Prospects for Decarbonizing California Industry Through Electrification

The Role of the Industrial Sector in Meeting California's Carbon Neutrality Goals

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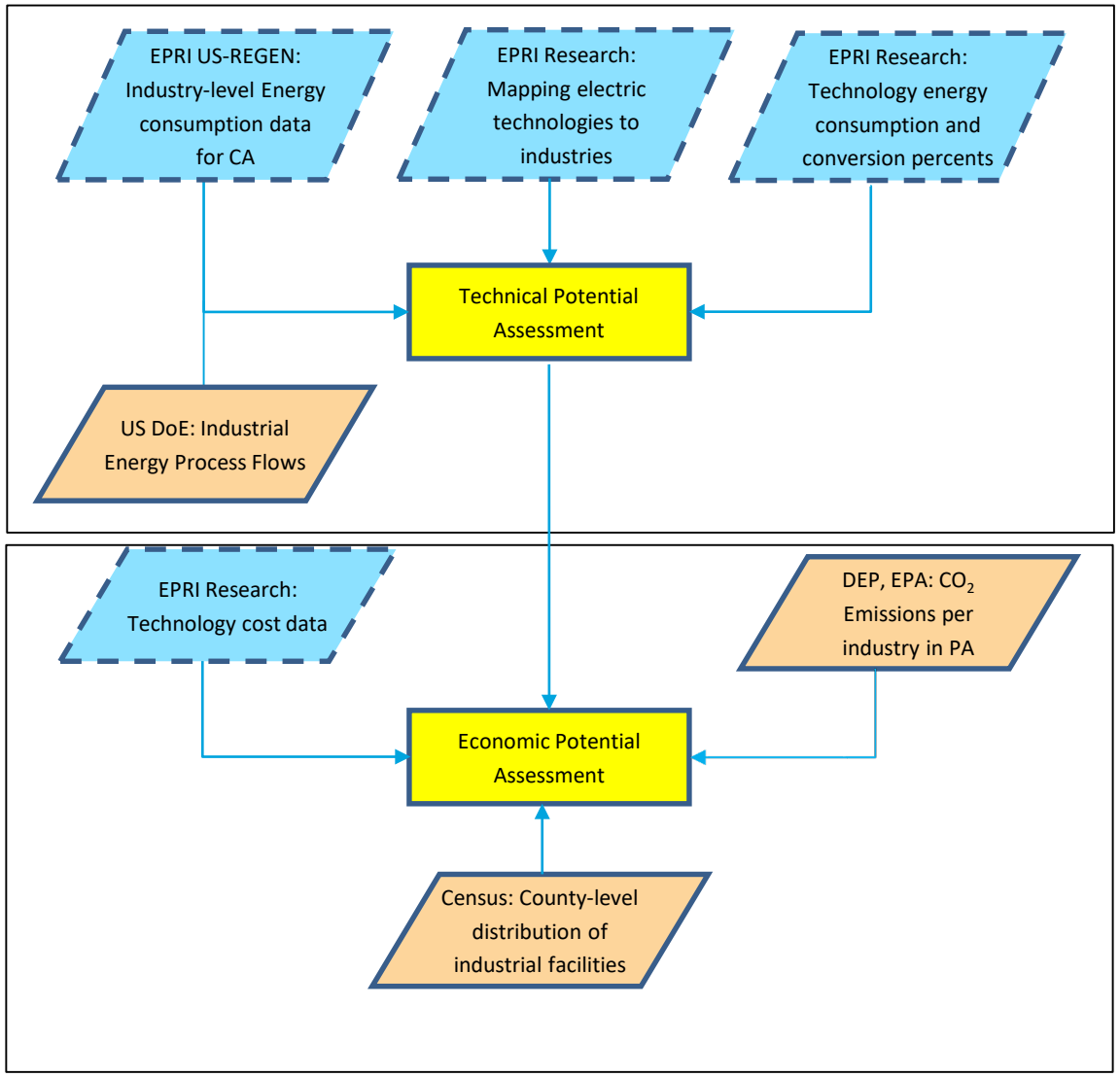
Agenda

- Overview of Project Approach
- Data Sources
- Data Analytics
  - Industry Targeting and Opportunity Model
  - Energy Analysis and Results
  - Cost Analysis and Results
- Emerging Technologies Discussion
- Take Aways

EPRI's Electrification Potential Study Approach



- Technical and Economic potential of manufacturing industries in CA was studied
- Industrial classification based on NAICS code was used
- Technologies mapped to industrial uses based on their relevance and application
- Electrification costs are calculated based on EPRI's technology cost and consumption data

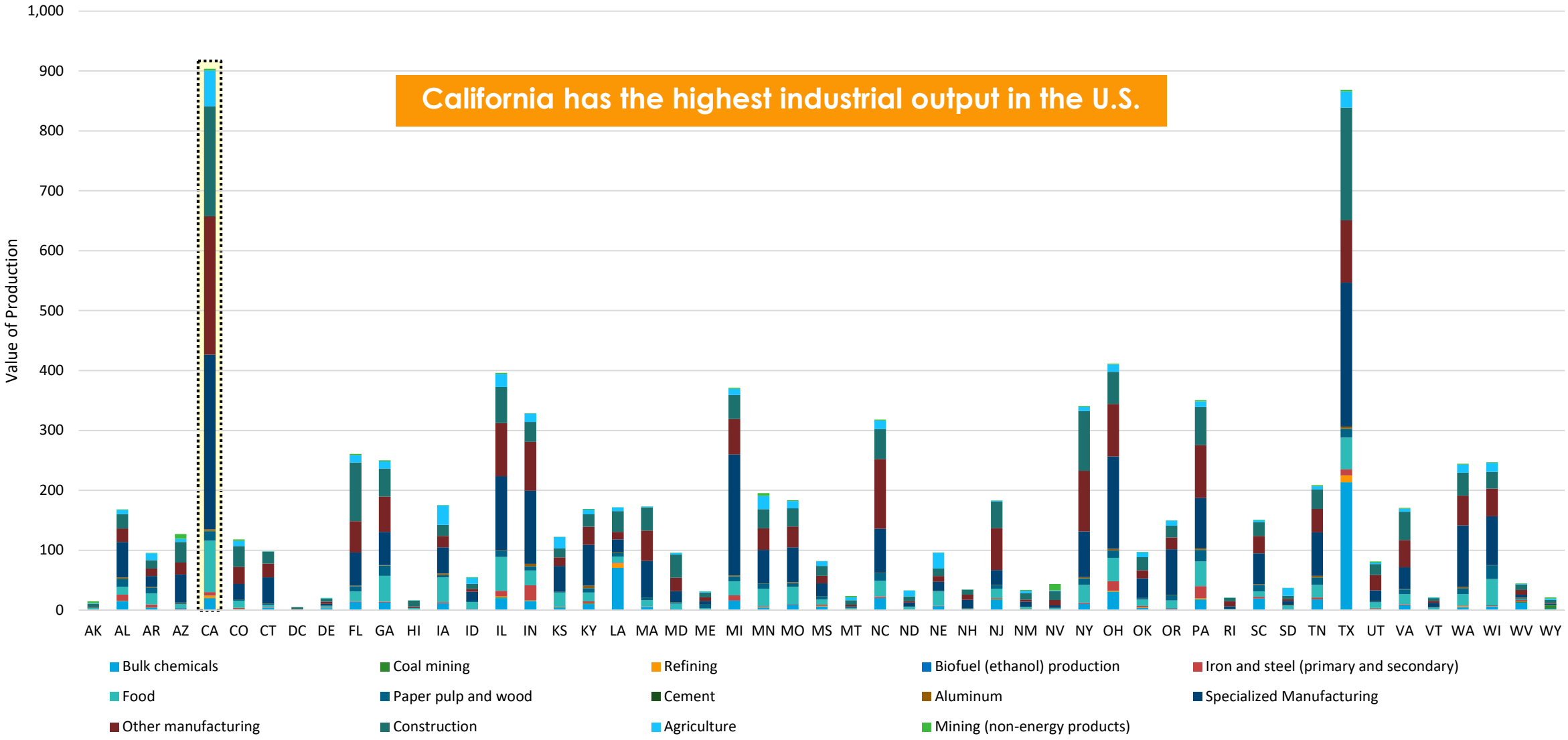
Data Collected from External Sources

- Census Data: Number of enterprises by California counties and NAICS code
  - Focused specifically on small, medium, and large enterprises, while excluding micro enterprises (those employing less that 10 people)
- California Air Resources Board (ARB) : Emissions of CO2
  - ARB maintains an annual GHG inventory for California
- US Environmental Protection Agency (EPA): Major Facilities that are emitters of CO2
  - EPA's F.L.I.G.H.T. data tool provides list of facilities in each industry that are emitters of CO2
  - Covers nearly 80% of emitters in each industry at state-level
- US DoE: Final energy consumption for each industry by fuel type
  - Sankey Diagrams showing process and non-process energy for Steam and Fossil Fuel

Data from EPRI Research

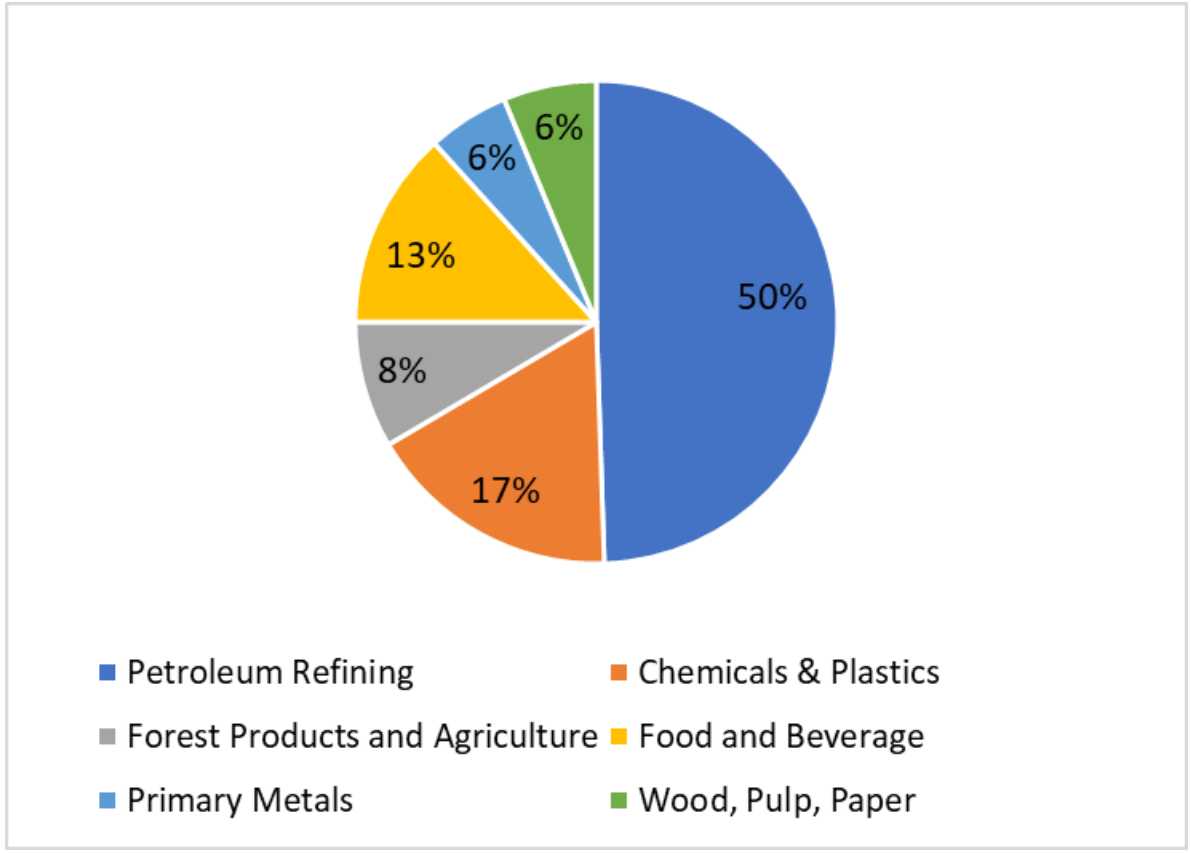
- Annual Energy Consumption in California by NAICS code
  - EPRI's US-REGEN model provides regional estimates for TBTUs of energy consumed for each industry
- Technology Mapping
  - Each electrification technology is mapped to one or more industries
  - Conversion percentage is determined based on final energy consumption and knowledge of end-uses
- Technology Cost
  - EPRI's electrification team has researched energy consumption and costs of typical electric end-use equipment

Industrial Structure in U.S. (from IMPLAN)



California Industrial Electrification Opportunity

Natural gas energy used by industrial segment



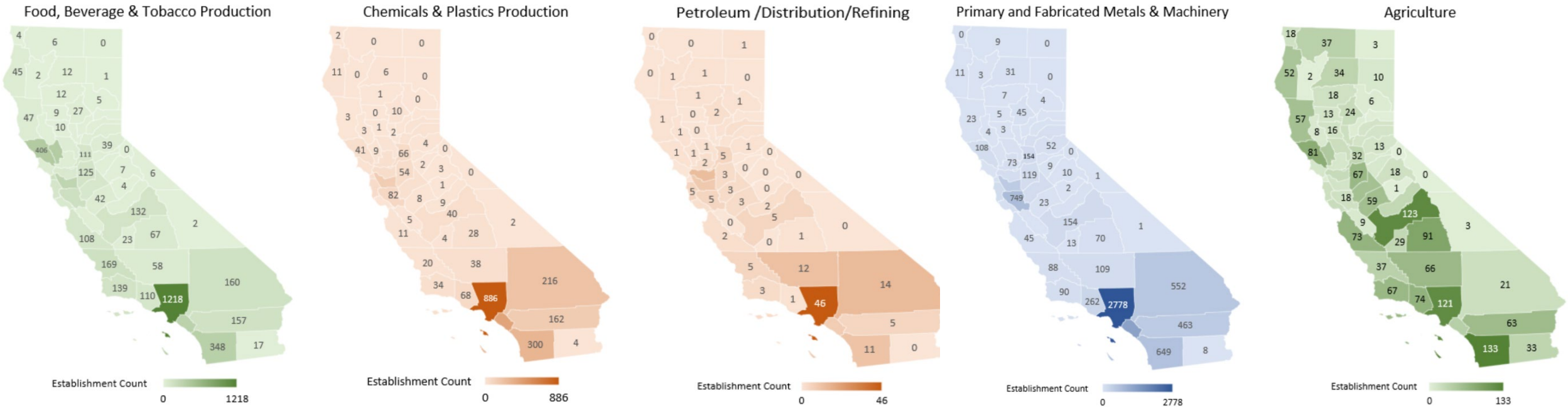
Note: EPRI Analysis assumes petroleum industry emissions reductions (decarbonization) will occur primarily through demand reduction resulting from electrification of the transportation sector.

EPRI's US Regional Economy, Greenhouse Gas, and Energy (REGEN) model

Six industries shown here capture 80% share of fossil fuel used by California industry

County-level distribution of California's major manufacturing industries

Number of Establishments



Distribution of industrial establishments vary across California counties by location and density count

- **Los Angeles County has the most industrial activity.**
- **Central Sierra and parts of Northern California have the least industrial activity.**
- **Accurate densities are essential to planning electrical infrastructure needs.**

(Data Source: 2016 County Business Patterns, U.S. Census)

Industrial Fossil-Fuel Energy Use and Emissions in California

Industry	Annual Energy Consumed from Fossil Fuel (TBtu)	Annual CO_2 emissions (MMT CO_2)
Petroleum Production/ Distribution/ Refining	380	23
Chemicals and Plastics	131	6.3
Food and Beverage	102	3.3
Forest Products and Agriculture	65	1.5
Wood, Pulp and Paper	48	Unavailable
Primary Metals	42	0.5
Fabricated Metals and Machinery	10	0.5
Stone, Clay, Cement and Glass	7	0.4
Transportation Equipment	5	0.3
Electronics	3	0.2

Source: 1. EPRI's US Regional Economy, Greenhouse Gas, and Energy (REGEN) model

EPRI Estimates top 6 industrial sectors emit over 35 MMT CO_2

Adoption Assumptions Influence Electrification Potential

2050 Adoption Rates for Agriculture, Industrial & Petroleum Sectors

Sector	Fuel Use Category	Electrification Share	Assumptions or Data source used
Agriculture	Heat	0%	No Electrification
	Other	0%	
Industrial	Boiler	98%	LTES Commercial Water Heating
	Motion	100%	Very high adoption
	Heat	60%	EPRI Assumption
	Chemicals	0%	No electrification
	Other	0%	
	Solvents	0%	
	Space Heat	80%	LTES Commercial Space Heating
Petroleum	Boiler	90%	Petroleum use reduction
	Heat		
	Other		

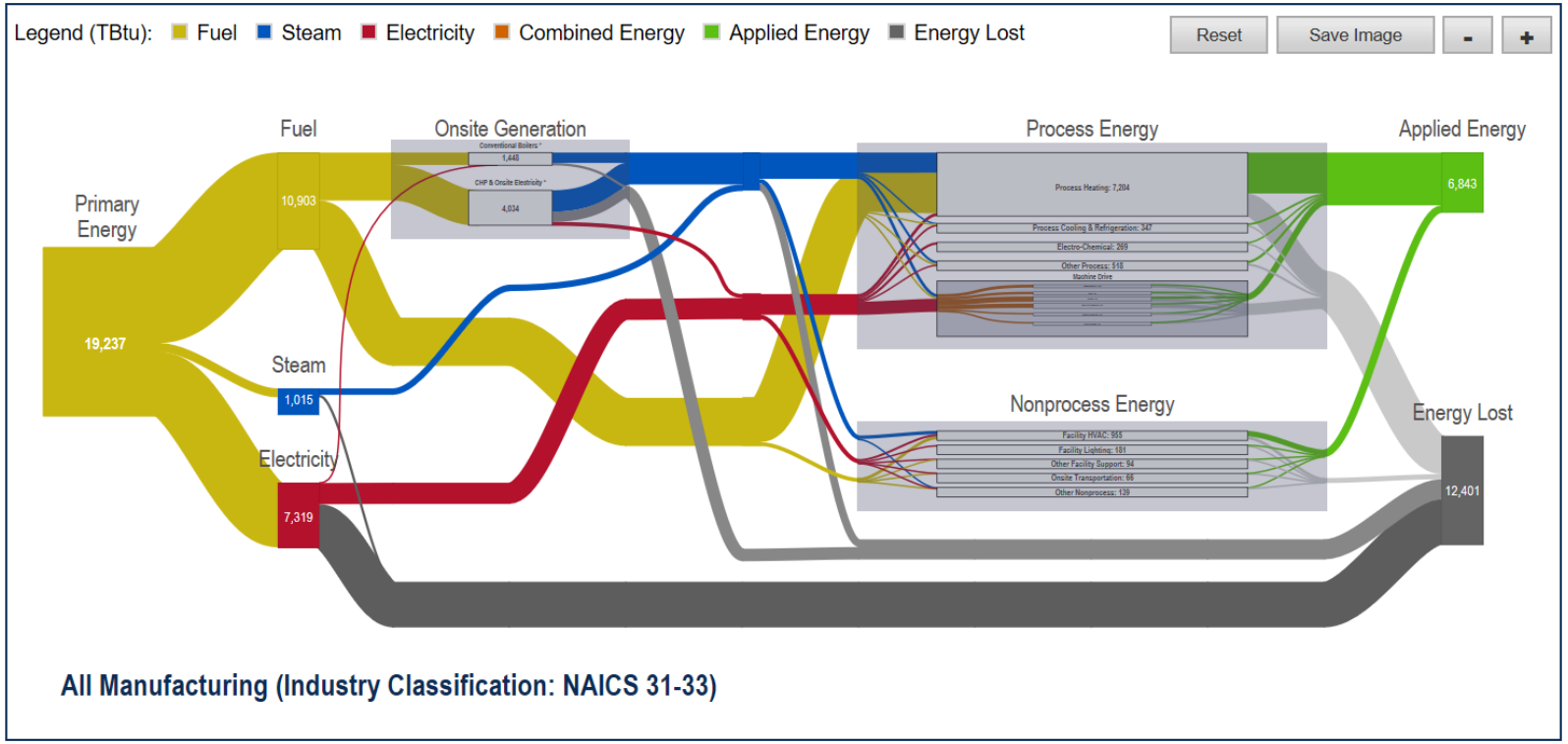
2050 Adoption Rates For Non-Road Transportation Fuel Use Categories

Fuel Use Category	Electrification Share	Assumptions or Data source used
Agriculture	15%	TAC Suggestion
Aviation	10%	
Construction and Mining	0%	
Forklift	100%	Aggressive adoption assumed
Ground Support Equipment	100%	
Lawn and Garden	100%	
Marine	10%	TAC Suggestion
Marine (port)	100%	Aggressive adoption assumed
Other non-road	0%	
Rail	0%	
Rail (yard)	100%	Aggressive adoption assumed
Recreational Equipment	0%	
Recreational Marine	25%	TAC Suggestion
Refrigeration	100%	Aggressive adoption assumed
Terminal Tractor	100%	Aggressive adoption assumed
Truck apu	100%	Aggressive adoption assumed

Determination of Fossil Energy Conversion Potential

New electricity energy use was calculated based on:

- Final Energy Consumption values (fraction of primary energy source) from DoE's Manufacturing Energy Sankey Flowcharts



- EPRI's SME experience was utilized to map process and non-process energy to end uses

Electrification Technologies by Energy Uses

Names of Energy Consuming Processes	Technologies that can be used to electrify - -
Process Heating and other heating (Fossil Fuel)	Infrared Heating, Resistance Heating, Resistance Melting, Ultraviolet Curing, Microwave Heating, Radio Frequency Heating, Induction Heating/ Hardening, Induction Melting, Electric Arc Furnace, Industrial Heat Pumps *(Mapping of exact technologies depends on the industry)
Process Heating and other heating (Steam)	Electrode Boiler, Medium Voltage Electric Boiler, Indirect Induction
Process Cooling (Steam and Fossil Fuel)	Advanced Refrigeration
Machine Drive (Steam and Fossil Fuel)	VFD Motor

Conversion Potentials by Industry and Technology

	Resistance Heating	Resistance Melting	Infrared and Microwave Heating	Radio Frequency Heating	Induction Heating	Induction Melting	Electric Arc Furnace	Electrode Boiler	Resistance Boiler	VFD Motor	Industrial Heat Pumps	Advanced Membrane	Electrochemical	Ultraviolet Curing	Advanced Refrigeration
Chemicals and Plastics	12%			3%	4%			40%	1%	10%	12%	9%	7%		2%
Food and Beverage	6%		12%	6%	6%			54%		3%	10%				5%
Forestry and Agriculture	10%			5%					5%	80%					
Primary Metals	13%	17%				13%	17%	10%		2%	17%		9%		
Wood, Pulp and Paper								73%		11%					2%
Petroleum Refining, Production & Distribution	19%				19%			18%		5%	15%	15%	8%		1%

Several technologies are available to achieve decarbonization through electrification

Electricity Requirement for Manufacturing Firms in California after Electrification

Industry	Realistic Conversion Potential of Fossil Fuel Energy	New Electricity Requirement (Annual, billion kWh)
Primary Metals	45%	2.3
Chemicals and Plastics	30%	4.6
Petroleum Production/ Distribution/ Refining	40%	1.9
Stone, Clay, Cement and Glass	50%	0.4
Food and Beverage	35%	4.2
Wood, Pulp and Paper	10%	0.7
Forest Products and Agriculture	50%	4.1
Fabricated Metals and Machinery	50%	0.6
Transportation Equipment	30%	0.2
Computers and Electronics	5%	0.03

Requirement for Petroleum Industry was de-rated by 90% assuming that decarbonization will occur primarily through demand reduction

Electrification of manufacturing industries trigger an additional annual electricity requirement of nearly 20 billion kWh across California State

Electrification Costs and Emissions

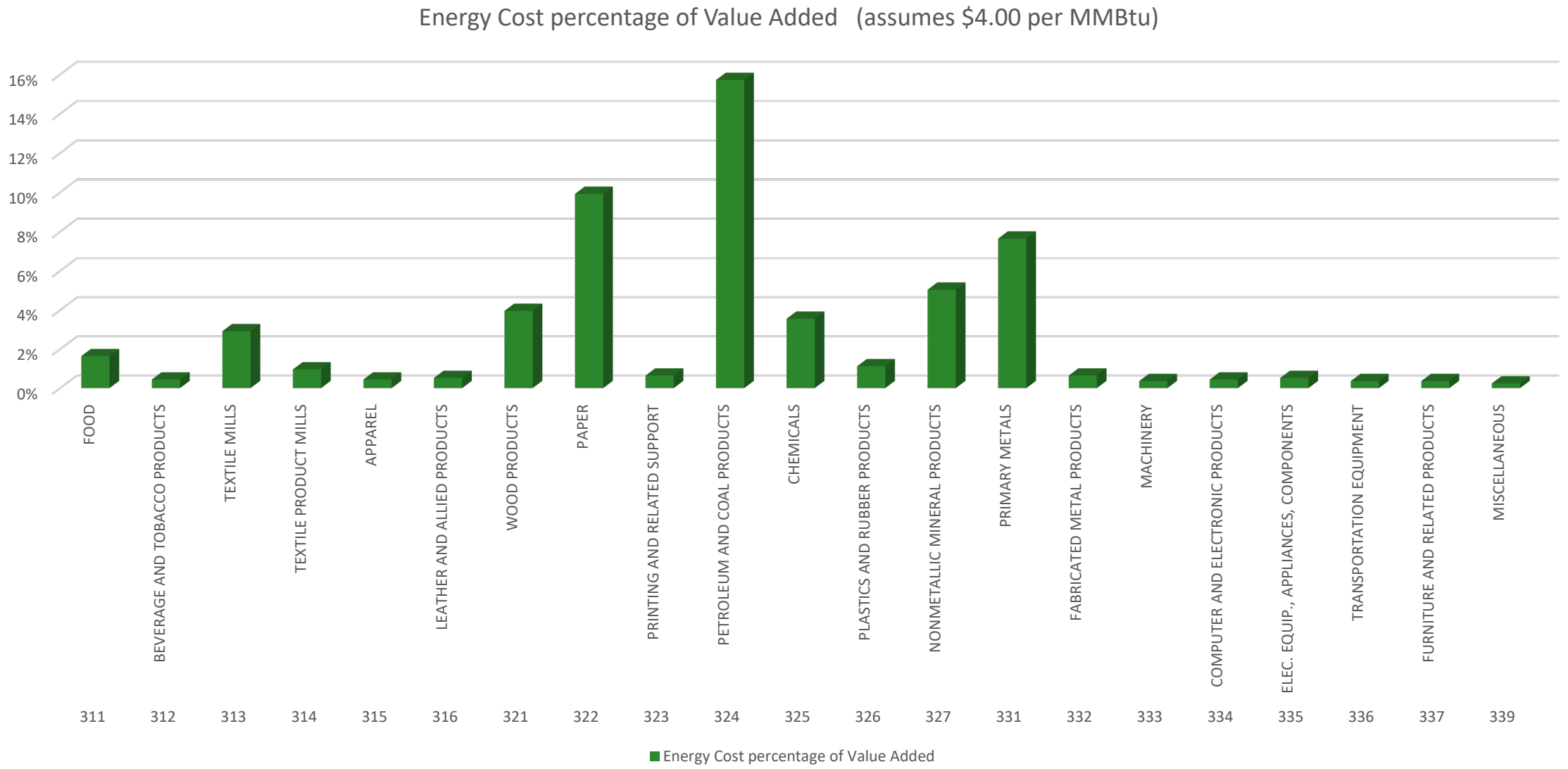
- Based on EPRI's data for "typical" electric equipment capacity and it's upfront costs
- Capital, Installation and Maintenance costs are considered
- CO_2 emissions calculated @ 119 lb/MMBtu for natural gas & 0.3 tons/MWh for electricity

Industry	Estimated Electrification Costs for CA State	Potential CO_2 Emissions (MMT CO_2/yr)
Petroleum Prod./Dist./Refining	$0.4 billion	0.59
Chemicals and Plastics	$1.7 billion	1.40
Forest Products and Agriculture	$4.2 billion	1.22
Primary Metals	$1.1 billion	0.71
Food and Beverage	$2.3 billion	1.25
Wood, Pulp and Paper	$2.0 billion	0.22
Fabricated Metals & Machinery	$0.23 billion	0.17
Stone, Clay, Cement & Glass	$0.18 billion	0.12
Transportation Equipment	$0.10 billion	0.06
TOTAL	**$12.2 billion**	**5.74**

California technical potential to reduce industrial CO_2 emissions by 62.5% with existing technologies at a cost of $1,276 per ton.

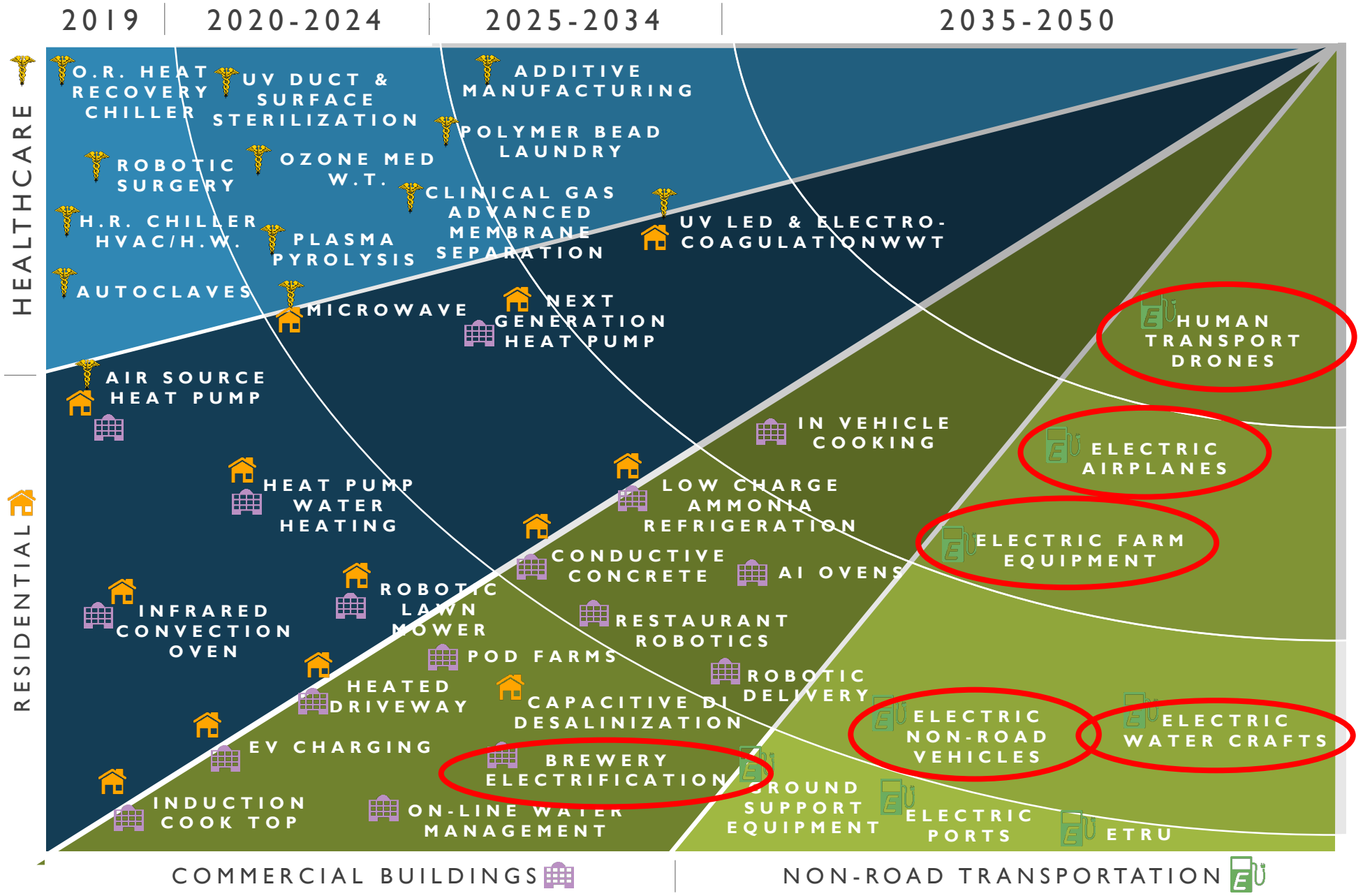
Emerging Technologies

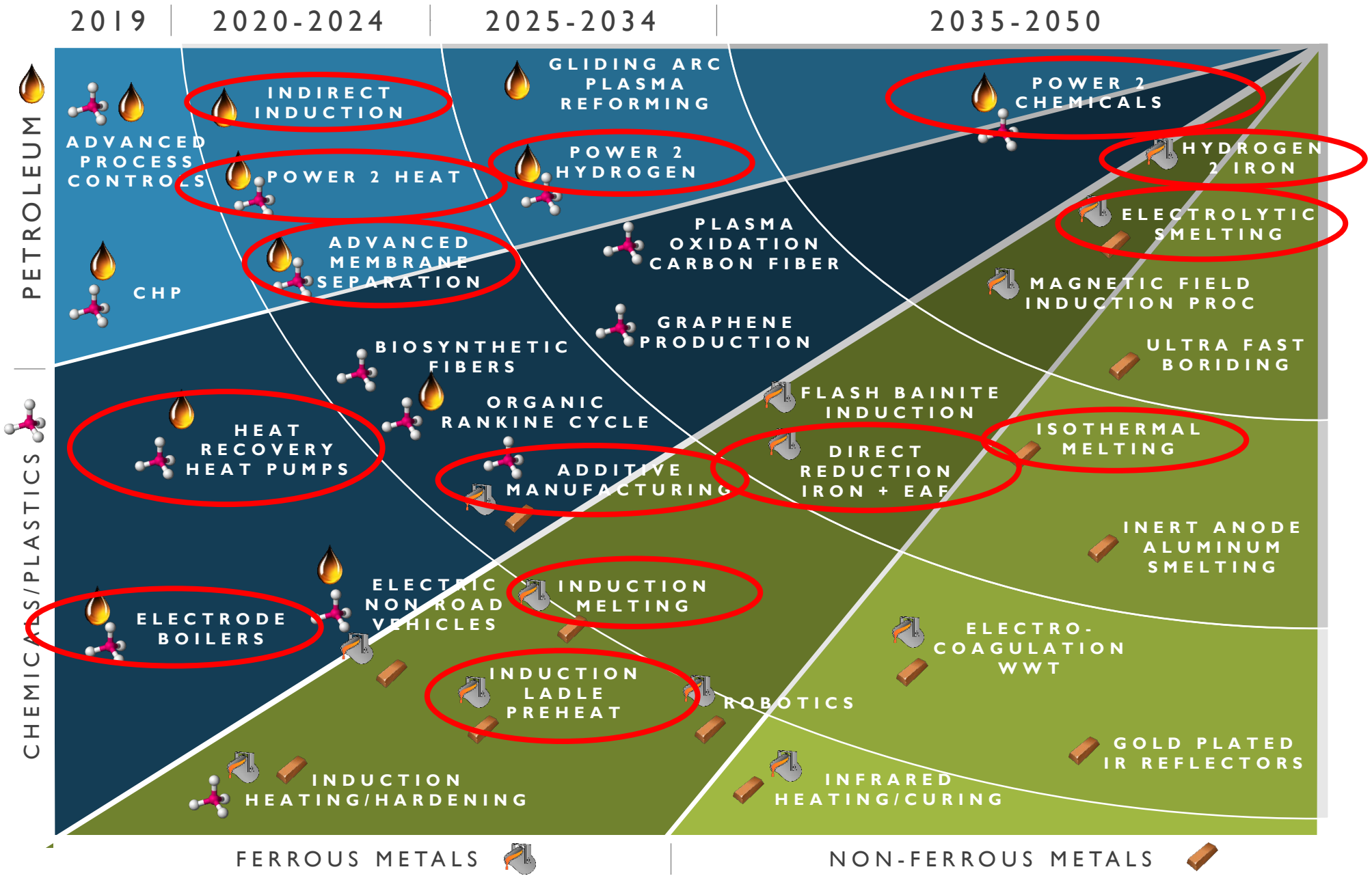
Fossil Energy Contribution to Industrial Cost of Production

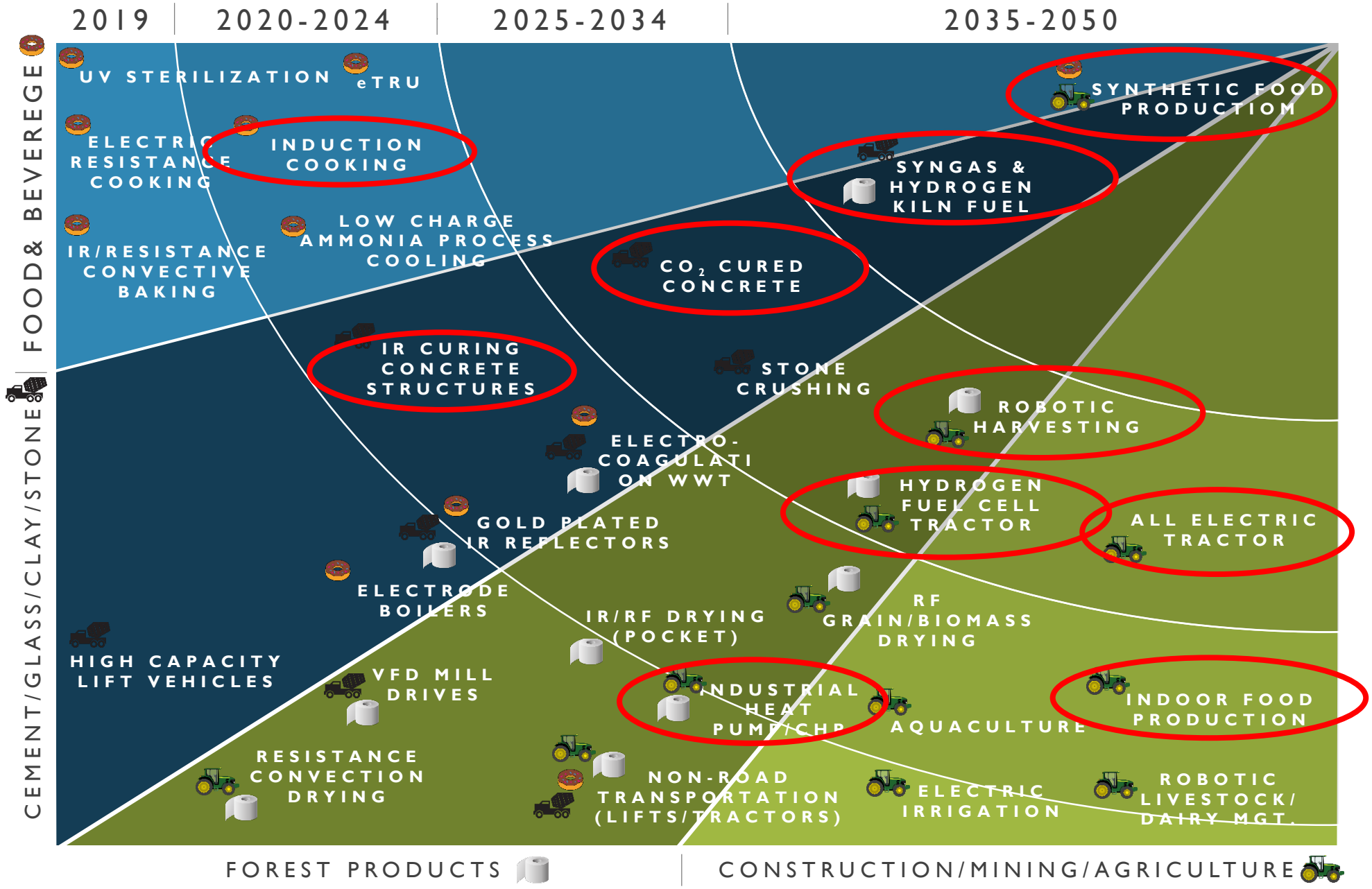


Non-Energy Drivers (Benefits)

- Lean Manufacturing
  - Productivity
  - Product Quality (Scrap & Repair)
  - Delivery
  - Process Flexibility
  - Inventory
  - Up-time
- Labor Cost
- Raw Material Costs
- Capital (Equipment & Inventory)
- MRO, Consumables & Tooling Costs
- Product Features & New Products
- Health & Safety
- Environmental
- Brand Enhancement







Key Findings

Summary of Key Take-Aways

- California has the largest industrial footprint of any state in the US.
- Six California industries account for 80 percent of the state's fossil fuel consumption totaling an estimated 768 Tbtu of electrification opportunity.
- Industrial process heating end-used are highly concentrated in specific coastal regions including Los Angeles and surrounding counties and San Francisco Bay area counties. Agriculture and forestry related industries are more broadly dispersed with concentrations in the central valley and costal forests.
- Petroleum industry emissions, the state's largest, are expected to decline inversely proportional to the EV adoption. Electrification in non-road transportation would further reduce refinery related carbon emissions.
- A handful of market-ready technologies represent the bulk of near term electrification potential totaling an estimated 20 TWh of additional electrical demand at an estimated cost to California industry of $ 12.2 Billion resulting in 5.74MMT CO_2
- Economic considerations will drive the need to develop competitive emerging electric technologies to supplant current fossil fuel fired processes in targeted industries.

Together…Shaping the Future of Electricity