DOCKETED

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BUILDING DECARBONIZATION: AB 3232 – FUEL SUBSTITUTION SCENARIO ANALYSIS (FSSAT) TOOL

Commissioner Workshop 1 of 2

California Energy Commission

June 9, 2020

Housekeeping: Zoom Overview

- Everyone will be muted by default
- Questions/Comments
  - Please submit questions in the Q & A, and/or chat box and we will address them after the presentation
  - Please include your name and the slide number
  - We will call on stakeholders by name and unmute them so they may ask a question after the presentation is completed.

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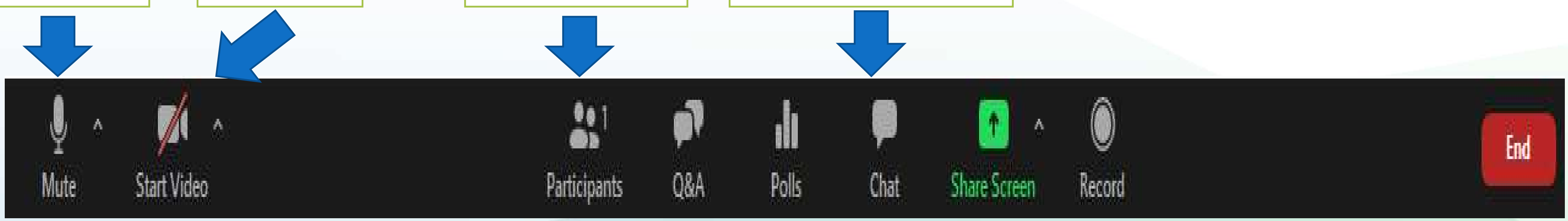


AB 3232 Public Workshops

Previous AB 3232 Workshops

- Dec 4th: Workshop on AB 3232 preliminary scope and GHG baseline
- Feb 22nd: Webinar on the Fuel Substitution Scenario Analysis Tool (FSSAT)
- May 22nd: Workshop on opportunities and challenges
- **TODAY, June 9th: Workshop 1 on FSSAT draft scenario results**

Upcoming AB 3232 Workshops

- **June 26th Workshop 2 on FSSAT draft scenario results**
- Fall 2020 Workshop on draft report

Stakeholder Comments:

- Accepting informal questions/comments which staff will address during June 26th workshop
- Written comments (Docket no. 19-DECARB-01) for ***both*** June workshops due: **July 10th at 5 pm**

Fuel Substitution Scenario Analysis Tool (FSSAT) Methodology Report

Sathe, Amul (Guidehouse), Karen Maoz (Guidehouse), John Aquino (Guidehouse), Abhijeet Pande (TRC), and Floyd Keneipp (Tierra Resource Consultants). 2020. Fuel Substitution Forecasting Tools, Methods Supporting Senate Bill 350 Analysis. CEC-200-2020-001.

- This report shows the methodology used in developing the FSSAT.
- Please refer to the References slide at the end of the slide deck for references to page numbers in the report for the content reported in the appropriate slides.

Informal methodological questions and comments

- Please review workshop's supplementary materials in docket (19-DECARB-01)
  - Fuel Substitution Forecasting Tools, Methods Supporting Senate Bill 350 Analysis (Sathe et al. 2020)
  - [June 9 2020 Selected Input Assumptions_FSSAT_5.7.xlsx]

- Please ask informal methodological questions and comments to nicholas.janusch@energy.ca.gov and staff will address them at the June 26th workshop (informal questions and comments due **June 15th at 5pm**)
- Also by **June 15th at 5pm**, Please use the *June 9 FSSAT Input Assumptions Workbook* above as a template to propose changes to input assumptions used for the FSSAT analysis
- Written comments for both June workshops due: **July 10th at 5 pm**

Outline of Today's Workshop

- AB 3232 Brief Background and GHG Baseline Recap
- FSSAT Analysis: Overview, Basic Approach, Scenario Design
- Draft FSSAT Scenario Results
    - GHG reduction potential and summary of results
    - The importance of HFC emissions
    - Disaggregation of costs
    - Rates
    - Electric load impacts
- Overview of findings and next steps
- Question and Answer

Brief background

Assembly Bill 3232

Assembly Bill 3232

Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018) requires the Energy Commission to:

> “[A]ssess the potential for the state to reduce the emissions of greenhouse gases in the state’s residential and commercial building stock by at least 40 percent below 1990 levels by January 1, 2030”

AB 3232 GHG Baseline (Residential and Commercial Buildings)

AB 3232 GHG Emission Category	1990 MMTCO2e	2017 MMTCO2e
Fuel combustion from natural gas	38.8	35.4
Fuel combustion from other fuels	5.4	3.5
Behind-the-meter methane emissions	1.7	1.9
HFCs from Refrigeration and Air-conditioning	8.5 (2013 level of HFC emissions)	11.7
Incremental electric generation emissions from fuel substitution	--	--
Total emissions from buildings	**54.4**	**53.2**
2030 Target: 32.6 MMTCO2e		

BASIC Approach

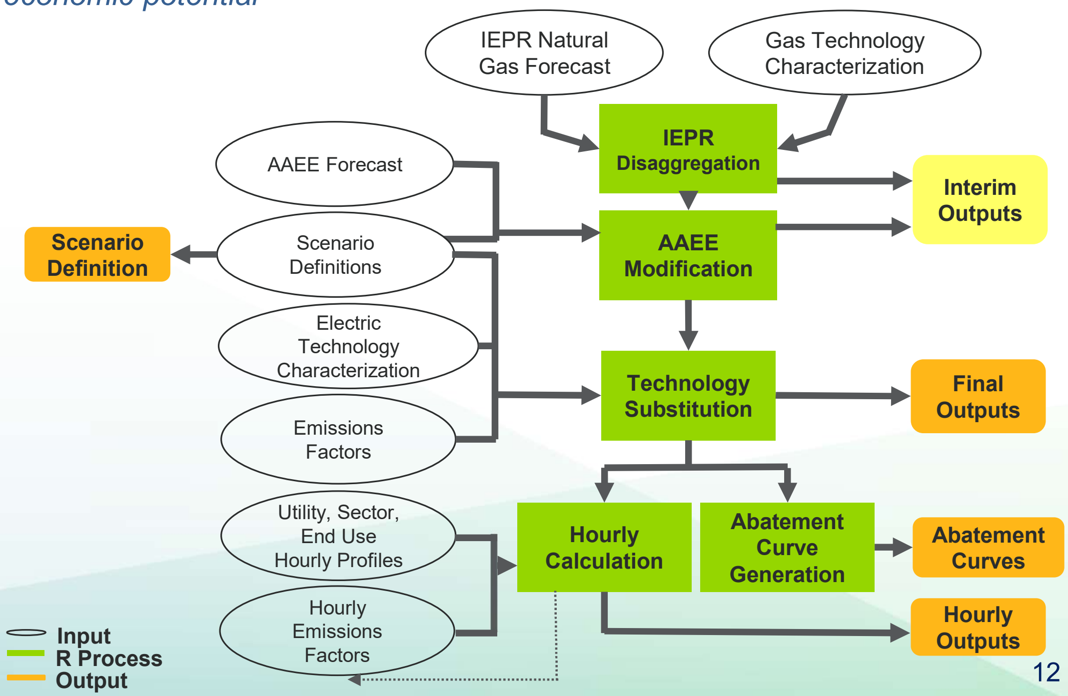
Overview of Fuel Substitution Scenario Analysis Tool (FSSAT)

How GHG emissions are projected in FSSAT

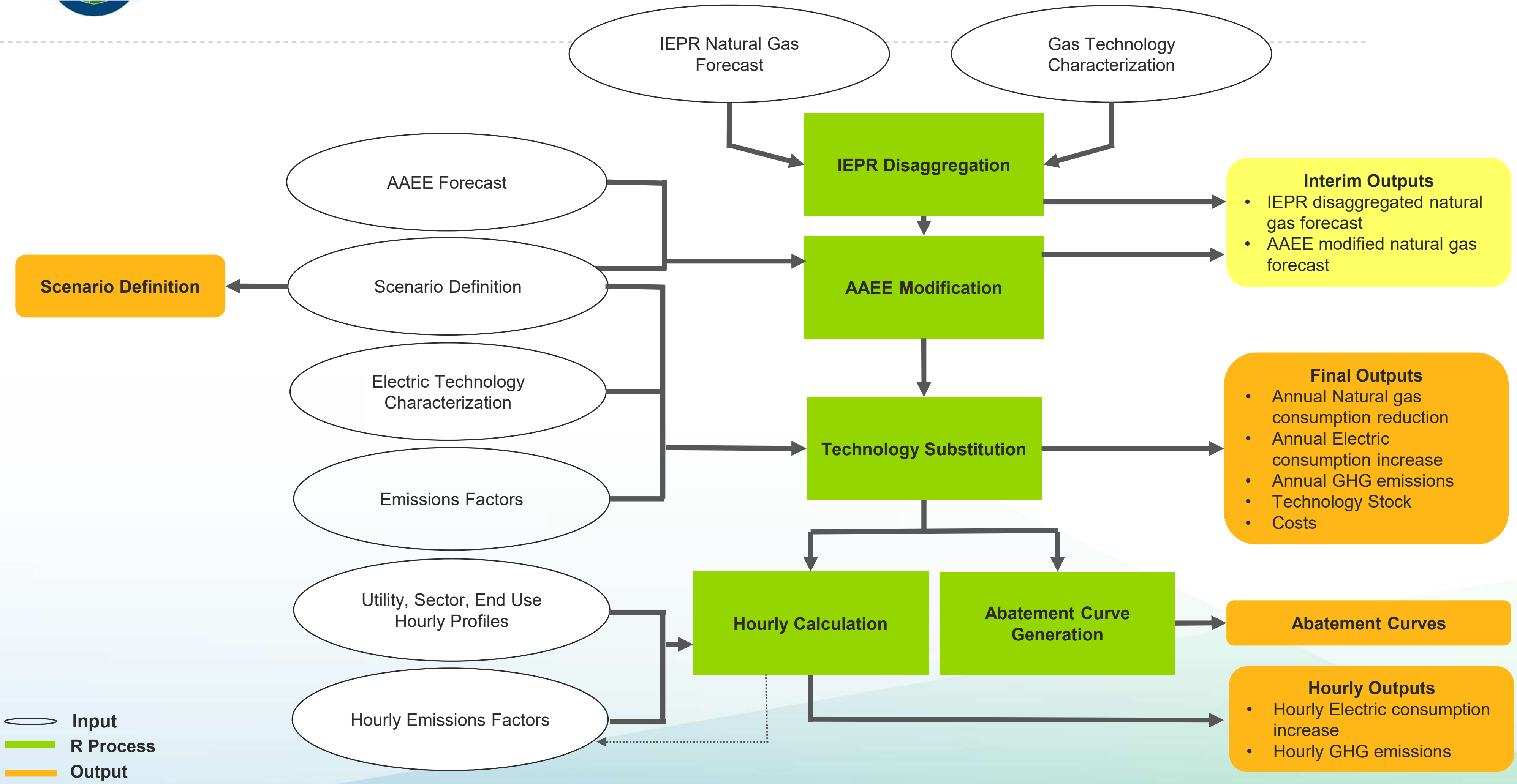
GHG Emission Category	Method for Assessing	FSSAT GHG Component
Fuel combustion from natural gas	• AAEE reduces baseline consumption • FSSAT "what if" scenarios of sector/end-use/technology displacement of natural gas *(Cost and rate ramifications of RNG are currently beyond the scope of FSSAT)*	Natural Gas Combustion
Fuel combustion from other fuels	Constant 2017 value from CARB emission inventory	Other Fuel Combustion
Behind-the-meter methane emissions	FSSAT computes using linear relationship with natural gas fuel combustion and proper EF	Natural Gas Leakage
HFCs from refrigeration and air-conditioning	• FSSAT computes incremental HFCs from heat pumps • "stock" emissions use CARB projections with or without "success" of SB1383	Refrigerant Leakage (HFC)
Incremental electric generation emissions from fuel substitution	FSSAT's incremental electric load converted to GHG emissions using emission factors based on hourly loads from *2019 IEPR* Exploratory Study, augmented resource plans, and production simulation modeling	Electric Generation Emissions

FSSAT Key Inputs, Processes, and Outputs

1. Start with the 2017 IEPR baseline natural gas demand forecast for five electric services areas by sector and end-use
2. Modify the baseline natural gas demand forecast using AAEE natural gas savings (six scenarios from low to high)
3. Create the set of electric technologies that can replace natural gas technologies for each sector/end-use combination
4. Define one or more scenarios with assumed 2030 penetration share for each end-use segment:
   New construction; Replace on burnout; Accelerated retrofit
   Note: these are "what if" scenarios depicting technical rather than economic potential
5. Run the FSSAT tool for 2030 and intermediate years from 2020 to 2030
   - SAO developed hourly Electric Generation emission factors for 2022,2025,2030 by creating resource plans that satisfied reliability criteria, ran Plexos to generate emissions, and computed incremental load emission factors hour by hour, then smoothed the results.
6. Optional: run the hourly module for one of more scenarios to develop comparison charts.
7. Optional: Run the comparison module to observe key differences among multiple scenarios



FSSAT Key Inputs, Processes, and Outputs



IEPR NG Forecast

- CEC staff develops NG demand forecast in common sector models with electricity demand
- Electric utility service area is the unit of geography for most end-uses
- Variation in end-use fuel choice saturations are embedded in this NG demand forecast
- Consequences of fuel substitution from displacing NG and adding electricity mean there are different implications by electric service area
- Fuel saturation data are somewhat dated and can be replaced with results of 2019/20 RASS once data is available
- Although AB3232 uses 1990 GHG emissions to define the 2030 target, the counterfactual NG forecast without FS is a critical input

Adjusting Baseline Forecast for AAEE Savings

- The IEPR NG baseline forecast includes the impacts of historic utility programs and standards, but not the further savings from incremental utility programs or other types of savings assessed in the SB 350 process

- Baseline IEPR forecast has to be adjusted to remove AAEE savings to become the starting point for fuel substitution efforts
- There are six AAEE NG savings scenarios paralleling those well known for electricity planning purposes
- The greater the adjustment of the baseline forecast by AAEE savings, the less need there is for fuel substitution to satisfy the AB3232 target

Adjusted Baseline Forecast

- Used the 2019 mid-mid AAEE (3) planning forecast to adjust the 2017 mid IEPR baseline NG forecast
- 90% of combined Residential and Commercial Sector End Use consumption is considered for fuel substitution
- 85% of the above NG consumption considered for fuel substitution is in the Residential Sector and 90% of that is split evenly between HVAC and Water Heating

Residential Natural Gas Technologies and Replacement Electric Technologies

End Use	Natural Gas Technologies	Electric Technologies Reviewed	Electric Technologies Included (Y/N)
Space Heating	Furnace*	Standard and High Efficiency Packaged/Split Heat Pump	Y
		Standard and High Efficiency Variable Capacity Heat Pump	Y
	Condensing Furnace	Packaged Terminal Heat Pump	Y
		Radiant Heating	N
		Space and Water Heating Combination Systems	N
Water Heating	Gas Storage Water Heater*	Small Electric Water Heater (0.86, 0.88 and 0.93 EF)	Y
	Condensing Gas Storage Water Heater	Tankless Resistance Water Heater	Y
		Heat Pump Water Heater (>= 2.0 EF)	Y
	Instantaneous Gas Water Heater	Solar Water Heater	N
		Space and Water Heating Combination Systems	N
Cooking	Standard Natural Gas Range	Electric Cooktop (Resistance)	Y
		Electric Range (Resistance)	Y
		Electric Cooktop (Induction Heating)	Y
Laundry	Gas Clothes Dryer*	Heat Pump Clothes Dryer	Y

**This technology is characterized at multiple efficiency levels.*

Source: Guidehouse

Commercial Natural Gas Technologies and Replacement Electric Technologies

End Use	Natural Gas Technologies	Electric Technologies Reviewed	Electric Technologies Included (Y/N)
Space Heating	Furnace*	Standard and High Efficiency Variable Capacity Heat Pump	Y
	Condensing Furnace	Standard and High Efficiency Split System Heat Pump	Y
		Standard and High Efficiency Packaged Rooftop Unit Heat Pump	Y
	Boiler*	Packaged Terminal Heat Pump (PTHP)	Y
	Condensing Boiler	Variable Refrigerant Flow Systems	N
		Geothermal Heat Pump	N
Water Heating	Gas Storage Water Heater*	Tankless Electric resistance water heater	Y
	Condensing Gas Storage Water Heater	Electric Resistance Water Heater (0.86, 0.88 and 0.93 EF)	Y
	Instantaneous Gas Water Heater Gas Water Heating Boiler*	Heat Pump Water Heater	Y
	Condensing Gas Water Heating Boiler	Pool heating equipment	N
Cooking	Convection Oven*	Electric Fryer/Broiler	Y
		Electric Oven	Y
	Steamer*	Electric Stove	N
		Electric Overhead Broiler	N
	Fryer*	Electric Griddles	N
		Combination Oven	N
Laundry	Gas Clothes Dryer*	Electric Dryer	N

**This technology is characterized at multiple efficiency levels.*

Source: Guidehouse

Basic Fuel Substitution Equation

The key assumption is that the tool calculates the electric load using the gas consumption of the baseline technology. Equation 1 provides the calculation of electric consumption increase using the baseline technology gas decrease.

Equation 1: Added Electricity Consumption – Electrification of Gas Load

$$Elec\ Consumption_{i,k} = Gas\ Avoided_{i,j,k} * \frac{Gas\ Tech\ Eff_j}{Elec\ Tech\ COP_k} * \frac{29.3\ kWh}{1\ therm}$$

$Where$:

$Elec\ Consumption_{yr=i, electec\ h=k}$ = Electric consumption by electric technology, k, in year, i.

$Gas\ Avoided_{i,j,k}$ = Gas consumption avoided by substituting gas technology, j, with electric technology, k, in year, i.

$Gas\ Tech\ Eff_j$ = Fuel efficiency of gas technology, j.

$Elec\ Tech\ COP_k$ = COP of electric technology, k.

* *Equation 5 in FS Methodology Report*

Electric Load Increase From Fuel Substitution Example: Electrification of Gas Load

Step	Example
1) Identify gas technology	Residential small gas water heater
2) Identify replacement electric technology	Residential heat pump water heater
3) Characterize annual unit energy consumption of replaced gas technology	403 therms
4) Determine COP of electrification technology	COP = 3.0
5) Electrify replaced gas technology based on COP and furnace efficiency	$\text{Unit energy consumption (kWh)} = \frac{\left[(403\ \text{therms})\left(29.3\frac{\text{kWh}}{\text{therms}}\right)(0.8\ \text{EF})\right]}{3.0\ \text{COP}} = 3{,}149\ \text{kWh}$

* *Table 19 in FS Methodology Report*

Summary: BASIC approach

- Adjust IEPR Natural Gas consumption forecast with AAEE savings forecast by Utility Service Territory
- Disaggregate from End Use to NG Technology
- 90% of the NG technology is available for substitution by Electric technologies
- Actual technology substitution is determined by user input scenarios
- FSSAT calculates annual and hourly changes in emissions from NG consumption reduction, Electricity consumption increase, BTM NG leakage, refrigerant leakage, and other fuel combustion
- FSSAT calculates annual costs of FS technology and net costs from NG consumption reduction & Electricity consumption increase

Scenario Design

Summary of scenario input variables

Scenario definitions used for draft results

FSSAT Scenario Input Variables

Scenario Parameter	Definition	Variable Range
New construction (NC)	Percentage of eligible technologies that will be electric in the last year of the forecast period (2030).	0%—100%
Replace on burnout (ROB)	Percentage of existing gas technologies that will burn out by the end of the forecast period (2030) and be replaced by an electric technology.	0%—100%
Early replacement (RET)	Percentage of existing gas technologies that will not burn out by the end of the forecast period (2030) and will be replaced by an electric technology.	0%—100%
Technology efficiency	A weighting that determines the distribution among potential electric replacement technologies according to their relative efficiencies.	Low efficiency weighted
		Evenly weighted
		High efficiency weighted
Cost threshold (% of maximum)	There is a range of technology costs by end use. This percentage defines the highest allowable technology cost by end use. When it is 100 percent, the highest cost electric technology may be used as a substitute. When it is 65 percent, only technologies at or below the sixty-fifth percentile cost are eligible electric substitutes.	Minimum value: 0%—100%
		Maximum value: 0%—100%
		Maximum value > minimum value
Ancillary costs	Designation if ancillary (that is, panel) costs are included in total costs.	Not included
		Include panel
SB 1383 goals	On: SB 1383 HFC reduction goals are assumed to be achieved.	On
	Off: SB 1383 HFC reduction goals are assumed to not be achieved, and output emissions are defined by the user input HFC emissions scenario.	Off
Industrial and Agricultural	Percentage of eligible industrial and agricultural gas technologies replaced by electric technologies by the end of the forecast period (2030).	0%—100%

Source: Guidehouse

Types of Scenarios Investigated

- Scenarios designed to illustrate capabilities of the FSSAT tool and implemented by Guidehouse team
  - Scenario 1 – Minimize Cost to End Users
    - Residential New Construction 35% all electric by 2030
    - Residential ROB 30-40% by end use
    - Cap cost threshold at 25% of maximum
  - Scenario 2 – Limited Cost Impacts to End-Users
    - Residential & Commercial New Construction 50% all electric by 2030
    - Residential ROB 40-50% by end use
    - Residential early replacement 10-15% by end use
    - Cap cost threshold at 60% of maximum
  - Scenario 3 – Major Decarbonization Program
    - Residential & Commercial New Construction 95% & 50% all electric by 2030
    - Residential & Commercial ROB 60-75% & 40-50% by end use
    - Residential & Commercial early replacement 15-20% & 10-15% by end use
    - Cap cost threshold at 60% of maximum

All three Scenarios above are set to meet SB 1383 goals, use default HFC emission values, a 1% NG BTM leakage rate, a mix of technology efficiencies and AAEE Scenario 1

Types of Scenarios Investigated

- Scenarios designed and implemented by CEC/EAD staff to satisfy AB3232 GHG reduction goal
- Scenarios designed and implemented by CEC/EAD staff to illustrate sensitivity to critical input assumptions
- Used CARB/CEC updated HFC emission values, 0.475% NG BTM leakage rate, and AAEE mid-mid planning Scenario 3
- Used 100% all electric new construction in both Residential & Commercial Sectors by 2030 and did not impose any cost cap thresholds
- Compare results between all else equal scenarios meeting and not meeting SB 1383 goals
- Compare results between all else equal scenarios using a high efficiency weighted mix of technology efficiencies (“mix”) and those using only the single most efficient technology available (“best”)

FSSAT Scenario Definitions

Scenario Parameter	Scenario 1: NC100 ROB90 RET40 mixEF newHFC newNO	Scenario 2: NC100 ROB90 RET50 mixEF newHFC newNO	Scenario 3: NC100 ROB90 RET60 mixEF newHFC newNO	Scenario 4: NC100 ROB90 RET70 mixEF newHFC newNO	Scenario 5: NC100 ROB90 RET80 mixEF newHFC newNO	Scenario 6: ALL100 bestEF newHFC newNO	Scenario 7: ALL100 mixEF newHFC newNO	Scenario 8: NC100 ROB90 RET70 bestEF newHFC newYES	Scenario 9: NC100 ROB100 RET70 bestEF newHFC newYES	Scenario 10: ALL100 mixEF newHFC newYES	Scenario 11: ALL100 bestEF newHFC newYES
New Construction	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%
Replace on Burnout	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 90% Commercial 90%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 100% Commercial 100%
Early Replacement	Residential 40% Commercial 40%	Residential 50% Commercial 50%	Residential 60% Commercial 60%	Residential 70% Commercial 70%	Residential 80% Commercial 80%	Residential 100% Commercial 100%	Residential 100% Commercial 100%	Residential 70% Commercial 70%	Residential 70% Commercial 70%	Residential 100% Commercial 100%	Residential 100% Commercial 100%
Technology efficiency	High Efficiency Weighted	High Efficiency Weighted	High Efficiency Weighted	High Efficiency Weighted	High Efficiency Weighted	single best	High Efficiency Weighted	single best	single best	High Efficiency Weighted	single best
SB 1383 goals	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES

For more details please refer to [June 9 2020 Selected Input Assumptions_FSSAT_5.7.xls] workbook in docket.

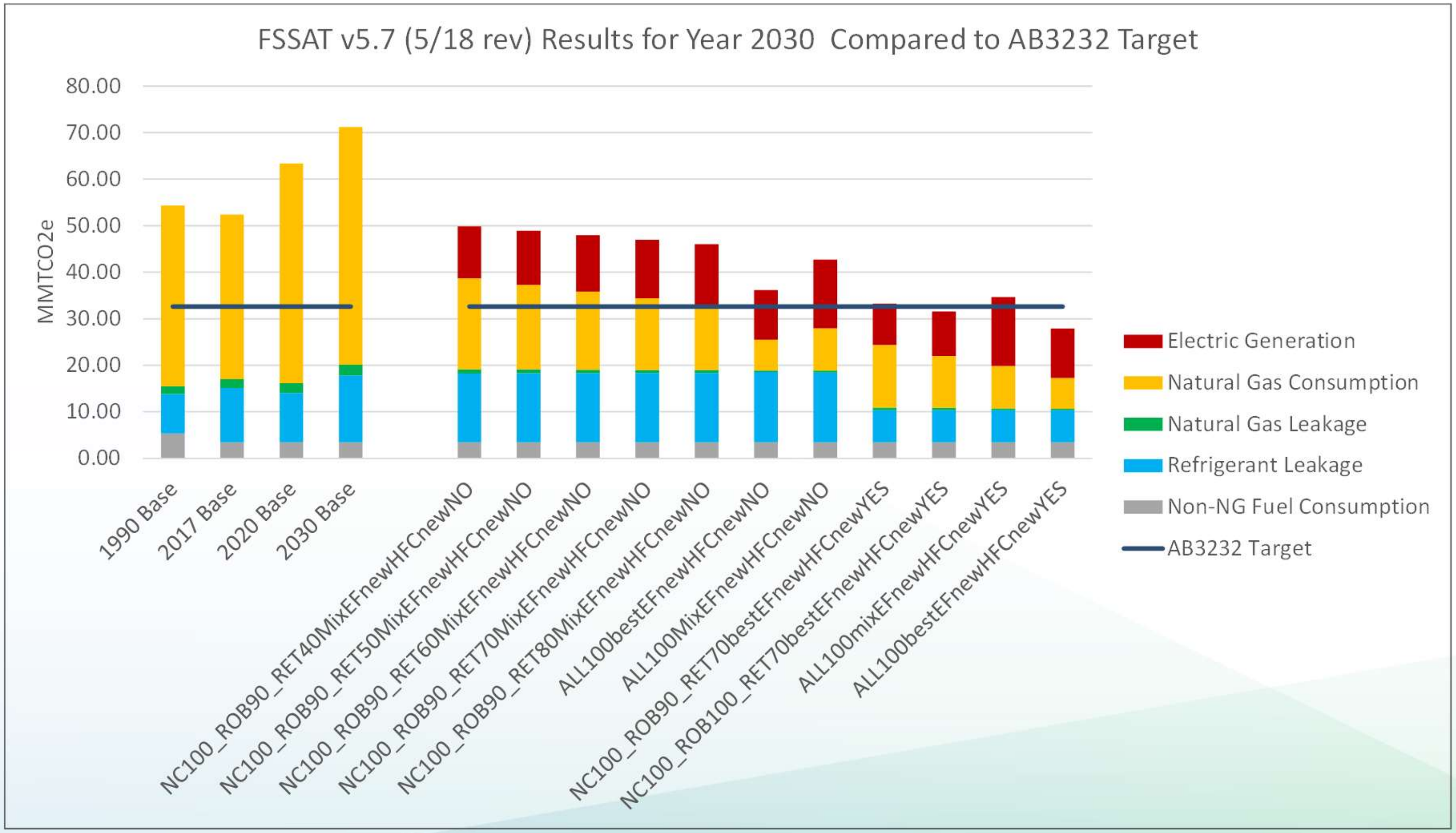
Scenario Results

GHG reduction potential and results summary

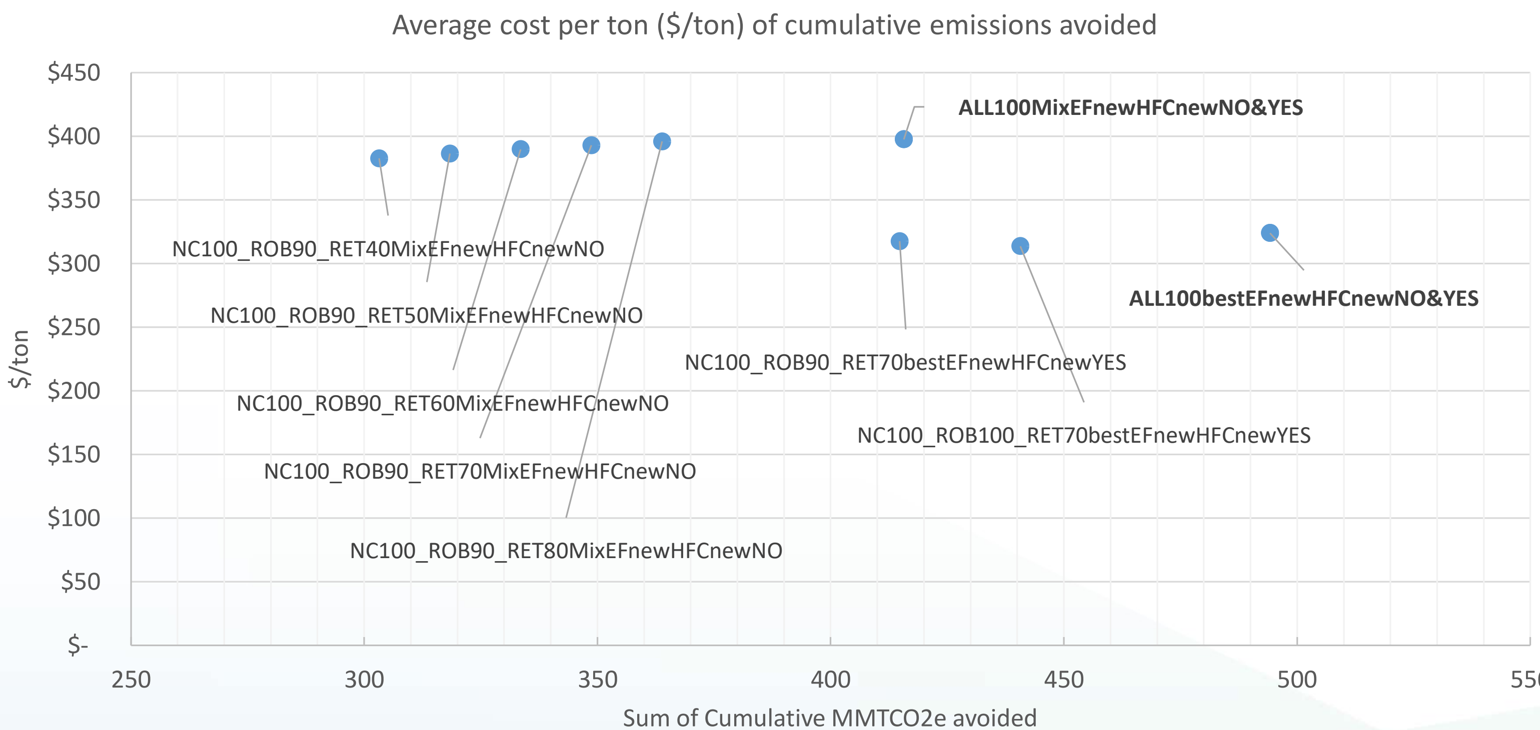
Initial FSSAT Results

- The following will be discussed at an aggregate level today:
  - GHG reduction potential and summary of results
  - The importance of HFC emissions
  - Disaggregation of costs
  - Rates
  - Electric load impacts
- Workshop #2 will report and discuss
  - Respond to informal questions and comments
  - Cost effectiveness / marginal abatement curves
  - Technology level analysis that explains aggregate results
  - GHG reduction potential of emissions outside of baseline

GHG Reduction Potential By Scenario

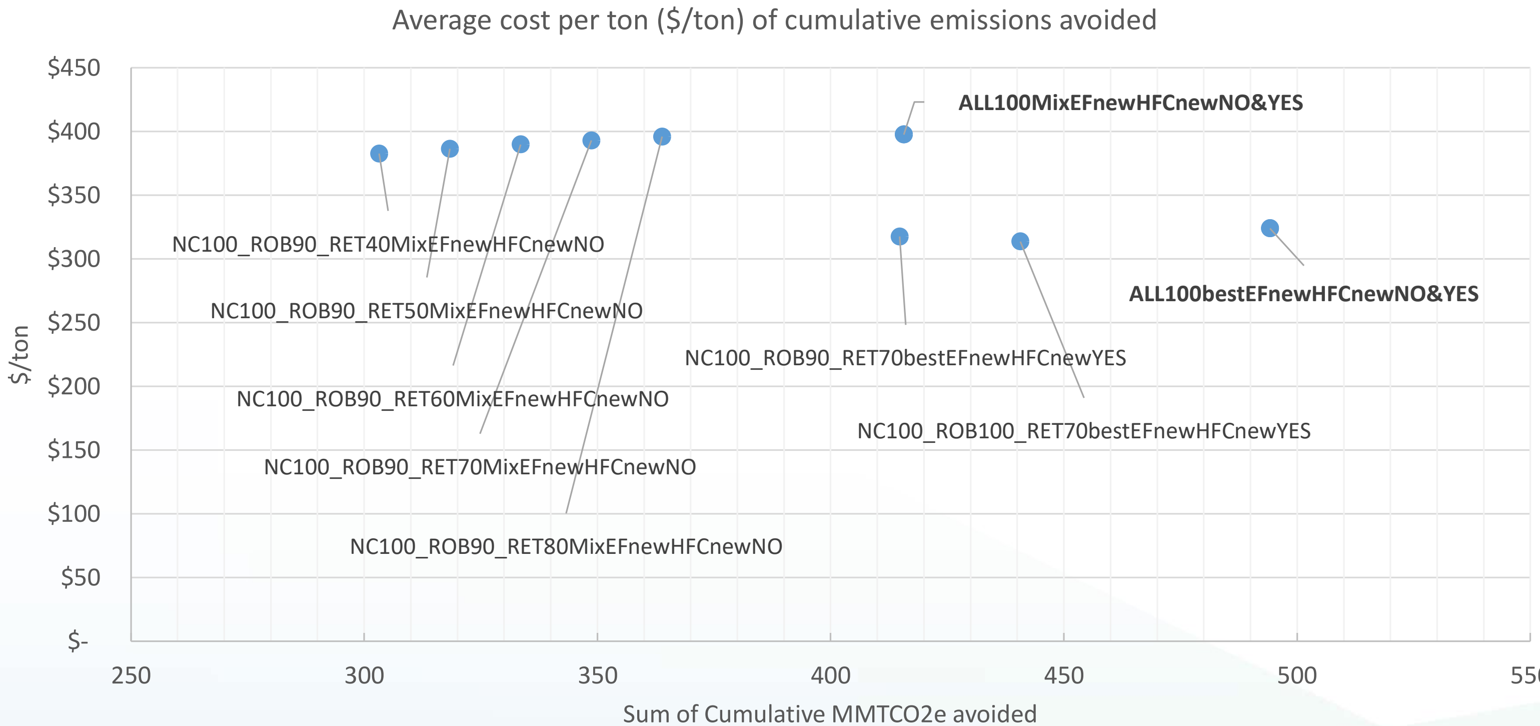


Rough cost per metric ton estimates of avoided cumulative emissions by scenario



Caveats: These gross costs estimates were generated from the FSSAT generated marginal abatement cost curves, which excludes panel cost upgrades, HFC emission costs and impacts, and other important factors exploring within FSSAT when examining cost-effectiveness.

Rough cost per metric ton estimates of avoided cumulative emissions by scenario



- Range of $313-$395 ($/ton)
- Having “best” efficiency brings down costs

Scenario Results Highlights: GHGs

- Takes more than a 40% reduction in gas to get a 40% reduction in 1990 GHG emissions
- Incremental annual electricity will lead to substantial growth in renewable requirements due to SB 100
- Very large peak impacts but these might be reduced to some extent if staff can develop residential space heating load profiles that reflect diversity of residential building vintages and end user operating practices
- Staff analysis shows that the modeled scenarios do not achieve the 2030 AB 3232 target except under the most extreme assumptions
- Estimates of average cost per metric ton ($/ton) of cumulative emissions reduction ranged from **$313-$395**, which are relatively high compared to the strategies examined in Table 10 in CARB's 2017 Scoping Plan (CARB 2017)

Scenario Results

The importance of HFC emissions and coordination with CARB

Importance of HFC Emissions and coordination with CARB

CARB's Official GHG Inventory

- No *official* accounting of *total* refrigerant emissions (HFCs & ODSs) in 1990 exists
  - The magnitude of these ozone-depleting substances (ODSs) emissions in 1990 were large (~25 MMTCO2e)
  - The amount of hydrofluorocarbons (HFCs) in 1990 were negligible (0.01 MMTCO2e)
  - Both are not realistic values to use for a 1990 baseline value for AB 3232
- CARB's inventory of HFCs grew to very substantial values in 2017 and in counter-factual projections for 2030
- CARB originally requested that the CEC use 2013 as the base year for HFC emissions, but this is infeasible

Staff Adjustments to Guidehouse's Version of Refrigerant Emissions and AB 3232 baseline

- Applied the 2013 value of HFC emissions (8.49 MMTCO2e) for 1990 instead
- Staff accepted CARB's projections with and with out SB1383

Implications of Changes in HFC Emissions

- The greater the 1990 value, the easier it is to achieve AB 3232 40% target
- CARB's HFC counterfactual without SB1383 results in very high 2030 GHG emissions
- CARB's projected HFC emissions with SB1383 are about 1/4 of the AB3232 target

Problem:
Not all refrigerants are in CARB's GHG inventory

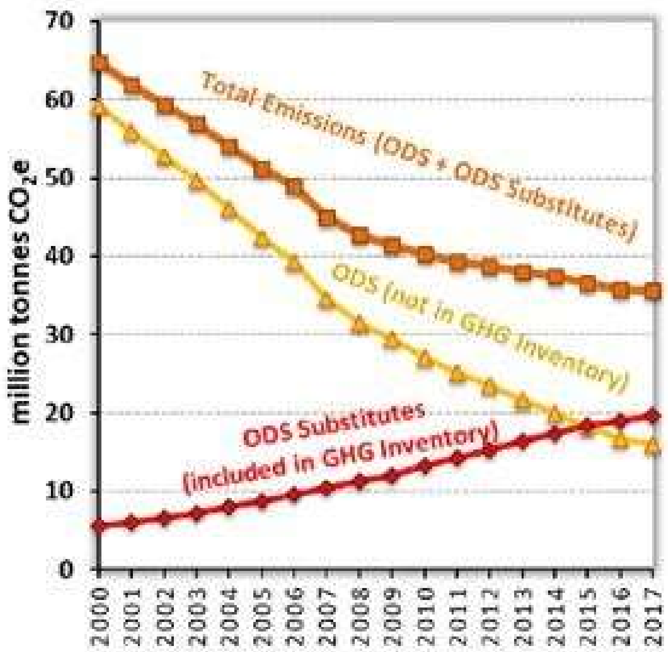


Figure 17a. Trends in ODS and ODS Substitutes Emissions. This figure presents the trends in emissions from ODS Substitutes, ODS, and their sum ("Total Emissions"). ODS Substitutes emissions are specified in IPCC Guidelines and AB 32 and are included in the inventory. ODS are also GHGs, but are tracked separately outside of the inventory.

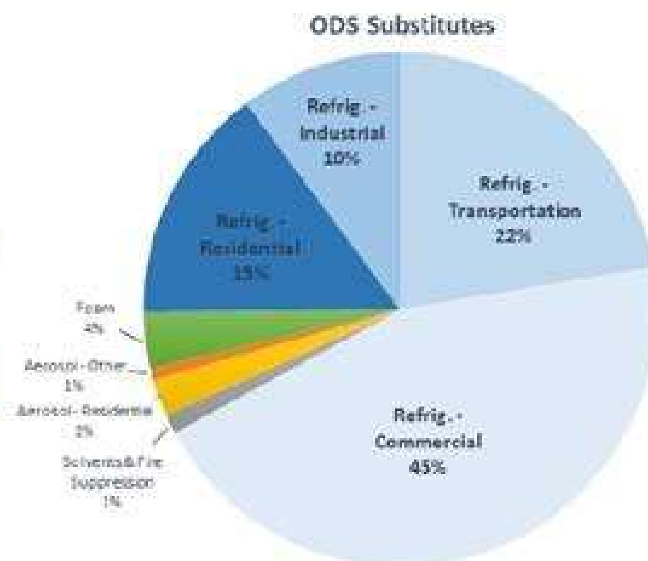
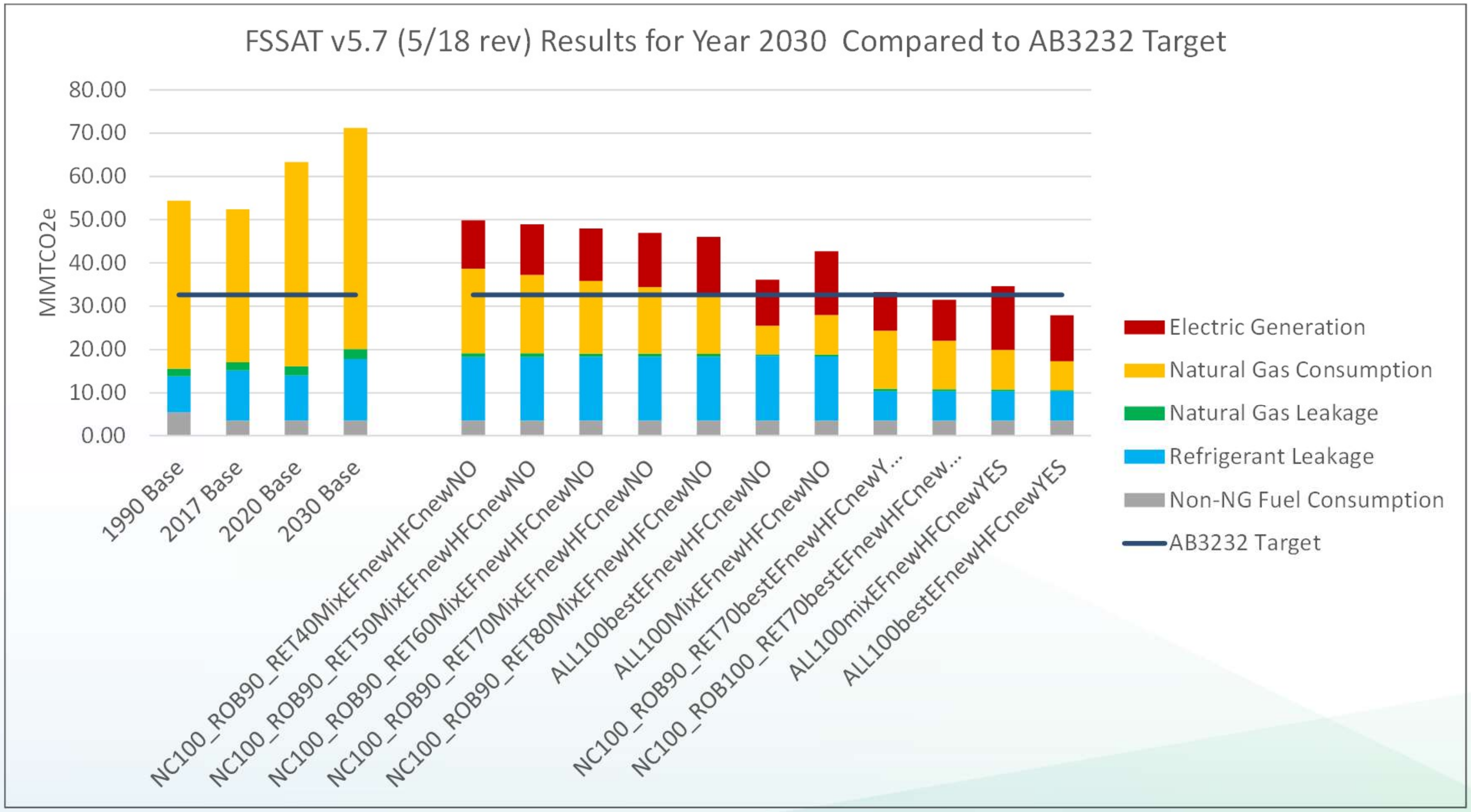


Figure 17b. ODS Substitutes Emissions by Category. This figure presents the breakdown of ODS substitutes emissions by product type and sector category in 2017. Refrigerants ("Refrig.") used in various sectors make up the majority of ODS substitutes emissions.

Source: CARB (2019)

The likelihood that the 2030 AB 3232 target is met depends on the success of SB 1383



"YES" = SB 1383 meets 2030 target

Scenario Results Highlights:

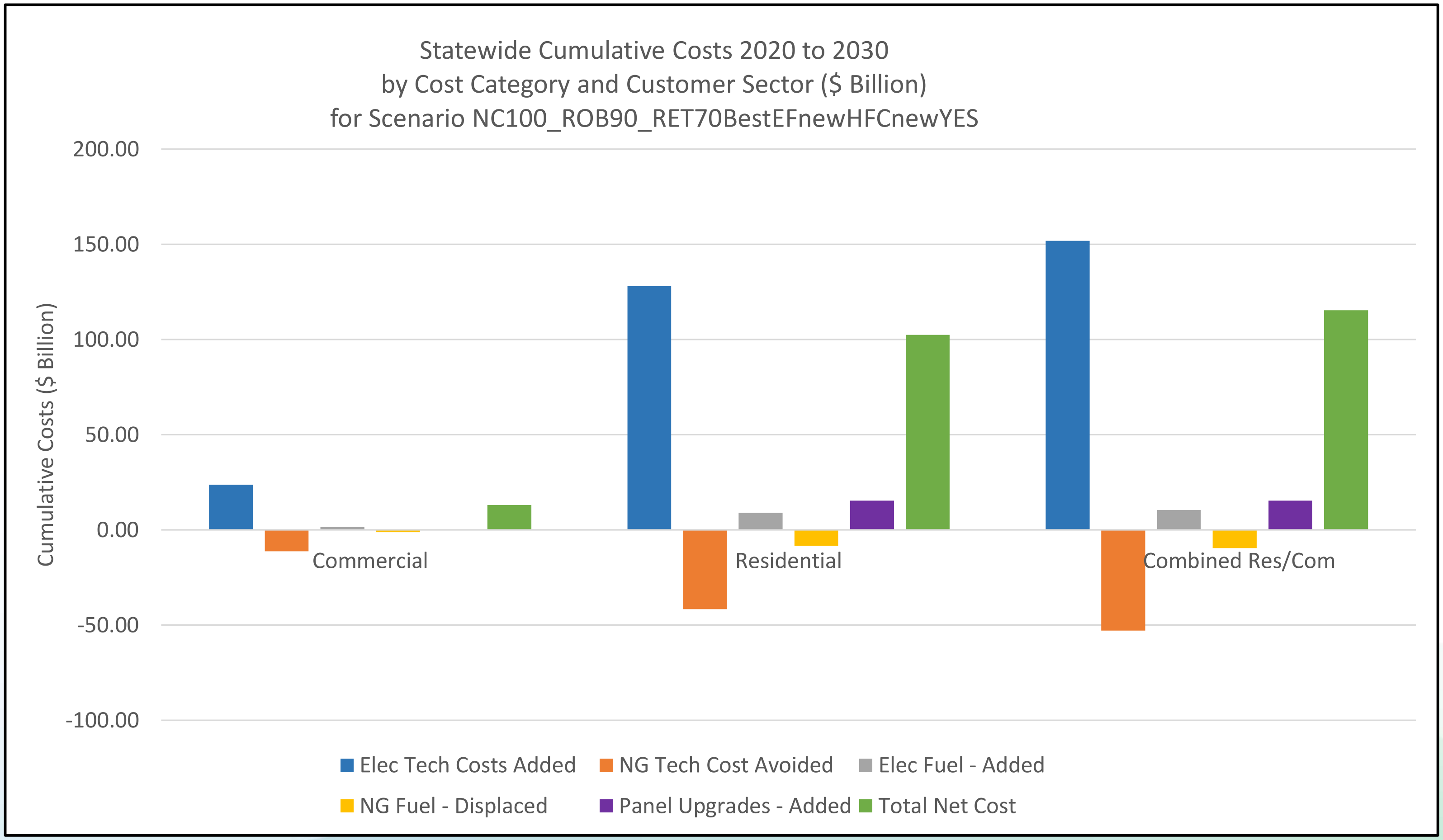
- 1990 refrigerant emission baseline revised to 8.49 MMTCO2e, reflecting a realistic value of emissions and consistent with Senate Bill 1383's (Lara, Chapter 395, Statutes of 2016) 2013 base year
- Achieving the HFC emission targets in Senate Bill 1383 is crucial for AB 3232 to meet its 2030 goal
- According to CARB, even with current and proposed regulations, additional measures are needed to reduce HFC emissions 40 percent below 2013 levels by 2030 as required by SB 1383
- FSSAT's SB 1383 toggle off and on illustrates the importance of achieving the SB1383 goal given that this is a mandate
- FSSAT's SB 1383 toggle currently does not affect output costs. To understand these costs requires much more detailed work with CARB

15-minute BREAK

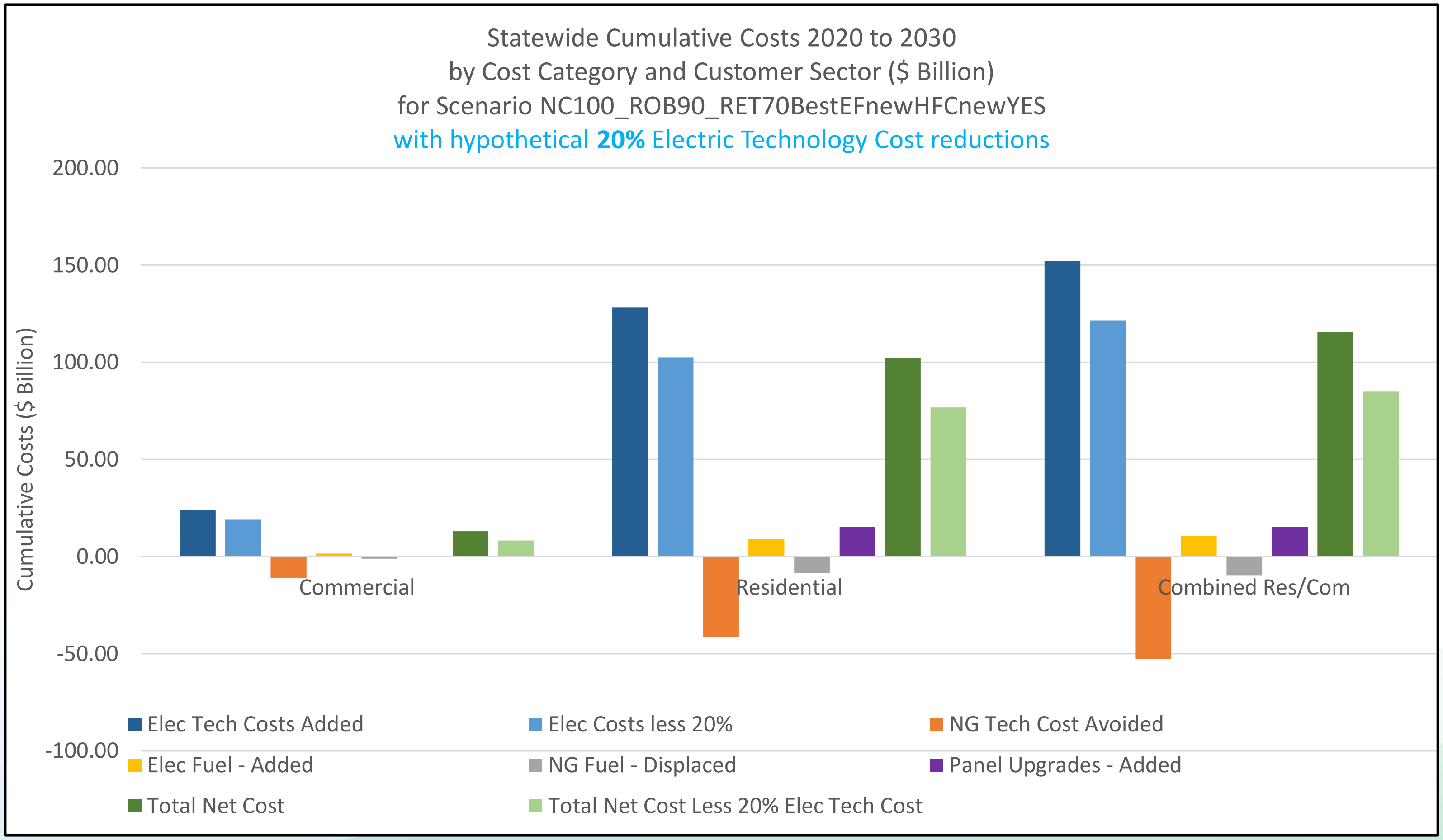
Scenario Results

Disaggregation of Costs

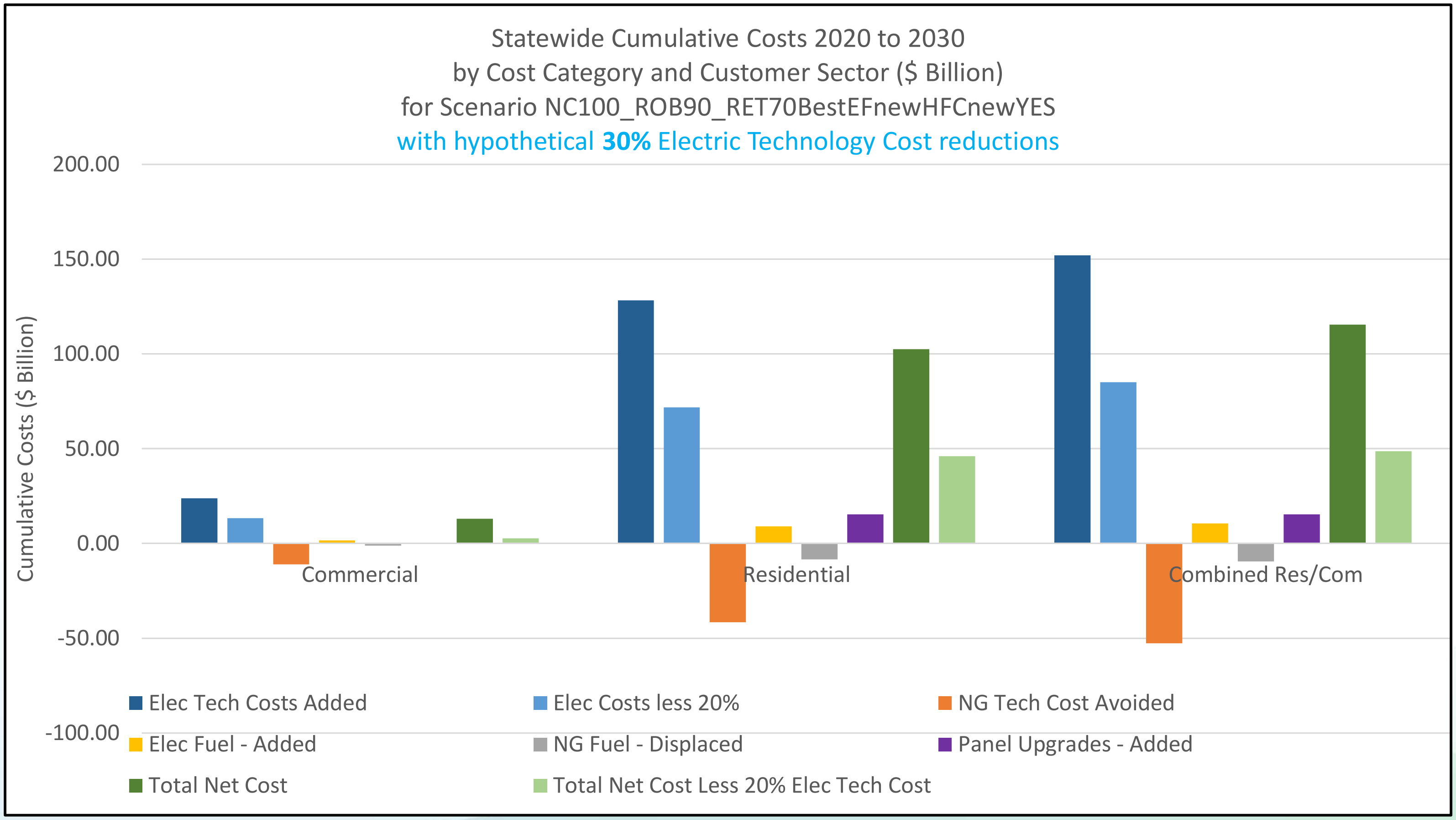
Statewide Cumulative Costs for 2020 to 2030 for Scenario 8 (100% NC, 90% ROB, 70% RET)



Statewide Cumulative Costs for 2020 to 2030 for Scenario 8 (100% NC, 90% ROB, 70% RET)



Statewide Cumulative Costs for 2020 to 2030 for Scenario 8 (100% NC, 90% ROB, 70% RET)



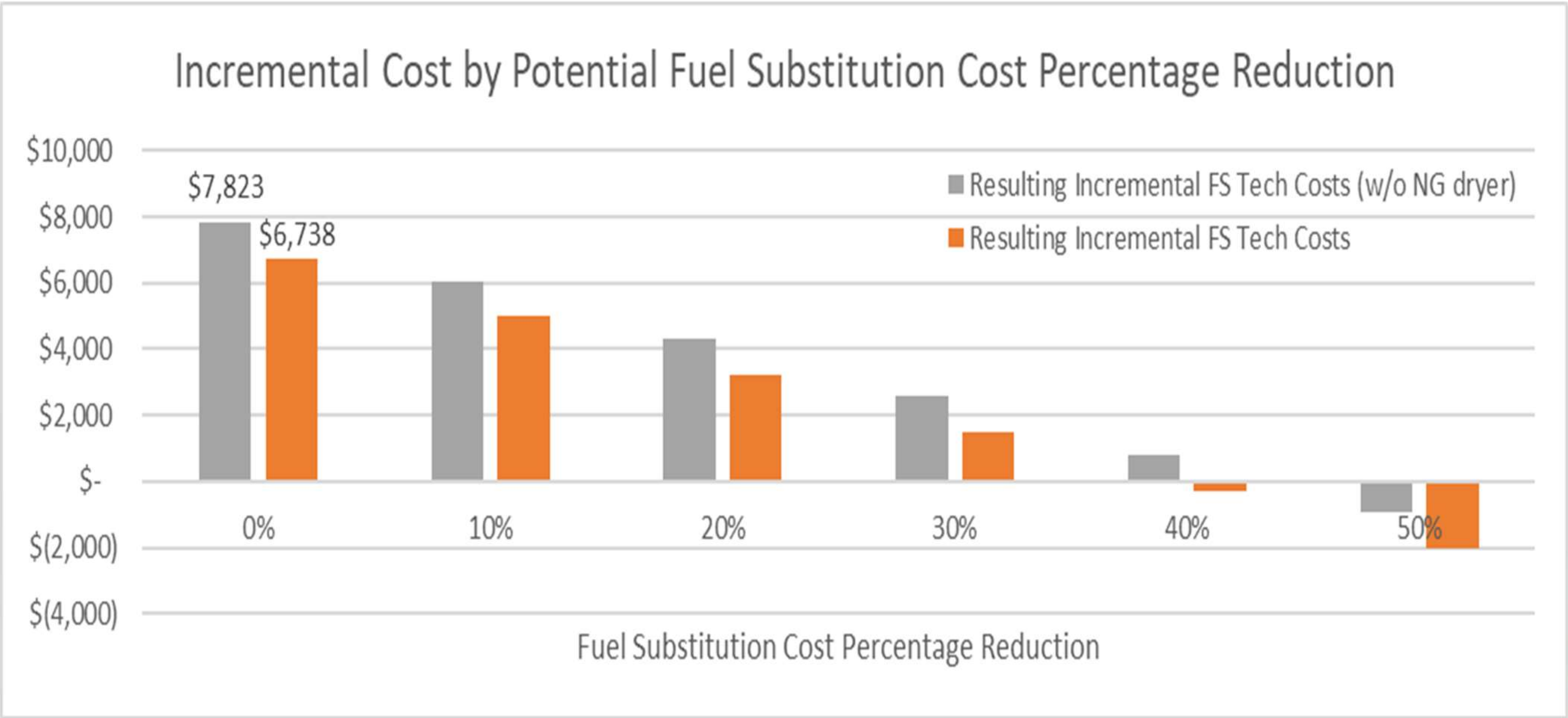
Comparison of Gross and Incremental Household Technology Replacement Costs

	Natural Gas Replacement	*End Use*		Fuel Substitution
$ 583	Res | Gas Cooktop	*Cooking*	$ 2,232	Res Induction Cooking Stove
$ 728	Res | Gas Oven	*Cooking*	$ 1,133	Res Electric Resistance Oven
$ 1,085	Res | High Eff. Gas Clothes Dryer - 3.48 CEF	*Laundry*		
		Space Heating	*$ 10,770*	*High Eff. Variable Capacity Heat Pump*
		Space Heating	*$ 8,982*	*High Efficiency Packaged/Split Heat Pump*
		Space Heating	*$ 5,605*	*Packaged/Split Heat Pump*
		Space Heating	*$ 7,533*	*PTHP*
$ 6,650	Res | High Eff. Furnace (AFUE = 90.6, HIR = 1.07)	*Space Heating*	$ 10,291	Variable Capacity Heat Pump
$ 1,745	Res | High Eff. Small Gas Storage Water Heater (0.70 EF - 50 Gal)	*Water Heating*	$ 3,873	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)
$ 10,791	Replacement Gas Technology Cost	*Total Gross*	**$ 17,529**	Total Gross Technology Fuel Substitution Cost (Induction CT, ER Stove, VCHP, HPWH)
$ 9,706	Total w/o NG dryer replacement	*Total Gross*		

→Total **Incremental** FS Technology Costs:

$6,738 (= $17,529 - $10,791) or **$7,823** (= $17,529 - $9,701) w/o NG dryer

Comparison of Gross and Incremental Household Technology Replacement Costs



Scenario Results Highlights: Technology Costs

- When looking at the “best fit” scenario (100% NC, 90% ROB, 70% RET) which achieves the 2030 target
  - The residential sector has largest net costs
  - The costs of added electric appliance dominates as the largest cost that drives total net costs
  - Technology cost reductions of 20-30% does bring net costs down
- Incremental costs are positive compared to natural gas appliance replacement
- Incremental costs can potentially diminish or become negative when the costs of electric appliances are reduced

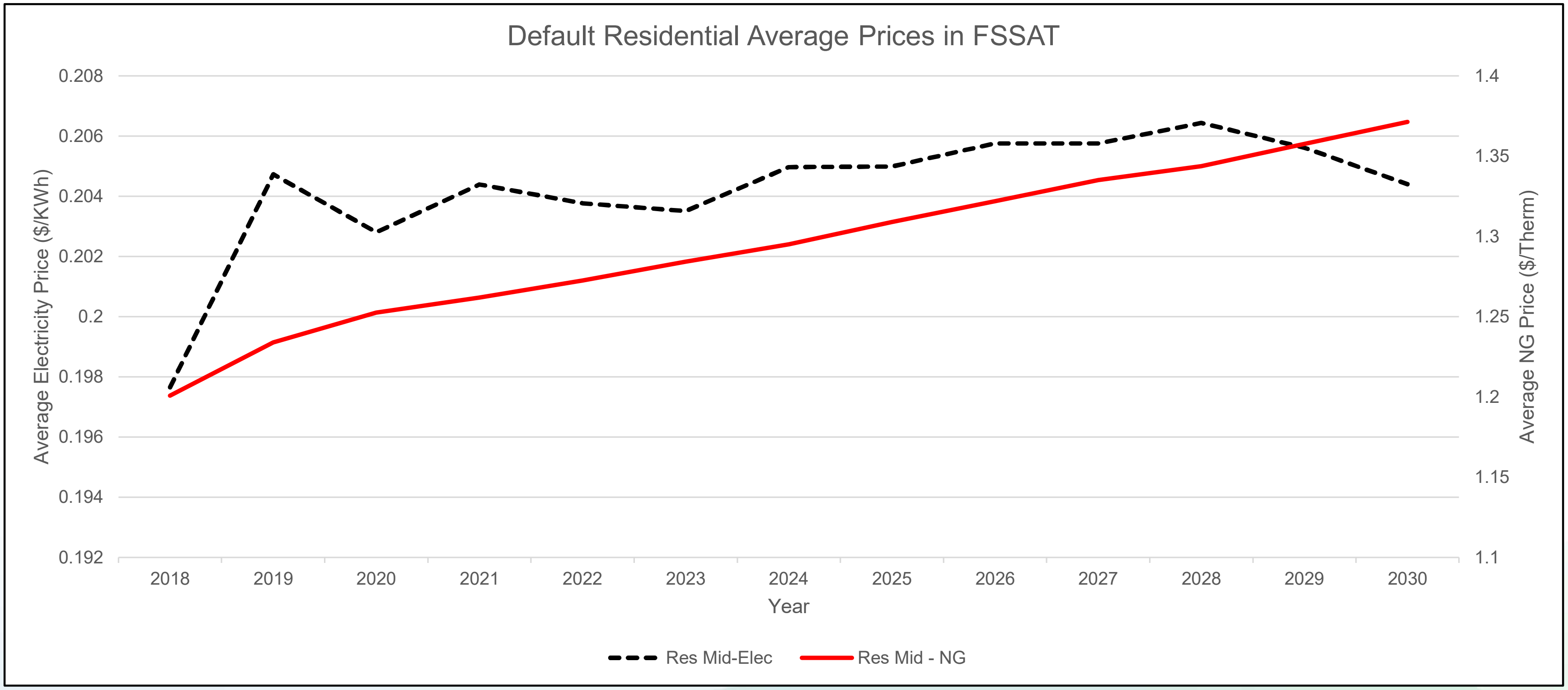
Scenario Results

Rates

Role of Rates in FSSAT

- FSSAT uses average prices – not rate structure detail
- Average prices are used to compute increased expenditures on incremental electric consumption, and saved expenditures on displaced natural gas consumption
- Since FSSAT is designed to explore consequences of “what if” scenarios, electric and natural gas rates or prices play no role in determining the penetration of fuel substitution

Default Rates in FSSAT



Cost Impacts of Fuel Substitution

- Incremental electric load resulting from fuel substitution requires two types of resource additions:
  - Additional resources to provide incremental electric energy, of which at least 60 percent must be renewables in 2030 with increasing proportions in future years to comply with SB100
  - Additional capacity (supply side or demand side) to satisfy peak demand and other aspects of system reliability
- To the extent that renewable natural gas (RNG) is a component of a decarbonization strategy, then average costs of gas delivered to end-users will increase

Rate Impacts of Additional Electric Costs

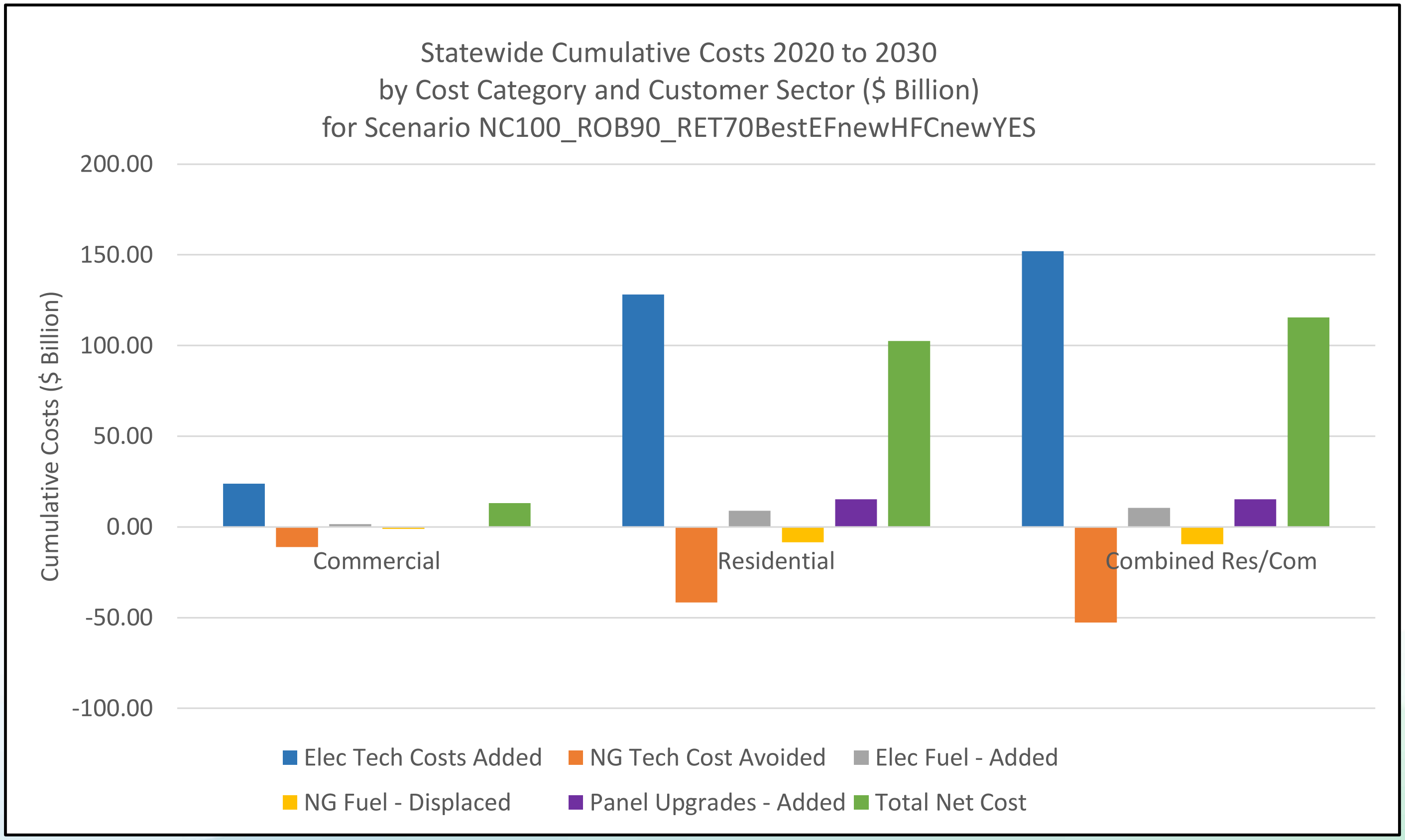
- No clear public policy exists to guide development of rates in a highly electrified future
- The electric rates used to cost out annual expenditures on incremental electric consumption use “business as usual” average process from the CEC/EAD staff 2017 IEPR demand forecast
- Possible refinements:
    - Update to average prices from the 2019 IEPR demand forecast
    - Augment 2019 IEPR average prices with incremental costs reflective of high levels of fuel substitution
    - Create new cost category – impacts of incremental electrification costs on all electric customers

Rate Impacts on Natural Gas Customers

- No clear public policy exists to guide development of natural gas rates in a building decarbonization future
- The natural gas rates used to cost out annual expenditures on displaced natural gas consumption use "business as usual" average process from the CEC/EAD staff 2017 IEPR demand forecast
- Possible refinements:
  - Identify increased volumetric costs as RNG becomes a larger proportion of delivered gas
  - Develop increases in average prices to account for fixed costs components of total revenue requirements as volume decreases
  - Create new cost category – impacts of incremental RNG costs and rate implications of fixed costs recovery on remaining natural gas customers

Statewide Cumulative Costs for 2020 to 2030 for Scenario 8 (100% NC, 90% ROB, 70% RET)

Changes in electric ("Elec Fuel – Added) and natural gas (NG Fuel – Displaced) operating costs will affect total net costs



Scenario Results Highlights: Rates

- Electric and natural gas average prices used to compute net operating costs are simplistic and do not reflect either electric or natural gas costs beyond “business as usual” scale of energy consumption
- Improvements in cost calculations and average rate consequences are possible with substantial input from utilities
- CPUC R.20-01-007 is examining a wide range of issues linked to natural gas planning in a decarbonized future

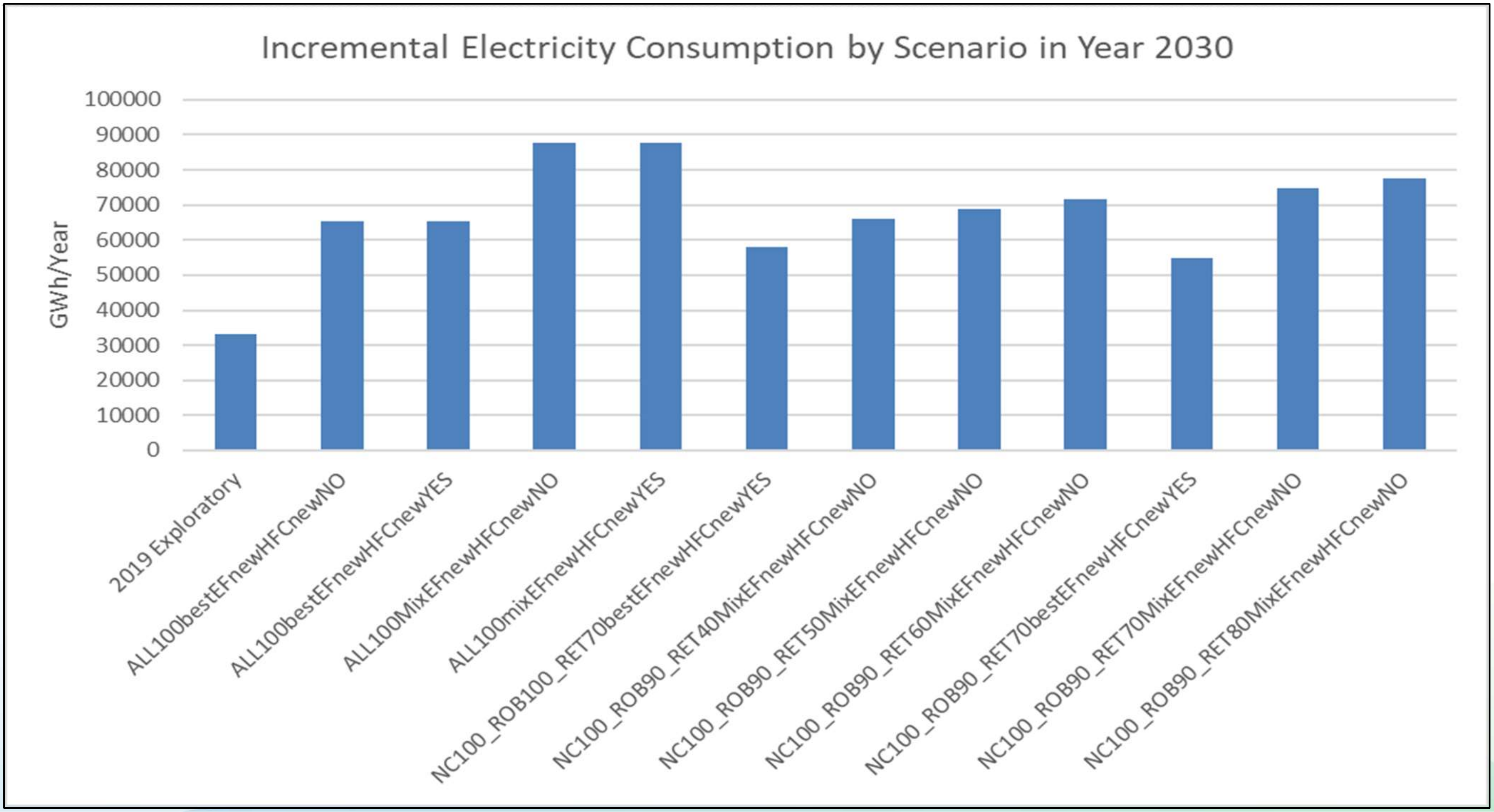
Scenario Results

Electric Load Impacts

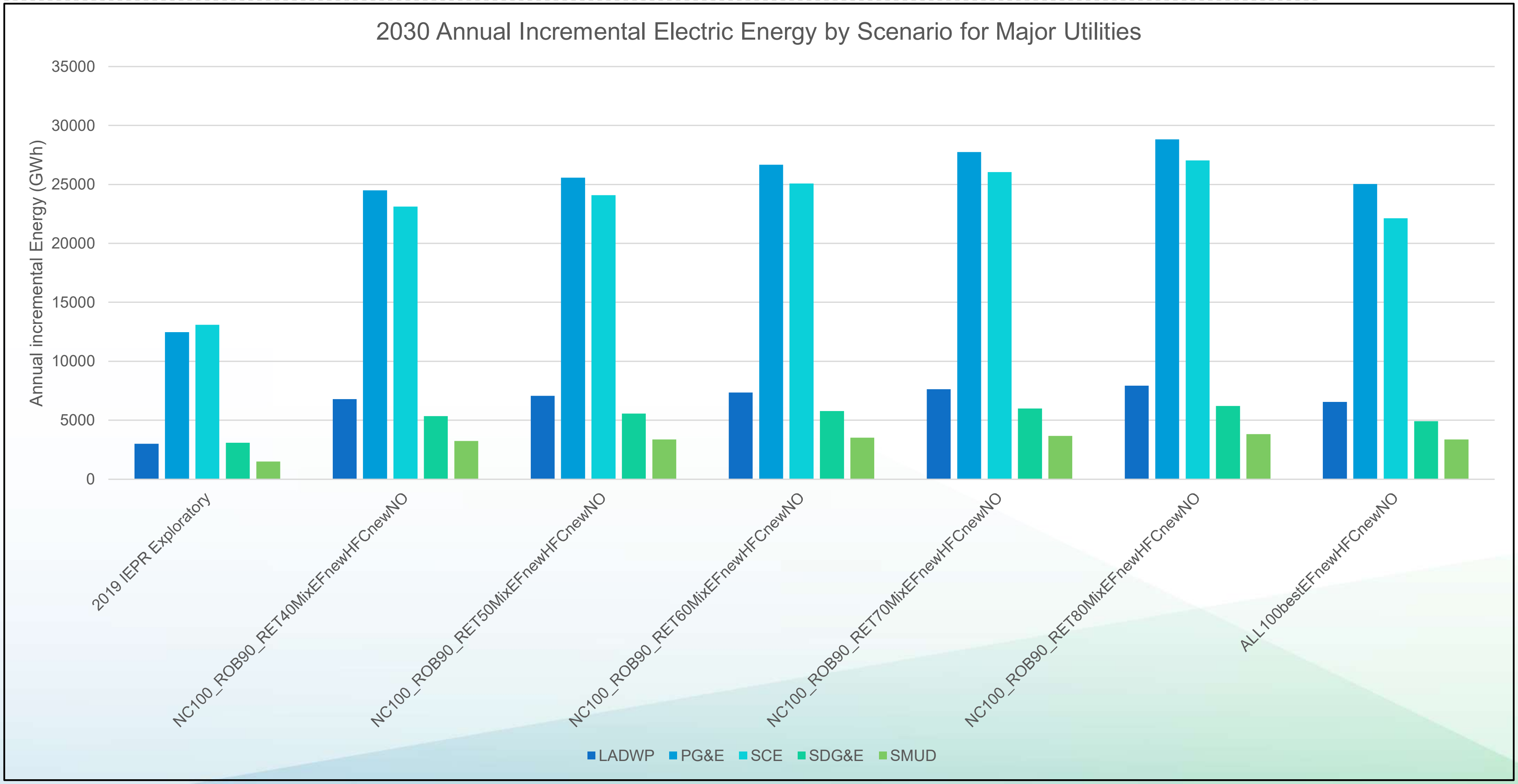
Incremental Annual Electric Energy

- FSSAT computes incremental electric energy with granularity of utility/sector/end-use/technology
- Scenarios can be designed that have differential penetration rates for each major utility service area
- To date staff has only designed scenarios that have common statewide penetration rates
- As shown on the following slide, all of the scenarios that are close to the AB3232 target have much larger incremental electric energy because:
  - Much larger NG reductions from the 2030 counterfactual
  - “fixed” GHG sources that are not being mitigated

Annual Incremental Electricity Demand



Annual Incremental Electric Energy by Utility



Developing Hourly Load Impacts

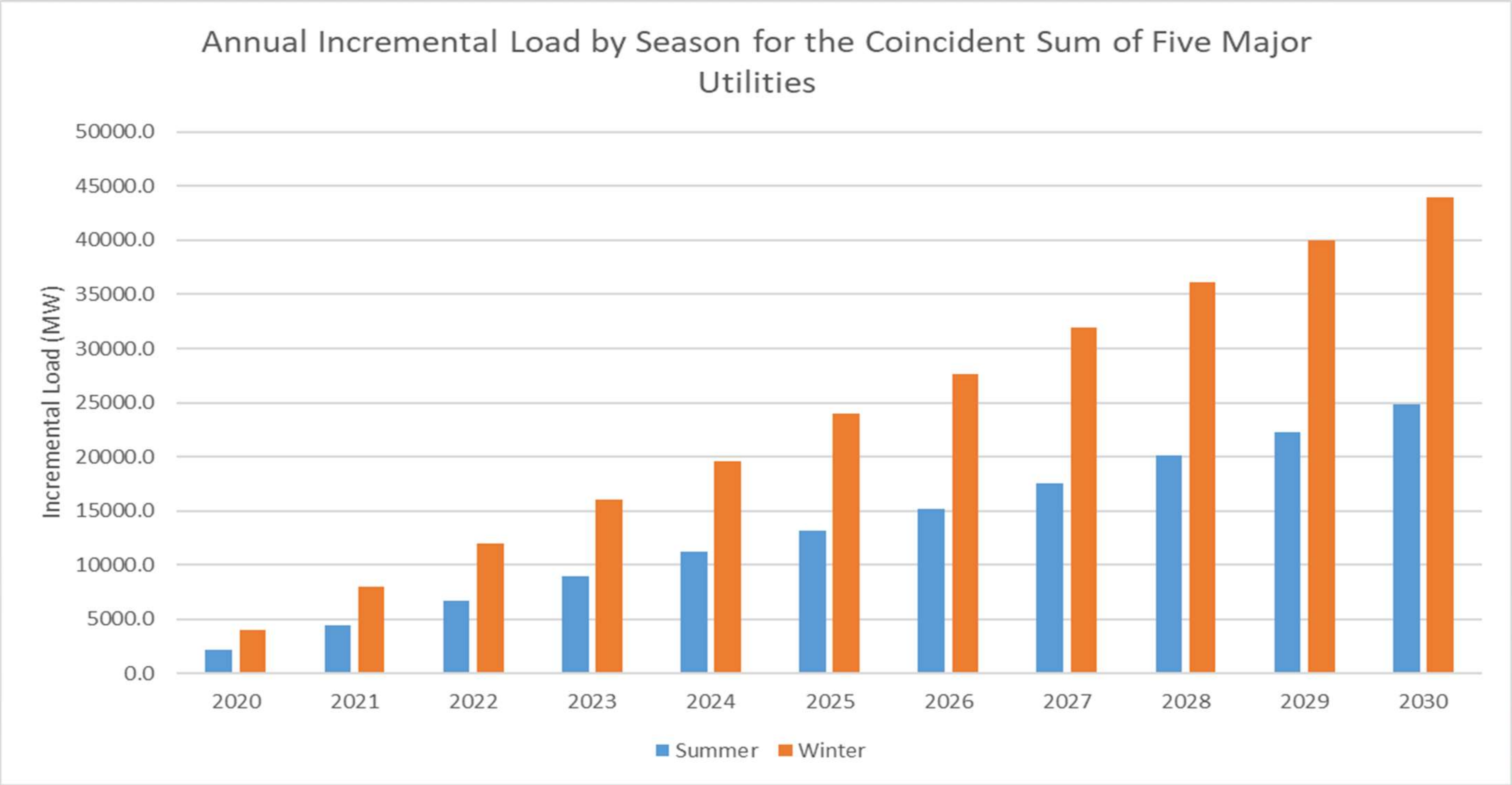
- FSSAT has a separate module that combines annual electric energy at the sector/end-use/technology level with an hourly load profile to develop hourly loads for each major electric utility
- These disaggregated hourly impacts are summed across sector/end-use/technology to develop aggregate load impacts for each major electric utility
- The hourly load profiles used in FSSAT started from the 2019 IEPR hourly AAEE projection tool, but were modified as follows:
  - Guidehouse conducted additional load profile studies for heat pump technologies
  - CEC staff reprocessed the heat pump space conditioning load profiles to better distinguish between heating and cooling

Incremental Air Conditioning Load

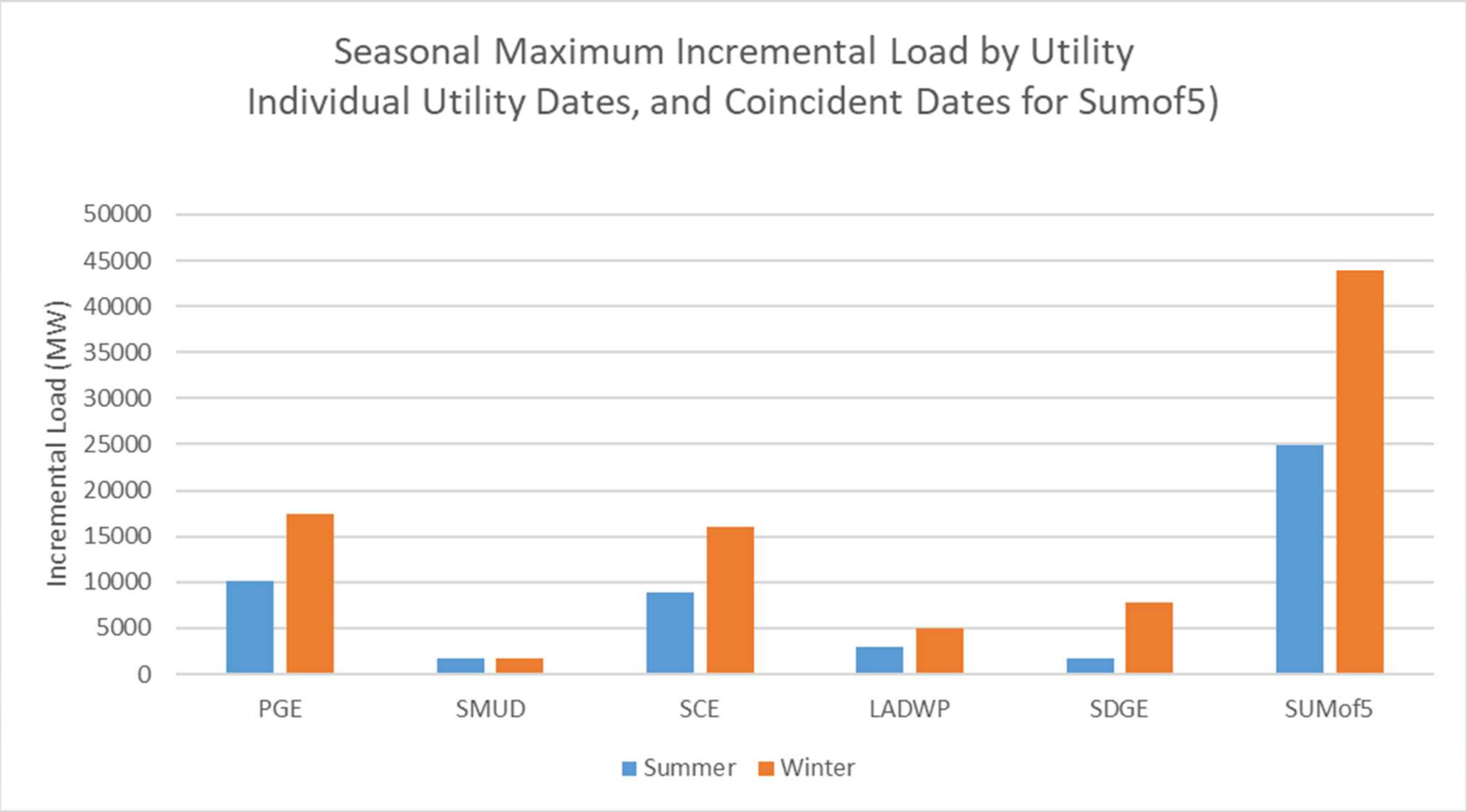
- FSSAT improves upon the 2019 IEPR exploratory study by estimating incremental air conditioning load for those residential housing units that did not have air conditioning, but will have air conditioning when a heat pump replaces the natural gas space heating equipment
- As a result summer loads are much higher than in the exploratory study

- The following slide illustrates the growth of summer and winter incremental loads for the scenario closest to meeting the AB3232 target
- Winter loads still increase more than summer loads

Seasonal Maximum Load Growth



Maximum Hour Impacts by Season



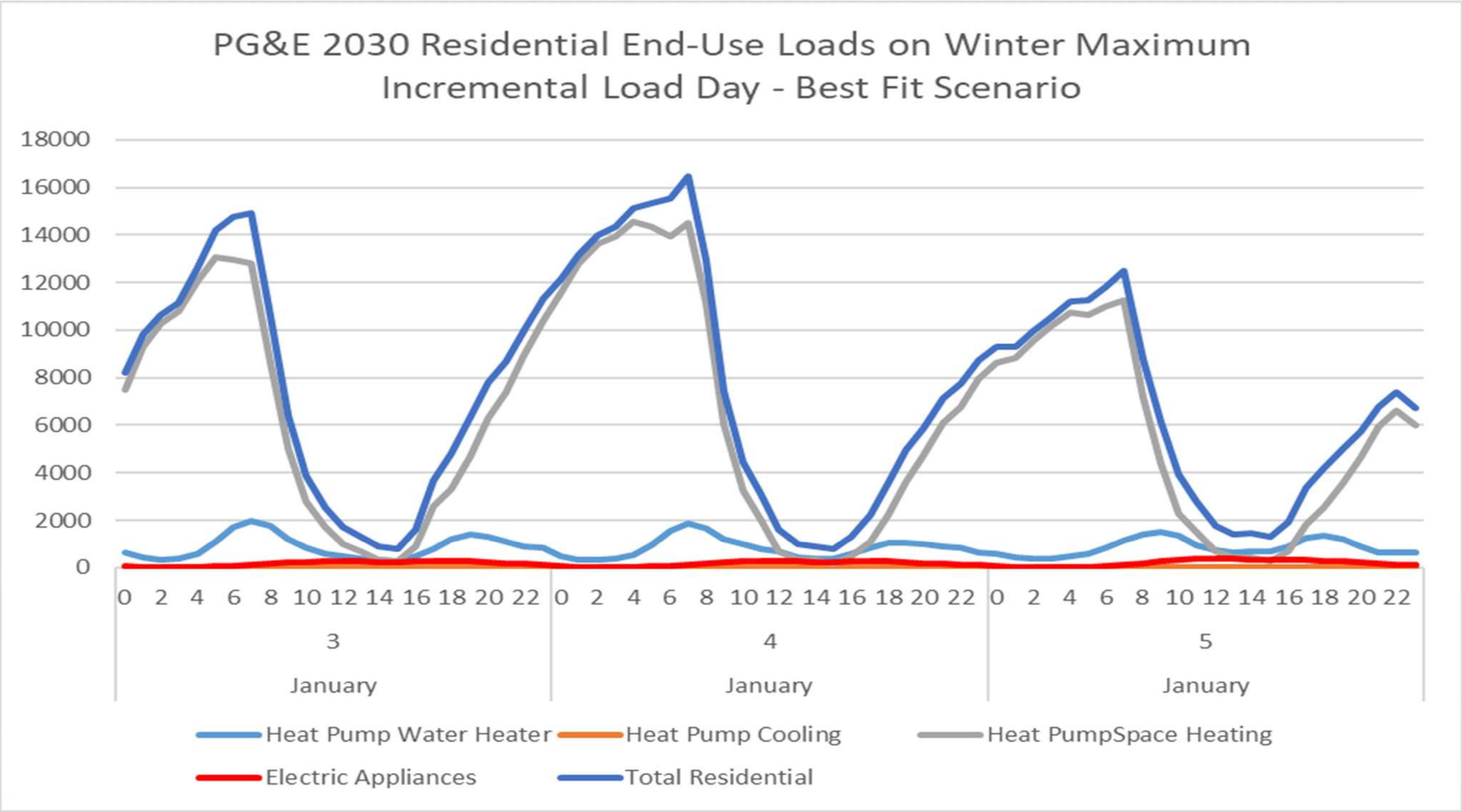
Hourly Load Patterns

- In the following slides PG&E is shown, but the general patterns are similar for all utilities

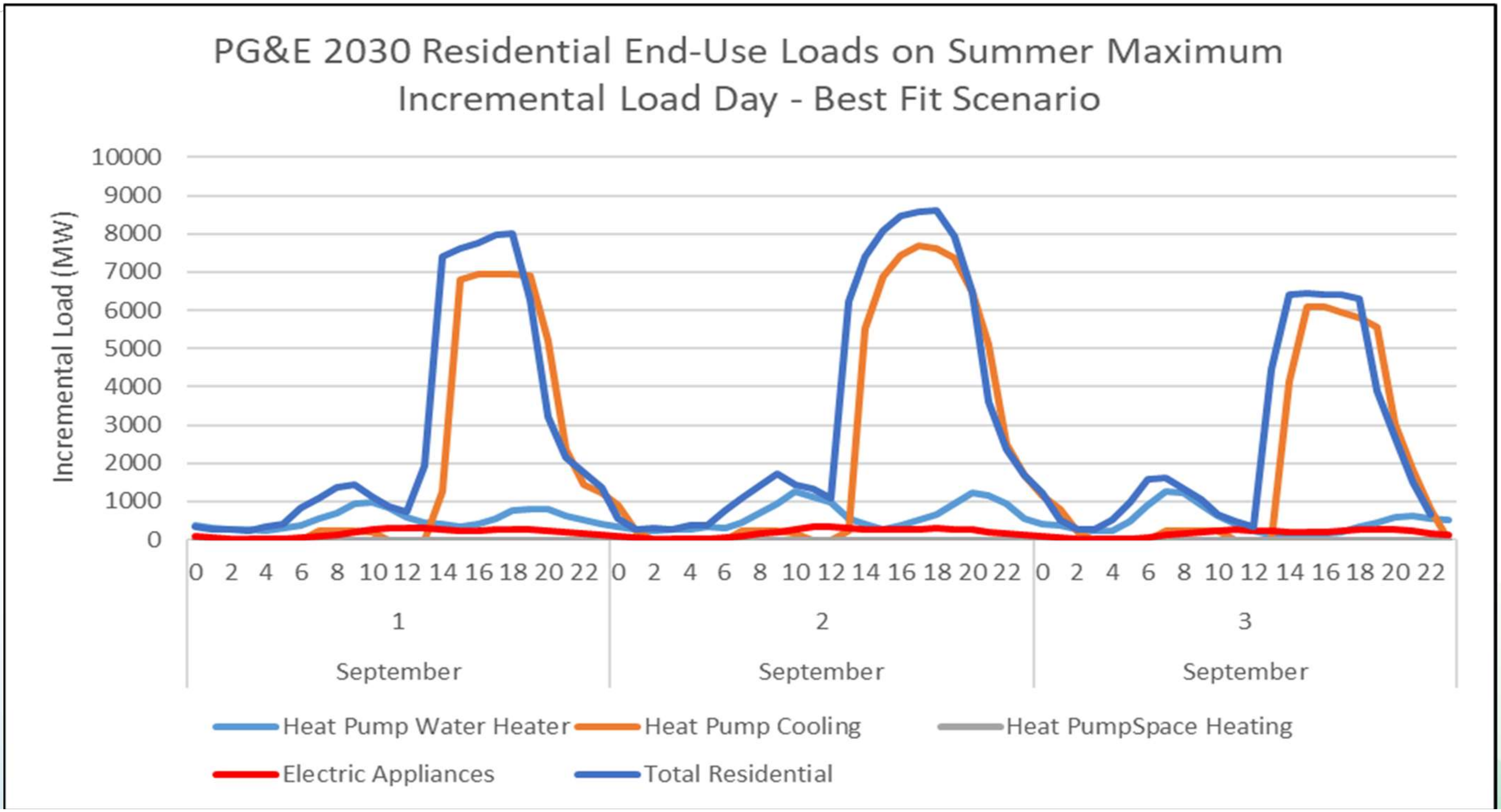
- Both winter and summer hourly load results exhibit extreme “peakiness” with daily cycles ramping up and down on consecutive days
- There is slight diversity between space heating and water heating and the other electrified appliances are not consequential

- Space heat and air conditioning load profiles are not yet based on diversity of housing thermal integrity or behavioral patterns of occupants. Once completed, staff expects to use less “peaky” load profiles

Illustrative Winter Maximum Results



Illustrative Summer Maximum Results



Load Flexibility

- By itself, FSSAT has no capability to determine the proportion of incremental electric load that could be flexible
- FSSAT can, using additional hourly load profiles, show how assumed proportions of sector/end-use loads that are flexible would affect the overall incremental load
- In effect, this would be a “potential” load shift that could be an input into separate load flexibility studies that might be able to determine how much value exists from incentivizing end-use participation in flexible load programs
- Yet further studies would be needed to determine what incentive level or mandates could be developed to induce a given proportion of end-users to participate

Hourly Electric Generation GHG Emissions

CEC/EAD staff developed a starting point for hourly incremental GHG emission factors using the CEC's 2019 IEPR exploratory study of fuel substitution impacts

- Resources plans for years 2022, 2025, and 2030 were modified to add sufficient renewable resources to satisfy RPS requirements and battery storage capacity was added to satisfy reliability criteria
- Plexos production simulation was used to develop hourly electric generation emission of GHG emissions from instate resources and imports
- The difference between GHG emissions and load for the fuel substitution case and the 2019 IEPR mid-mid case was used to develop hourly emission factors for incremental fuel substitution load, and then smoothed to reduce outliers
- Hourly values for intermediate years were interpolated hour by hour

Overview of Findings

Overview of Initial Results

- FSSAT reveals that:
  - the AB3232 GHG emission reduction goal is extremely difficult to achieve
  - No programs have been designed that have the capability to accomplish the penetrations required to meet the AB3232 target
  - Any scenario at or near the AB3232 target is very expensive
  - Stringently controlling the electric technology options to the “single best” can reduce total costs and reduce incremental electric loads
  - Due to federal preemption, the CEC lacks the ability to mandate a “single best” heat pump technology through Title 20 standards
  - Seemingly simple descriptive data on the need for residential electric panel box upgrades can change costs by $billions

Data Uncertainty

- Key input data may be available to improve these initial results
- CEC/EAD staff propose that stakeholders be enabled to provide alternative input assumptions for two types of data, which CEC/EAD staff would review, and possibly use to revise results
  - Electric end-use/technology performance and cost
  - Proportion of residential housing units that require panel box upgrades to support complete electrification of building end-uses and the average “all in” costs per panel box of such upgrades
- CEC/EAD staff have posted two templates showing current FSSAT input files along with instructions about how stakeholders can propose alternative values

Informal methodological questions and comments

- Please review workshop's supplementary materials in docket (19-DECARB-01)
  - Fuel Substitution Forecasting Tools, Methods Supporting Senate Bill 350 Analysis (Sathe et al. 2020)
  - [June 9 2020 Selected Input Assumptions_FSSAT_5.7.xlsx]

- Please ask informal methodological questions and comments to nicholas.janusch@energy.ca.gov and staff will address them at the June 26th workshop (informal questions and comments due **June 15th at 5pm**)
- Also by **June 15th at 5pm**, Please use the *June 9 FSSAT Input Assumptions Workbook* above as a template to propose changes to input assumptions used for the FSSAT analysis
- Written comments for both June workshops due: **July 10th at 5 pm**

Next Steps

Next steps for EAD FSSAT Team to improve the tool

- **Short-term augmentations before Commissioner Draft Report in August**
  - Develop an RNG scenario that leverages the assumptions in EPIC's E3 PATHWAYS Report (April 2020)
  - Develop an accounting for end-of-life venting of refrigerants which will occur after the 2020-2030 time horizon but are expected to be significant under current industry practices
  - Update input assumptions based on stakeholder feedback

Next steps for EAD FSSAT Team to improve the tool

Long-term Structural changes to FSSAT

- Segment out Low Income from the Residential sector
- Allow for the handling of flexible loads: Heat Pump Water Heater & Heat Pump Space Heater
- Start modeling decay
- Research natural gas and electricity retail price feedback loops
- Determine the cost per unit of a particular fuel substitution scenario including the cost for the fraction of residential units requiring a panel box upgrade
- Add consumer adoption mechanism to provide choice based on program incentives

Long-term Data updates for use in FSSAT

- Add appropriate cost info for additional NG EE captured in AAEE
- Obtain saturation and density input variation for different utility territories
- Obtain detailed cost data as well as temporal and geographical penetration projections of RNG
- Update EUL data
- Add layered envelope improvements
- Adding the data required to extend modeling time horizon to 2045 or beyond
- Create a 20- versus 100-year GWP toggle

Questions?

- Next steps:
  - AB 3232 Workshop 2 of 2 on Friday June 26
  - Fall 2020 Workshop on AB 3232 draft report
  - January 2021 report due to the Legislature

References

References in slide deck

- Basic Approach
  - FSSAT Key Inputs (Sathe et al., 2020; pp. 76-77)
  - Basic Fuel Substitution Equation, FS Example (Sathe et al., 2020; p 94)
  - Residential NGT, Commercial NGT (Sathe et al., 2020; F-2—7)
- Scenario Design
  - Scenario Input Variables (Sathe et al., 2020; p106)
- Scenario Results
  - Scenario Results Highlights: GHGs (Table 10) (CARB 2017; p 46)
  - The Importance of HFC emissions (CARB, 2019; p16)
- Electric Load Impacts
  - Developing Hourly Load Impacts (Sathe et al., 2020; pp 121-124)

References

- CARB. 2017. California's 2017 Climate Change Scoping Plan. Available at: https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf
- CARB. 2019. California Greenhouse Gas Emissions for 2000 to 2017: Trends of Emissions and Other Indicators. Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf.
- Sathe, Amul (Guidehouse), Karen Maoz (Guidehouse), John Aquino (Guidehouse), Abhijeet Pande (TRC), and Floyd Keneipp (Tierra Resource Consultants). 2020. Fuel Substitution Forecasting Tools, Methods Supporting Senate Bill 350 Analysis. CEC-200-2020-001. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725