Demand Analysis Working Group

AB 3232 – Fuel Substitution

Introduction

STATE OF CALIFORNIA
ENERGY COMMISSION

June 23, 2021

Purpose of DAWG Meetings

- Start discussion on forecast
- Inform stakeholders of model assumptions and changes
- Solicit input/feedback from stakeholders
- Better understand stakeholders' needs and preferences
- Connect analysts and contractors with stakeholders

Objective of this DAWG meeting

1. Showcase the Fuel Substitution Scenario Analysis Tool (FSSAT) and assumptions used for the AB 3232 report. Summarize the current and planned updates to FSSAT's capabilities by Demand Analysis Office (DAO) Staff and Consultants
2. Report and solicit feedback on DAO staff efforts to introduce an electrification load modifier for the 2021 IEPR Demand Forecast
3. Solicit input and feedback regarding data needs as we explore expanding our analytical capabilities to provide these types of building electrification projections

Meeting Agenda

Topic	Time	Facilitator
Welcome and Introductions	9:00 to 9:15	Nicholas Janusch, Energy Commission
Fuel Substitution Scenario Analysis Tool (FSSAT) used for AB 3232 report	9:15 to 9:50	Nicholas Janusch, Energy Commission
PLEXOS modeling used in support of AB 3232 Report	9:50 to 10:30	Richard Jensen, Energy Commission
Break	10:30 to 10:45	--
Electrification Rate Impacts	10:45 to 11:00	Lynn Marshall, Energy Commission
Building Electrification Load Modifier for the 2021 IEPR Demand Forecast	11:00 to 11:30	Ingrid Neumann, Energy Commission
Wrap-up Discussion & Comments	11:30 to 12:00	All Participants

IEPR Timeline (fuel substitution technical analysis)

- **Today (June 23)**: AB 3232/Fuel Substitution DAWG
- **August 5**: Inputs and Assumptions IEPR workshop
- **Mid-Late August**: DAWG meeting on AAEE and AAFS – Preliminary Designs
- **Late-September**: DAWG meeting on AAEE and AAFS – Preliminary Results
- **December 2**: IEPR Commissioner workshop on forecast results

Resources

Resource	Link
19-DECARB-01 Docket	https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-DECARB-01
Draft Staff Report - California Building Decarbonization Assessment	https://efiling.energy.ca.gov/GetDocument.aspx?tn=237733&DocumentContentId=70963
Supplementary materials for AB 3232 report (i.e., workbook for Appendix C)	https://efiling.energy.ca.gov/GetDocument.aspx?tn=237504&DocumentContentId=70704
Fuel Substitution Scenario Analysis Tool (FSSAT) manual ("Fuel Substitution Forecasting Tools Methods Supporting Senate Bill 350 Analysis")	https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725
Senate Bill 100	https://www.energy.ca.gov/sb100
Greenhouse Gas Emission Intensity Projections – Methods and Assumptions (IEPR workshop June 7, 2018)	https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2018-integrated-energy-policy-report-update-0
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	https://ww2.energy.ca.gov/2019publications/CEC-500-2019-055/index.html

Information solicited

- Feedback on current fuel substitution analytical framework
- Data needs as we explore expanding our analytical capabilities to provide these types of projections
  - Improve data on retrofit costs in existing buildings ancillary to the end-use equipment costs
  - Improve modeling of electric technology load shapes
  - Understanding of distribution system upgrades needed to support building electrification with and without additional load increases from use of electric vehicles
  - Technology characterization updates
  - Program evaluation data collected from near-term electrification programs (e.g., BUILD and TECH from SB 1477) to better inform consumer behavior assumptions
- Feedback on the proposed building electrification load modifier methodology

Demand Analysis Working Group

AB 3232 – Fuel Substitution

Fuel Substitution Scenario Analysis Tool

Nicholas Janusch, Ph.D.

June 23, 2021

Presentation Outline

- Recap of AB 3232 Building Decarbonization Assessment
- Details of analysis
  - Scope of GHG emissions
  - Building electrification
- Fuel Substitution Scenario Analysis Tool (FSSAT)
  - How it is used
  - Inputs and assumptions used
    - Costs
    - Substitution replacement mapping
    - SB 1383 HFC assumptions
  - FSSAT Outputs
- Updates to FSSAT and Fuel Substitution analysis for 2021 IEPR and beyond

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

Recap: AB3232 Timeline

Date	Workshop	Summary
August 28, 2019	IEPR Joint Agency Workshop on Energy Efficiency and Building Decarbonization	Discussed AB 3232 and GHG emission baseline
December 4, 2019	Commissioner Workshop on Building Decarbonization	Discussed GHG emission baseline recommendation
February 27, 2020	Staff Workshop (webinar) on the Fuel Substitution Scenario Analysis Tool	Introduced the Fuel Substitution Scenario Analysis Tool (FSSAT) developed by Guidehouse for the CEC
May 22, 2020	Commissioner Workshop on Building Decarbonization: Opportunities and challenges of the residential and commercial building sectors	CEC's Efficiency Division held panel discussion on building decarbonization topics
June 9, 2020	Building Decarbonization: AB 3232 – Fuel Substitution Scenario Analysis Tool Workshop	Discussed preliminary results from FSSAT; introduced baseline options.
May 21, 2021	Commissioner Workshop: Draft Building Decarbonization Assessment	Discussed draft assessment
June 23, 2021 (today)	DAWG: AB3232/Fuel Substitution	Showcase and discuss CEC's fuel substitution analytical framework

Summary of the Two Baselines Considered in the Assessment ($MMTCO_2e$)

	GHG Emission Sources	1990 Emissions	2020-30 Baseline Case (SB 100 trajectory the status quo)	2030 GHG Emissions Target (40% below 1990)	Annual GHG Emissions Reduction Needed in 2030
Baseline 1: Systemwide Emissions	• Gas combustion • Behind-the meter gas leakage • Non-gas fuel combustion • Hydrofluorocarbon leakage from refrigeration and air conditioners* • **Electric generation system emissions attributed to the residential and commercial sectors**	124.1	79.9	74.4	5.5
Baseline 2: Direct Emissions	• Gas combustion • Behind-the meter gas leakage • Non-gas fuel combustion • Hydrofluorocarbon leakage from refrigeration and air conditioners* • **Incremental electric generation system emissions from building electrification**	54.4	54.7	32.6	22.1

Source: CEC staff

*Please refer to the main report for how CEC staff handled HFC emissions in the 1990 base year.

Why Bring In the Electric Generating System to AB 3232?

- SB100 requires major changes in the electric generating system that greatly reduce its carbon emissions through time.
- Under business-as-usual demand assumptions the residential and commercial building sectors are about 70 percent of total electric system load.
- Emissions from the generating system are directly influenced by changes in electric consumption by the buildings sector.
- Reductions in electric consumption (energy efficiency, rooftop PV) included in the 2020-30 baseline or in new building decarb strategies will reduce electric generating system emissions.
- Increases in electric consumption through building electrification will increase electric generating system emissions in all years to 2045.

AB 3232: 2020-30 Baseline Case

Staff relied on the 2019 Integrated Energy Policy Report's (IEPR) California Energy Demand forecast to establish the baseline annual 2030 GHG emissions for the AB 3232 analysis.

Building Decarbonization Strategy	Related Assumptions Used in the 2020-30 Baseline Case
1. Building end-use electrification	Additional Achievable (AAEE) Scenario 3 includes low penetration of all electric new construction in both residential and commercial building sectors
2. Decarbonizing the electricity system	60% Renewable Portfolio Standard (RPS) by 2030 as required by SB100
3. Energy efficiency	Additional Achievable Energy Efficiency (AAEE) business as usual
	Additional Achievable Energy Efficiency (AAEE) business as usual
4. Refrigerant conversion and reduction	None
5. Distributed generation and storage	Additional Achievable Photovoltaics (AAPV) business as usual
6. Decarbonizing the gas system	None
7. Demand flexibility	Traditional non-event-based load management programs business as usual

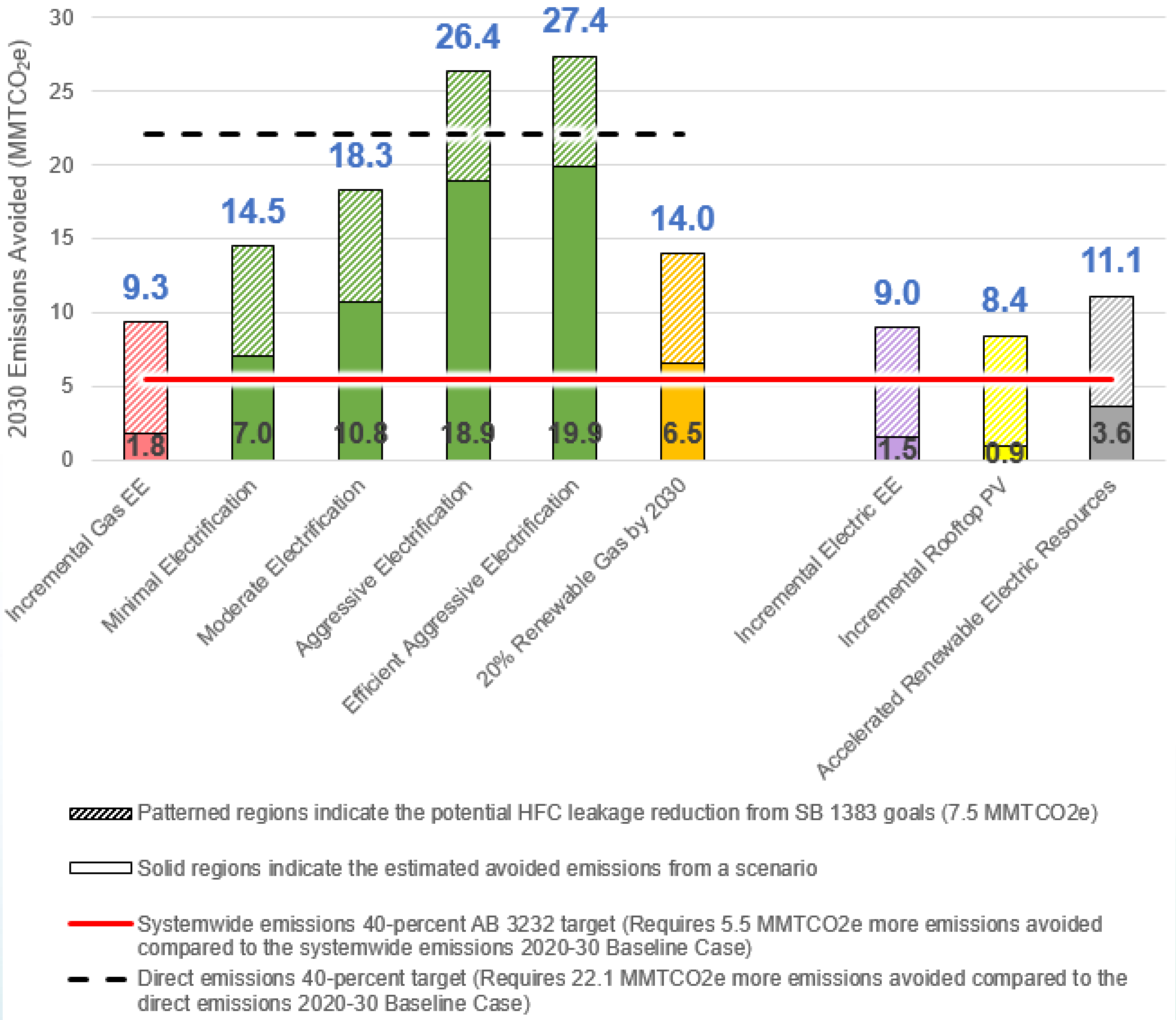
Scope of AB 3232 analysis

Building Decarbonization Strategy	Decarbonization Scenario(s) Analyzed	Used in Decarbonization Scenarios
1. Building end-use electrification	• Minimal • Moderate • Aggressive • Efficient Aggressive	A broad range and combination of electrification through new construction, appliance burnouts, and early appliance replacements
2. Decarbonizing the electricity system	Accelerated renewable electric generation resources	65-70% RPS by 2030
3. Energy efficiency	Incremental electric energy efficiency	AAEE optimistic (AAEE Scenario 5)
	Incremental gas energy efficiency	AAEE optimistic (AAEE Scenario 5)
4. Refrigerant conversion and reduction	Not assessed	None
5. Distributed generation and storage	Incremental rooftop solar PV systems	IEPR High penetration PV Scenario
6. Decarbonizing the gas system	Decarbonizing gas system with renewable gas	Substitution of 20 percent of fossil gas pipeline throughput with renewable gas by 2030
7. Demand flexibility	Demand flexibility	Automated systems that take advantage of curtailment and avoid net-peak consumption

Mapping the strategies to analyzed scenarios & comparing to baseline

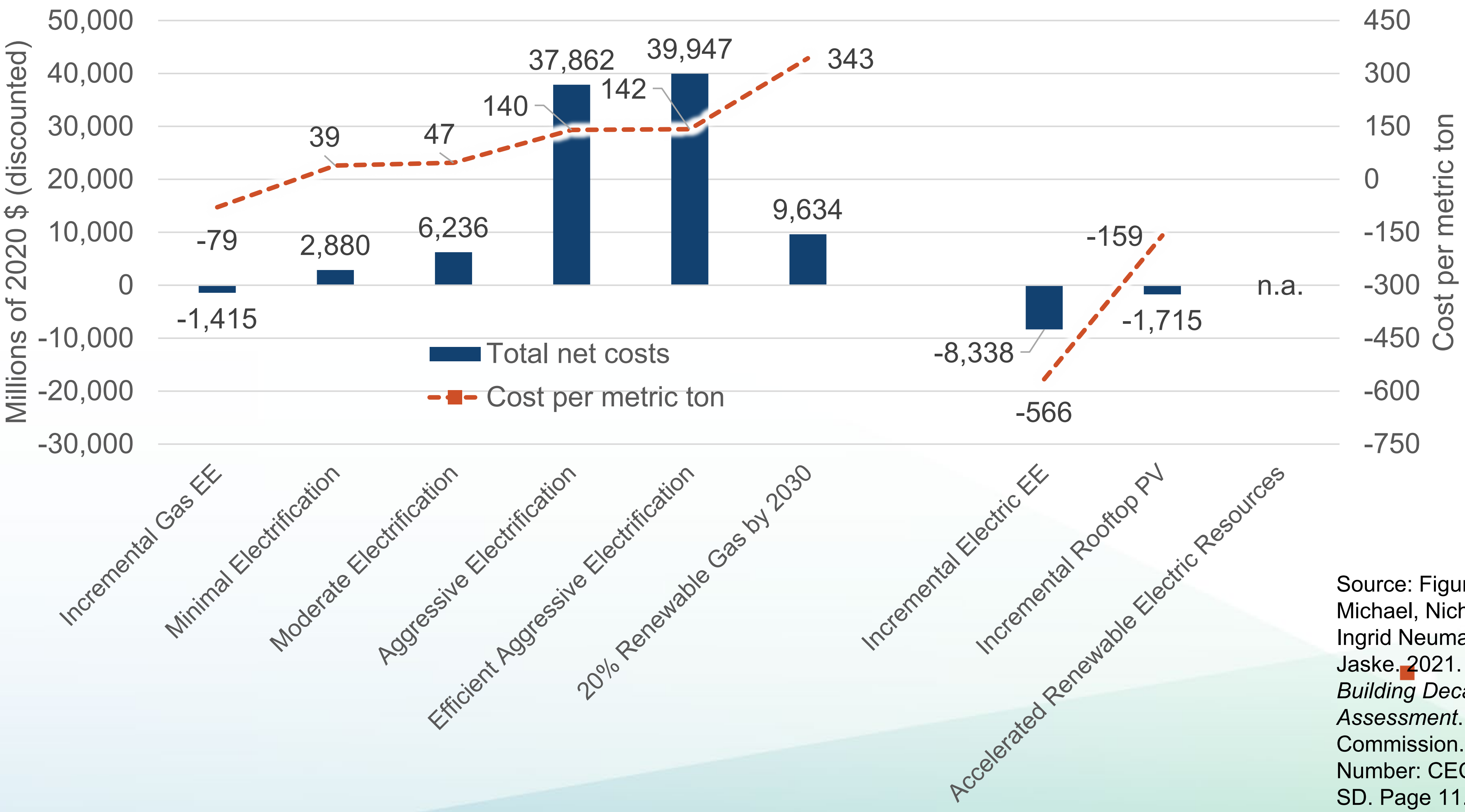
Building Decarbonization Strategy	Decarbonization Scenario(s) Analyzed	Used in the 2020-2030 Baseline Case	Used in AB 3232 Decarbonization Scenarios
1. Building end-use electrification	• Minimal • Moderate • Aggressive • Efficient Aggressive	AAEE Scenario 3 includes a very low penetration of all electric new construction in both residential and commercial building sectors	A broad range and combination of electrification through new construction, appliance burnouts, and early appliance replacements
2. Decarbonizing the electricity system	Accelerated renewable electric generation resources	60% RPS by 2030	65-70% RPS by 2030
3. Energy efficiency	Incremental electric energy efficiency	AAEE business as usual (AAEE Sc. 3)	AAEE optimistic (AAEE Sc. 5)
	Incremental gas energy efficiency	AAEE business as usual (AAEE Sc. 3)	AAEE optimistic (AAEE Sc. 5)
4. Refrigerant conversion and reduction	Not assessed	None	None
5. Distributed generation and storage	Incremental rooftop solar PV systems	AAPV business as usual (Mid)	IEPR High penetration
6. Decarbonizing the gas system	Decarbonizing gas system with renewable gas	None	Substitution of 20 percent of fossil gas throughput with renewable gas by 2030
7. Demand flexibility	Demand flexibility	Traditional non-event-based load management programs business as usual	Automated systems that take advantage of curtailment and avoid net-peak consumption

Annual GHG Reduction for 2030



Source: Figure ES-4 in Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 10.

Cost Summary of the Assessed GHG Emission Reduction Strategies



Source: Figure ES-5 in Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 11.

Selected report conclusions:

- Reducing building-sector GHG emissions will require large investments in existing buildings.
- Accelerating efficient electrification of building end uses in both new and existing buildings represents the most predictable pathway to achieve deep reductions in building emissions.
- Additional analysis of the reliability impacts of increased electrification is needed
- The role of the gas system in achieving building decarbonization needs further assessment, including the roles of renewable gas, hydrogen, and engineered carbon removal.

APPENDIX C: Detailed Analysis of Building Decarbonization Strategies

- Provides a comprehensive description of the analysis, including the additional building electrification scenarios
- Discusses
  1. modeling framework,
  2. modeling approach for assessing each building decarbonization strategy,
  3. modeling results in terms of energy system impacts, GHG emission reductions, costs and cost-effectiveness, electricity rate impacts, uncertainties of results,
  4. next steps for future analytic iterations for upcoming IEPR cycles.

Decarbonization Analysis Using the Fuel Substitution Scenario Analysis Tool (FSSAT)

Modeling electrification: Fuel Substitution Scenario Analysis Tool (FSSAT) main processes flow chart

Source: Based on Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 185.

Integrated Energy Policy Report (IEPR)
- **Gas Demand Forecast**

Additional Achievable Energy Efficiency (AAEE)
- Reduces consumption of gas

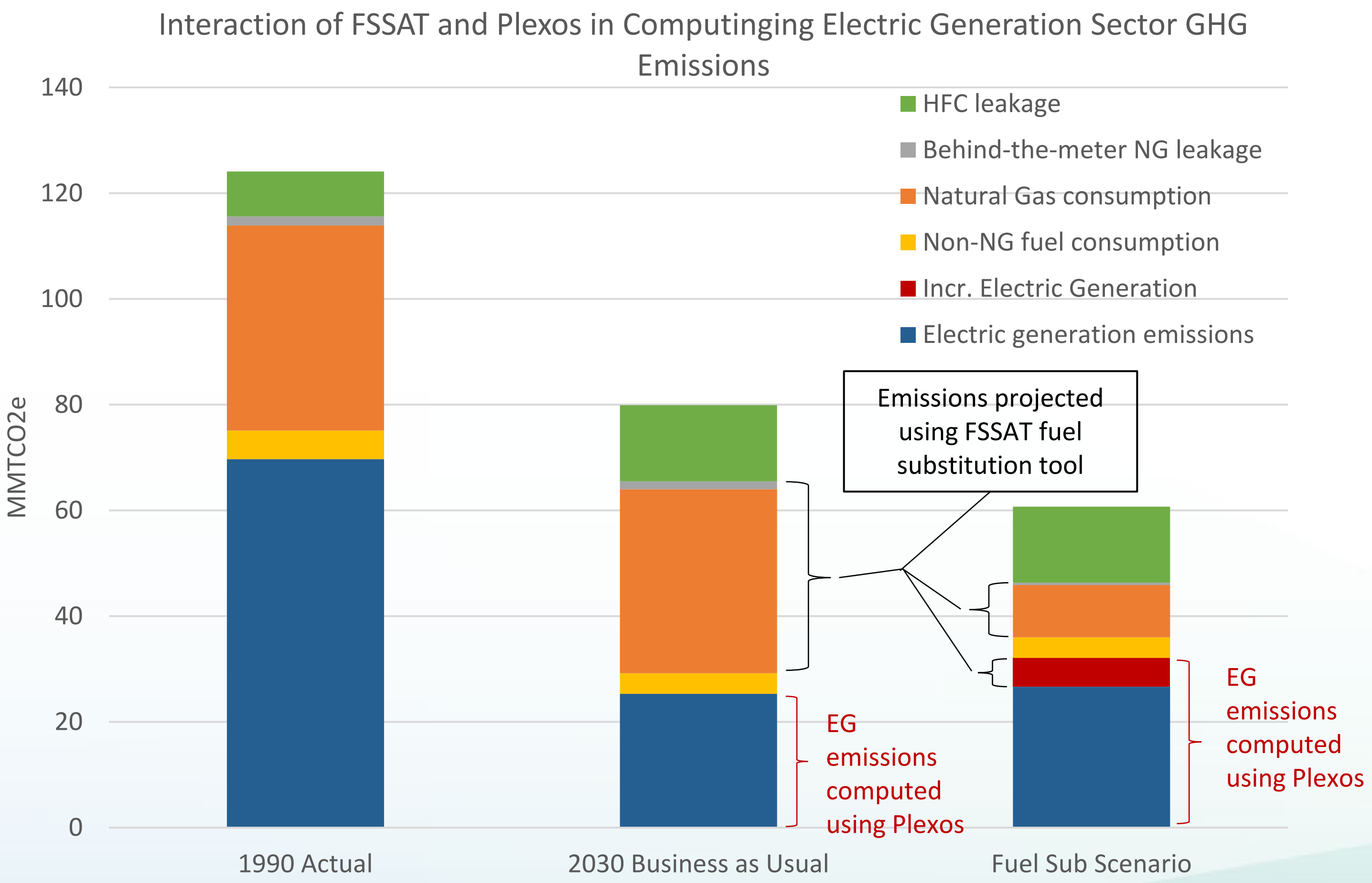
Technology Substitution
- Gas for various electric

Annual Outputs
- Technology Stock
- Costs of substitution
- Incremental electricity added
- **NET GHG emissions**

Hourly Calculation
- End use consumption load curves

Hourly Outputs
- Hourly Electric consumption increase
- Hourly GHG emissions

Interaction between FSSAT Modeling for Fuel Substitution Impacts and PLEXOS for Electric Generation Emissions



- Including the electric generation sector makes GHG emission analysis more complex but enables a more complete and accurate assessment

- There is a conceptual difference in GHG emissions from the incremental loads added and the “base” loads

Multi-step building electrification modeling process

FSSAT part 1

- Building electrification scenario parameters

Specify:

- NC/ROB/RET penetration
- Technology assumptions
  - Replacement Mix
  - Costs
- SB 1383 HFC assumptions

PLEXOS

- Use FSSAT scenario hourly load projections

Supply Analysis Office:

- Generate resource build out in PLEXOS based on FSSAT scenario
- Provide inputs for pricing impacts

FSSAT part 2

- Rerun scenario with revised GHG intensity factors

Outputs:

- Accurate accounting of GHG impacts
- Dollar per metric ton

Building end-use electrification scenarios:

Minimal, Moderate, Aggressive, Efficient Aggressive

<table>
<tr><th>Electrification Scenario Using FSSAT</th><th>New Construction (NC)</th><th>Replace on Burnout (ROB)</th><th>Early Replacement (RET)</th><th>Technology Efficiency</th><th>SB 1383 Goals Toggle</th></tr>
<tr><td>Minimal</td><td rowspan="4">100% by 2030</td><td>15%</td><td rowspan="2">5%</td><td rowspan="3">High-Efficiency Weighted Mix</td><td rowspan="4">Potential of reducing 7.5 $MMTCO_2e$ of HFC Leakage in 2030</td></tr>
<tr><td>Moderate</td><td>50%</td></tr>
<tr><td>Aggressive</td><td rowspan="2">90%</td><td rowspan="2">70%</td></tr>
<tr><td>Efficient Aggressive</td><td>Single-Best Efficiency</td></tr>
</table>

Where:

- NC, ROB, and RET are percentages of eligible technologies by sector/end-use that will be electric in 2030
- The Minimal electrification scenario just meets the 40-percent AB 3232 target
- The impacts of the SB 1383 toggle are external to the FSSAT framework

Appendix C Electrification scenarios

Appendix Scenario	Scenario Parameters	New Construction	Replace on Burnout	Early Replacement	Technology Efficiency	SB 1383 goals
Scenario 6.a: *Minimal Electrification Scenario in main report*	NC100 ROB35 RET05 mixModEf HFCno	100% by 2030	15%	5%	High Efficiency Weighted Mix	Not met (Toggle Off)
Scenario 6.b:	NC100 ROB35 RET05 bestModEf HFCno				single best	
Scenario 7:	NC100 ROB35 RET05 mixModEf HFCno		35%		High Efficiency Weighted Mix	
Scenario 8: *Moderate Electrification Scenario in main report*	NC100 ROB50 RET05 mixModEf HFCno		50%			
Scenario 9:	NC100 ROB75 RET05 mixModEf HFCno		75%			
Scenario 10:	NC100 ROB90 RET05 mixModEf HFCno		90%			
Scenario 11:	NC100 ROB90 RET35 mixModEf HFCno			35%		
Scenario 12.a: *Aggressive Electrification Scenario in main report*	NC100 ROB90 RET70 mixModEf HFCno			70%		
Scenario 12.b: *Efficient Aggressive Electrification Scenario in main report*	NC100 ROB90 RET70 bestModEf HFCno				single best	
Scenario 12.c:	NC100 ROB90 RET70 mixModEf HFCyes				High Efficiency Weighted Mix	Met (Toggle On)
Scenario 12.d:	NC100 ROB90 RET70 bestModEf HFCyes				single best	

Source: Table C-10 in Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 190.

Substitution Replacement Mapping

Modified Mix:

Substitution Replacement Map

Baseline Technology	End Use	Replacement Type	Least Efficient Repl. Tech. 1	Repl. Tech. 2	Repl. Tech. 3	Repl. Tech. 4
Res | Furnace (AFUE = 77, HIR = 1.25)	HVAC	ROB/RET	Packaged/Split Heat Pump	Variable Capacity Heat Pump	High Efficiency Packaged/Split Heat Pump	
Res | Furnace (AFUE = 80, HIR = 1.24)	HVAC	ROB/RET	Packaged/Split Heat Pump	Variable Capacity Heat Pump	High Efficiency Packaged/Split Heat Pump	
Res | High Eff. Furnace (AFUE = 90.6, HIR = 1.07)	HVAC	ROB/RET	Packaged/Split Heat Pump	Variable Capacity Heat Pump	High Efficiency Packaged/Split Heat Pump	
Res | Condensing Eff. Furnace (AFUE = 98)	HVAC	ROB/RET	Packaged/Split Heat Pump	Variable Capacity Heat Pump	High Efficiency Packaged/Split Heat Pump	
Res | Small Gas Storage Water Heater (0.53 EF - 50 Gal)	WaterHeat	ROB/RET	Small Electric Storage Water Heater (0.90 EF – 50	High Eff. Small Electric Storage Water Heater (0.9	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)	
Res | Small Gas Storage Water Heater (0.60 EF - 50 Gal)	WaterHeat	ROB/RET	Small Electric Storage Water Heater (0.90 EF – 50	High Eff. Small Electric Storage Water Heater (0.9	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)	
Res | High Eff. Small Gas Storage Water Heater (0.70 EF - 50 Gal)	WaterHeat	ROB/RET	Small Electric Storage Water Heater (0.90 EF – 50	High Eff. Small Electric Storage Water Heater (0.9	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)	
Res | Condensing Eff. Small Gas Storage Water Heater (0.82 EF - 50 Gal)	WaterHeat	ROB/RET	Small Electric Storage Water Heater (0.90 EF – 50	High Eff. Small Electric Storage Water Heater (0.9	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)	
Res | Instantaneous Gas Water Heater	WaterHeat	ROB/RET	Small Electric Storage Water Heater (0.90 EF – 50	High Eff. Small Electric Storage Water Heater (0.9	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)	
Res | Gas Clothes Dryer - 2.67 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | Gas Clothes Dryer - 3.30 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | High Eff. Gas Clothes Dryer - 3.48 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | Gas Cooktop	AppPlug	ROB/RET	Res Electric Resistance Cooktop	Res Induction Cooking Stove		
Res | Gas Oven	AppPlug	ROB/RET	Res Electric Resistance Oven			
Com | Average Existing Furnace (78 AFUE)	HVAC	ROB/RET	Packaged RTU HP – Air Source	Variable Capacity Heat Pump	High Efficiency Packaged RTU HP – Air Source	PTHP
Com | Code Furnace (81 AFUE)	HVAC	ROB/RET	Packaged RTU HP – Air Source	Variable Capacity Heat Pump	High Efficiency Packaged RTU HP – Air Source	PTHP
Com | High Eff. Furnace (92 AFUE)	HVAC	ROB/RET	Packaged RTU HP – Air Source	Variable Capacity Heat Pump	High Efficiency Packaged RTU HP – Air Source	PTHP
Com | Condensing Eff Furnace (98 AFUE)	HVAC	ROB/RET	Packaged RTU HP – Air Source	Variable Capacity Heat Pump	High Efficiency Packaged RTU HP – Air Source	PTHP

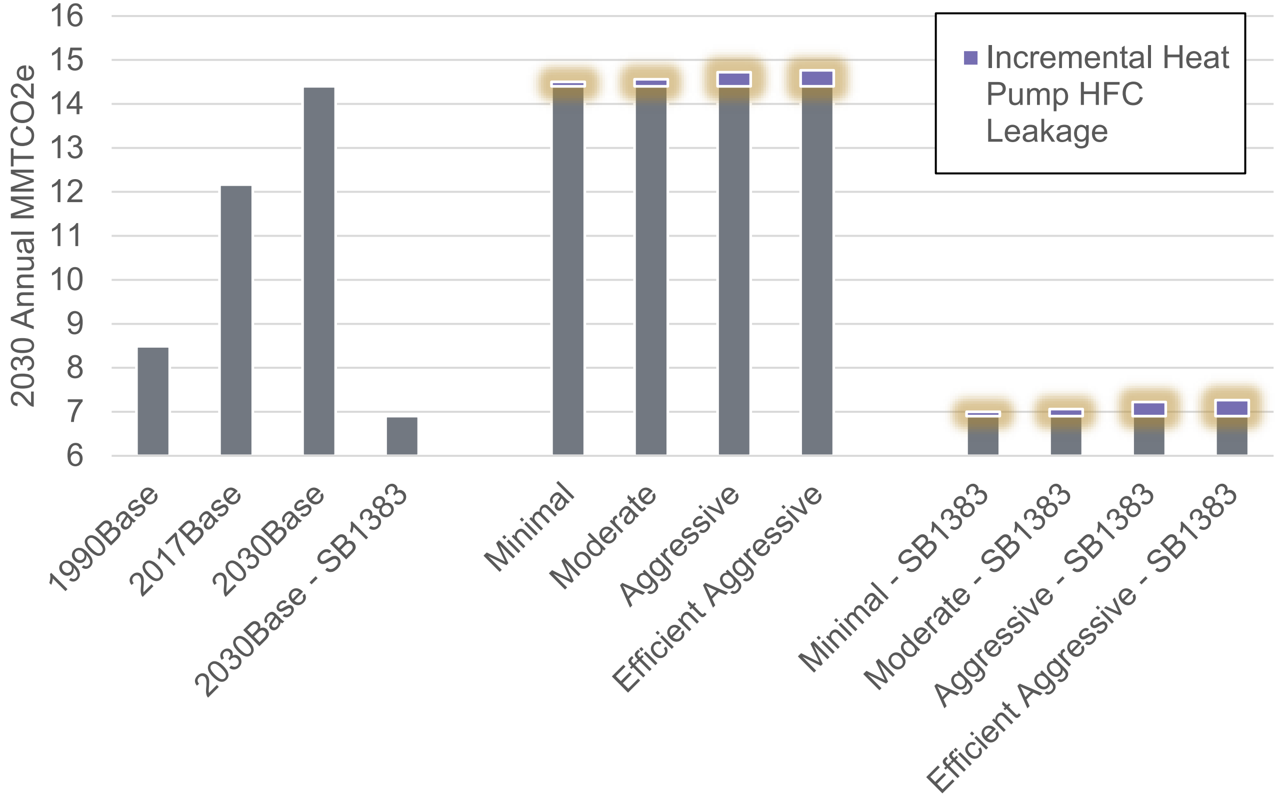
Single-Best Realistic:

Substitution Replacement Map

Baseline Technology	End Use	Replacement Typ	Best Mod Repl. Tech. 1	Repl. Tech. 2	Repl. Tech. 3	Repl. Tech. 4
Res | Furnace (AFUE = 77, HIR = 1.25)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Res | Furnace (AFUE = 80, HIR = 1.24)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Res | High Eff. Furnace (AFUE = 90.6, HIR = 1.07)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Res | Condensing Eff. Furnace (AFUE = 98)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Res | Small Gas Storage Water Heater (0.53 EF - 50 Gal)	WaterHeat	ROB/RET	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)			
Res | Small Gas Storage Water Heater (0.60 EF - 50 Gal)	WaterHeat	ROB/RET	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)			
Res | High Eff. Small Gas Storage Water Heater (0.70 EF - 50 Gal)	WaterHeat	ROB/RET	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)			
Res | Condensing Eff. Small Gas Storage Water Heater (0.82 EF - 50 Gal)	WaterHeat	ROB/RET	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)			
Res | Instantaneous Gas Water Heater	WaterHeat	ROB/RET	Heat Pump Water Heater (>= 2.0 EF - 50 Gal)			
Res | Gas Clothes Dryer - 2.67 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | Gas Clothes Dryer - 3.30 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | High Eff. Gas Clothes Dryer - 3.48 CEF	AppPlug	ROB/RET	Most Eff. Heat Pump Clothes Dryer			
Res | Gas Cooktop	AppPlug	ROB/RET	Res Induction Cooking Stove			
Res | Gas Oven	AppPlug	ROB/RET	Res Electric Resistance Oven			
Com | Average Existing Furnace (78 AFUE)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Com | Code Furnace (81 AFUE)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Com | High Eff. Furnace (92 AFUE)	HVAC	ROB/RET	Variable Capacity Heat Pump			
Com | Condensing Eff Furnace (98 AFUE)	HVAC	ROB/RET	Variable Capacity Heat Pump			

Source: April 30 2021 Supplementary material for AB 3232 Report Appendix C - Selected Input Data Assumptions used in AB 3232 analysis ("AB 3232 Appendix C"). California Energy Commission. TN# 237504. Docket Number 19-DECARB-01. April 20, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=237504&DocumentContentId=70704.

Statewide HFC-Based GHG Emissions in 2030



- FSSAT has a SB1383 toggle
- CARB provided HFC data projections for SB1383
- FSSAT calculates the buildings' attribution of HFC emissions from SB1383 (currently no data on costs consequences)
- FSSAT calculates the incremental emissions from the newly substituted equipment (note: figure only shows annual emissions for 2030; HFC emissions significant in the long term)

Source: Figure 30 in Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 84.

Technology characterizations

- Online Excel workbook: TN# 237504. Docket Number 19-DECARB-01. April 20, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=237504&DocumentContentId=70704.
- The online workbook contains an extensive set of technology characteristic inputs used by FSSAT to generate incremental electric energy and incremental electric technology cost results.
- Contains:
  - The **gas** characterization input worksheet
  - The **electric** technology characterization input worksheet (contains the effective COP to reflect the climate characteristics of each climate zone).
  - **Air conditioning technology** characterization so to account for added electric consumption load from the introduction of cooling to buildings that previously lacked space cooling
  - **Panel costs** by utility and climate zone

FSSAT Technology characterization

Technology Characterization Key Metrics

Technology characterization differentiated, as applicable by sector, end use, climate zone, building type, and replacement type.

Metrics	Description	**Notes:**
Energy Use	• Annual gas consumption (therms) • Annual electric consumption (kWh), as applicable	Electric consumption is calculated using **the baseline gas technology consumption** and the expected **coefficient of performance** of the mapped electric technology.
Technology Costs	• Equipment cost • Installation cost	Costs from variety of sources and years according to best available data. Costs are scaled to the same year using the Producer Price Index.
Market Information	• Density— the quantity of technology group in a territory. • Saturation— the proportion of technologies and given efficiency levels within a technology group.	Densities and Saturations are pulled from the 2019 Potential & Goals Study.
Other Items	• Technology lifetime	Gas technologies based on DEER and current default assumptions for electric technologies 15 years. No decay in consumption performance over time.
Technology Performance Metrics	• Efficiency or performance values such as HSPF, SEER, EER, COP, and EF	COPs are based on a sample of manufacturer ratings and scaled according to climate zone.

Guidehouse Fuel Substitution Scenario Analysis Tool (FSSAT) 5

Source: February 27, 2020. Presentation - Staff Workshop on the Fuel Substitution Analysis Tool (FSSAT). California Energy Commission. TN# 232239. Docket Number 19-DECARB-01. February 27, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=232239&DocumentContentId=64224. Slide 5.

FSSAT Energy Outputs

Energy & Technology Outputs

Name	Units	Description
IEPR Natural Gas Forecast	MM therms	The IEPR natural gas forecast at the building and forecast climate zone levels disaggregated to the technology level.
AAEE Modified Natural Gas Forecast	MM therms	IEPR natural gas forecast reduced by AAEE expected savings over the forecast period.
Revised NG Forecast	MM therms	The AAEE-modified IEPR natural gas forecast after a given fuel substitution scheme is applied.
Added Stock	Unit Basis	Electric technology stock added due to fuel substitution. Units vary based on technology (ex. appliance unit, tonnage, etc.)
Added Electric Cons. (ReplGas)	kWh	Electric consumption increases due to fuel substitution (without additional space cooling loads).
Added Electric Cons. (AC)	kWh	Electric consumption increases due to fuel substitution (additional space cooling only).

Guidehouse Fuel Substitution Scenario Analysis Tool (FSSAT) 10

Source: February 27, 2020. Presentation - Staff Workshop on the Fuel Substitution Analysis Tool (FSSAT). California Energy Commission. TN# 232239. Docket Number 19-DECARB-01. February 27, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=232239&DocumentContentId=64224. Slide 10.

FSSAT Cost Outputs

Cost Outputs*

Name	Description
Added Tech. Cost (Split)	Fuel substitution technology cost expected due to fuel substitution split by cost type: • Equipment cost (capital costs of the specific technology) • Installation cost (cost of labor and additional equipment including writing costs where pertinent) • Overhead and profit cost (additional costs to reflect contractor profit margins)
Added Tech. Cost (Total)	Total technology cost expected due to fuel substitution.
Added Tech. Cost (Inc Total)	Total technology incremental cost expected due to fuel substitution.
Fuel Costs (Split)	Fuel costs split into natural gas costs mitigated and electric costs added due to fuel substitution.
Fuel Costs (Net)	Net fuel costs of added electricity and reduced natural gas.
Panel Costs	Aggregate costs of panel upgrades at the utility, sector, building type, and building climate zone levels (not quantified per household but at dollar per full sector single family/multifamily homes basis)

* Costs do not include electric or gas supply-side infrastructure costs.

Source: February 27, 2020. Presentation - Staff Workshop on the Fuel Substitution Analysis Tool (FSSAT). California Energy Commission. TN# 232239. Docket Number 19-DECARB-01. February 27, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=232239&DocumentContentId=64224. Slide 11.

FSSAT Emissions and Marginal Abatement Cost Outputs

Emissions & Abatement Curve Outputs

Name	Units	Description
HFC Emissions (FS)*	kg CO2e	Additional HFC emissions from refrigerant leakage due to fuel substitution.
HFC Emissions (Non-FS)	mTCO2e	Expected HFC emissions from refrigerant leakage independent of fuel substitution.
NG Leakage Emissions	kg CO2e	Emissions from natural gas leaks downstream of the commercial and residential meter.
NG Emissions Avoided	kg CO2e	Direct emissions from combustion of natural gas consumption.
Electric Emissions Added	kg CO2e	Indirect generation emissions from additional electric consumption due to fuel substitution.
Total Emissions Added	kg CO2e	The net aggregate emissions added due to fuel substitution.
Emissions Reduction Cost	Various	This tab includes cumulative avoided emissions, cumulative net present cost incremental to the gas technology replacement cost, and cumulative cost per metric ton avoided ($/mTCO2e).

*Cases in which a heat pump replaces a furnace in a home with existing air conditioning, net refrigerant emissions added is assumed to be zero.

Emissions avoided due to fuel substitution. (green)
Emissions added due to fuel substitution. (red)

Guidehouse

Fuel Substitution Scenario Analysis Tool (FSSAT) 12

Source: February 27, 2020. Presentation - Staff Workshop on the Fuel Substitution Analysis Tool (FSSAT). California Energy Commission. TN# 232239. Docket Number 19-DECARB-01. February 27, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=232239&DocumentContentId=64224. Slide 12.

FSSAT Hourly Outputs

Workbook Tab Name	Description
FS Hourly Impacts Out (MW)	The hourly electric load impacts for the input utility or utility group at the sector level.
FS Hourly Impacts Out (GHG)	The hourly electric emissions impacts for the input utility or utility group at the sector level.
FS Hourly Impacts Scenario Out	The statewide hourly electric load impacts for the input utility or utility group.
Hourly Impacts Compare	The annualized summary of hourly emissions factors to be compared against the user input annual emissions factors.
Load shape Map Input	A record of the load shape mappings defined in the master map.
Transmission Inputs	A record of the transmission inputs defined in the master map.
Distribution Inputs	A record of the distribution inputs defined in the master map.
Residential End Use Output	The hourly electric load impacts for the input utility or utility group at the end use level in the residential sector.
Commercial End Use Output	The hourly electric load impacts for the input utility or utility group at the end use level in the commercial sector.
Agricultural End Use Output	The hourly electric load impacts for the input utility or utility group at the end use level in the agricultural sector.
Industrial End Use Output	The hourly electric load impacts for the input utility or utility group at the end-use level in the industrial sector.

Source: Guidehouse

Source: Table 14 in Sathe, Amul Sathe (Guidehouse), Karen Maoz (Guidehouse), John Aquino (Guidehouse), Abhijeet Pande (TRC), and Floyd Keneipp (Tierra Resource Consultants). 2020. Fuel Substitution Reporting Tools. California Energy Commission. Publication Number: CEC-200-2020-001. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725. Page 85.

Ag and Industrial

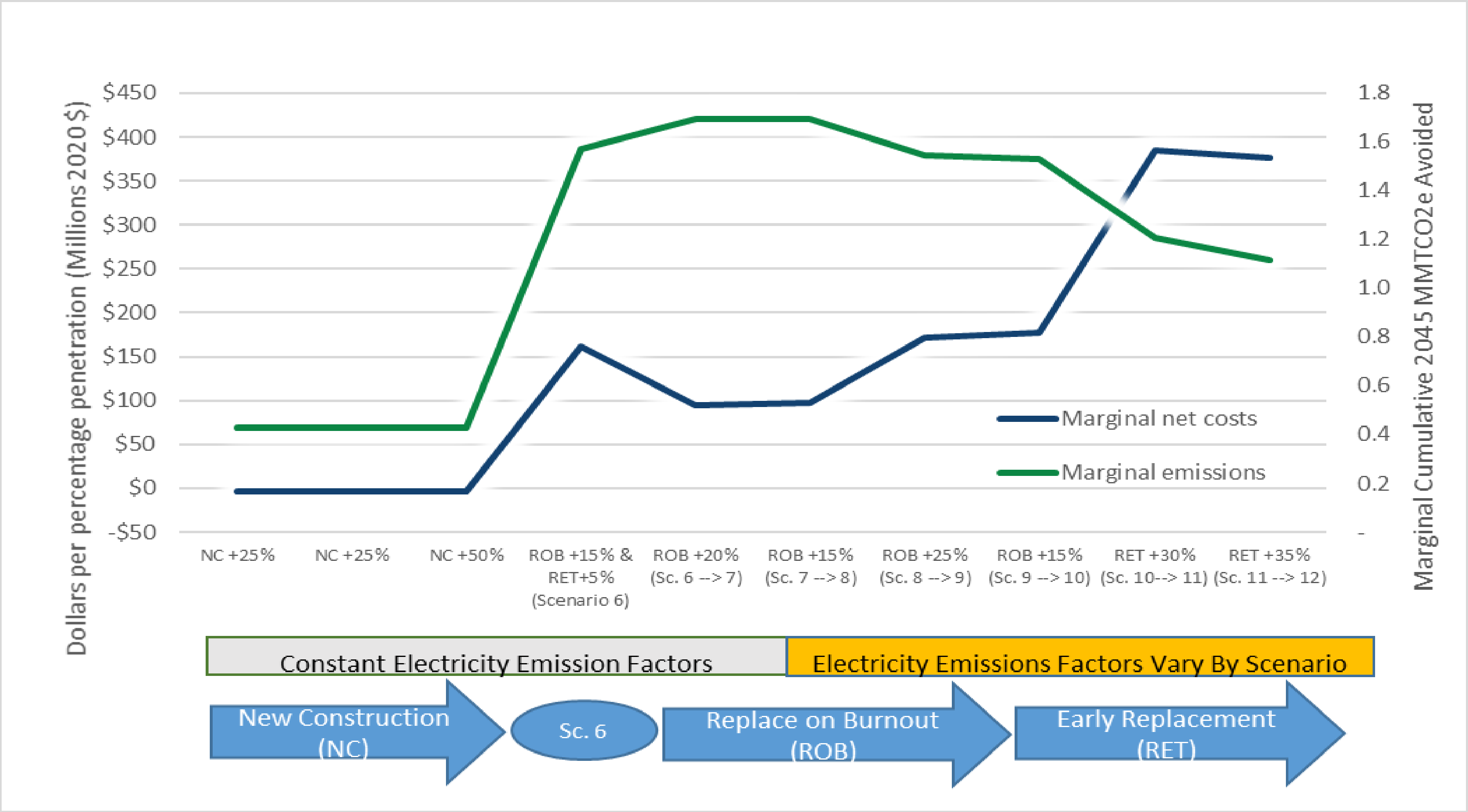
- Part of FSSAT, but not part of AB3232 analysis
- Works differently than the Residential and Commercial sectors
  - Can toggle percentage replacement of:
    - Agricultural – Water heating
    - Agricultural – HVAC
    - Industrial – Process Heating
  - Technology costs are incremental to avoided gas

FSSAT updates made by CEC staff since the June 9th workshop

#	Description
1	Updated baseline forecast from 2017 IEPR to 2019 IEPR
2	Updated heat pump load shapes and hourly emission factors
3	Updated fuel substitution replacement mapping assumptions
4	Updated the efficiency values for commercial cooking appliances and repaired a formula error in the FSSAT input workbook
5	Adjusted electric water heating technology costs to make them comparable to the baseline natural gas technology costs that were used in the 2019 Potential and Goals Study
6	Discovered and repaired a unit conversion coding bug that prevented incremental costs for some technologies to become negative
7	Updated annual emission factors for each FSSAT scenario based on PLEXOS work done by CEC's Supply Analysis Office

Costs and cost effectiveness

Marginal emissions and net costs for various rates of building electrification



Source: Figure C-46 in Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *Draft California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-SD. Page 190..

Costs and Cost effectiveness

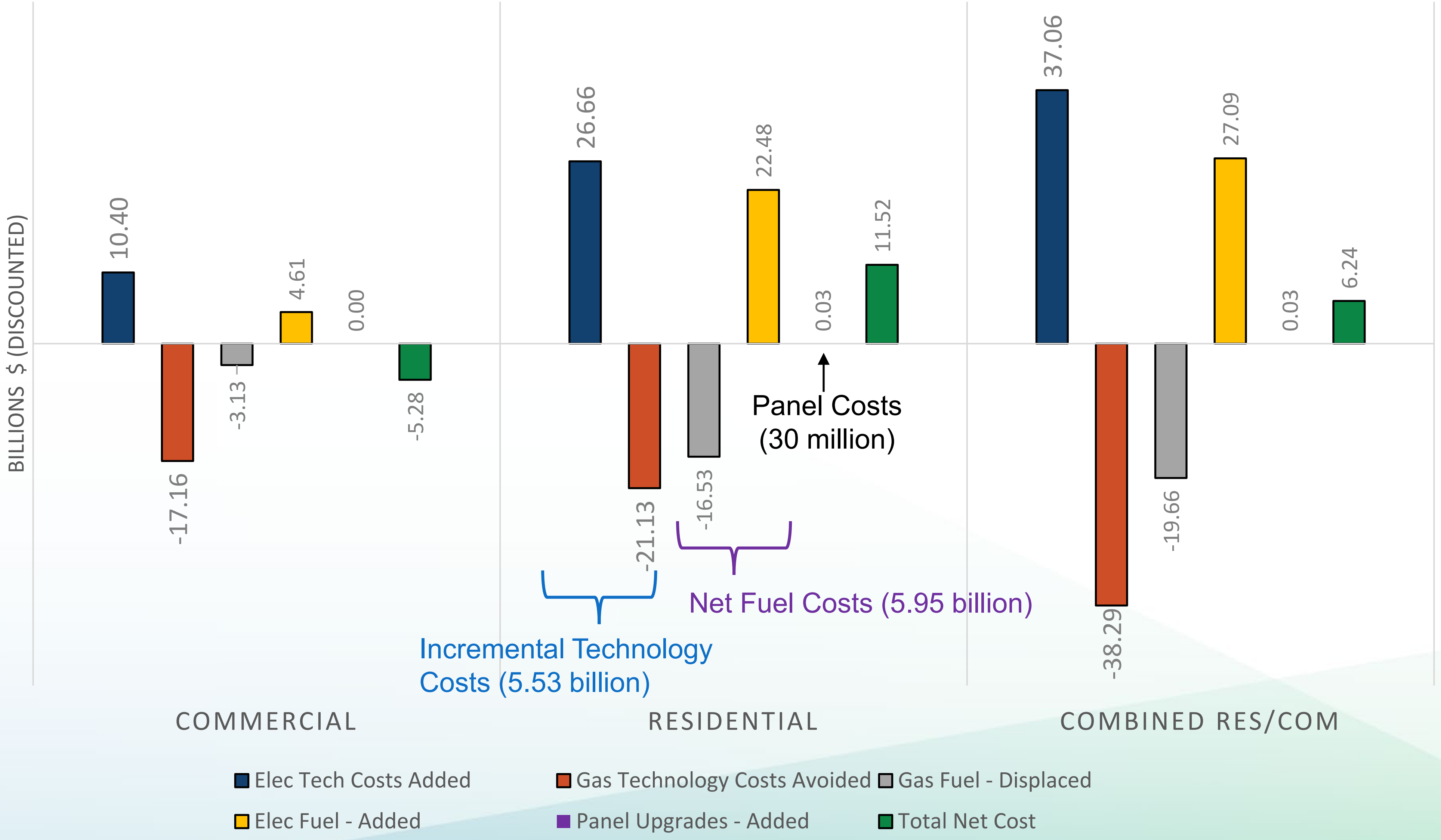
- Many definitions of cost effectiveness
- AB 3232 analysis applies the same definition of **cost effectiveness** as *CARB 2017 Scoping Plan:*
  - "Under AB 32 [(Nuñez, Chapter 488, Statutes of 2006)], cost-effectiveness means the relative ***cost per metric ton*** of various GHG reduction strategies, which is the traditional cost metric associated with emission control." (Page 44)
- The calculated dollar per ton estimates reflect the average costs of activities occurring between 2020-2030 over a time horizon out to 2045 since emissions reductions and costs occur beyond 2030

Source: CARB 2017 Scoping Plan https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf

Cost calculation assumptions

- All scenarios:
  - Assume a 2 percent annual **inflation rate**
  - Apply a 10 percent **discount rate** to all costs, same as *2017 CARB Scoping Plan*
  - **Net fuel costs** calculated using the retail rates from the 2019 IEPR Demand Forecast
- Cost components of electrification scenarios:
  - **Incremental technology costs**
    - **Air conditioning costs**
  - **Net fuel costs**
  - **Electrical panel upgrade costs**

“Moderate Electrification Scenario” Cumulative Costs by Category and Customer Sector



Next steps for improving FSSAT and fuel substitution analysis

Updates to FSSAT since AB 3232 report

Recent Updates:

1. Extension of the analysis to 2050
2. Implementing saturation as marginal saturation with adoption curves able to be defined in the inputs.
3. Functionality to have technology cost changing over time (i.e., allow for market transformation).
4. Functionality to have gas emissions intensity changing over time
5. Panel cost inputs are disaggregated by building type and calculated from RASS data. Allows for Electric Vehicle attribution to panel costs.
6. Modified SB1383 HFC emission toggle so that it is no longer an “all-or-nothing” switch
7. Updates to the Ag and Industrial Analysis (not examined in AB3232 analysis)
8. Updated cost values for some technologies
9. Added new output files to assist with staff analysis

Planned updates for this summer (given IEPR time constraints):

1. More granular version of marginal saturation
2. Link ‘new’ historic fuel substitution data to projected data
3. Add more functionality in modeling and the electrification potential of other combustion fuels (e.g., propane)
4. Other tasks to improve/expand the analysis.
5. Improve input and data assumptions as provided by stakeholder input

Near-term improvements

- Identify an input of near-term reach codes and electrification efforts
- Acquire improved data and expand assessment tools to understand the nature of propane and wood use in rural California
- Work with CARB staff to acquire improved data and expand assessment tools for modeling HFC impacts
- Improve cost impact assessments by shifting from annual average electric prices to TOU rates as the basis for incremental electrical operating costs
- Improve modeling of building envelope efficiency measures to better reflect electrical load consequences of electrification
- Improve disaggregated impact assessments by improving the modeling of Low-income households in the residential sector
- Improve linkages to supply-side assessment tools to support improved understanding of impacts of building decarbonization on bulk energy generation and supply systems
- Improve modeling of electric technology load shapes
- Build on the work assessing seasonal and peak impacts of incremental building electrification conducted in this report and integrally incorporate a reliability assessment into the first forecast

Mid-Term Improvements Requiring Improved Data Collection by Distribution Utilities

- Revise, as necessary, IOU energy efficiency measure tracking systems to distinguish between electrification versus same fuel energy efficiency measures and coordinate reporting of building electrification programs by publicly owned electric utilities
- Improve data on retrofit costs in existing buildings ancillary to the end-use equipment costs
- Work with electric utilities to acquire an understanding of distribution system upgrades needed to support building electrification with and without additional load increases from use of electric vehicles
- Further refinement of the miscellaneous share of commercial building consumption may be possible in future updates and lower the percentage of gas consumption attributed to uncategorized end-uses in commercial buildings.
- Coordinate customer-specific distribution mapping to understand how gas customers map to electric distribution circuits, especially in Southern California with a multitude of single fuel utilities
- Work with gas utilities to obtain more detailed cost data to improve the modeling of the cost consequences from renewable gas penetration.
- Further exploration is needed of the building decarbonization potential of behind-the-meter storage systems, both paired with a PV system and as a standalone system

Longer-Term Improvements Needed to Predict Consumer Participation in Retrofit Programs

- Use program evaluation data collected from near-term electrification programs (e.g., BUILD and TECH from SB 1477) to better inform the consumer behavior assumptions used in future analyses
- Disaggregate assessment tools to better identify electrification and GHG savings attributable to multi-family, low-income and disadvantaged communities for which substantial barriers appear to exist, thus enabling better program design
- Develop an improved understanding of consumer awareness about building electrification goals, willingness to undertake retrofits, and financial support required to offset costs.

Thank you! Questions?

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Resources

Resource	Link
19-DECARB-01 Docket	https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-DECARB-01
Draft Staff Report - California Building Decarbonization Assessment	https://efiling.energy.ca.gov/GetDocument.aspx?tn=237733&DocumentContentId=70963
Supplementary materials for AB 3232 report (i.e., workbook for Appendix C)	https://efiling.energy.ca.gov/GetDocument.aspx?tn=237504&DocumentContentId=70704
Fuel Substitution Scenario Analysis Tool (FSSAT) manual ("Fuel Substitution Forecasting Tools Methods Supporting Senate Bill 350 Analysis")	https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725
Senate Bill 100	https://www.energy.ca.gov/sb100
Greenhouse Gas Emission Intensity Projections – Methods and Assumptions (IEPR workshop June 7, 2018)	https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2018-integrated-energy-policy-report-update-0
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	https://ww2.energy.ca.gov/2019publications/CEC-500-2019-055/index.html