential

- **Goal: to assess the electricity and natural gas savings achievable through the adoption of all technically feasible (regardless of cost), commercially-available energy efficient technologies and energy saving measures**

- **Key 2025 scenario assumptions for buildings:**
  - **Measures limited to those commercially available today**
  - **All retrofit measures (e.g., CFLs) applied**
  - **Replacement measures applied on "burn out"**
  - **New construction energy demand ranges based on CPUC's Big Bold Energy Efficiency Strategies performance standards**
  - **CEC/DOF-derived projections for energy demand drivers (slide 12)**

- **Key 2025 scenario assumptions for industry:**
  - **Measures limited to those commercially available today**
  - **All retrofit and replacement measures applied**
  - **New construction (very limited) based on best practice technologies**
  - **CEC-derived projections for CA industrial output (slides 13 and 14)**

Energy demand drivers: buildings

Building Energy Demand Driver Projections for the 2025 Technical Potential Scenario Example

Residential Buildings	Millions of units		
	2006	2025	% Change
Single Family	8.4	10.7	28%
Multi Family	3.8	4.7	24%

Commercial Buildings	Millions of square feet		
	2006	2025	% Change
Retail	1,198	1,584	32%
Large Office (>=30k ft2)	1,177	1,509	28%
Miscellaneous	798	1,054	32%
School	653	804	23%
Unrefrigerated Warehouse	651	894	37%
Small Office (<30k ft2)	469	598	27%
Lodging	410	528	29%
Health	370	481	30%
College	340	434	28%
Food Store	331	436	32%
Restaurant	239	312	30%
Refrigerated Warehouse	91	123	36%
Total	**6,727**	**8,757**	**30%**

Energy demand drivers: industry

Industrial Energy Demand Driver Projections for the 2025 Technical Potential Scenario Example

Projected % Change in Real Economic Output (GSP) 2000-2025	
NAICS Code (Industry Sub-Sector)	**% Change**
325 (Chemicals)	174%
3273 (Cement)	118%
326 (Plastics and Rubber Products)	109%
336 (Transportation Equipment)	83%
327x (Nonmetallic Mineral Products (ex. Glass and Cement))	56%
334x (Computer and Electronics (ex. Semiconductors))	40%
3344 (Semiconductors and Components)	36%
311x, 312 (Food and Beverage)	9%
339 (Misc. Manufacturing)	8%
324 (Petroleum and Coal)	6%
322x (Paper (excluding Mills))	4%

Source: Adapted from CEC Demand Analysis Office data

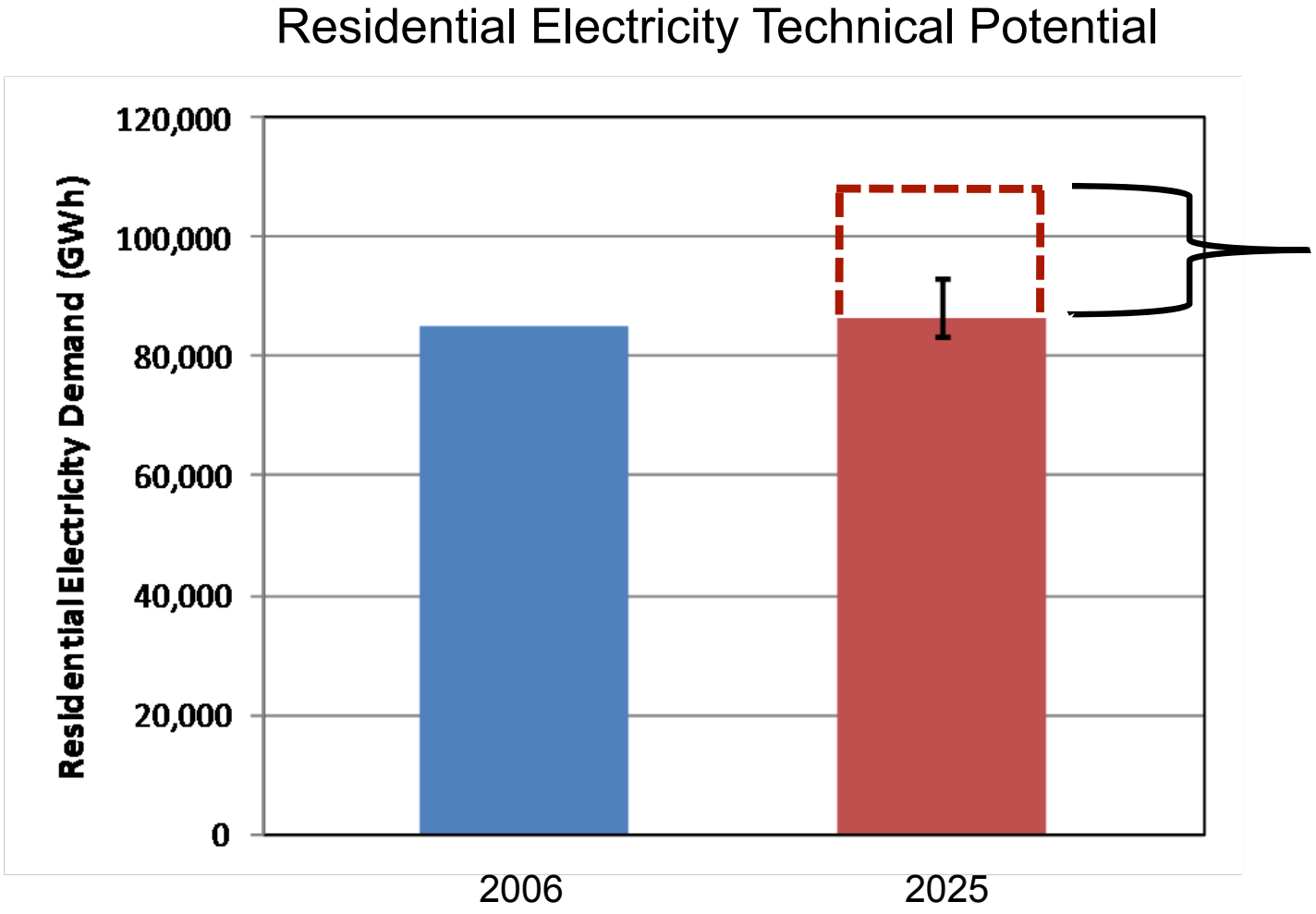
Energy demand drivers: industry

Industrial Energy Demand Driver Projections for the Mid-Term Technical Potential Scenario Example

Projected % Change in Real Economic Output (GSP) 2000-2025	
NAICS Code (Industry Sub-Sector)	**% Change**
332 (Fabricated Metals)	-1%
333 (Machinery)	-6%
335 (Electrical Equipment, Appliance, and Components)	-7%
323 (Printing)	-8%
1133, 321 (Logging and Wood Products)	-11%
331 (Primary Metals)	-12%
3272 (Glass)	-15%
3113, 3114 (Food Processing)	-21%
3221 (Pulp, Paper, and Paperboard Mills)	-23%
314 (Textile Product Mills)	-27%
315, 316 (Apparel and Leather Products)	-31%
337 (Furniture)	-33%
313 (Textile Mills)	-36%

Source: Adapted from CEC Demand Analysis Office data

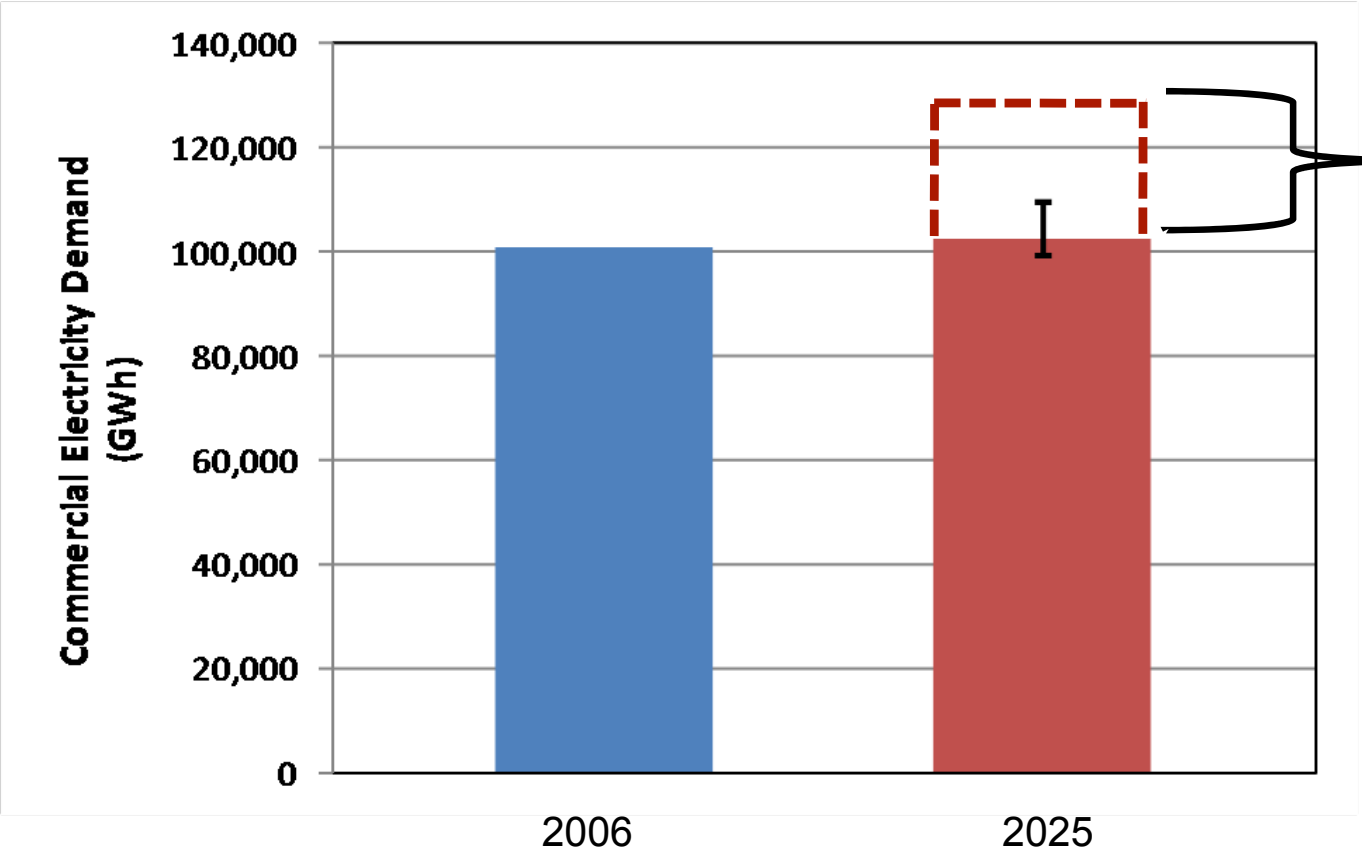
2025 technical potential scenario results: electricity demand



Technical potential for energy savings = 15 – 25 GWh

<u>Savings by end use:</u>
Lighting = 64%
Central AC = 10%
Space heating = 7%
Refrigerator = 6%
Water heating = 6%
Clothes washer = 3%
Dishwasher = 2%

2025 technical potential scenario results: CA commercial electricity demand

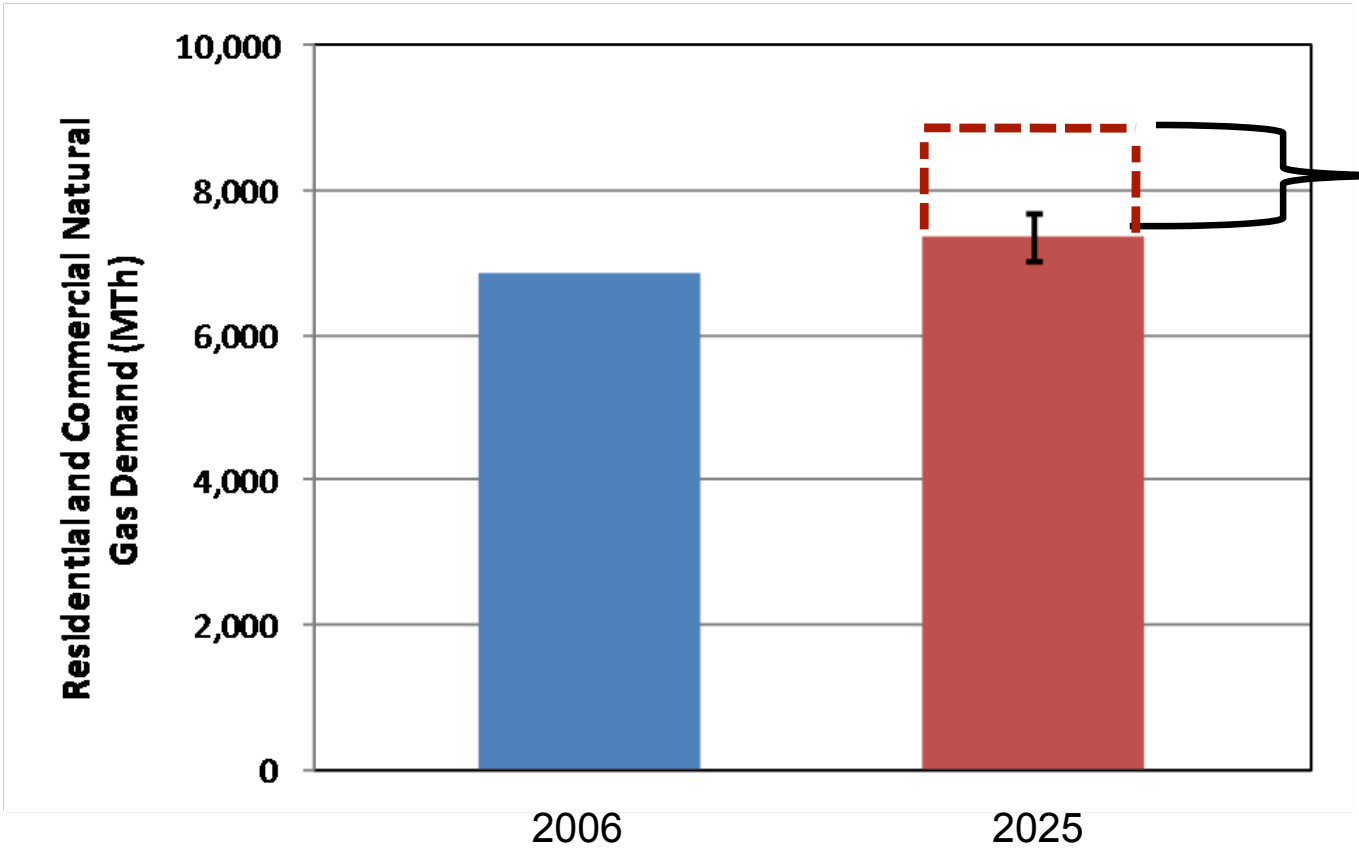


Technical potential for energy savings = 18 – 29 GWh

<u>Savings by end use:</u>
Interior lighting = 42%
Refrigeration = 19%
Cooling = 18%
Ventilation = 7%
Cooking = 6%
Office equipment = 4%
Exterior lighting = 4%

2025 technical potential scenario results: CA building natural gas demand

Residential and Commercial Natural Gas Technical Potential

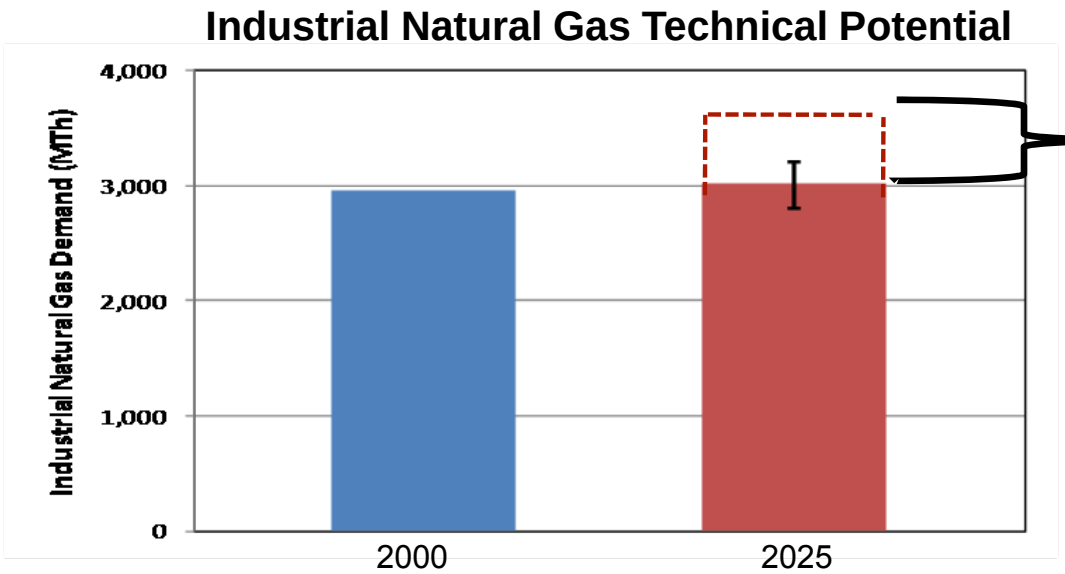


Technical potential for gas savings = 1,100 – 1,700 MTh

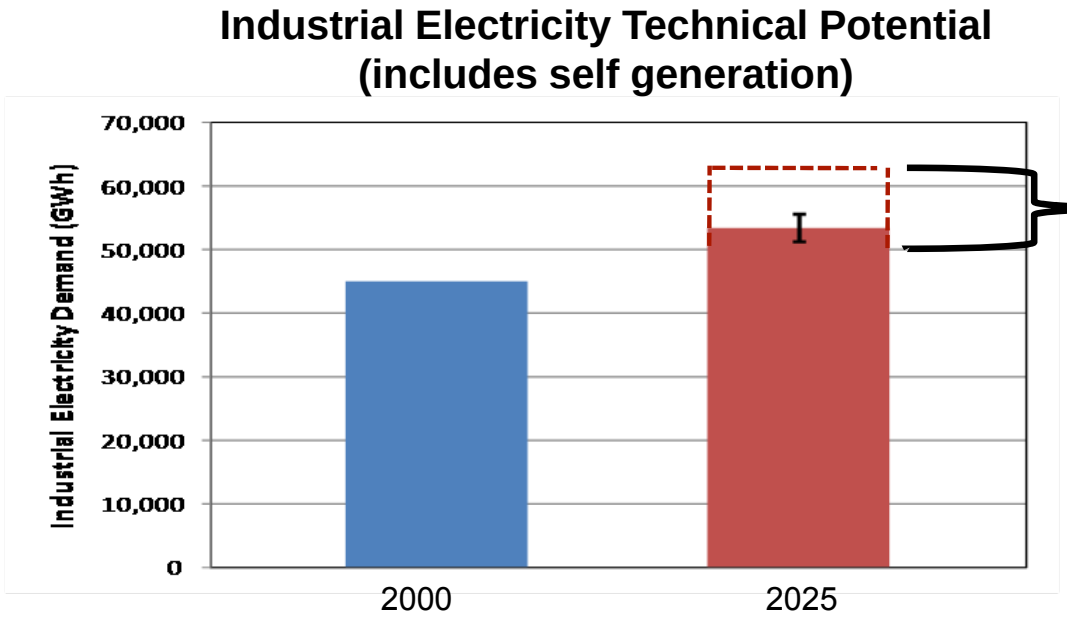
<u>~90% of savings due to residential measures</u>

<u>Residential end use savings:</u>
Space heating = 44%
Water heating = 32%
WH-clothes washer = 15%
WH-dishwasher = 9%

2025 technical potential scenario results: CA industrial electricity and natural gas demand

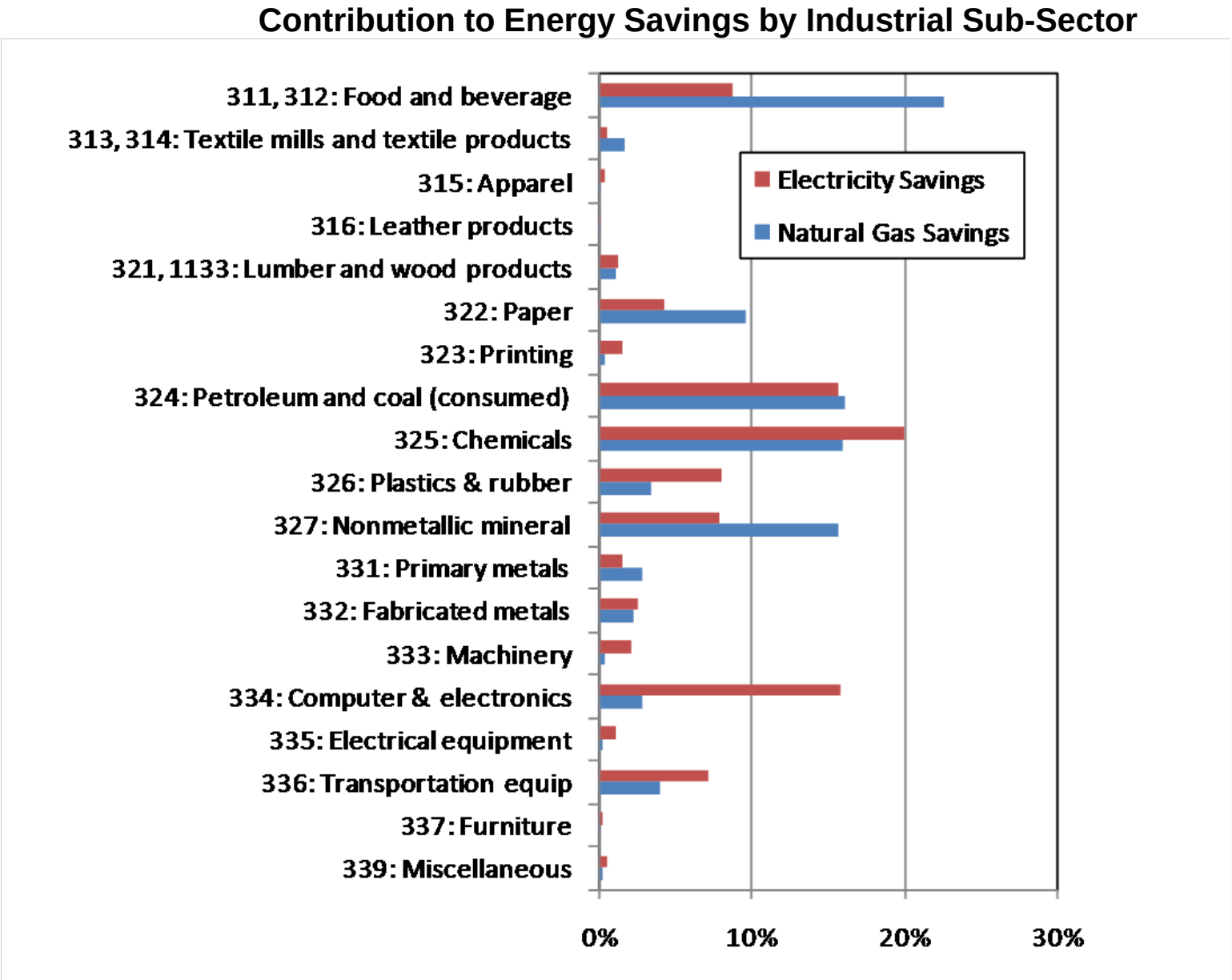


Technical potential for natural gas savings = 560-980 MTh

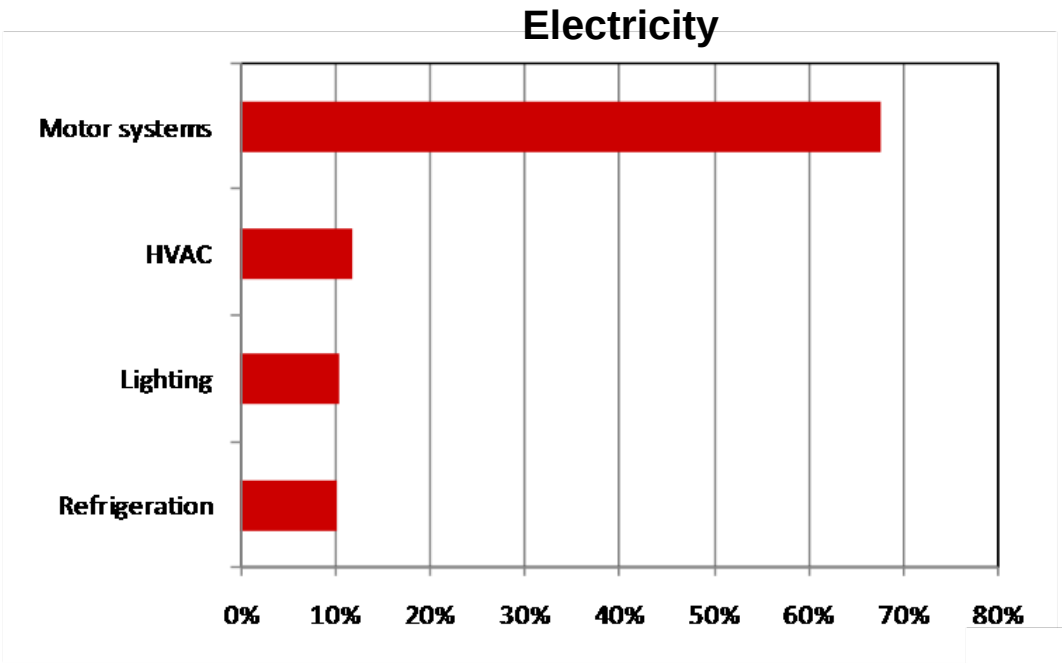


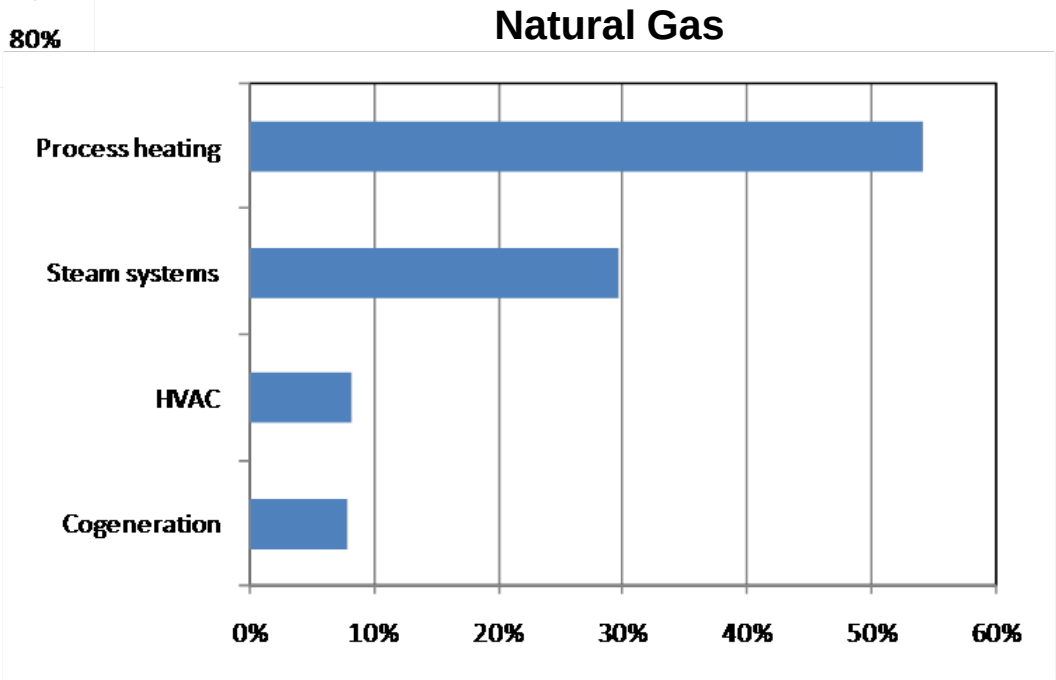
Technical potential for electricity savings = 5,700-9,900 GWh

2025 technical potential scenario results: industrial energy savings by sub-sector



2025 technical potential scenario results: industrial energy savings by end use





Work underway and next steps

- **Current work is focused on 2025-2050 framework:**
  - **Exploration of technology development and technological limits for each end use based on expert interviews, thermodynamic analysis, and review of R&D initiatives and trends**
  - **Development of plausible long-term scenarios for key structural, economic, and regulatory considerations to bound results in an interesting and policy-relevant way**
  - **Finalization of long-term cost models for technologies and energy sources for generation of cost curves and other results to support external economic analysis efforts**

- **Final step:**
  - **Generation of integrated modeling results based on final scenario definitions**

Conclusions

- **Growth in energy demand drivers for California buildings and industry will significantly increase the challenge of reducing aggregate electricity and natural gas use**

- **Long-term, technology-focused modeling efforts can help illuminate the greatest opportunities for efficiency improvements in California related to specific technologies, end uses, and building/industry types**

- **Uncertainties are significant and pervasive in such modeling efforts, but uncertainty and scenario analyses can help us understand the limits of our knowledge and identify robust decisions**

- **This work should help identify critical areas of opportunity, challenges, and knowledge gaps in future planning and modeling efforts toward meeting the state's ambitious energy use and GHG emissions reduction goals**

Contact information

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