

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

Remote-Only Format

In compliance with Governor Newsom's Executive Orders N-25-20 and N-29-20, and the recommendations from California Department of Public Health, we are utilizing a remote-only format today.

Housekeeping: Zoom Overview

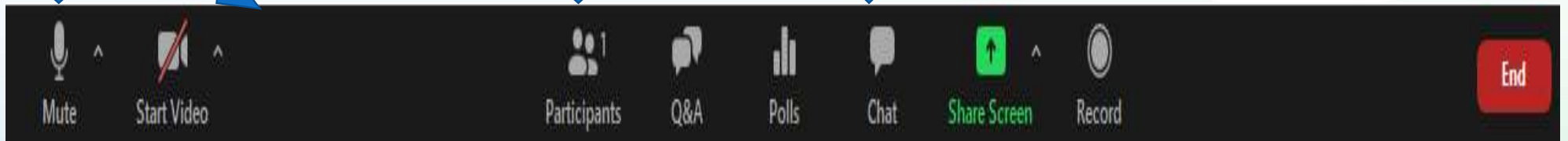
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AB 3232 Public Workshops

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
 - Technology replacement 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”

Source: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232

GHG Emissions for Residential and Commercial Buildings

AB 3232 GHG Emission Category (MMTCO ₂ e)	1990			2017		
	Res	Comm	Total	Res	Comm	Total
Fuel combustion from natural gas	27.7	11.1	38.8	23.6	13.7	35.4
Fuel combustion from other fuels	2.0	3.4	5.4	1.5	2.0	3.5
Behind-the-meter methane emissions	0.7	1.0	1.7	0.9	1.0	1.9
HFCs from Refrigeration and Air-conditioning	1.6*	6.9*	8.5*	2.9	8.8	11.7
<i>Electric generation emissions</i>	33.8	35.9	69.7	20.6	23.9	44.6
Total on-site emissions	32	22.4	54.4	28.9	25.5	52.5
Total on-site and electric generation emissions	65.8	58.3	124.1	49.5	49.4	97.1

*2013 level of HFC emissions according to CARB's GHG inventory



What is included in the 1990 baseline impacts AB 3232 target

1990 GHG Baseline	1990 GHGs (MMTCO ₂ e)	2030 40% AB 3232 Reduction Target (MMTCO ₂ e)
1. Only on-site emissions	54.4	32.6
2. On-site emissions and incremental electric generation emissions	54.4	32.6
3. On-site emissions and electric generation emissions in 1990	124.1	74.5



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	<ul style="list-style-type: none"> AAEE reduces baseline consumption FSSAT “what if” scenarios of sector/end-use/technology displacement of natural gas <i>(Cost and rate ramifications of RNG are currently beyond the scope of FSSAT)</i> 	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	<ul style="list-style-type: none"> 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

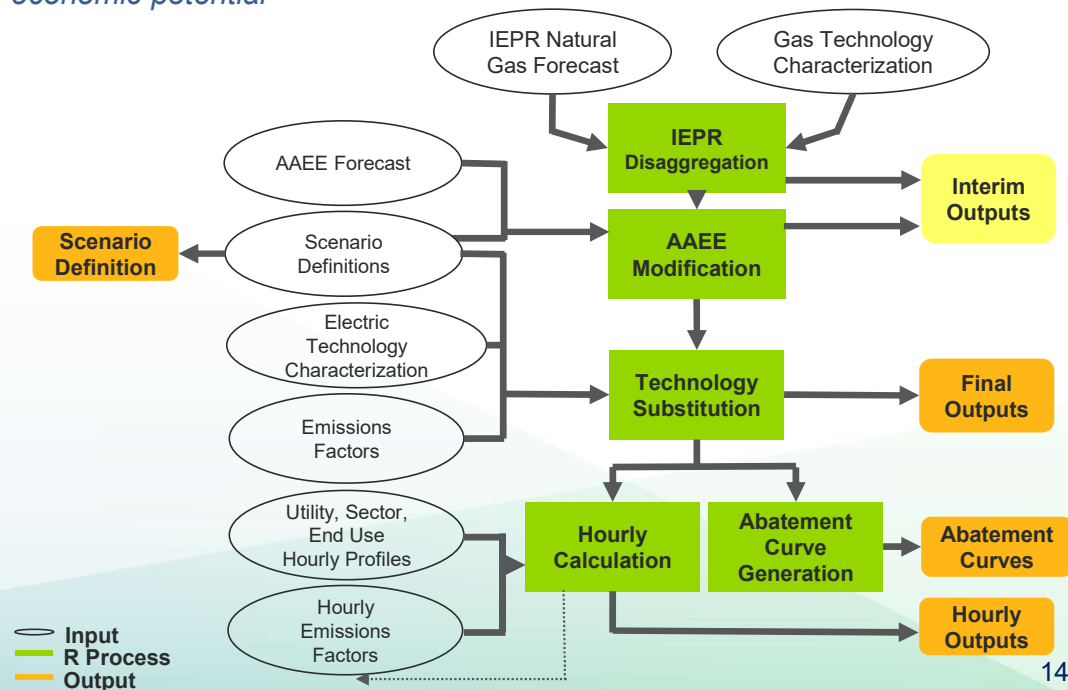
1. Start with the 2017 IEPR baseline natural gas demand forecast for five electric services areas by sector and end-use
2. Modify the baseline natural gas demand forecast using AEE natural gas savings (six scenarios from low to high)
3. Create the set of electric technologies that can replace natural 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

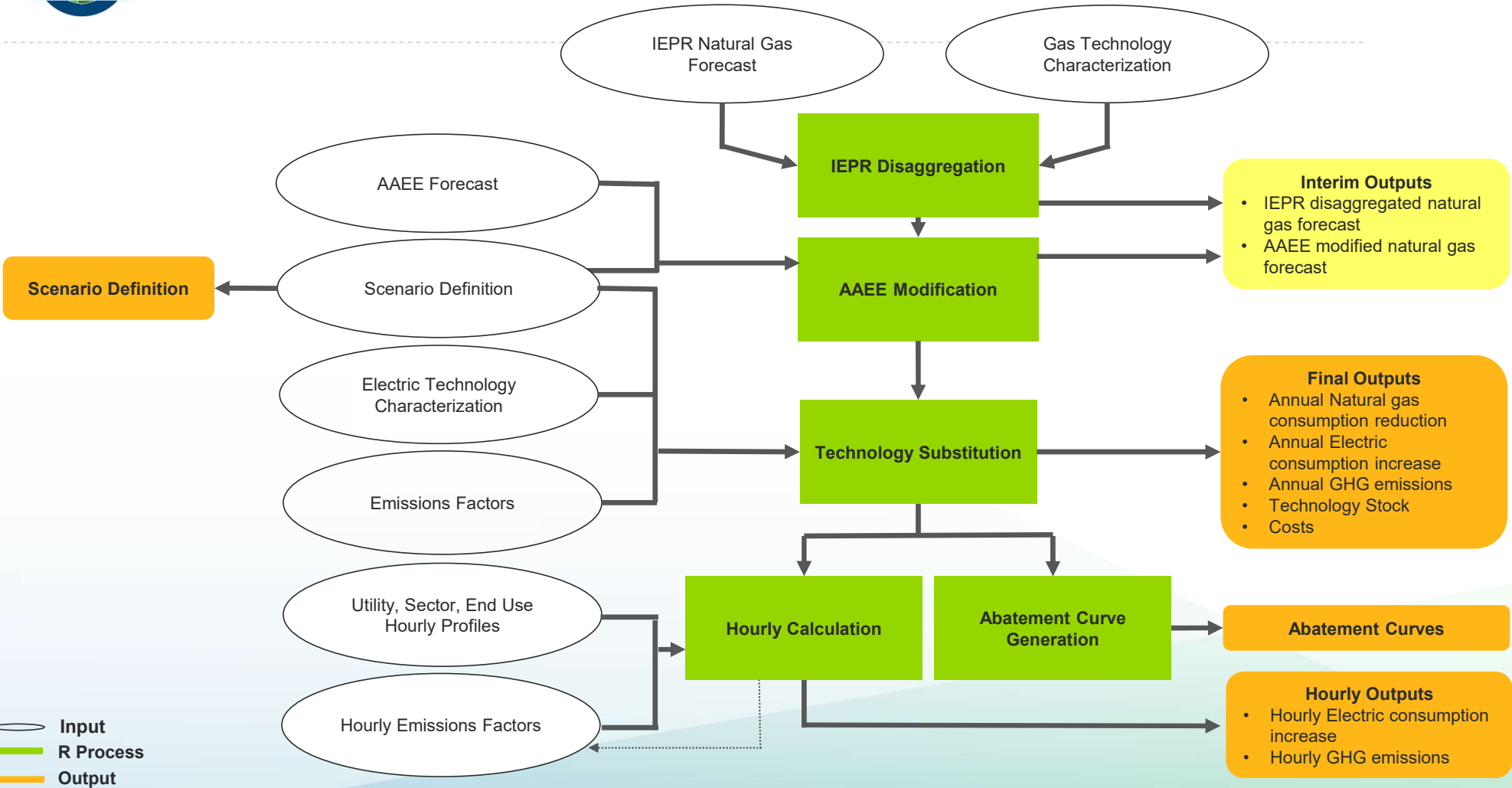
- SAO developed hourly Electric Generation emission factors for 2022,2025,2030 by creating resource plans that satisfied reliability criteria, ran Plexos to generate emissions, and computed incremental load emission factors hour by hour, then smoothed the results.

6. Run the FSSAT tool for 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 Demand 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 by utility 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
 - Note: A 2017 IEPR AAEE for NG was not developed, thus 2019 IEPR AAEE was used instead
- 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
<i>*This technology is characterized at multiple efficiency levels.</i>			
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	Heat Pump Water Heater	Y
	Gas Water Heating Boiler*		
	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:

$Elec\ Consumption_{yr=i,elec\ tech=k}$ = 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.



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	Unit energy consumption (kWh) $= \frac{[(403 \text{ therms}) \left(29.3 \frac{\text{kWh}}{\text{therms}}\right) (0.8 \text{ EF})]}{3.0 \text{ COP}}$ = 3,149 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



Current Limitations of FSSAT

- Can not independently determine the impacts of load management strategies
 - Can show how assumed flexible proportions of sector/end-use loads would affect the overall incremental load
- Ability to incorporate rate structures and impacts from natural penetration of fuel substitution is limited
- Can not optimize
 - For measures that yield the lowest cost
 - Between rate impacts between residential and commercial customers
- No HFC mitigation strategies incorporated
- No ability to analyze low-income subsector



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 Parameters	Scenario 1: NC100 ROB45 RET20 mixEF newHFC newNO	Scenario 2: NC100 ROB90 RET40 mixEF newHFC newNO	Scenario 3: NC100 ROB90 RET60 mixEF newHFC newNO	Scenario 4: NC100 ROB90 RET70 mixEF newHFC newNO	Scenario 5: NC100 ROB90 RET70 bestEF newHFC newNO	Scenario 6: NC100 ROB100 RET70 bestEF newHFC newNO	Scenario 7: NC100 ROB90 RET70 mixEF newHFC newYES	Scenario 8: NC100 ROB90 RET70 bestEF newHFC newYES	Scenario 9: NC100 ROB100 RET70 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%
Replace on Burnout	Residential 45% Commercial 45%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 100% Commercial 100%	Residential 90% Commercial 90%	Residential 90% Commercial 90%	Residential 100% Commercial 100%
Early Replacement	Residential 20% Commercial 20%	Residential 40% Commercial 40%	Residential 60% Commercial 60%	Residential 70% Commercial 70%	Residential 70% Commercial 70%	Residential 70% Commercial 70%	Residential 70% Commercial 70%	Residential 70% Commercial 70%	Residential 70% Commercial 70%
Technology Efficiency	High Efficiency Weighted	High Efficiency Weighted	High Efficiency Weighted	High Efficiency Weighted	single best	single best	High Efficiency Weighted	single best	single best
SB 1383 goals	NO	NO	NO	NO	NO	NO	YES	YES	YES

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



Scenario Results

GHG reduction potential and results summary



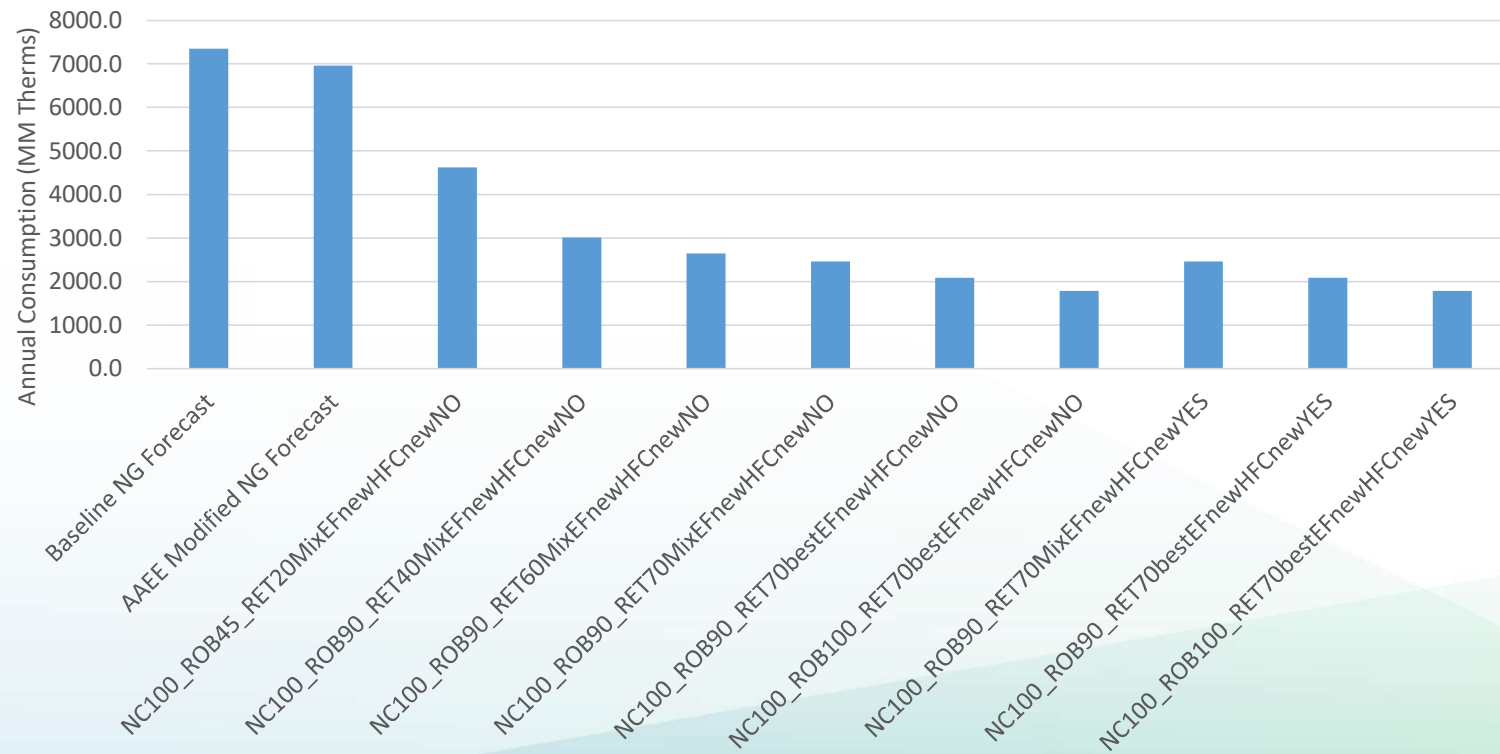
Initial FSSAT Results

- The following will be discussed at an aggregate level today:
 - GHG reduction potential and summary of results
 - The importance of HFC emissions
 - Technology replacement costs
 - Rates
 - Electric load impacts
- Workshop #2 on June 26th will report and discuss
 - Respond to informal questions and comments
 - Disaggregation of costs
 - Cost effectiveness / marginal abatement curves
 - Technology level analysis that explains aggregate results
 - GHG reduction potential of emissions outside of baseline



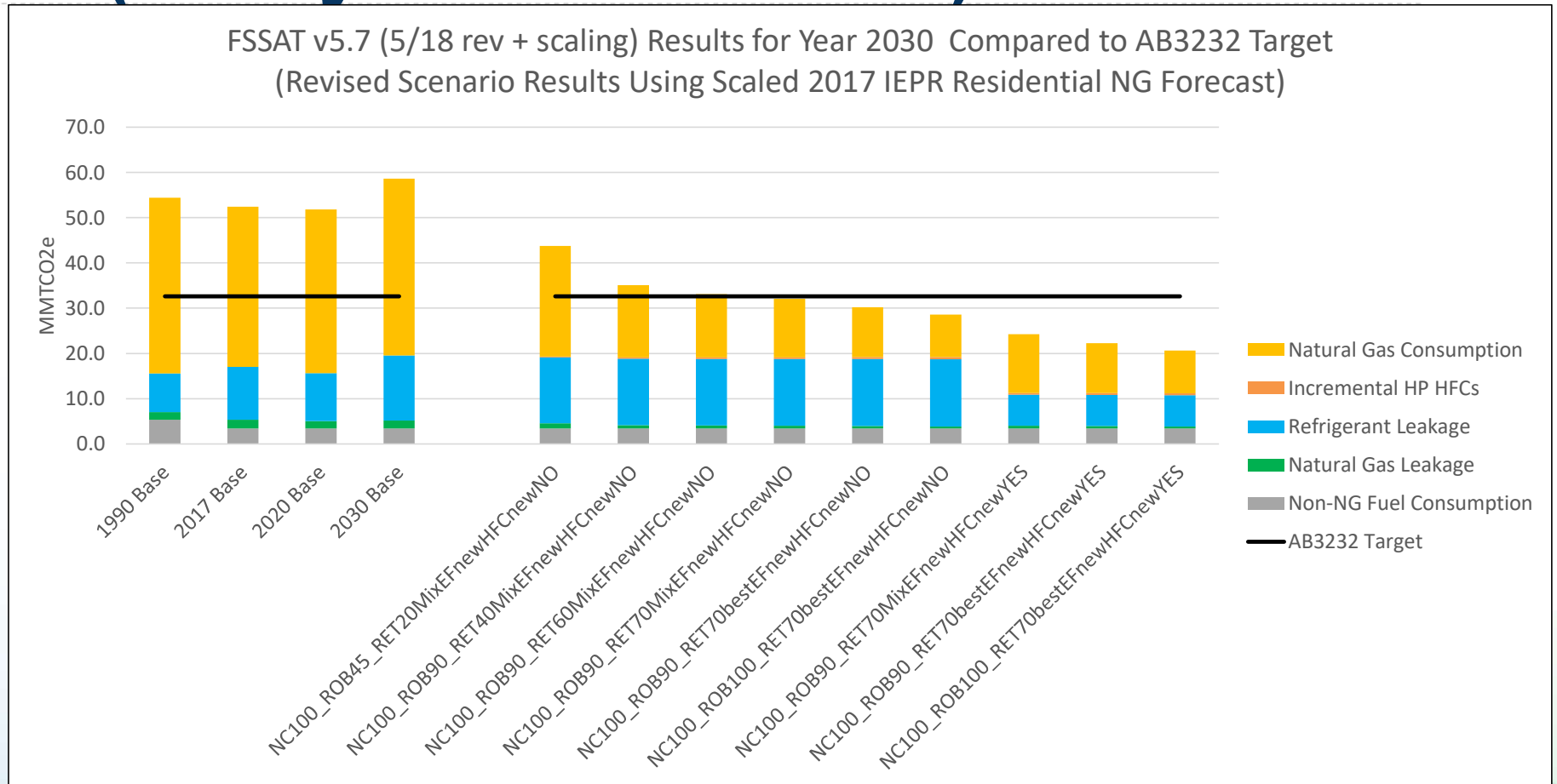
Impacts to NG demand

2030 Statewide
Scaled NG Forecast Modified by AAEE and Scenario-Specific
Fuel Substitution Activities





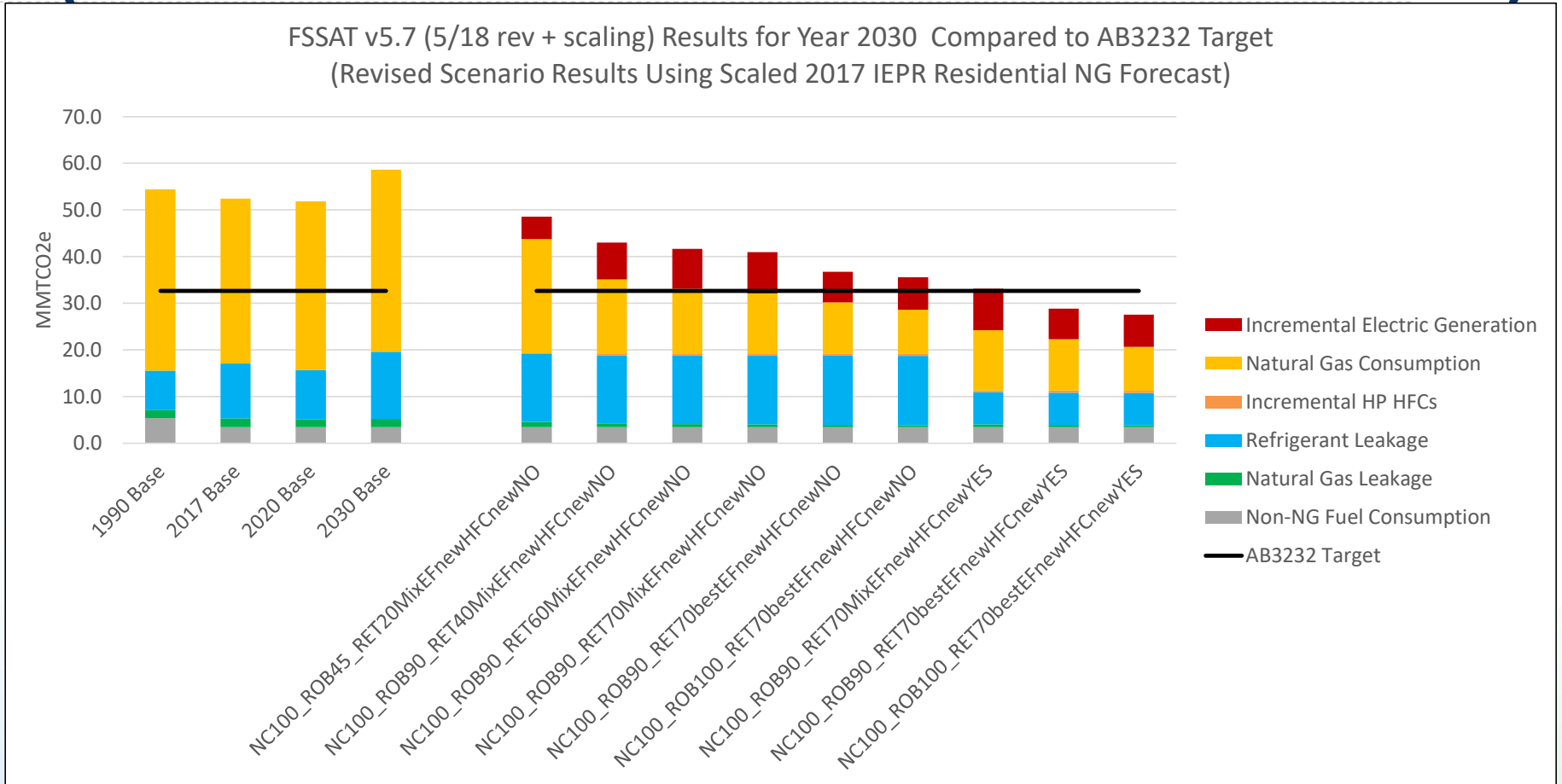
GHG Reduction Potential By Scenario (1. Only on-site emissions)



Note: Values are not final. Staff will update FSSAT using 2019 IEPR data for the final report.



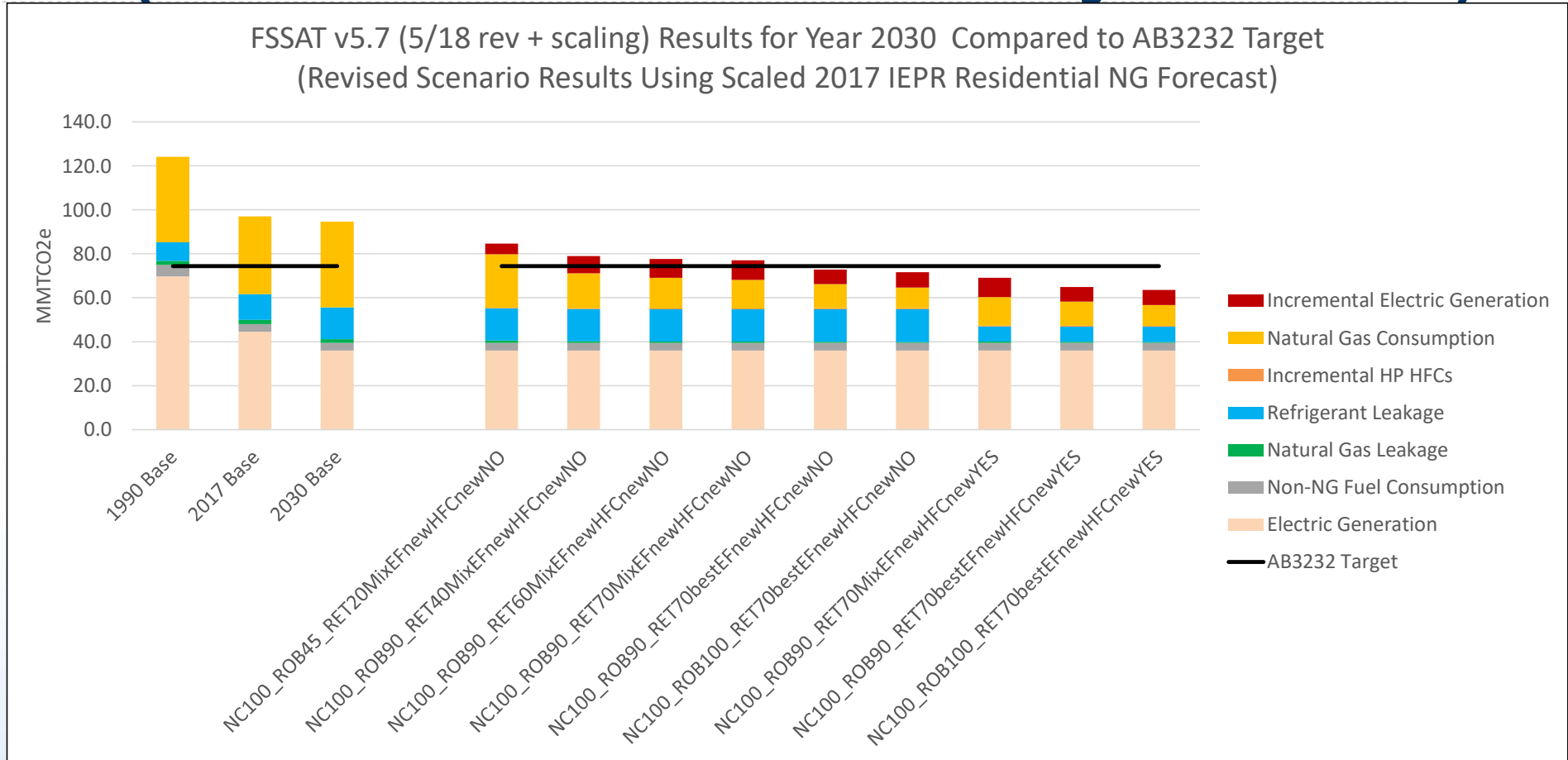
GHG Reduction Potential By Scenario (2. On-site and incremental elect. emissions)



Note: Values are not final. Staff will update FSSAT using 2019 IEPR data for the final report.



GHG Reduction Potential By Scenario (3. On-site and 1990 electricity emissions)



Note: Values are not final. Staff will update FSSAT using 2019 IEPR data for the final report.



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 aggressive assumptions
- Preliminary estimates of average cost per metric ton (\$/ton) of cumulative emissions are relatively high compared to the strategies examined in Table 10 in CARB's 2017 Scoping Plan (CARB 2017)
 - Note: The June 26th workshop will have a deeper cost-effectiveness discussion



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 recommended 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 without 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

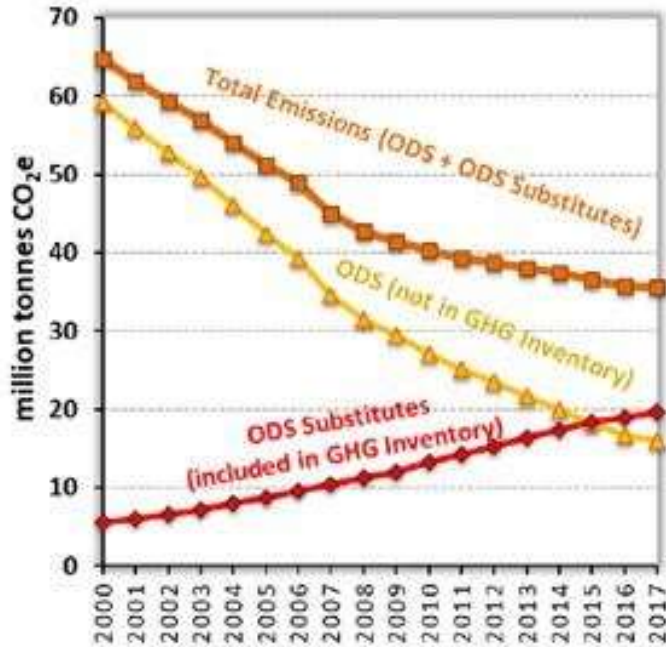


Figure 17a. Trends in ODS and ODS Substitutes Emissions. This figure presents the trends in emissions from ODS Substitutes, ODS, and their sum ("Total Emissions"). ODS Substitutes emissions are specified in IPCC Guidelines and AB 32 and are included in the inventory. ODS are also GHGs, but are tracked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

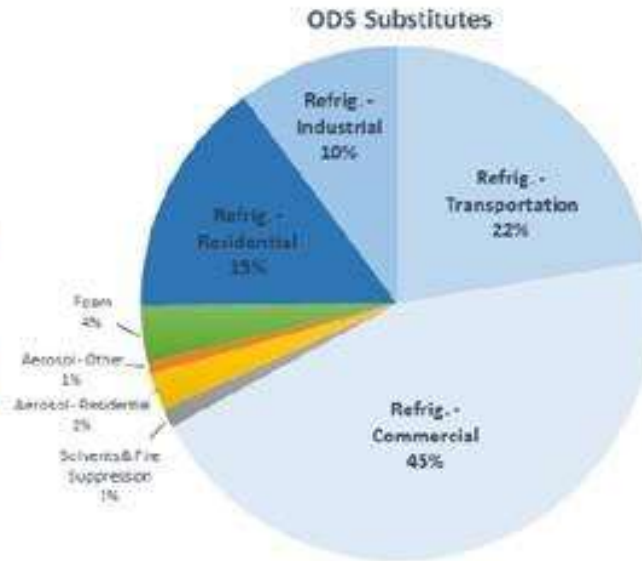
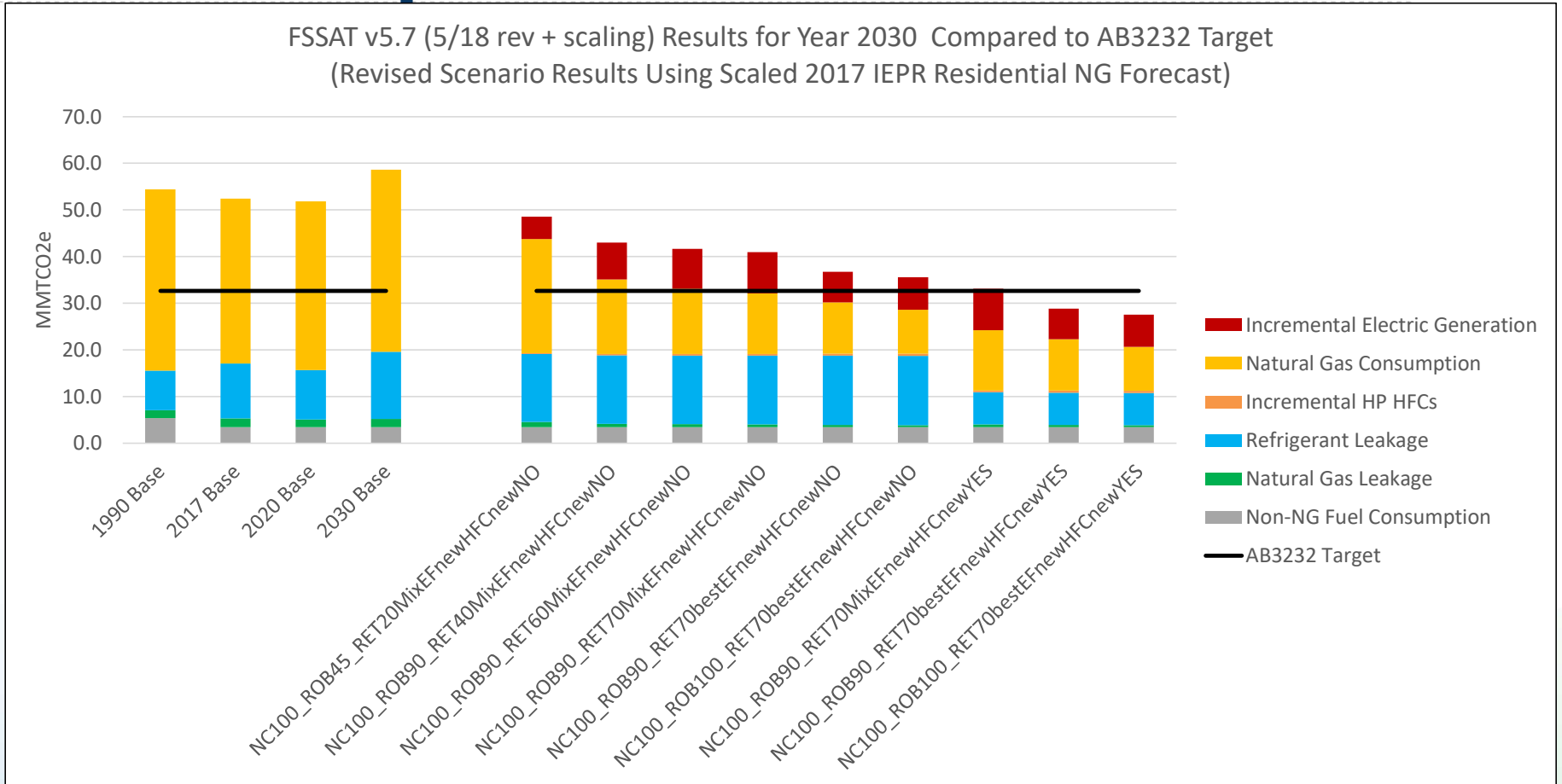


Figure 17b. ODS Substitutes Emissions by Category. This figure presents the breakdown of ODS substitutes emissions by product type and sector category in 2017. Refrigerants ("Refrig.") used in various sectors make up the majority of ODS substitutes emissions.

Source: CARB (2019)



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



Note: Values are not final. Staff will update FSSAT using 2019 IEPR data for the final report.



Scenario Results Highlights: HFCs

- 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



Senate Bill 1383

Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) says:

“[T]he state board shall approve and begin implementing the comprehensive short-lived climate pollutant strategy developed pursuant to Section 39730 to achieve a reduction in the statewide emissions of methane by 40 percent, **hydrofluorocarbon gases by 40 percent**, and anthropogenic black carbon by 50 percent below 2013 levels by 2030.”

Source: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383



15-minute BREAK



Scenario Results

Technology replacement costs



Comparison of Gross and Incremental Household Technology Replacement Costs

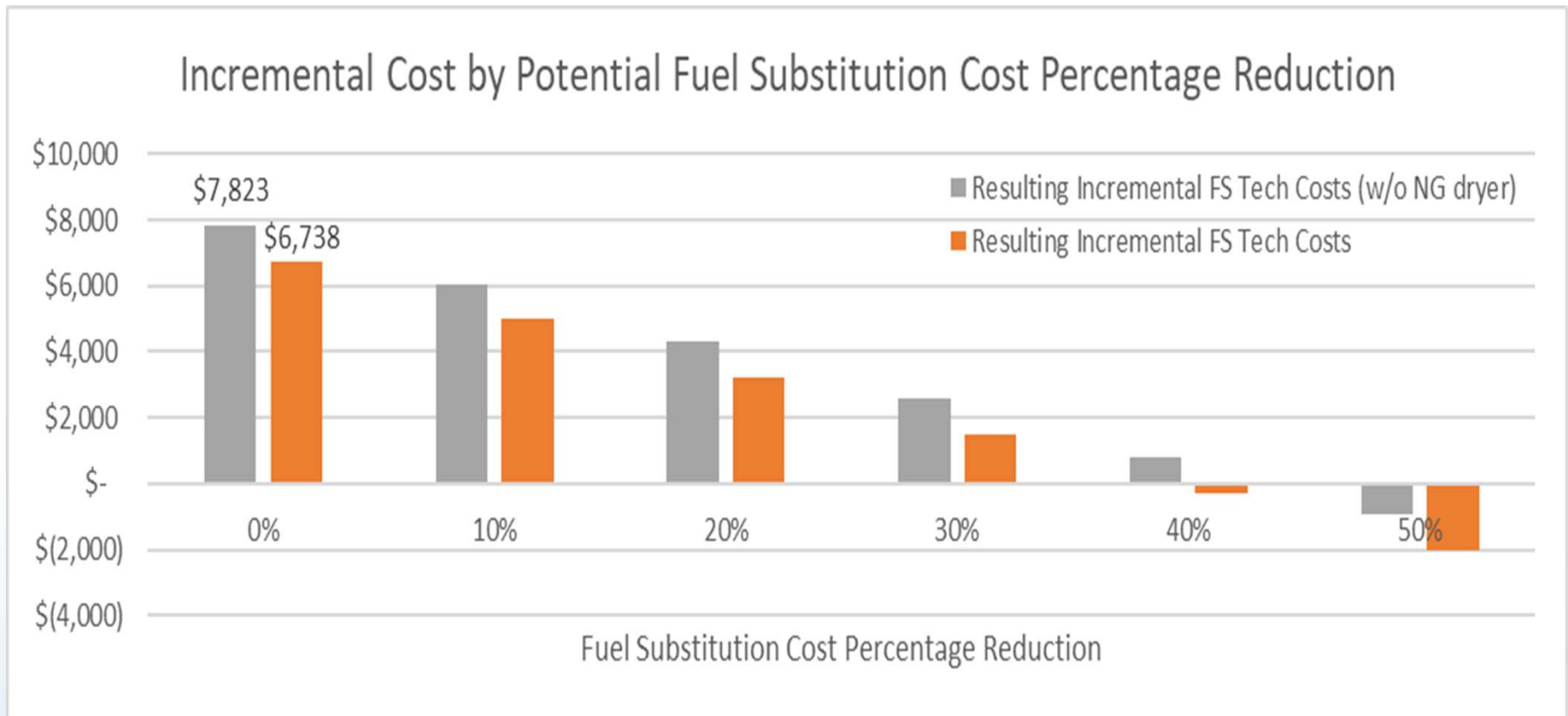
Natural Gas Replacement		End Use	Fuel Substitution	
\$ 583	Res Gas Cooktop	Cooking	\$ 2,232	Res Induction Cooking Stove
\$ 728	Res Gas Oven		\$ 1,133	Res Electric Resistance Oven
\$ 1,085	Res High Eff. Gas Clothes Dryer - 3.48 CEF	Laundry		
		Space Heating	\$ 10,770	High Eff. Variable Capacity Heat Pump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

- 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

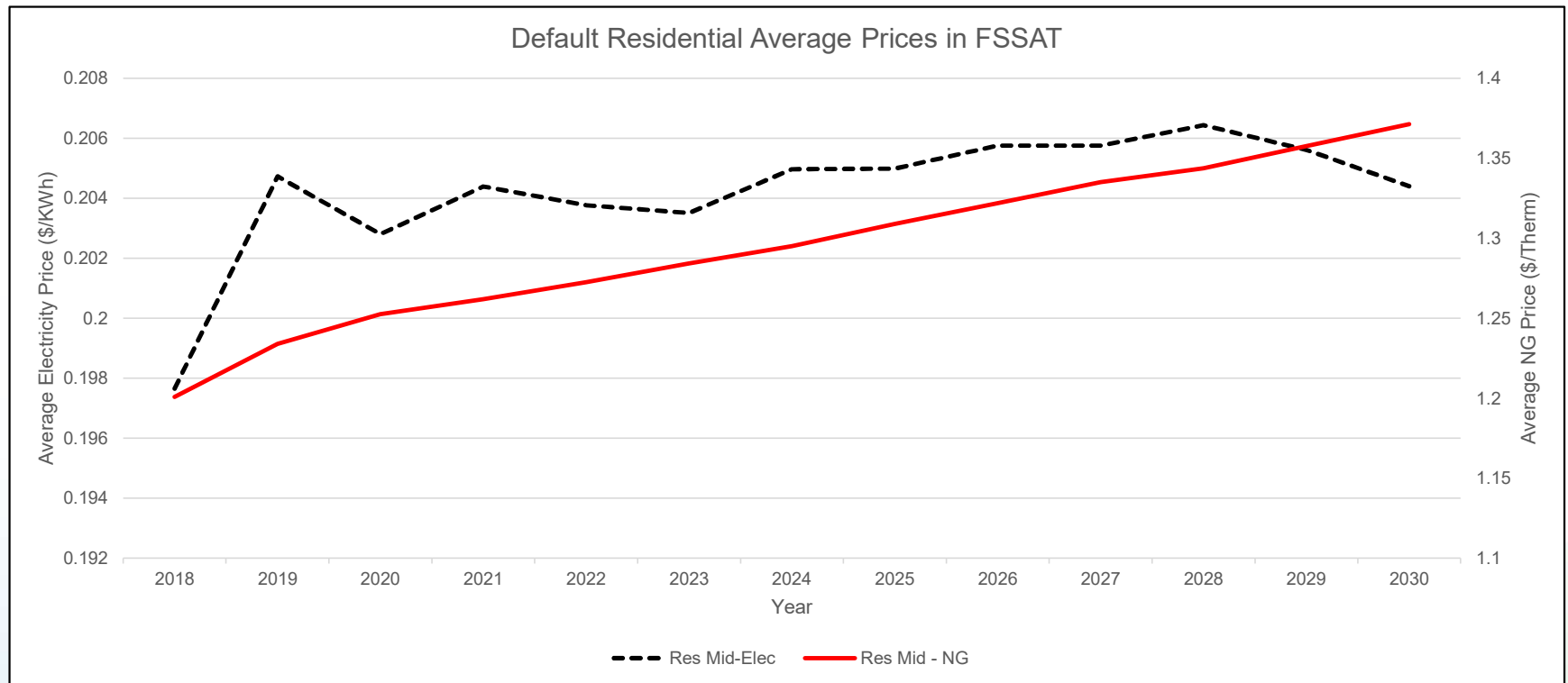


Role of Rates in FSSAT

- 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 prices 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



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

Natural Gas & Electric Load Impacts



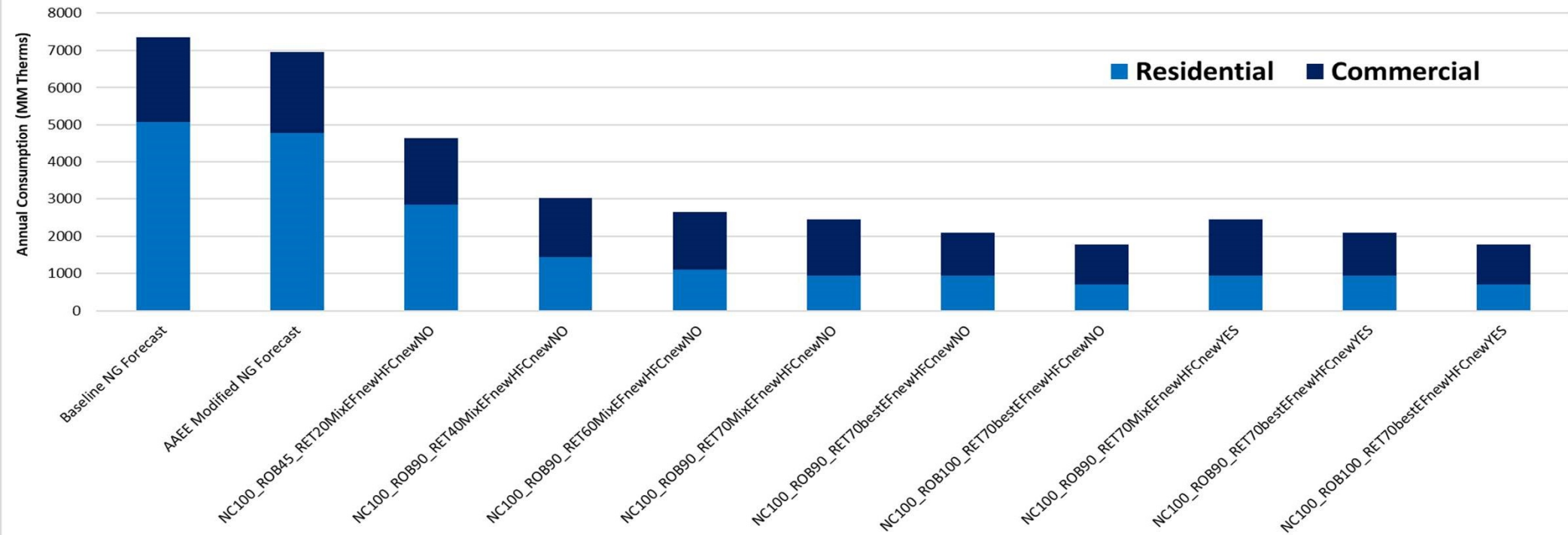
Adjusted Annual Natural Gas Consumption

- Used the 2019 mid-mid AEE (3) planning forecast to adjust the 2017 mid IEPR baseline NG forecast
- FSSAT computes remaining natural gas consumption 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 smaller remaining natural gas consumption than can be achieved by added energy efficiency alone:



Annual NG Demand Modified by AAEE and Scenario-Specific Fuel Substitution Activities

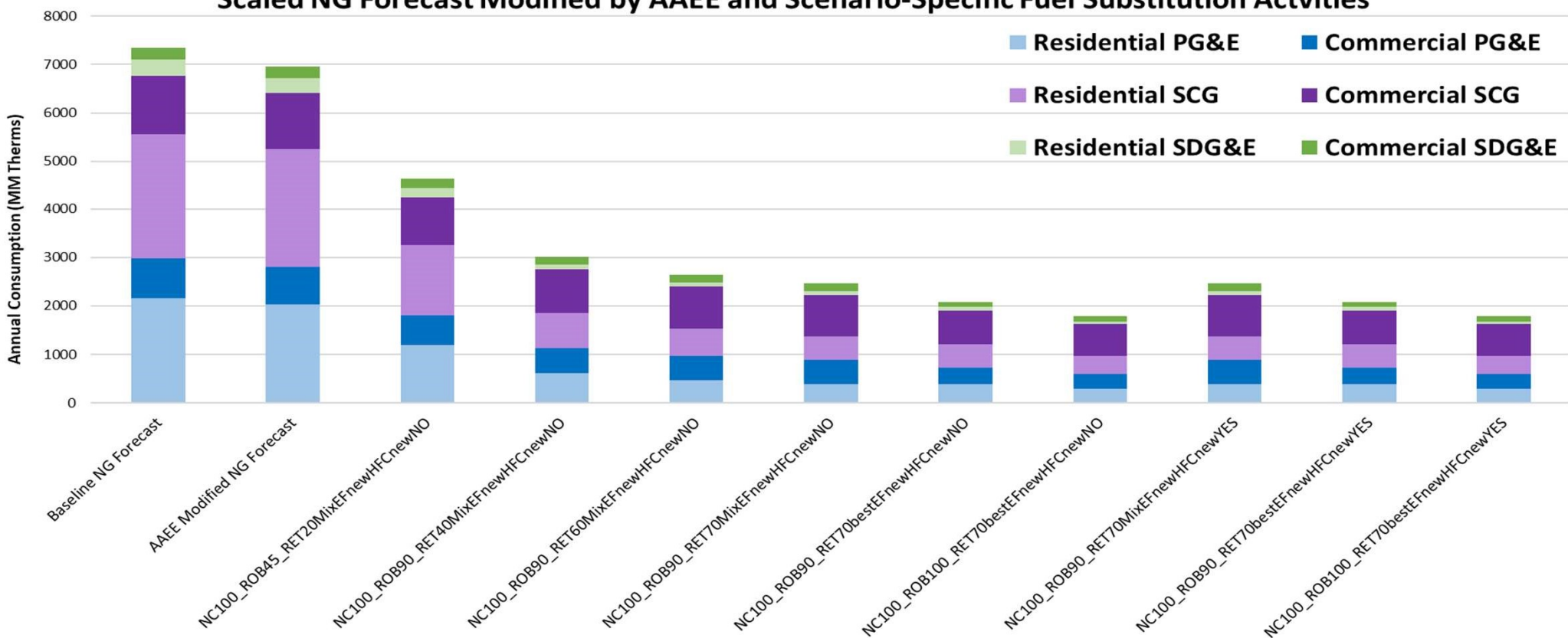
2030 Statewide by Sector NG Forecast Modified by AAEE and Scenario-Specific Fuel Substitution Activities





Annual NG Demand Modified by AAEE and Scenario-Specific Fuel Substitution Activities

2030 Statewide by Sector and Utility
 Scaled NG Forecast Modified by AAEE and Scenario-Specific Fuel Substitution Activities



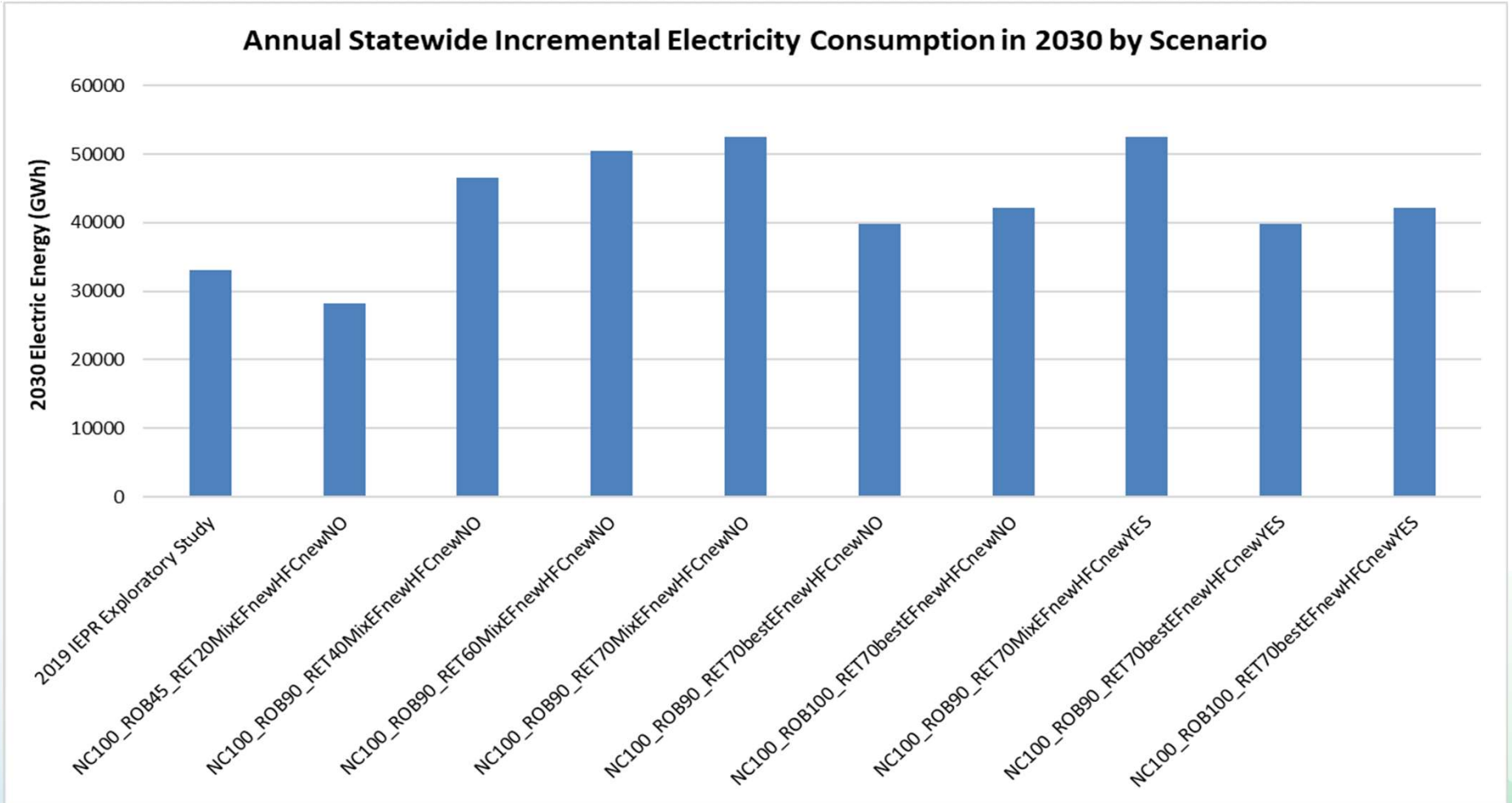


Incremental Annual Electric Energy

- 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 than in the exploratory study because:
 - Much larger NG reductions from the 2030 counterfactual
 - “fixed” GHG sources that are not being mitigated

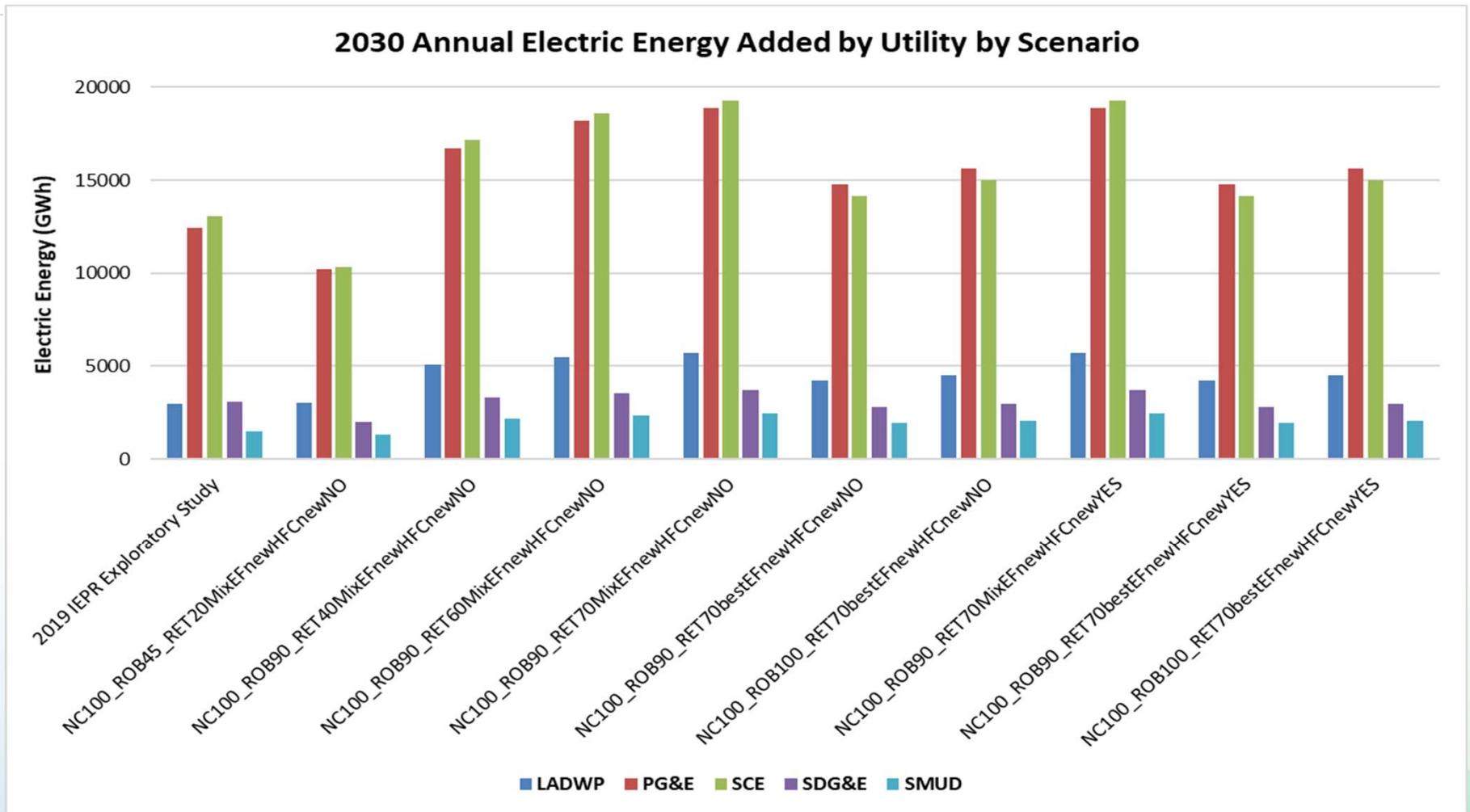


Annual Incremental Electricity Demand





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



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

- Initial analysis reveals that:
 - The AB3232 GHG emission reduction goal is extremely difficult to achieve based on the current baseline option and the high levels of 2013 HFC emissions included in the 1990 baseline
 - Achieving the goal will likely require a portfolio of decarbonization strategies (e.g., load management standards might have significant impacts on the GHG reductions)
 - There is a need for policies and programs designed to accomplish the penetrations required to meet the AB3232 target
 - Scenarios that meet or come close to the AB3232 target have significant associated costs
 - 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 (Aas et al., 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 AEE
- 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)
- Next steps
 - The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use (Aas et al. 2020)



References

- ❑ Aas, Dan, Amber Mahone, Zack Subin, Michael Mac Kinnon, Blake Lane, and Snuller Price. 2020. The Challenge of Retail Gas in California’s Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use. California Energy Commission. Publication Number: CEC-500-2019-055-F. Available at: <https://ww2.energy.ca.gov/2019publications/CEC-500-2019-055/index.html>
- ❑ 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>