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Filer:	Patty Paul
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Energy+Environmental Economics

Title 24 2022 TDV Updates

California Energy Commission

March 26, 2020

Snuller Price, Senior Partner
Michael Sontag, Senior Consultant
Brian Conlon, Consultant
Gabe Mantegna, Consultant

Agenda

- **Updates to TDV Since Previous Workshop**
- **Sensitivities to be presented today**
  - Retail Rate Adjustment in Electricity TDV
  - Methane Leakage in Natural Gas TDV
- **Under Development: Refrigerant Leakage**

Retail Rate Adjustment

Retail Rate Adjustment FAQ

- **What is the retail rate adjustment?**
  - The retail rate adjustment component is included to build total TDV up as a cost test from the perspective of the building owner; it closes the gap between volumetric utility marginal costs and volumetric retail rate forecasts.
  - The retail rate adjustment represents the fixed costs that are required to operate a utility.
- **Does a “flat” retail rate adjustment mean that it is a fixed charge?**
  - No, it is not a fixed charge. While the retail rate adjustment does not vary between hours, it is applied on a volumetric basis ($/kWh). This reflects typical retail rate structures that recover fixed costs largely on a volumetric basis. If a building reduces its energy consumption by 25%, the total retail rate adjustment “costs” to the building will similarly decrease by 25%.
- **Why has the retail rate adder historically been “flat”?**
  - This spreads volumetric cost recovery for utility fixed costs across all hours evenly, similar to volumetric retail rate design. Even in hours where the marginal cost of electricity is zero or negative, retail rates still recover fixed costs based on volumetric consumption

TDV as a Representation of Retail Rates

- TDV is meant to represent a participant cost test and customer bill impacts, forecasted over a 30-year time horizon
- Actual retail rates vary significantly between utilities and over time, due to impacts from rate design principles, outlined in Bonbright's principles of rate design
- TDV does not intend to predict retail rate design. TDV represents the forecast of a combination of the utility marginal cost of service plus the forecast of utility recovery of system fixed costs

Standard Rate Design Principles

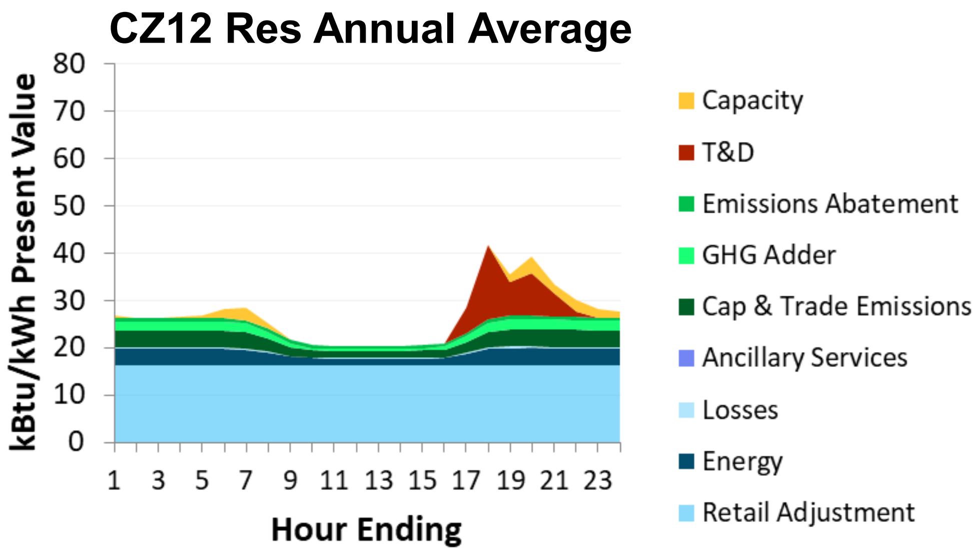
1. Recovery of the revenue requirement
2. Fair apportionment of costs among customers
3. **Price signals that encourage efficient use**
4. Customer understanding and acceptance
5. Practical and cost effective to implement
6. Rate and bill stability
7. Provision of revenue stability
8. Avoidance of undue discrimination

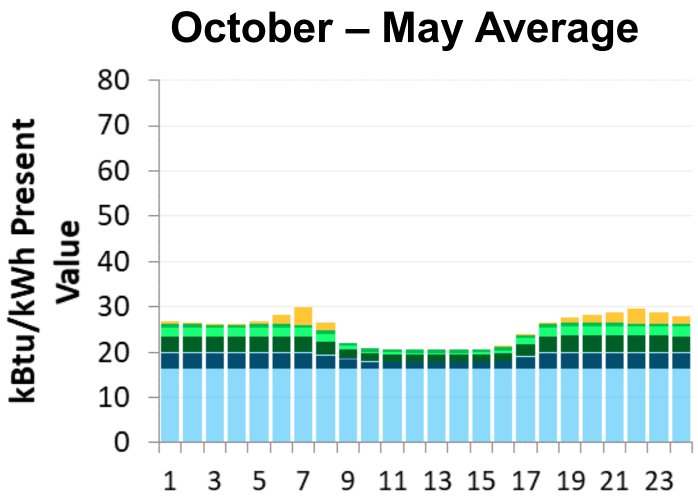
From Bonbright's Principles of Public Utility Rates

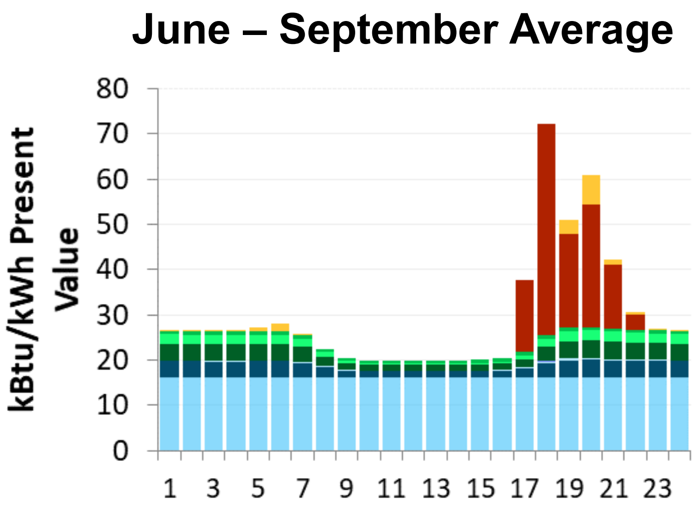
The challenge and complexity of rate design is that these principles are often in conflict with each other

Comparison of Hourly Variability by Season

- Hourly variability in TDV is dependent on day of the week, temperature, season, etc
- Summer days typically have greater variability

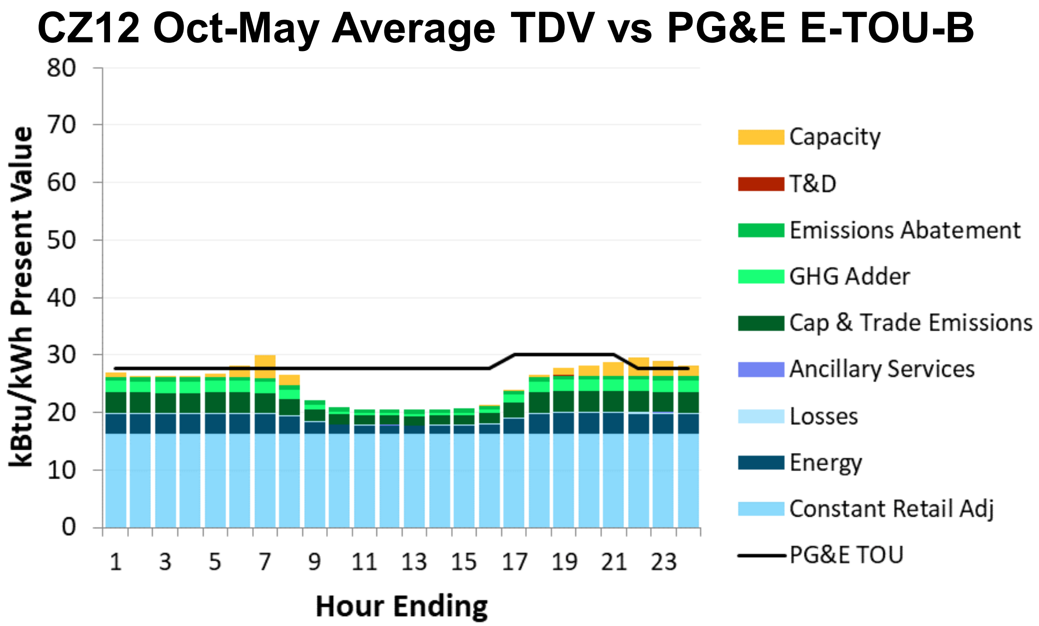


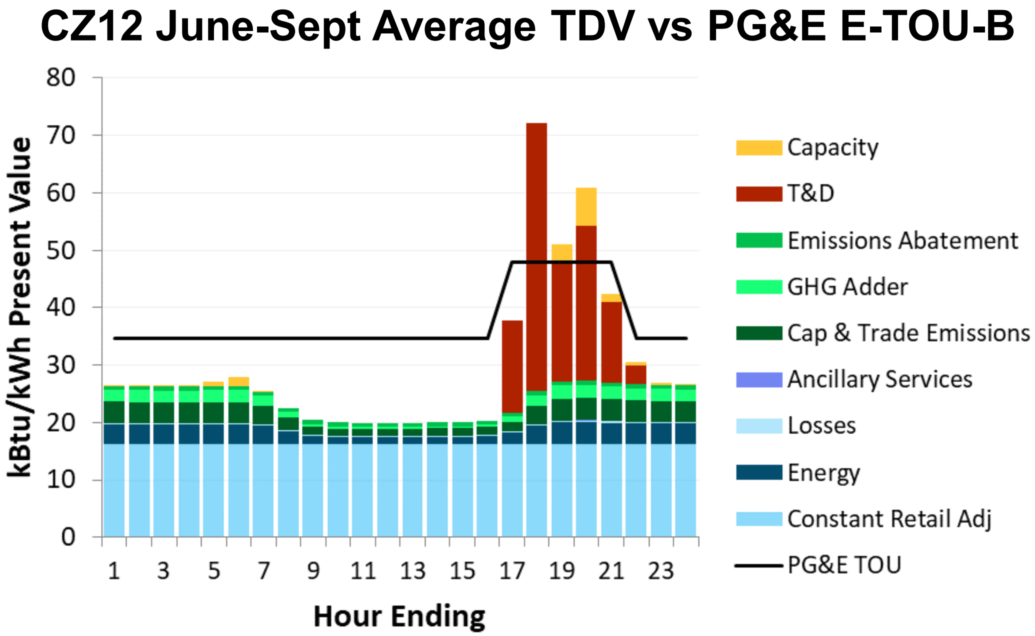




TDV Compared to Existing Retail Rates

- TDV has generally higher hourly variability than existing retail rates, including TOU rates
- These charts show the average seasonal days. Note that TDV is an hourly metric, and many days have significantly greater hourly variation
- Difference between low cost mid-day hours, and evening peaks provide signal for load shifting



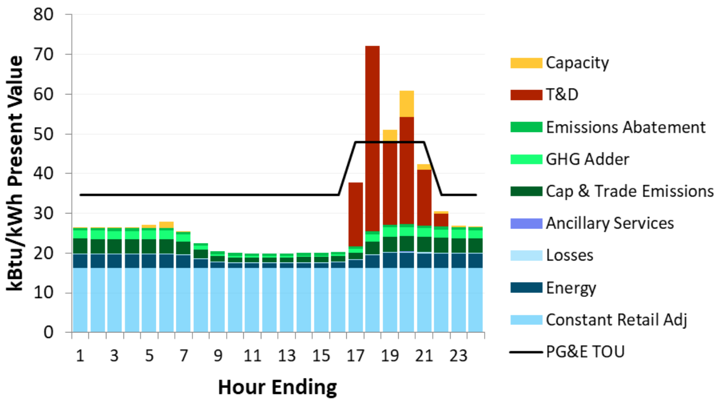


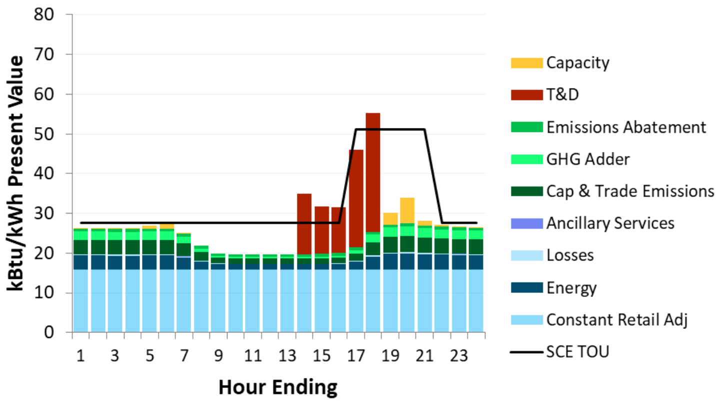
Residential TDV vs TOU Retail Rates
Flat Retail Adjustment

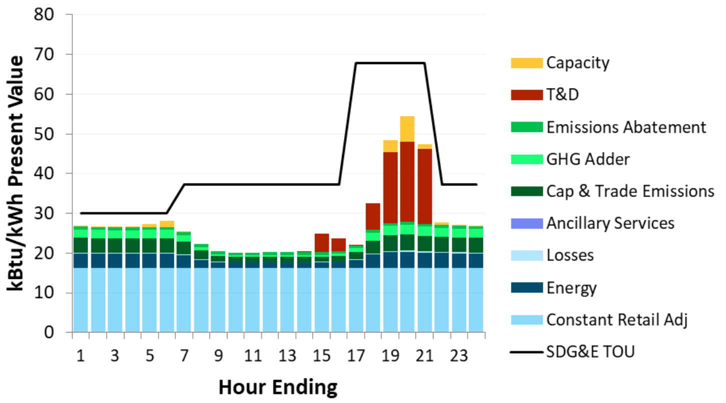
+ **TDV with flat retail adder provides strong signal compared to existing IOU TOU rates**

	CZ12, PG&E E-TOU-B Weekday	CZ9, SCE TOU-D-4-9PM Weekday	CZ7, SDG&E TOU-DR1 Weekday

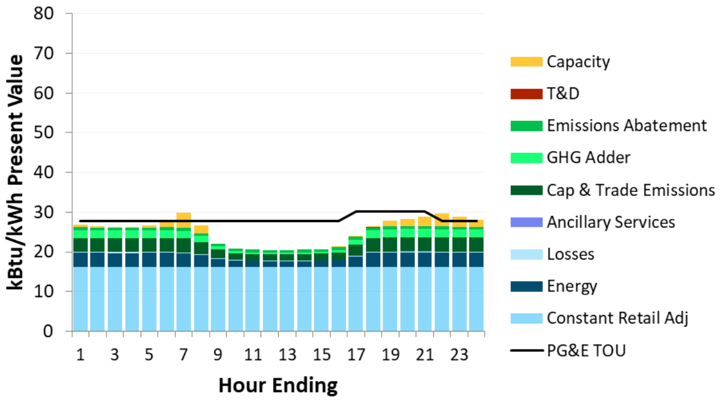
June – Sept Average

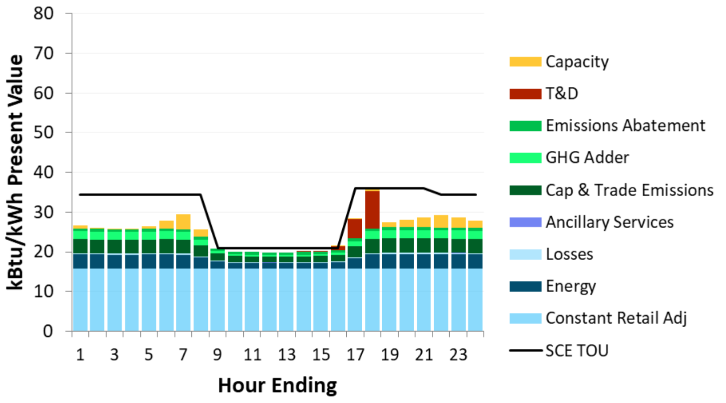


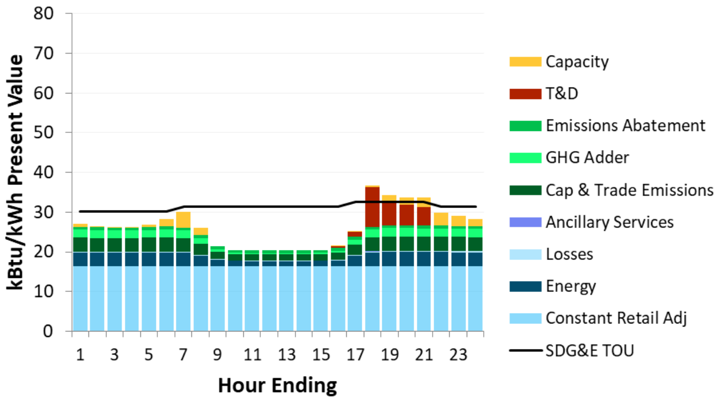




Oct – May Average

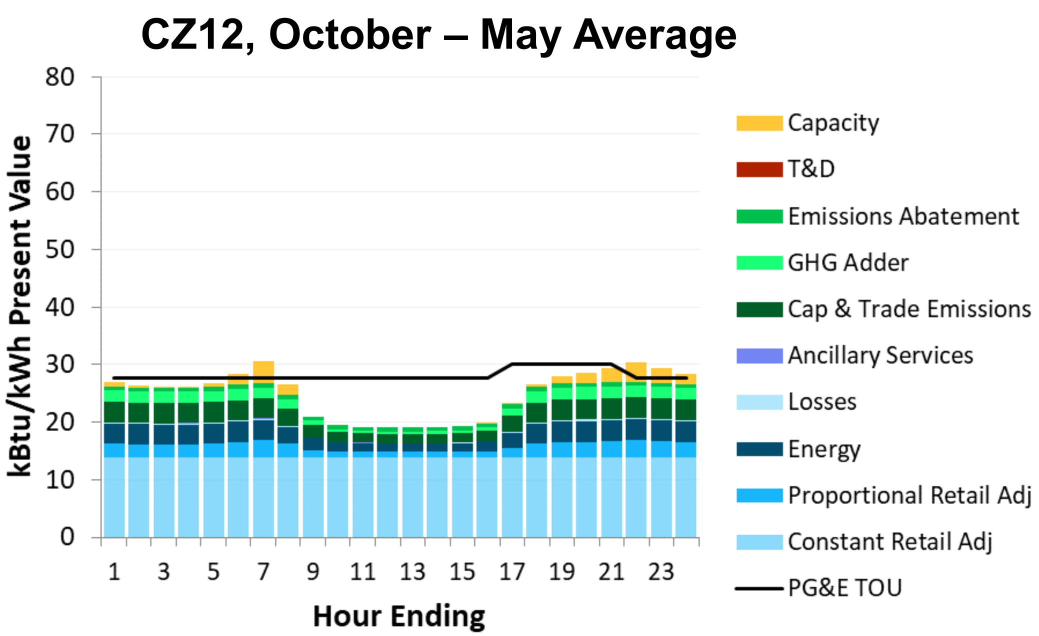


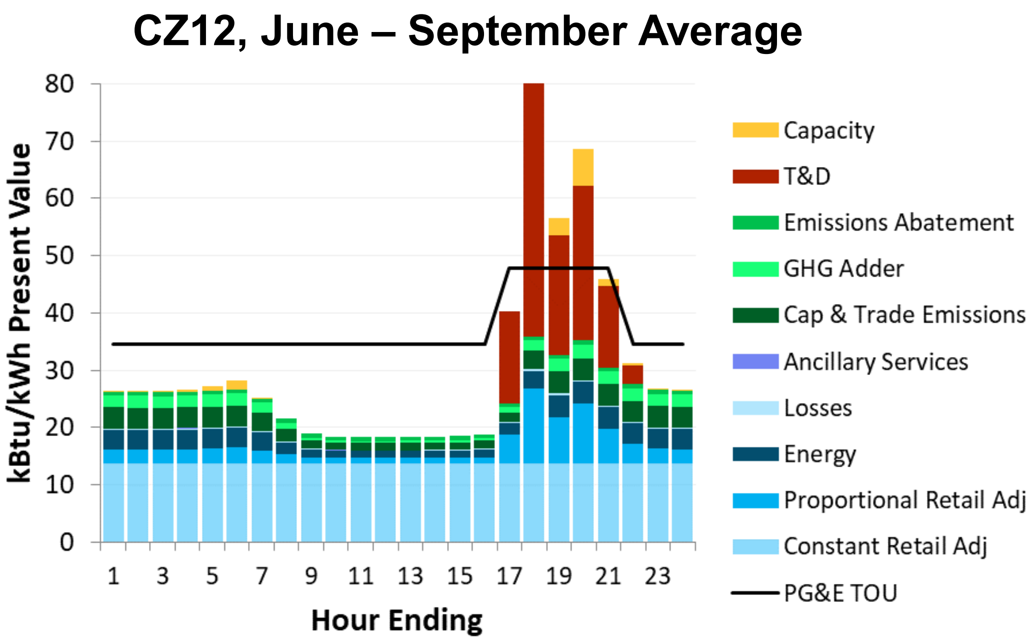




Partially Scaled Retail Rate Adjustment Option

- Stakeholders suggested scaling a portion of the retail rate adder to utility system costs that vary by hour, potentially enhancing the value of energy storage/load shifting while not overly diminishing signal for energy efficiency and photovoltaics
- This option proposes scaling 15% of the retail rate adjustment component to the hourly utility system costs
  - 15% selected based on sensitivity analysis to balance impact on different measures

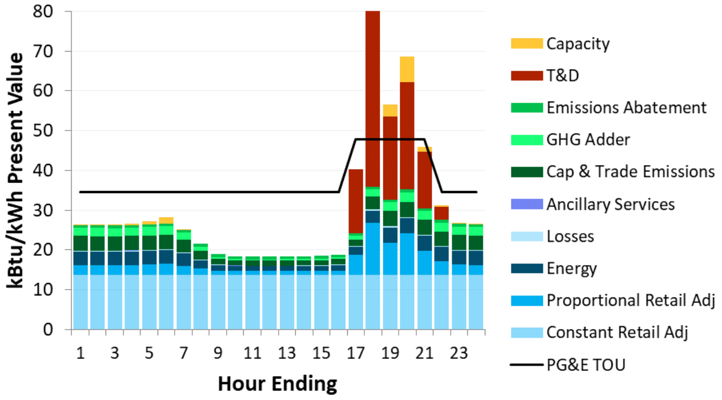




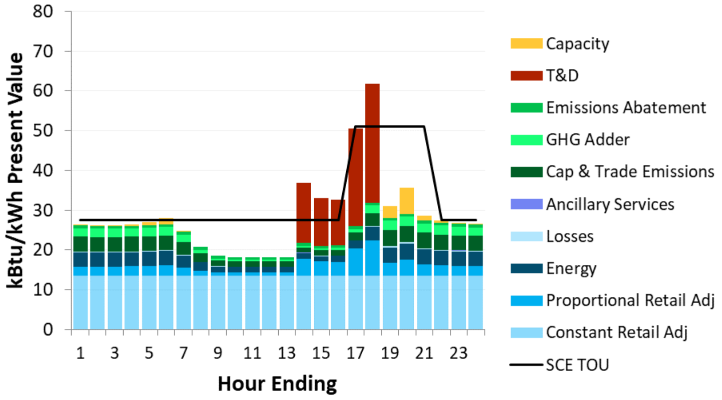
Residential TDV vs TOU Retail Rates
15% Scaled Retail Adjustment

June – Sept Average

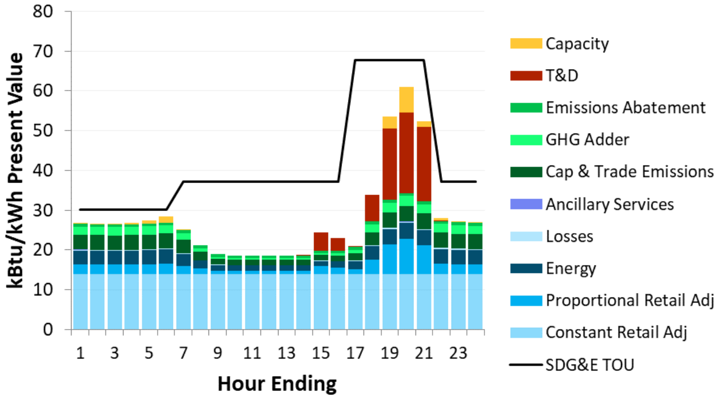
CZ12, PG&E E-TOU-B Weekday



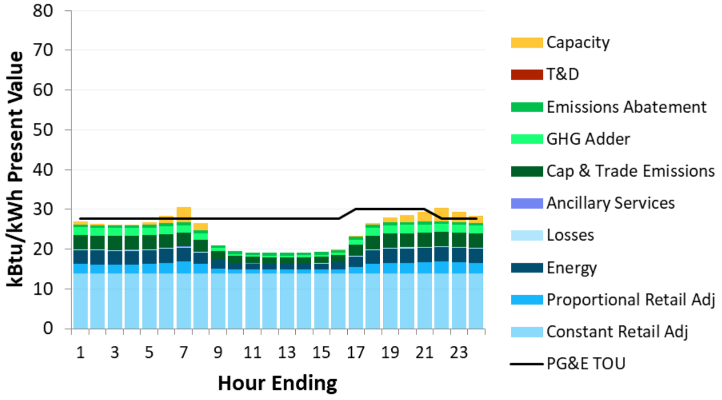
CZ9, SCE TOU-D-4-9PM Weekday

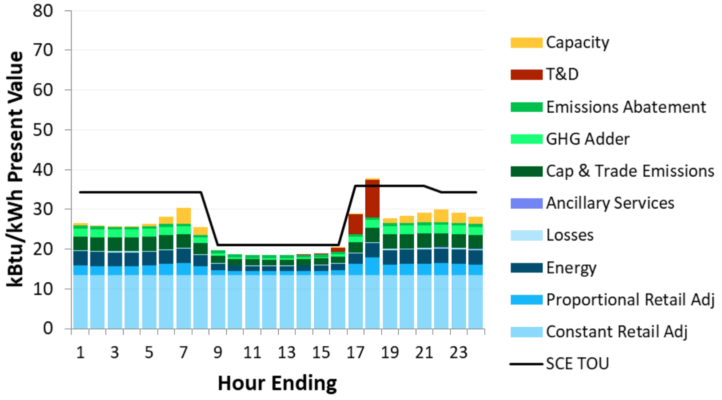


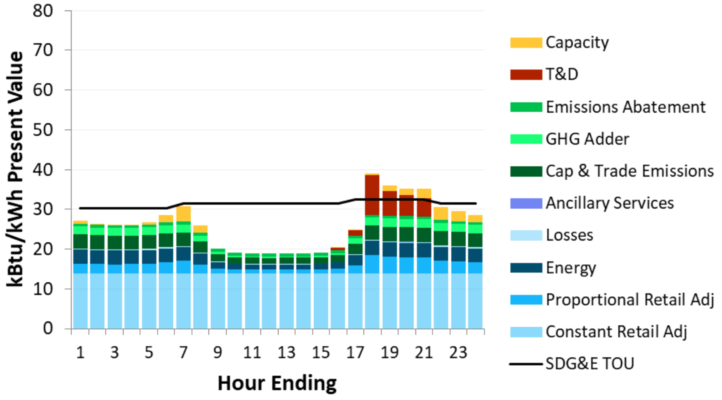
CZ7, SDG&E TOU-DR1 Weekday



Oct – May Average

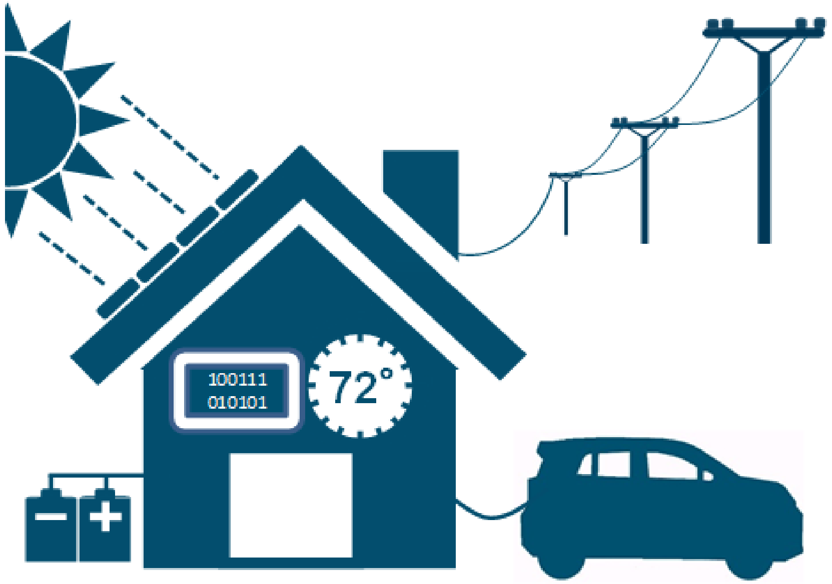






Retail Rate Adjustment Sensitivities

- Presentations from Bruce Wilcox, NORESCO will show results of various building design measures with Flat and 15%-Scaled retail adjustment



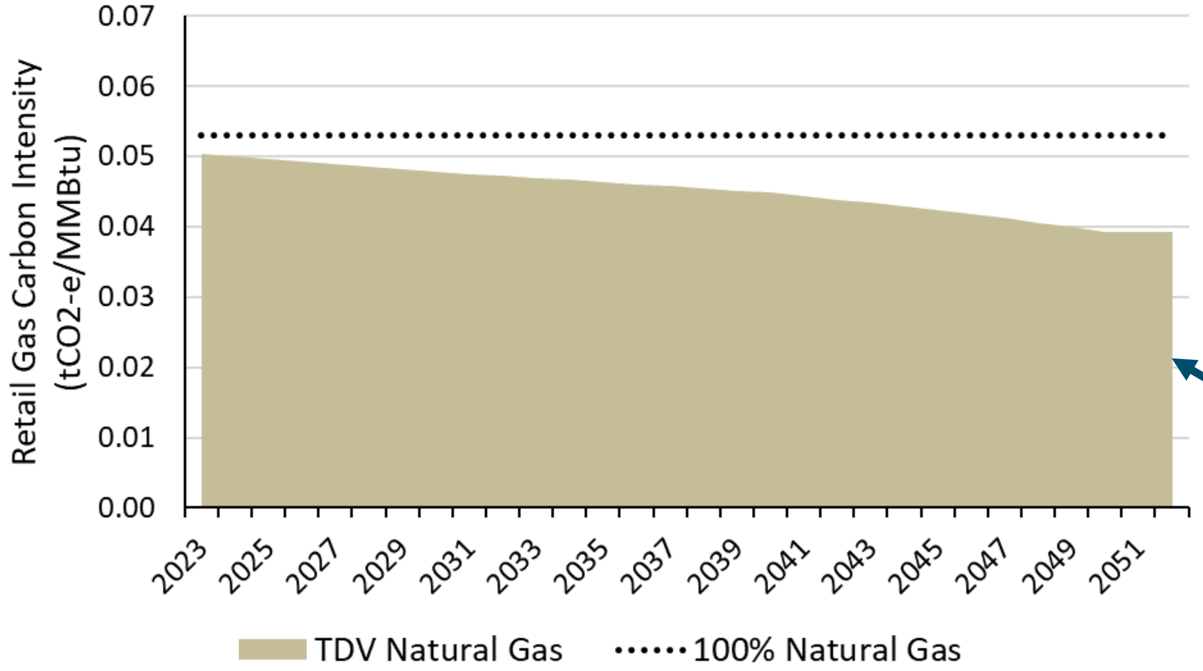
Methane Leakage Emissions

Methane Leakage Sensitivities

+ **Two sensitivities considered on methane leakage**
  - Without Methane Leakage
    - This was how results were presented at previous workshop
  - With Methane Leakage
    - Methane leakage included in emissions cost component of natural gas TDV

Natural Gas Emissions without Leakage

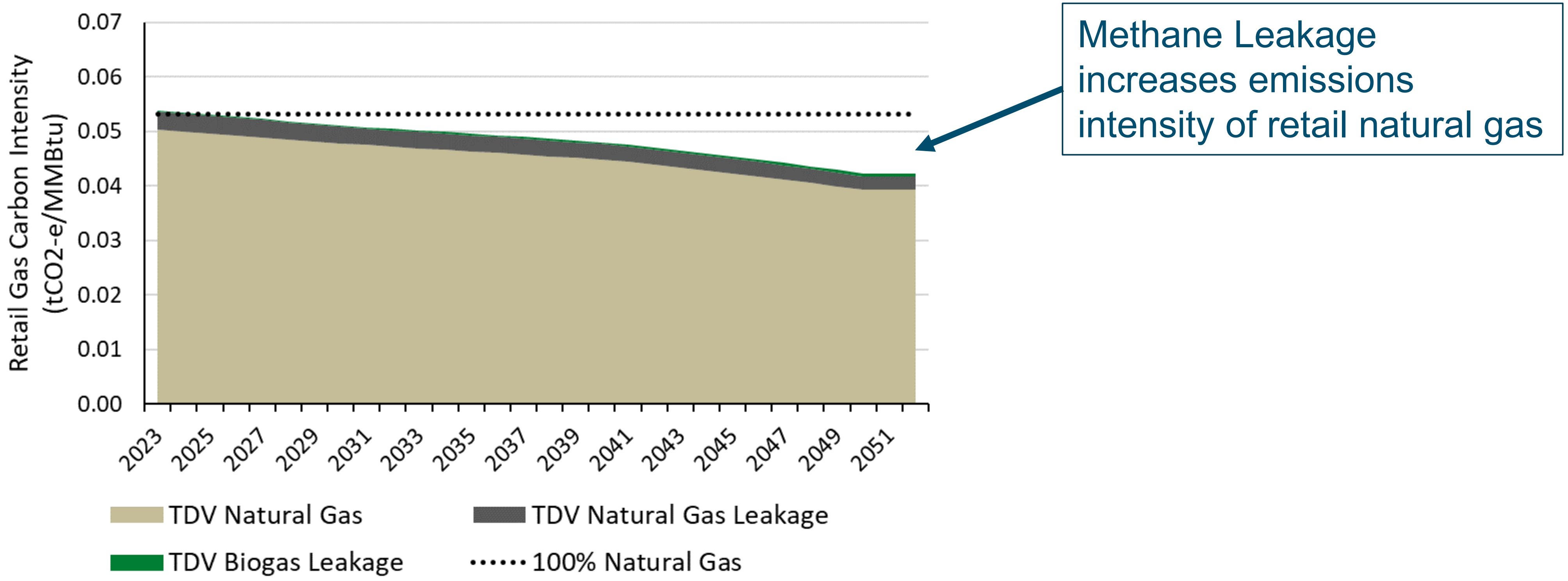
+ **Previously presented Natural Gas TDV results did not include emissions component of methane leakage**



Natural gas emissions intensity decreasing over time due to assumed renewable natural gas supply

Natural Gas Emissions with Leakage – 100-yr GWP

- **Leakage rate of 0.7% yields an increase in emissions intensity of 6.4%[1].**
  - Emissions-related costs make up about 25% of annual natural gas TDV, so this yields a small overall impact
- **Biogas leakage in the gas distribution system is considered, but makes a minimal impact**



[1] A100 year GWP of 25 converts to a factor of 9.1 for leaked methane on a per MMBtu basis. GWP is calculated on a mass basis: 1 kg of combusted methane yields ~2.75kg of CO_2
For explanation of conversion, see: https://static.berkeleyearth.org/memos/fugitive-methane-and-greenhouse-warming.pdf

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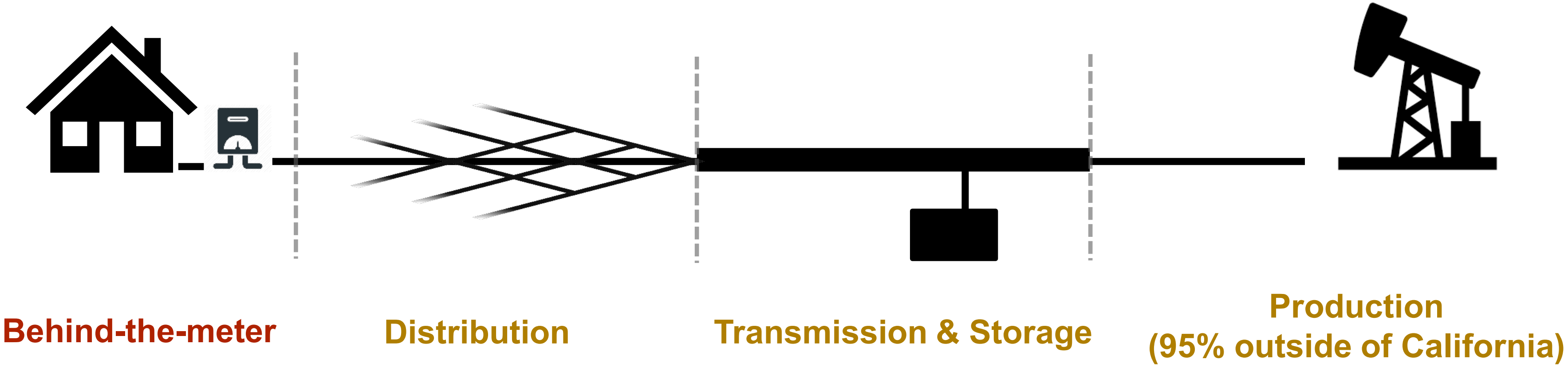
POST-WORKSHOP
Methane Leakage Update – 20-yr GWP

Methane Leakage Methodology Update

- **Refined allocation of ARB inventory data: Residential leakage from ARB inventory only allocated to residential consumption**
  - Previous analysis showed a leakage adder of 6.4% (this is based on a 0.7% leakage rate and a 100-yr GWP)
  - New approach splits leakage adder between upstream and residential leakage based on detailed ARB data
  - Leakage adder is applied to natural gas combustion emissions (including for electricity generation), as a percent increase in emissions
    - Ex. For 100 tCO_2-e in emissions from natural gas combustion, including a 6.4% leakage adder yields 106.4 tCO_2-e in total CO_2-e emissions
- **20-yr GWP used for methane gas**
  - GWP for methane of 72, compared to the 100-yr GWP of 25
  - Leakage Adder percentages are scaled from the 100-yr GWP values to 20-yr GWP values

Refined Approach to ARB Leakage Allocation

- **Since the March 26th workshop, through coordination with CARB and the CPUC, the previous 6.4% leakage adder methodology has been updated, splitting into two components:**
  - an upstream methane leakage adder of 5.57%, and
  - a residential behind-the-meter leakage adder of 3.78%.



Note: these values are based on a 100-yr GWP

$$6.4\% = \frac{\text{Res behind-the-meter leakage + Distribution leakage + Transmission \& Storage leakage + In-state production leakage}}{\text{Total in-state natural gas consumption}}$$

$$5.57\% = \frac{\text{Distribution leakage + Transmission \& Storage leakage + In-state production leakage}}{\text{Total in-state natural gas consumption}}$$

$$3.78\% = \frac{\text{Res behind-the-meter leakage}}{\text{Res natural gas consumption}}$$

Scaling to 20-yr GWP

- **California ARB Short-Lived Climate Pollutants (SLCP)[1] impact analysis considers both 20-yr and 100-yr GWP impacts of methane leakage**
  - 20-yr GWP are used in cost benefit analyses by California ARB to evaluate economic impacts of regulations[2]
- **20-yr GWP reflects the urgency of reducing greenhouse gas emissions over lifetime of buildings**
- **20-yr GWP of methane leakage set at 72 to remain consistent with ARB inventory**

100-yr GWP

Upstream methane leakage adder 5.57%

Residential behind-the-meter leakage adder of 3.78%

20-yr GWP

Upstream methane leakage adder 16.0%

Residential behind-the-meter leakage adder of 10.9%

TDV Leakage Adders

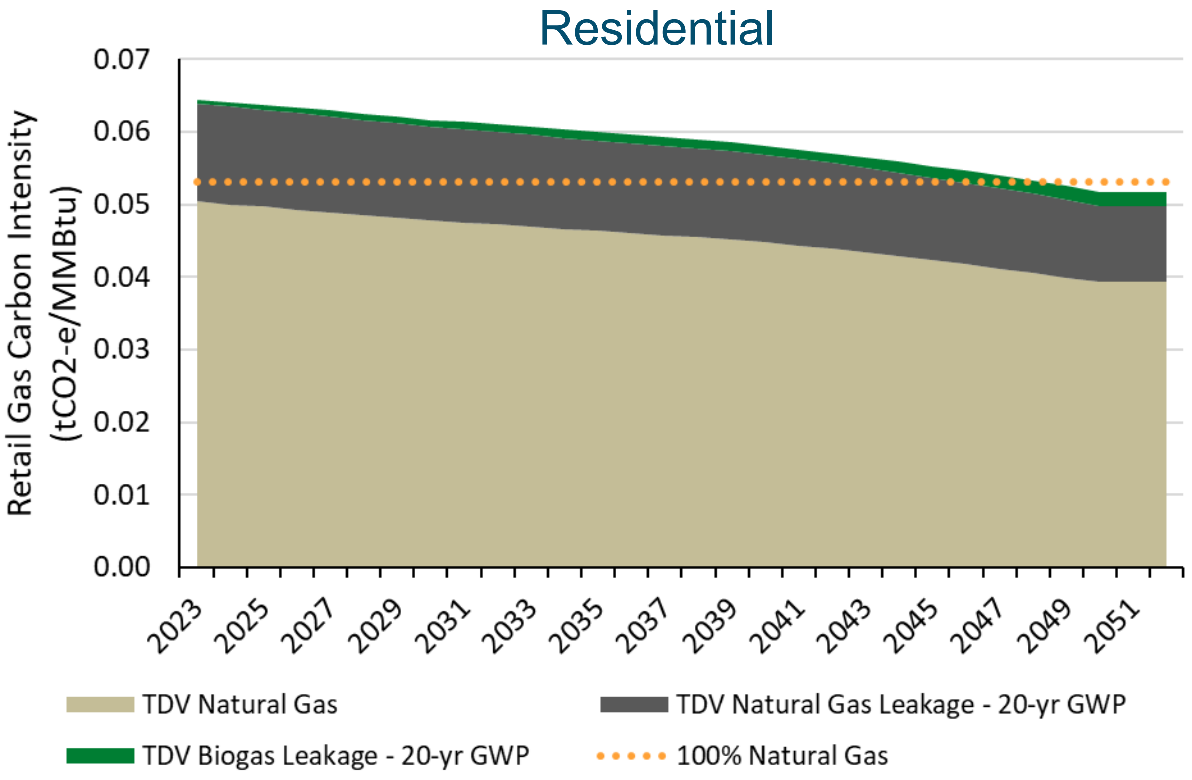
Non-Residential leakage adder 16.0%

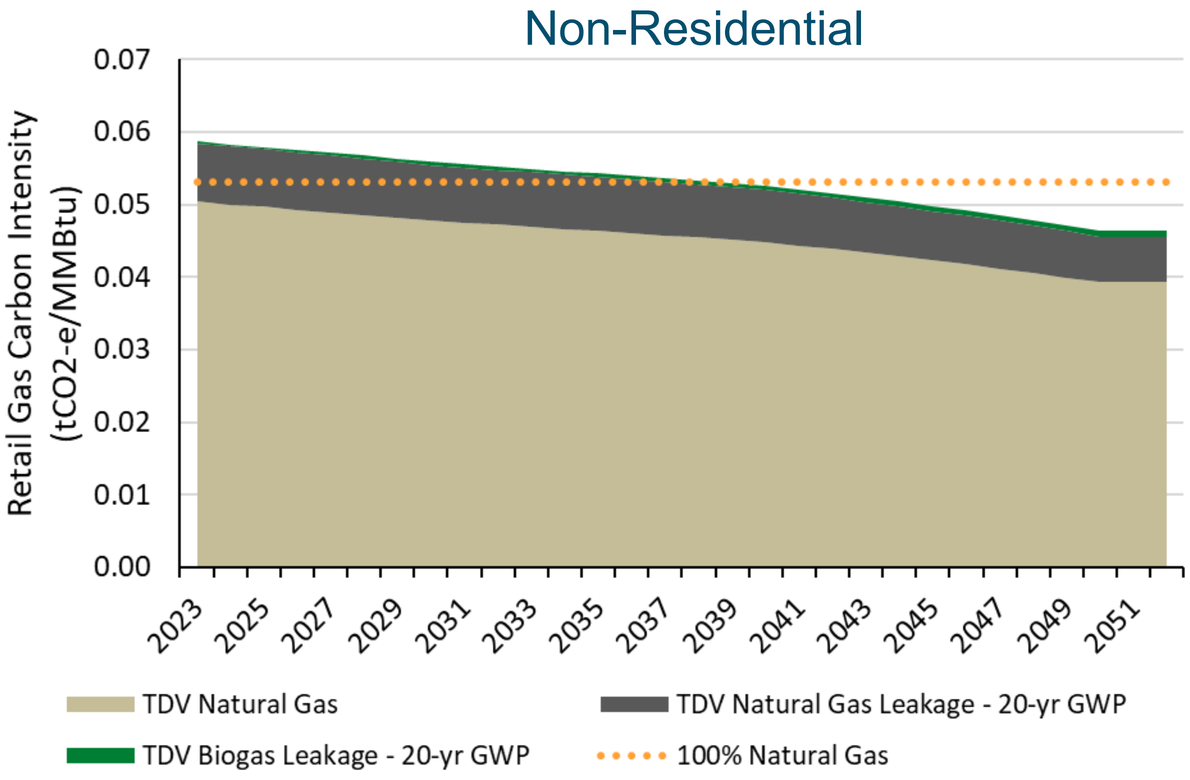
Residential total leakage adder 27%

1) SLCP Impact analysis: https://ww2.arb.ca.gov/node/2217/about
2) Example: CARB Oil and Gas Regulation Staff Report: https://ww3.arb.ca.gov/regact/2016/oilandgas2016/oilgasisor.pdf

Natural Gas Emissions with Leakage – 20-yr GWP

+ **Compared to non-leakage scenario, 20-yr GWP yields an increase in emissions intensity of 16% for Non-Residential Gas and 27% for Residential Gas**
  - Emissions-related costs make up about 25% of annual natural gas TDV, so this yields a 4-6% increase in TDV
+ **Biogas leakage behind the meter and in gas distribution is considered, but makes a minimal impact**





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Refrigerant Leakage Emissions

Including Refrigerant Leakage Emissions in TDV

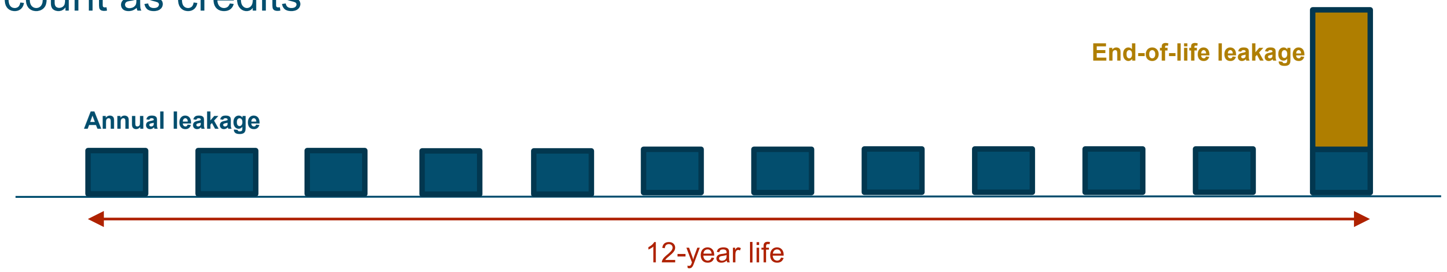
- **Framework for including refrigerant leakage emissions in TDV is under development**
- **Important to include as non-combustion emission source along with methane leakage**
- **Including these emissions in the TDV framework allows a comparison of the total CO_2-e emissions between all-electric and mixed-fuel buildings, and more importantly, incentivize the use of lower-GWP refrigerants**
  - Low-GWP heat pumps (ex. CO_2 heat pump water heaters) are becoming available in the market and should get credit for climate benefits
- **To be determined:**
  - How to balance trade-offs of refrigerant choice with energy characteristics of building standards
  - Is there a stable enough market for this to be included in TDV
  - Are there redundant pathways to incentivize low-GWP refrigerants (ex. SB 1477 or ARB actions)

Methodology for Refrigerant Leakage in TDV

+ **TDV impacts of refrigerant leakage can be calculated based on data available from California ARB**
  - Determine refrigerant leakage based on equipment type, sizing
  - Compute the CO_2-e of lifecycle refrigerant leakage based on established GWP factors
  - Value in TDV in alignment other CO_2-e emissions cost components, and add to the total building TDV score
  - Reduction from the baseline refrigerant leakage would count as credits

California Air Resources Board Refrigerant Leakage Database

Appliance	Typical refrigerant	Refrigerant GWP	Average refrigerant charge	Average annual leakage	Average end-of-life leakage
Central A/C	R410A	2088	7.5 lbs	5%	80%
Air-source ducted heat pump	R410A	2088	8.2 lbs	5.3%	80%
Heat pump water heater	R134A	1430	2.4 lbs	1%	95%
Heat pump clothes dryer	R134A	1430	0.88 lbs	1%	100%



$$\text{Annualized emissions} = \textit{Refrigerant charge} * GWP * \left(\textit{Annual leakage rate} + \frac{\textit{End–of–life leakage rate}}{\textit{lifetime}} \right)$$

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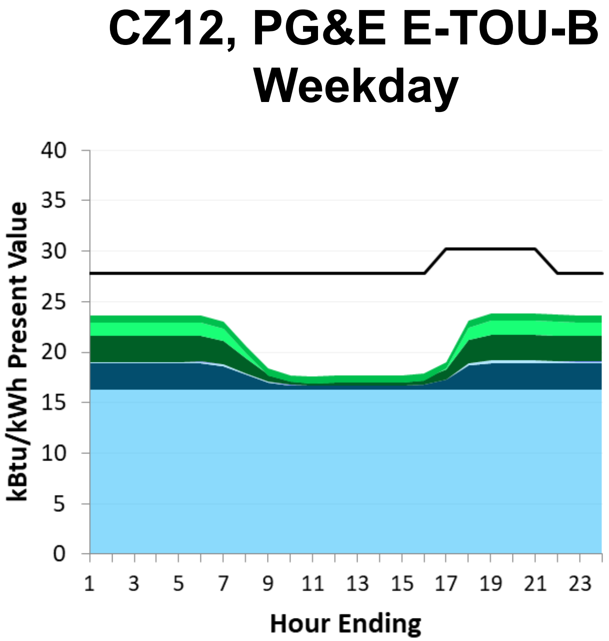
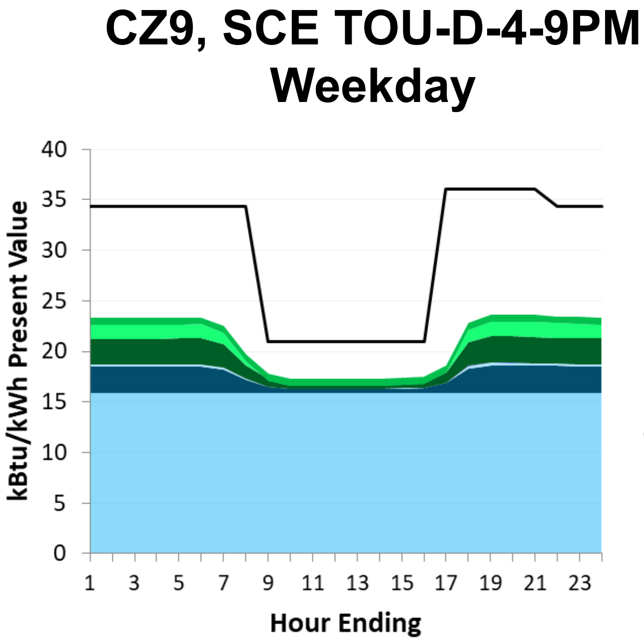
Thank You!

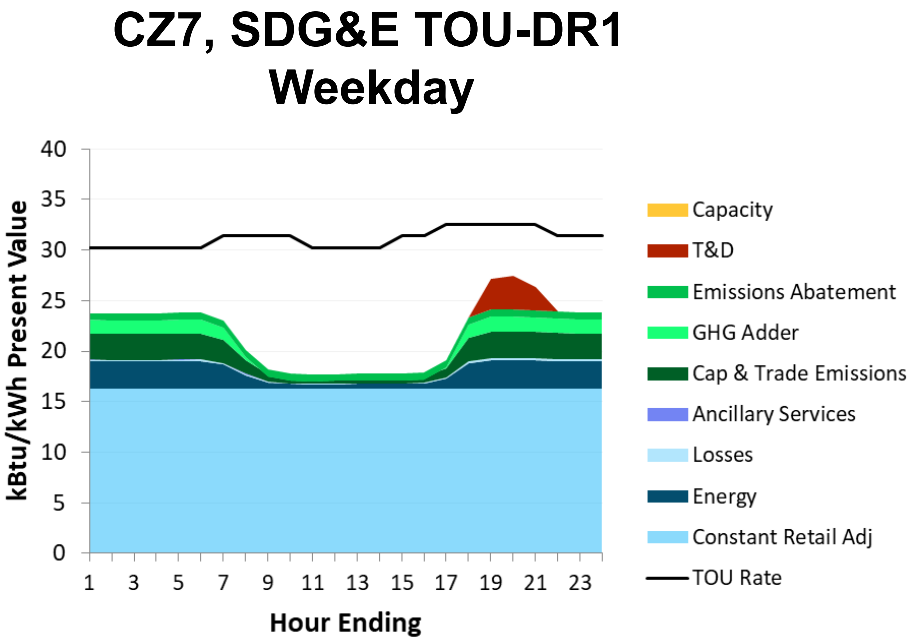
Appendix

Spring Residential TDV vs TOU Retail Rate
Flat Retail Rate Adjustment

Mar-May Average

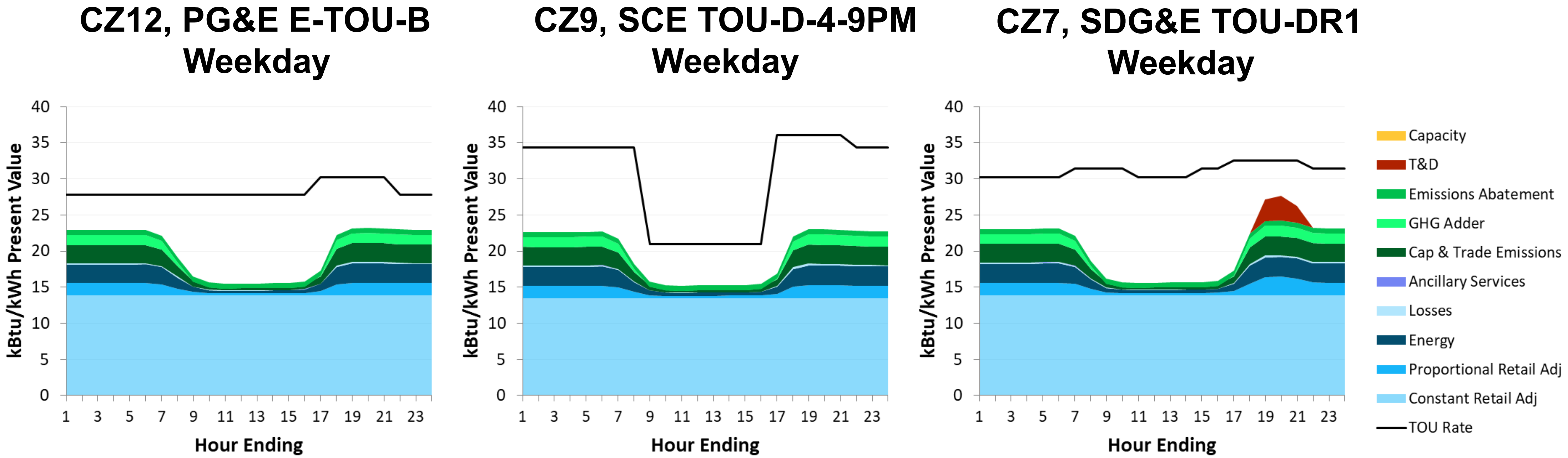






Spring Residential TDV vs TOU Retail Rate
15% Retail Rate Adjustment

Mar-May Average



Availability of Lower-GWP Refrigerants

- **Including refrigerant leakage in TDV provides strong signals for Low-GWP refrigerants, but has some limitations due to market availability**
- **Some appliances, such as CO_2 heat pump water heaters, are currently available**
- **Lower-GWP refrigerants for other appliances are available, but not yet commonly used in the US**
- **The most promising near-term low-GWP refrigerant for use in residential heat pumps are lower-GWP HFCs, such as HFC-32**
  - These refrigerants are generally mildly flammable, so different installation practices are required.
  - Fire Code and Mechanical Code currently don't allow mildly flammable HFCs
- **For other, smaller heat pumps such as water heaters, the most promising option is HFOs, which are similar to HFCs but have a very low GWP**
- **Another option being used in some places, such as Europe and India, is hydrocarbons such as propane– but have flammability issues**

Low-GWP refrigerant alternatives

Refrigerant	GWP	Appropriate for…
HFC-32	675	HVAC Heat Pumps
HFO-1234yf	4	All heat pumps except HVAC
R-290	3	All
R-744 (CO2)	1	All heat pumps except HVAC

Previous Workshop Slides

Previous Workshop

- **Title 24 2022 Time-Dependent Value Development**
  - Background
  - Policy Framework
    - AB32, SB32, SB100
  - Scenarios
- **Draft TDV Values**
- **Draft Source Energy Metrics**
- **Non-combustion emissions**
  - Refrigerant gases
  - Methane

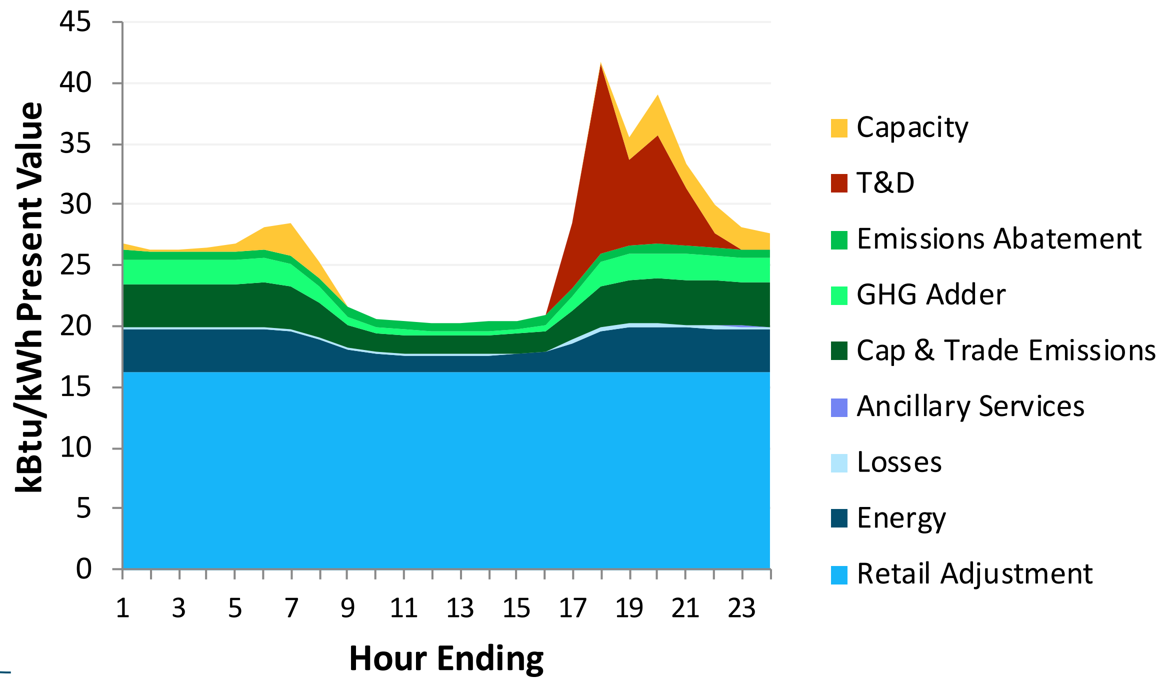
Time-Dependent Value (TDV) Background

What are TDVs?

+ **The TDVs are a long-term forecast of hourly electricity, natural gas and propane costs to building owners and are used for cost-effectiveness activities in Title 24 Building Code**
+ **The TDVs answer the question of what is cost-effective in the long term, as required by the Warren-Alquist Act**

- Time-differentiation reflects the underlying marginal cost of producing and delivering energy
- Area-correlation reflects underlying marginal cost shapes correlated with each climate zones weather file

Sample Annual Average Electric TDV, 2022, CZ12



Similar for natural gas and propane

What are TDVs used for?

+ **Two main uses for TDVs**
    1. Cost-effectiveness analysis in the CASE studies (Codes And Standards Enhancement studies) used to adopt new building measures in the prescriptive standard
    2. Code compliance for buildings that wish to vary from the prescriptive standard using the ACM (alternative calculation methodology). TDVs are embedded in California Building Energy Code Compliance software (CBECC)

Frequently Asked Questions (1)

+ **Why do we use statewide average electricity and natural gas retail rate levels?**
  - With this approach, the code has similar overall stringency statewide and there can be similar construction practices across the state. Note that there are still variations for climate.
+ **Why don't we use the actual retail rate structures that are in place?**
  - We want the building code to be relatively stable over time and from cycle to cycle, the TDVs reflect a 'perfect' marginal cost of service which is a long-term signal for retail rates
  - By using the underlying system marginal costs we are reflecting building measures that provide the greatest underlying value to the energy system, even if retail rates are flat or have a different time of use period

Frequently Asked Questions (2)

- **Why are the units of TDV in kBtu/kWh and kBtu/therm if they measure cost-effectiveness?**
  - The TDVs are calculated in lifecycle dollars per unit of energy ($/kWh, $/therm) in each hour and climate zone in California
  - For the building code compliance, they are converted to different units of kBtu/kWh and kBtu/therm using fixed multipliers

Frequently Asked Questions (3)

+ What are the source energy factors used for?

- Beginning in the 2022 Title 24 code cycle, the CEC is considering adding an additional metric to measure source energy. The source energy metric would be used to set a maximum source energy consumption in the building. This is complimentary to the measurement of cost-effectiveness.

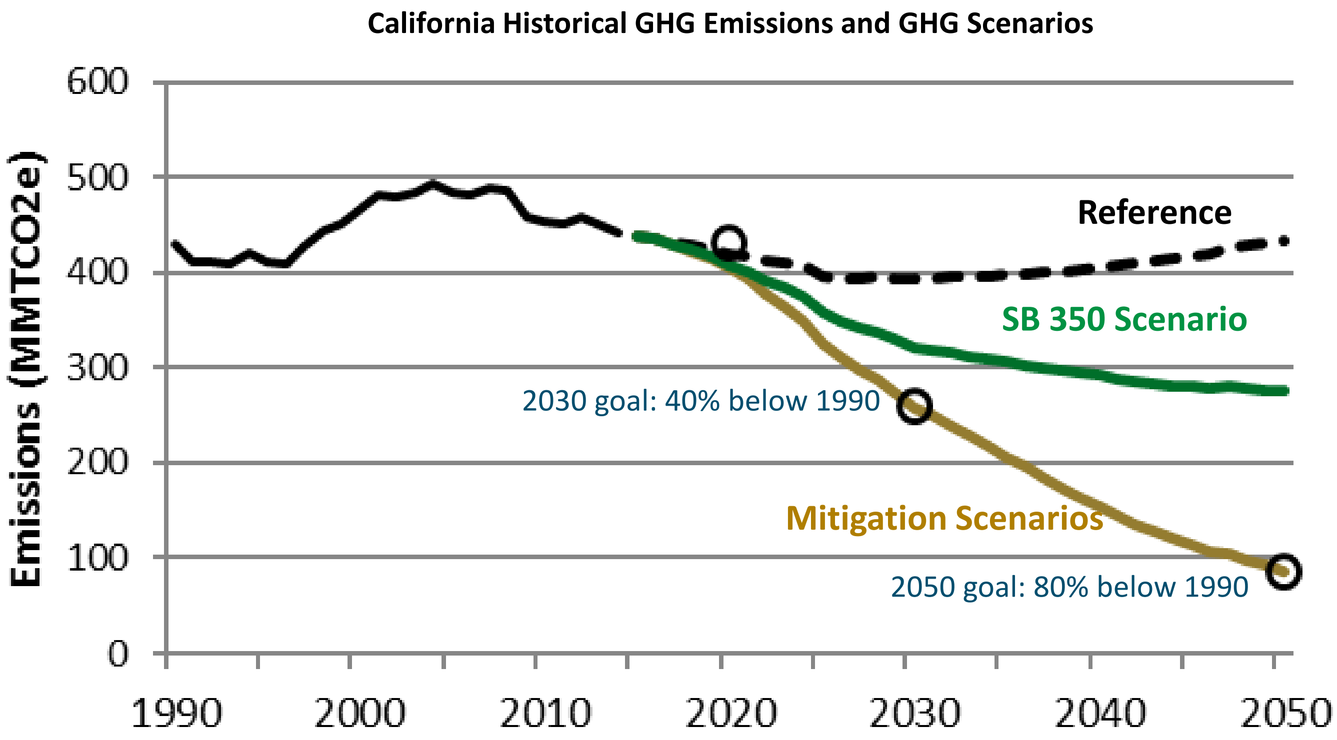
+ Why include non-combustion emissions?

- Beginning in the 2022 Title 24 code cycle, the CEC is considering adding the effect of high Global Warming Potential (GWP) gasses including refrigerants and methane leakage. With the interest in heat pumps, this allows greater compliance to be placed on low-GWP options and potentially better leak-prevention and disposal.

TDV Policy Assumptions

California’s Deep Decarbonized Future

+ **By 2020: return GHGs to 1990 levels** (AB 32, 2006)
+ **By 2030: 40% below 1990 levels** (SB 32, 2015)
+ **By 2050: 80% below 1990 levels** (EO B-30-15 and EO S-3-05)
+ ***By 2045: Carbon neutrality*** *(EO B-55-18)* ***not included***



4 Pillars of Energy Decarbonization

+ **New Buildings will exist in the future energy system which is fundamentally changing**
  - Demand-side; efficiency, electrification of buildings and vehicles, storage
  - Supply-side; renewable and decarbonized generation, biofuels

Energy Demands		Energy Supply	
Energy efficiency & conservation	**Electrification**	**Low carbon electricity**	**Low carbon fuels**
✓ Appliance EE ✓ Building shells ✓ Urban infill / transport mode-shift	✓ Heat pumps ✓ ZEV cars and trucks ✓ Industry & off-road vehicles	✓ Renewables & integration ✓ Nuclear, fossil with CCS	✓ Biofuels ✓ Electrolytic fuels (H_2 and P2X) ✓ CCS

Major Policy Targets

+ Major policy included in Title 24

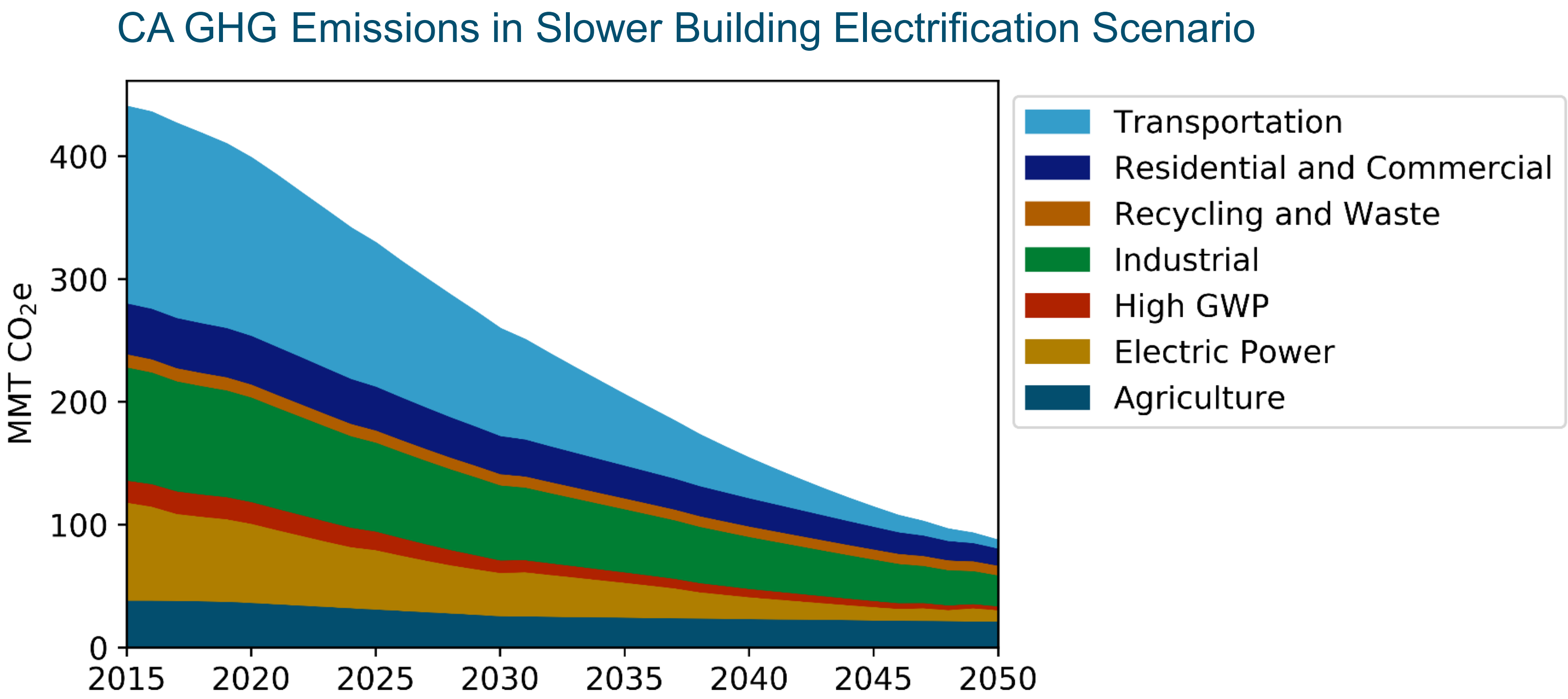
- California electricity sector targets set by SB100 to achieve 60% RPS by 2030, and 100% decarbonized by 2045
- California emissions reductions goals AB32 (1990 levels by 2020), SB32 (40% below 1990 levels by 2030), 80 x 50 (80% below 1990 levels by 2050)
  - We have not included Gov. Browns Executive Order for statewide carbon neutrality by 2045

+ Key Input Assumptions to reflect the policy landscape

- Assumes a statewide economy that meets 2030, 2050 emissions reduction goals
- Included impacts on the grid
  - Significant change in generation resource portfolio to decarbonize electricity generation
  - Increase in loads due to significant transportation electrification, some building electrification
- Updated cost of emissions abatement in the electricity system
- Introducing biofuel into natural gas pipeline, and reduced pipeline throughput

Sector Emissions Projections in Policy Compliant Scenario

+ **Emissions decline in all sectors to reach 80 x 50 target**



Building Decarbonization Assumptions

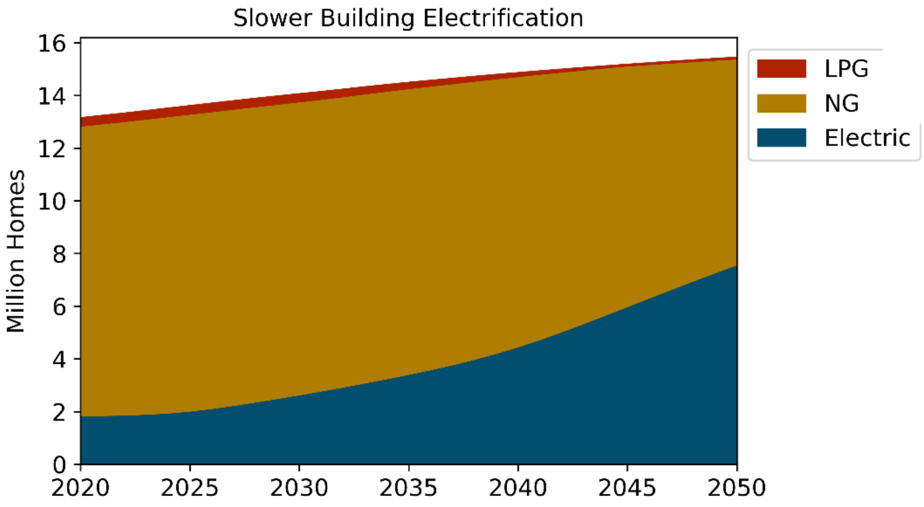
- **In addition to building electrification, gas efficiency and renewable natural gas are utilized to reduce GHGs from buildings.**
  - Only very high efficiency natural gas appliances are installed by 2025.
  - Renewable Natural Gas is blended in the pipeline, with 10% biomethane blended by 2030 and 19% by 2050, with 7% renewable hydrogen blend by 2050.
- **From CEC Pathways study, we decided to use the 'Slower Building Electrification" Scenario which has a mix of electrification and biofuel**
  - 2018 CEC PATHWAYS Study Available HERE. Publication forthcoming of chosen scenario forthcoming in Future of Natural Gas PIER Research.
- **Comparison to Energy Futures Initiative Study (2019)**
  - EFI (2019) assessed strategies to meet the 2030 goal with 40% reductions in all sectors, so not directly comparable to a combined 40% reduction by 2030.
  - EFI study achieved 40% in buildings with greater assumed gas energy efficiency, greater rates of electrification including all new all-electric construction by 202afdsfasfkal0, and similar utilization of RNG to the CEC PATHWAYS scenario.

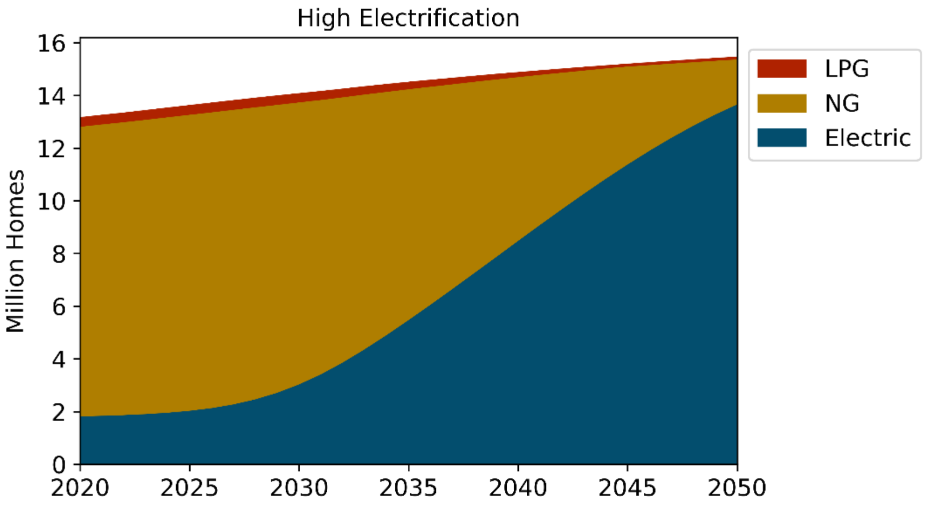
2018 CEC Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model
https://ww2.energy.ca.gov/2018publications/CEC-500-2018-012/CEC-500-2018-012.pdf for

Residential Space Heating Stock (E.g.)

+ **"Slower Building Electrification" scenario reflects a mid-range level of building electrification among scenarios that meet the economywide GHG reduction goals (40% below 1990 levels by 2030 and 80% by 2050).**
  - About 18% of homes are electrified by 2030 and 49% by 2050.
  - Assumes a rollover rate of ~75% for existing buildings

Selected Scenario

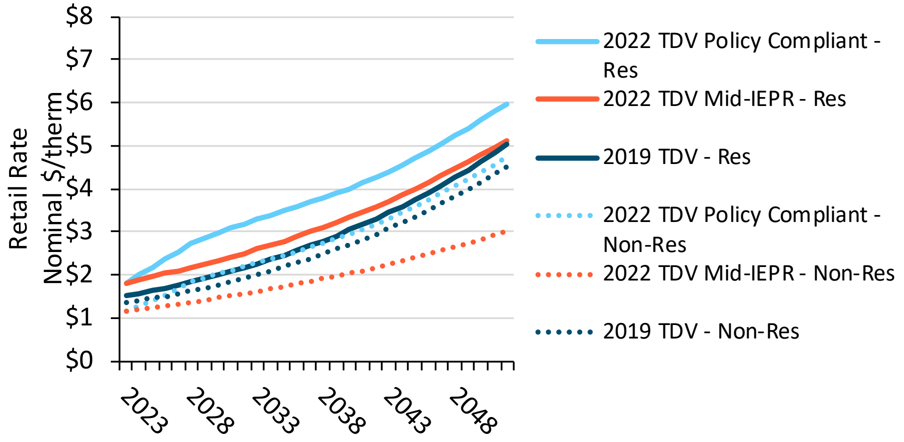




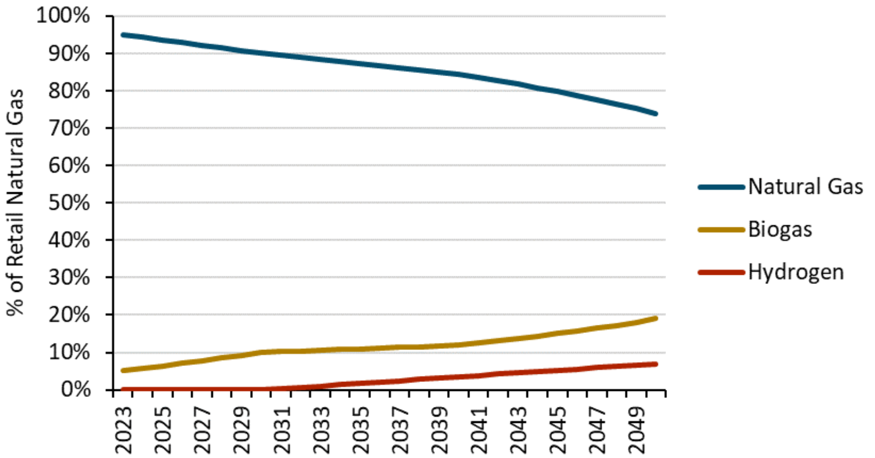
Natural Gas TDV Scenario Analysis

+ **Policy Compliant**
  - Uses retail rate forecasts from 2019 CEC Future of Natural Gas study – Multi-Prong with Slower Building Electrification scenario
  - Includes CPUC-approved rate increase, has some assumed reduced throughput due to building electrification (conservative compared to other scenarios), has biofuel and H2 costs
  - Source energy is lower due to renewable fuel
+ **Mid-IEPR**
  - Uses 2019 Preliminary IEPR Mid-Demand retail rate forecasts
  - Does not include recent CPUC approved retail rate increases over the next 3 years
  - Forecast is for 8 years, and then trended to 2050

Natural Gas Retail Rates for each Scenario



Source Energy – Share of Fossil Natural Gas



TDV Development

Modeling Framework

New CEC Weather Files

PATHWAYS → RESOLVE → PLEXOS → TDV Spreadsheet

PATHWAYS: Set major policy and investment requirements necessary to reach Economy-wide GHG targets

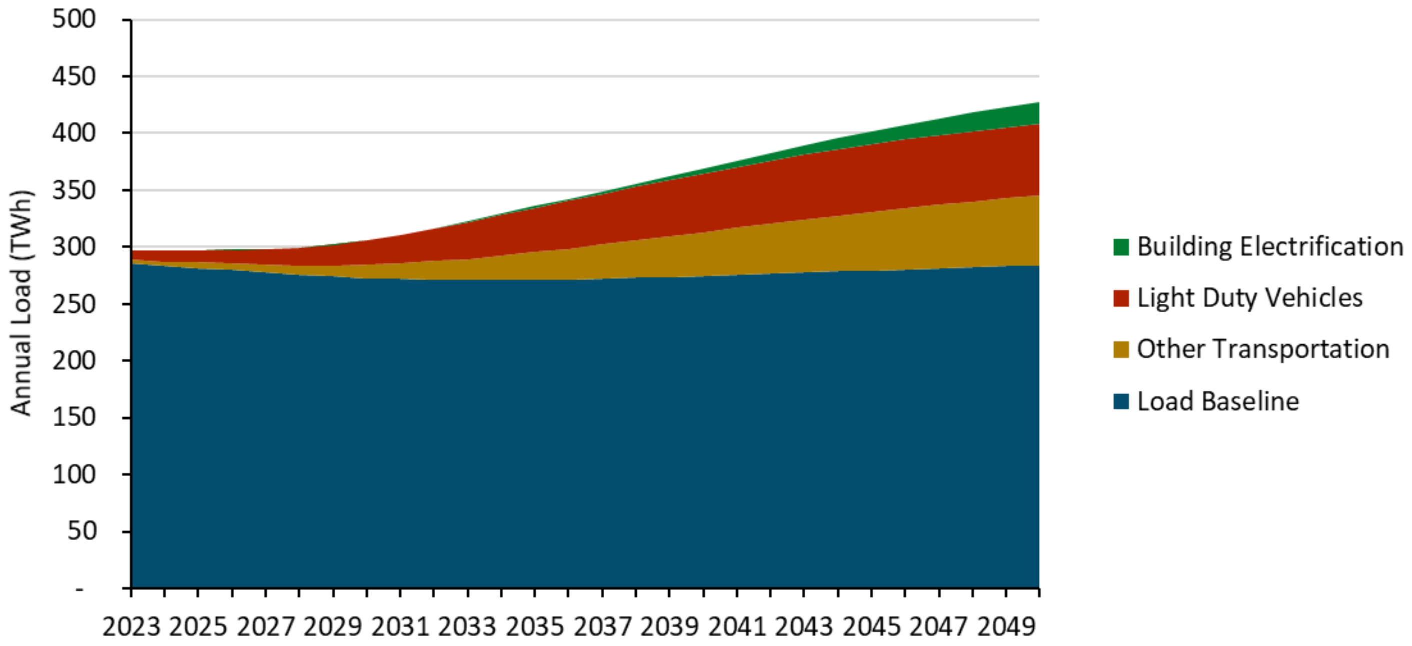
RESOLVE: Identify optimal statewide electricity resource portfolio to achieve electricity sector goals (SB100)

PLEXOS: Simulate detailed electricity-sector operations given new loads including EV and electric buildings, and weather

TDV Spreadsheet: Combine all outputs to generate 8760 TDV values and source energy metric

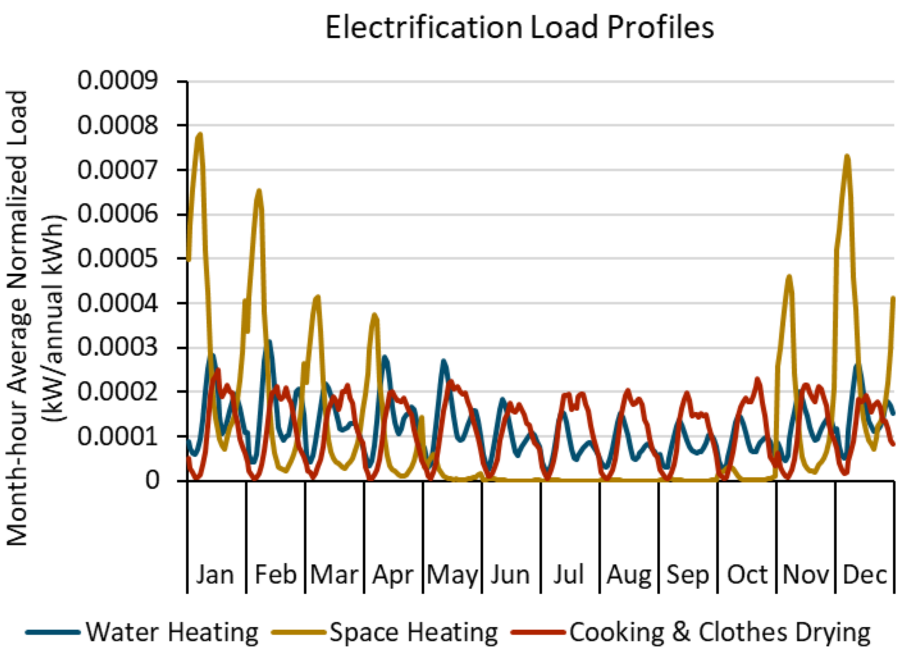
Annual Load Forecast

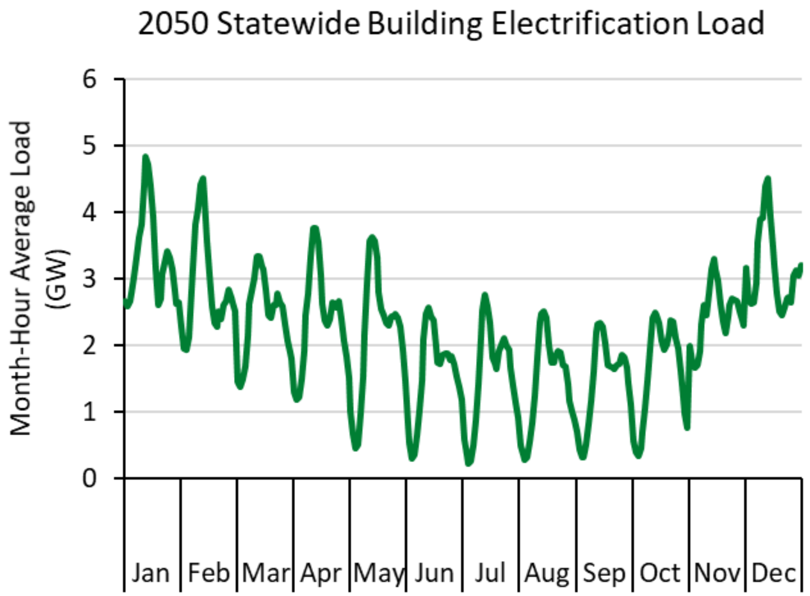
+ **Annual load forecast taken from this scenario to determine an optimal system plan to meet the new load**
  - Baseline load decreases over time with energy efficiency, despite population increases projected for California
  - New load added from transportation, building electrification



Building Electrification Load Profile

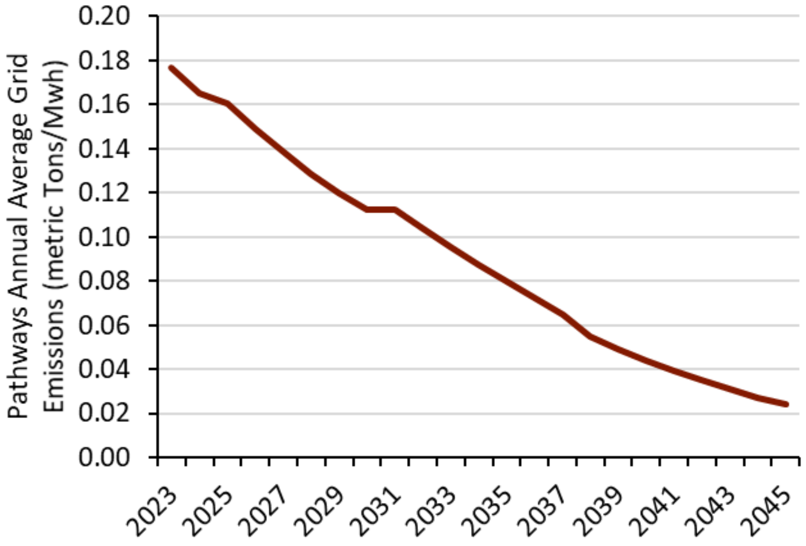
+ Hourly building electrification load shapes developed using parametric building simulations across 16 climate zones in new CTZ year
+ Scaled up by end-use, by PATHWAYS scenario annual forecasted load

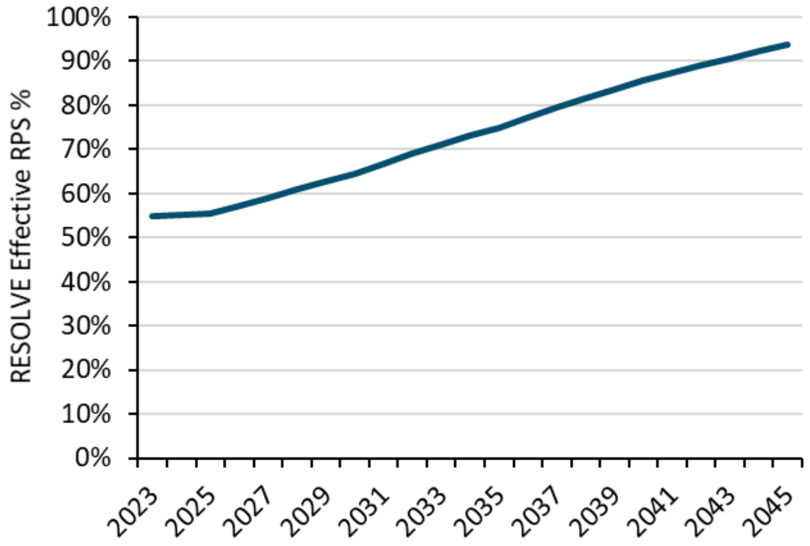




RESOLVE Resource Plan

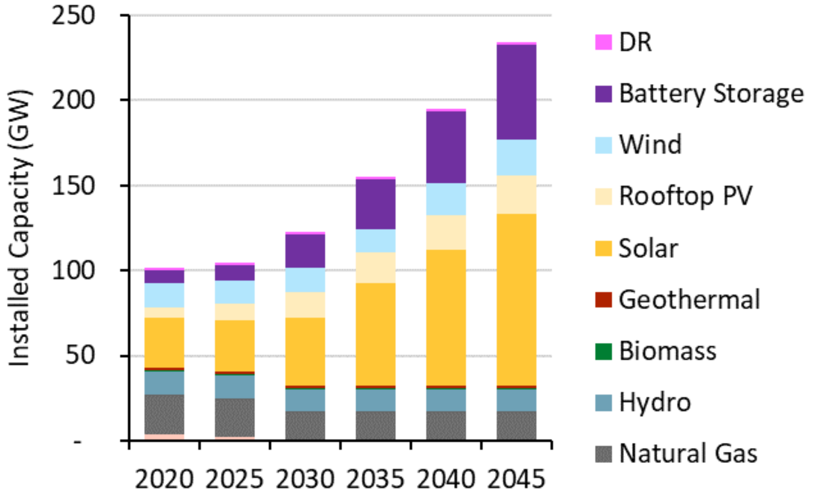
- RESOLVE is a resource procurement model that determines the optimal electricity generation plan to meet statewide energy procurement targets
- GHG emissions target comes from PATHWAYS, consistent with statewide emissions scenario
- RESOLVE procures renewable resources to serve all electricity load while meeting the GHG constraint. As an effect of this constraint, the RPS% exceeds near-term current state targets

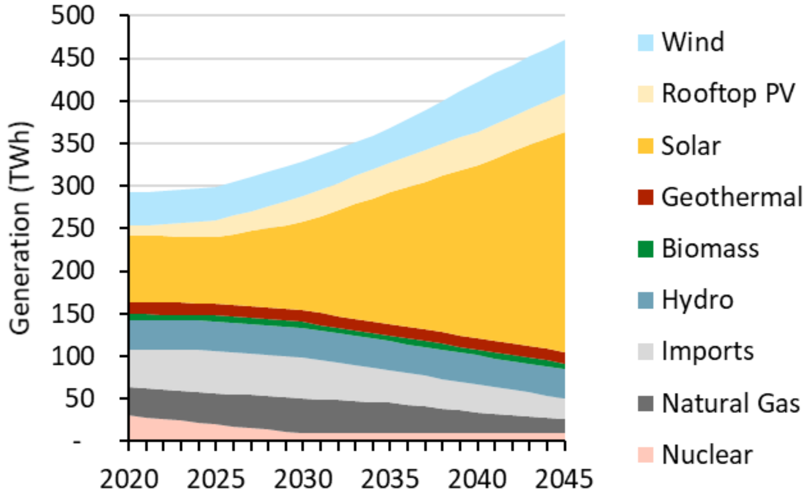




RESOLVE Resource Portfolio

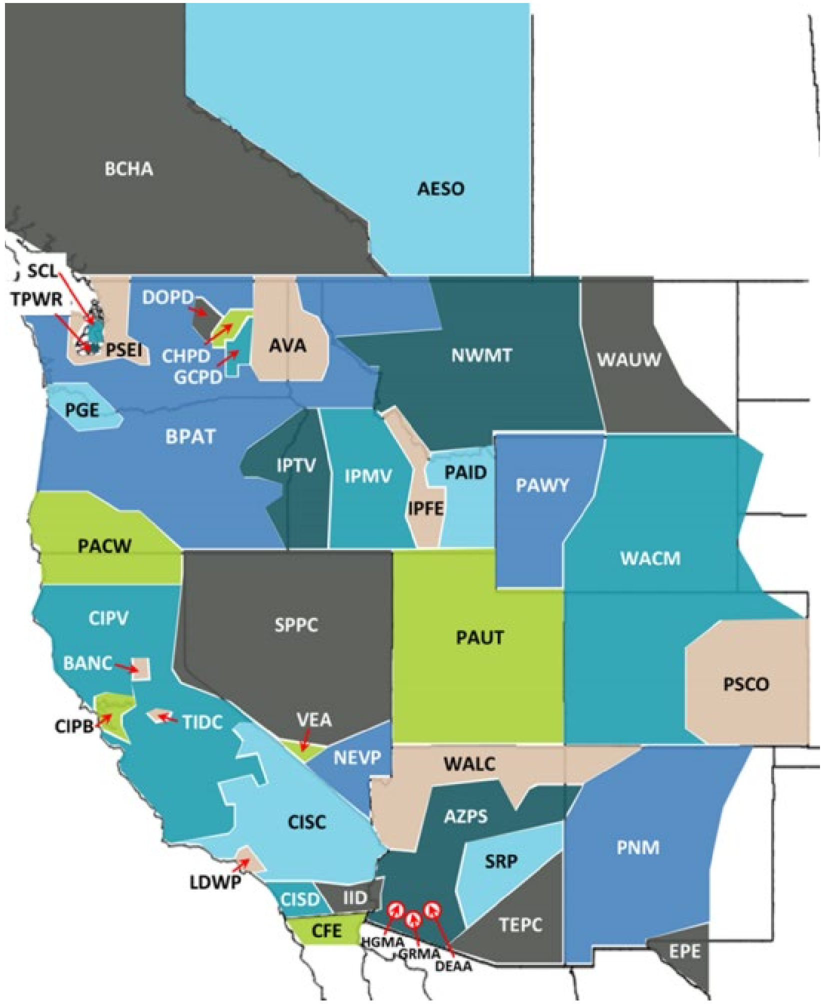
+ To meet SB100 goals in 2045, as well as emissions targets, RESOLVE builds significant amounts of renewable resources and storage
+ This analysis is based on the publicly available 2018 CEC statewide RESOLVE model, with updated cost information





Avoided Energy Costs

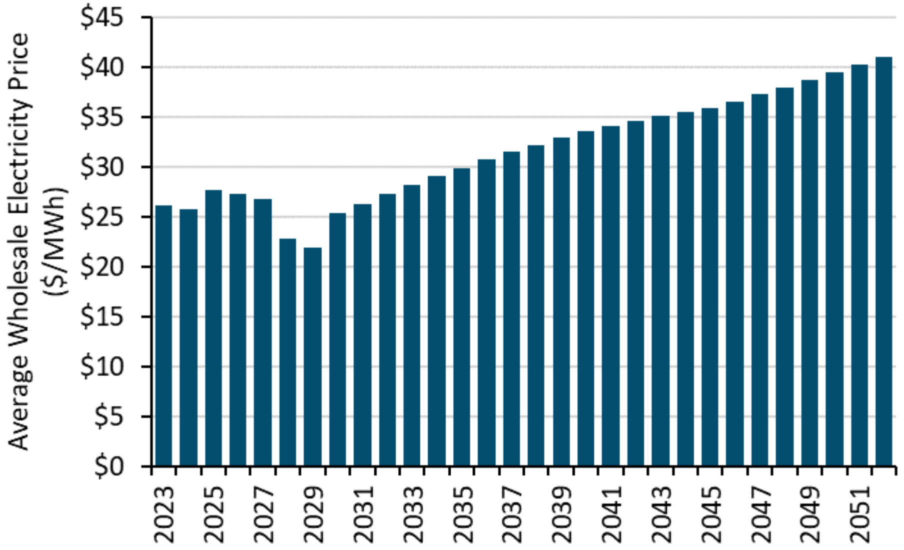
+ **New production simulation run in PLEXOS model**
+ **Model footprint is entire Western Interconnection to reflect the impacts of interzonal trade, transmission, and generation on California energy prices**
+ **CEC and E3 updated inputs to IEPR PLEXOS model**
  - Changes in annual load due to efficiency, transportation electrification, building electrification
  - Changes in hourly load due to new weather year
  - Changes in supply side generation mix to meet SB100
  - Update renewable generation shapes to match new weather year

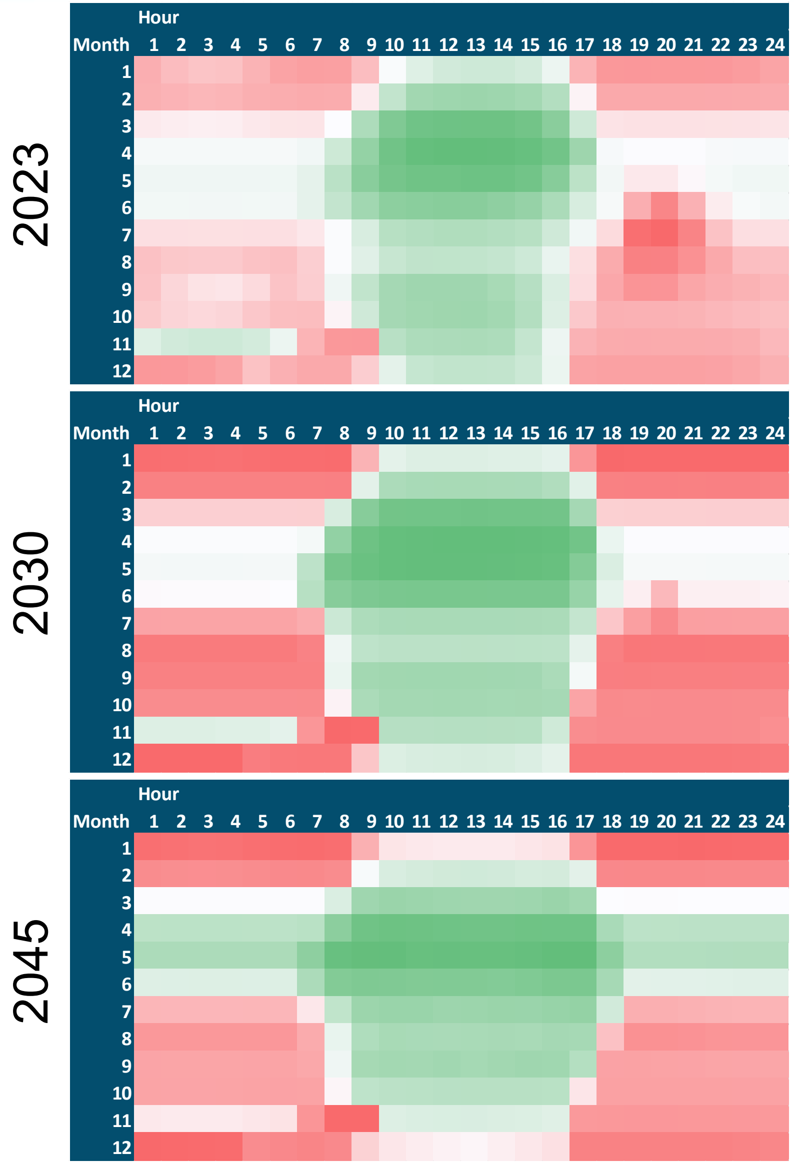


wecc.org

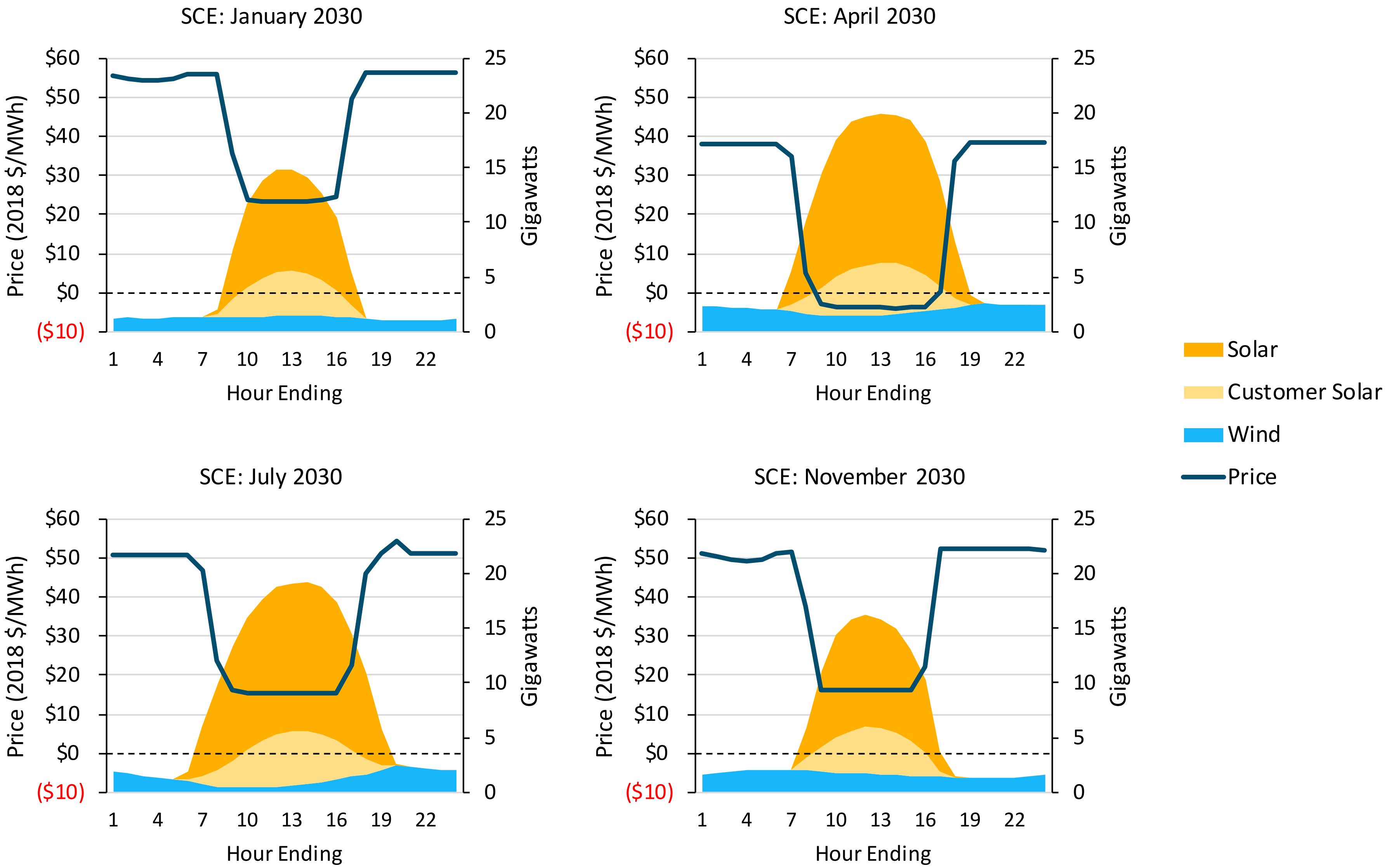
Wholesale Electricity Price Forecast

- Marginal energy price shape generated from PLEXOS production simulation modeling at CEC
- SB100-compliant portfolio calculated with RESOLVE model
- Ran PLEXOS for 2023-2030 and 2045, interpolating prices for complete 2023-2052 scope



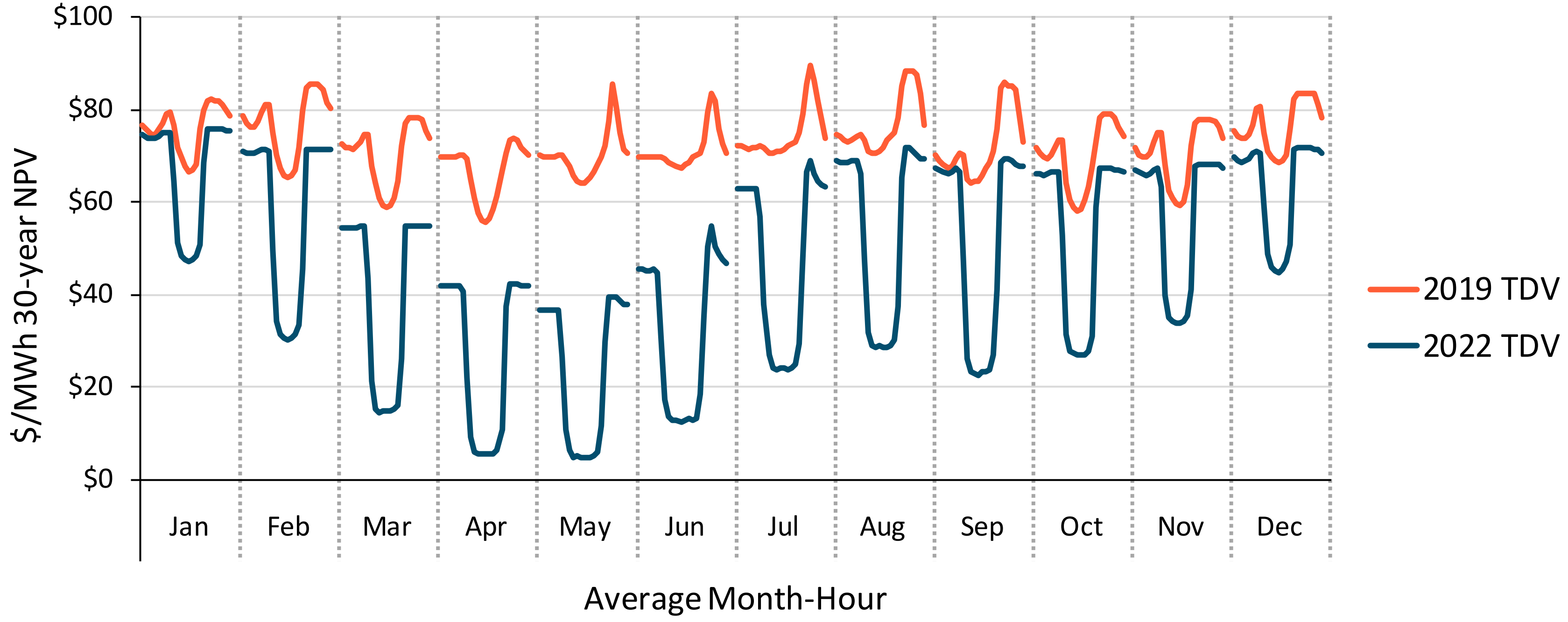


PLEXOS Energy Price Shape Example: SCE 2030



Energy Price Shape Comparison

+ **Higher buildout of solar in PLEXOS drives down midday prices**
+ **Abundant near-zero variable cost resources – solar, wind, and storage – contribute to lower prices overall – particularly with Spring's low loads, high solar, and hydro runoff**
+ **Storage discharge reduces peak prices in morning and evening "shoulder hours"**

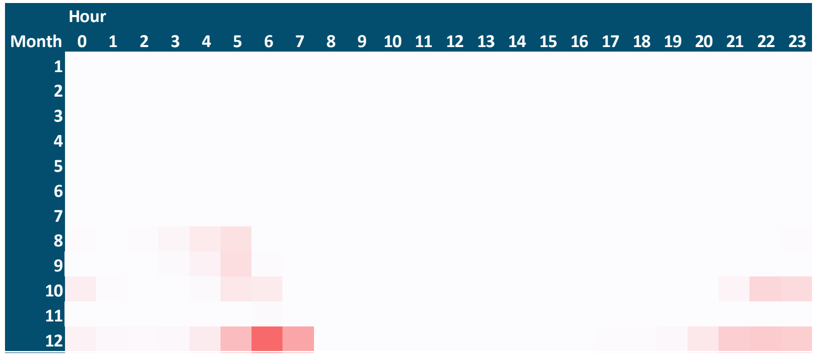


Generation Capacity

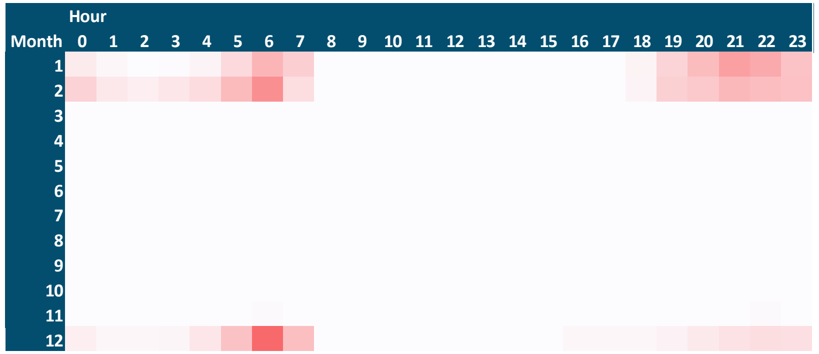
+ **System Net Peak expected to transition as renewable penetration increases**
  - 2023 – summer evenings
  - 2033 – mornings after batteries dispatch
  - 2045 – winter periods of low renewable energy availability
+ **With significant solar and storage, early morning before sun rises will be capacity defining event**

2023

2033



2045

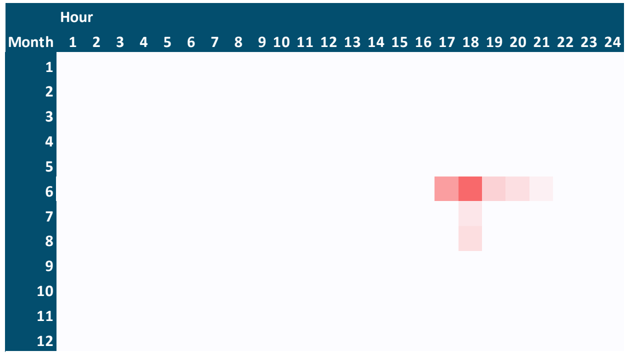


T&D Capacity

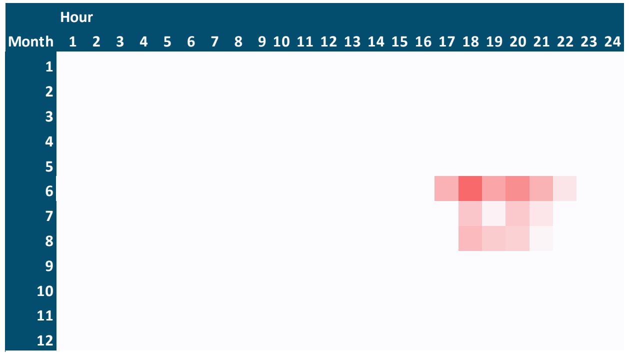
+ **New weather year used in for T&D Allocator model, along with regional rooftop PV penetration forecasts**
+ **Peaks generally remain in historical patterns**
+ **T&D avoided costs are calculated using weighted average from the latest utility GRCs, consistent with 2019 CPUC Avoided Cost Calculator**
  - Transmission: $24.47/kW-yr
  - Distribution: $102.54/kW-yr

CZ12

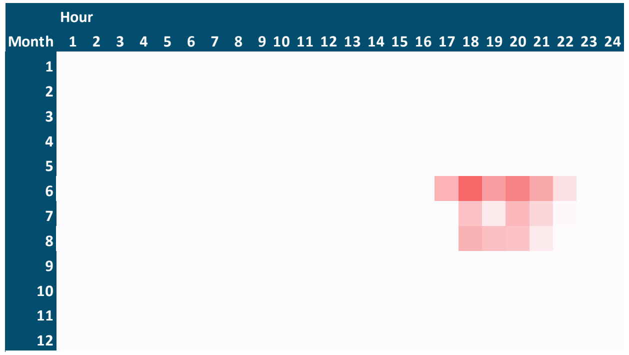
2023



2033



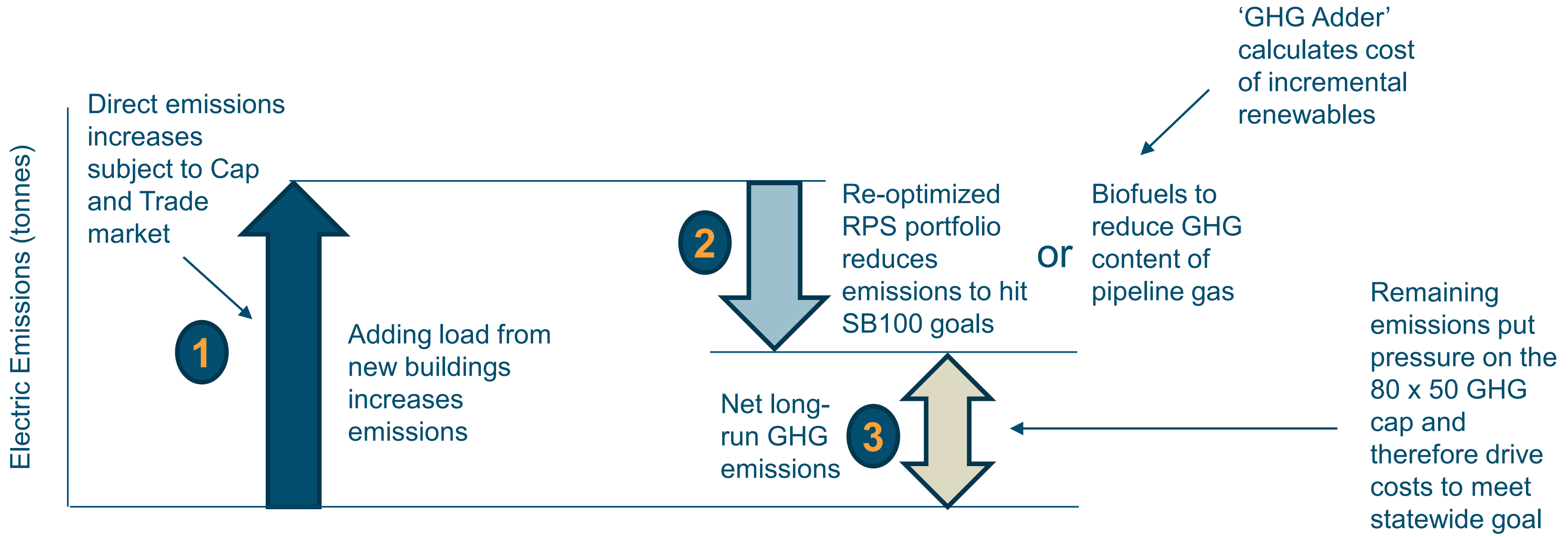
2045



Emissions Accounting for Electricity

+ Three emissions cost streams for electricity

1. **Cap and Trade Emissions**: Direct plant emissions from directly serving load
2. **GHG Adder:** Additional cost of procuring the necessary supply-side resources to achieve the electricity-sector long run emissions intensity target. Replaces previous 'RPS Adder' field
3. **Emissions Abatement:** Economy-wide cost of abating remaining emissions after supply-side actions have been taken



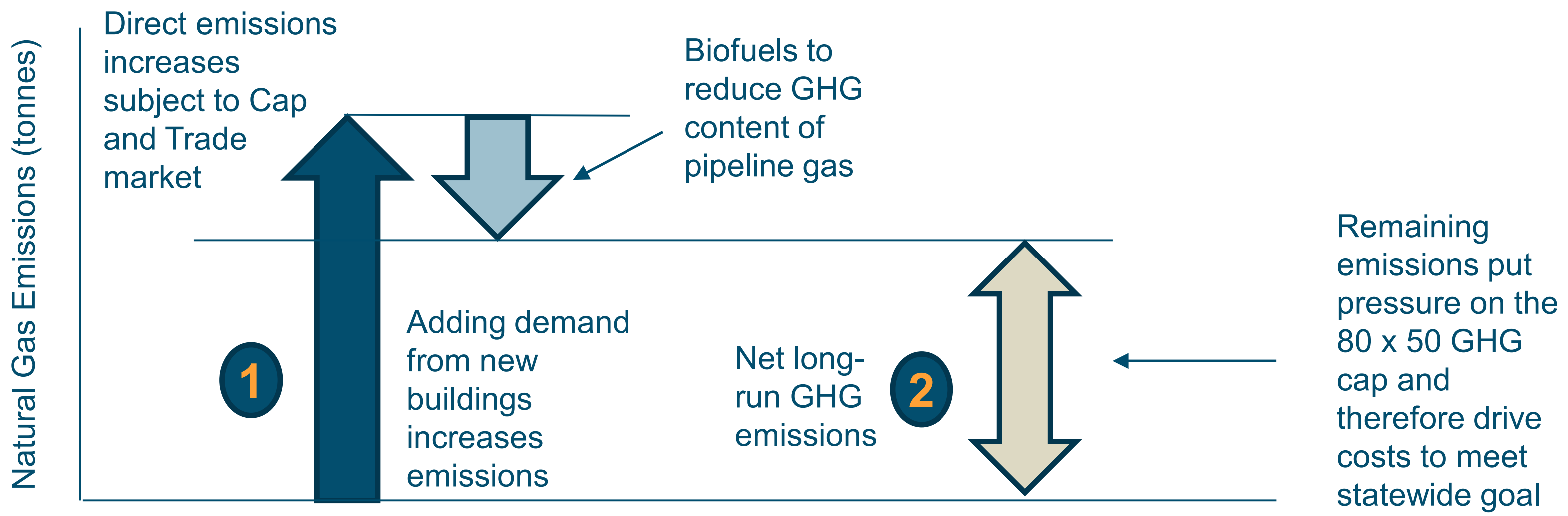
Emissions Accounting for Natural Gas

Two emissions cost streams for natural gas

1. **Cap and Trade Emissions**: Direct emissions from non-renewable gas delivered (net of RNG)

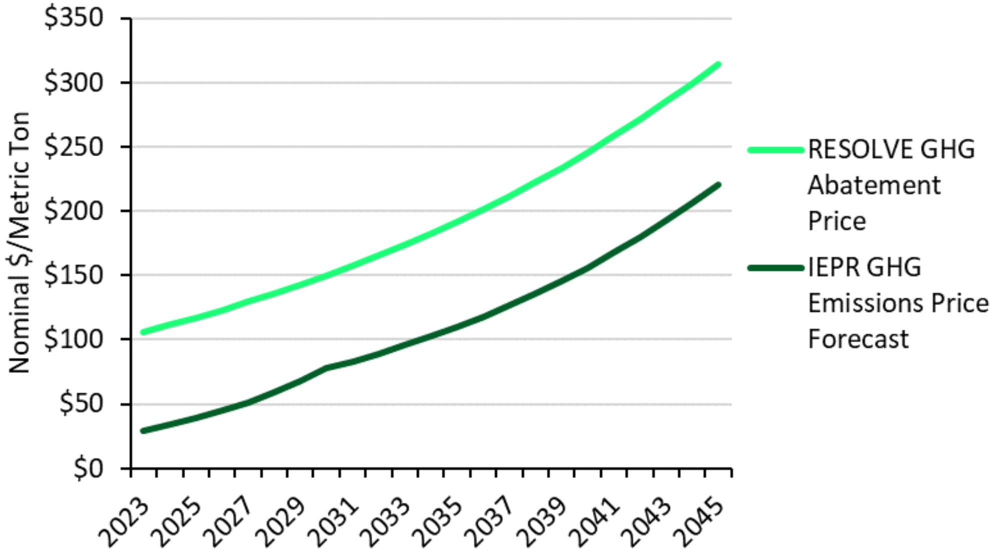
   Additional cost of procuring renewable natural gas included in the commodity price.

2. **Emissions Abatement:** Economy-wide cost of abating remaining emissions after supply-side actions have been taken



GHG Emissions Accounting

- **Cap and Trade Emissions:** Cost from IEPR GHG Allowance Price forecast; direct cost of emissions from combusting natural gas, factored into retail rates
- **Emissions Abatement:** Assumed that in a SB32-compliant future, cheapest economy-wide incremental emissions reduction is from electricity supply side, so RESOLVE GHG Abatement price is used. Represents cost of meeting state economy-wide emissions target



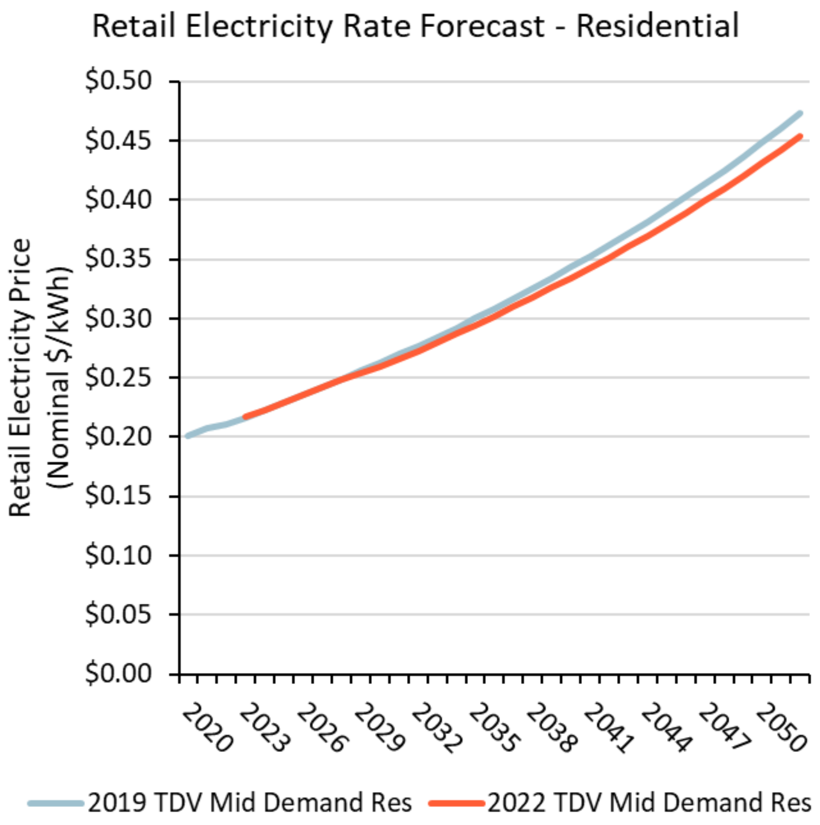
Used for Electricity GHG Reduction and Used for Economy-side Abatement

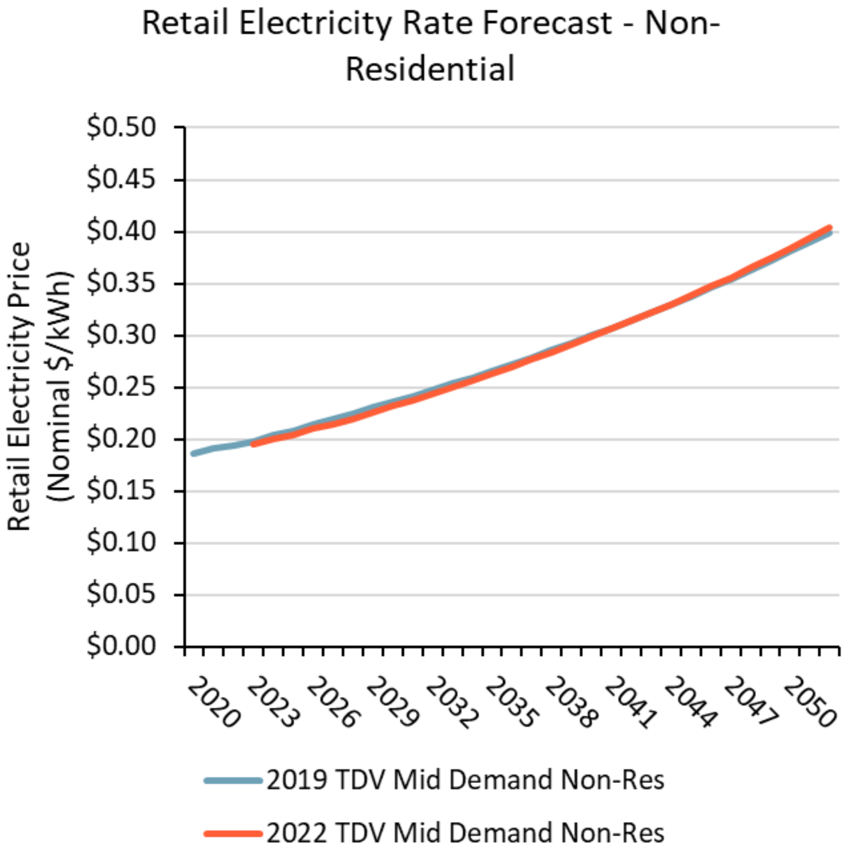
Used for GHG Allowance Price

Electricity Retail Rate Adjustment

+ Little change in electricity retail rate forecasts from 2019 TDV

- 2019 TDV used Mid Demand case from 2015 IEPR
- 2022 TDV uses Mid Demand case from 2019 IEPR



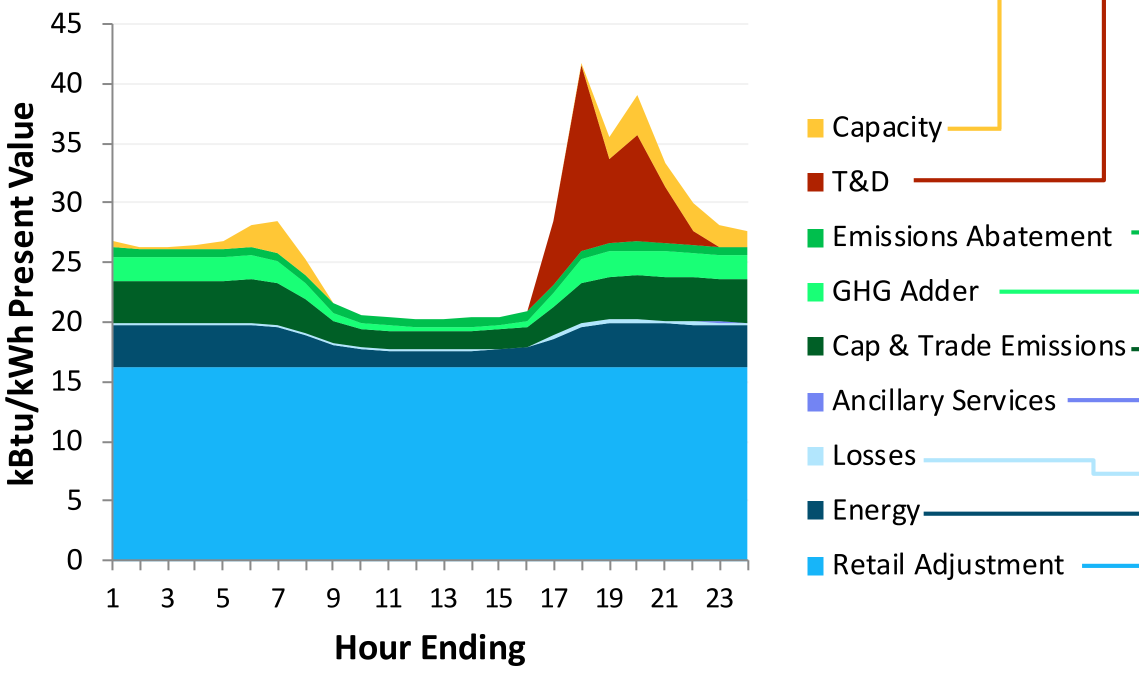


Energy+Environmental Economics

Title 24 2022 TDV Results

Updated Inputs to Electricity TDV

Sample Electric 2022 TDV – Residential CZ12

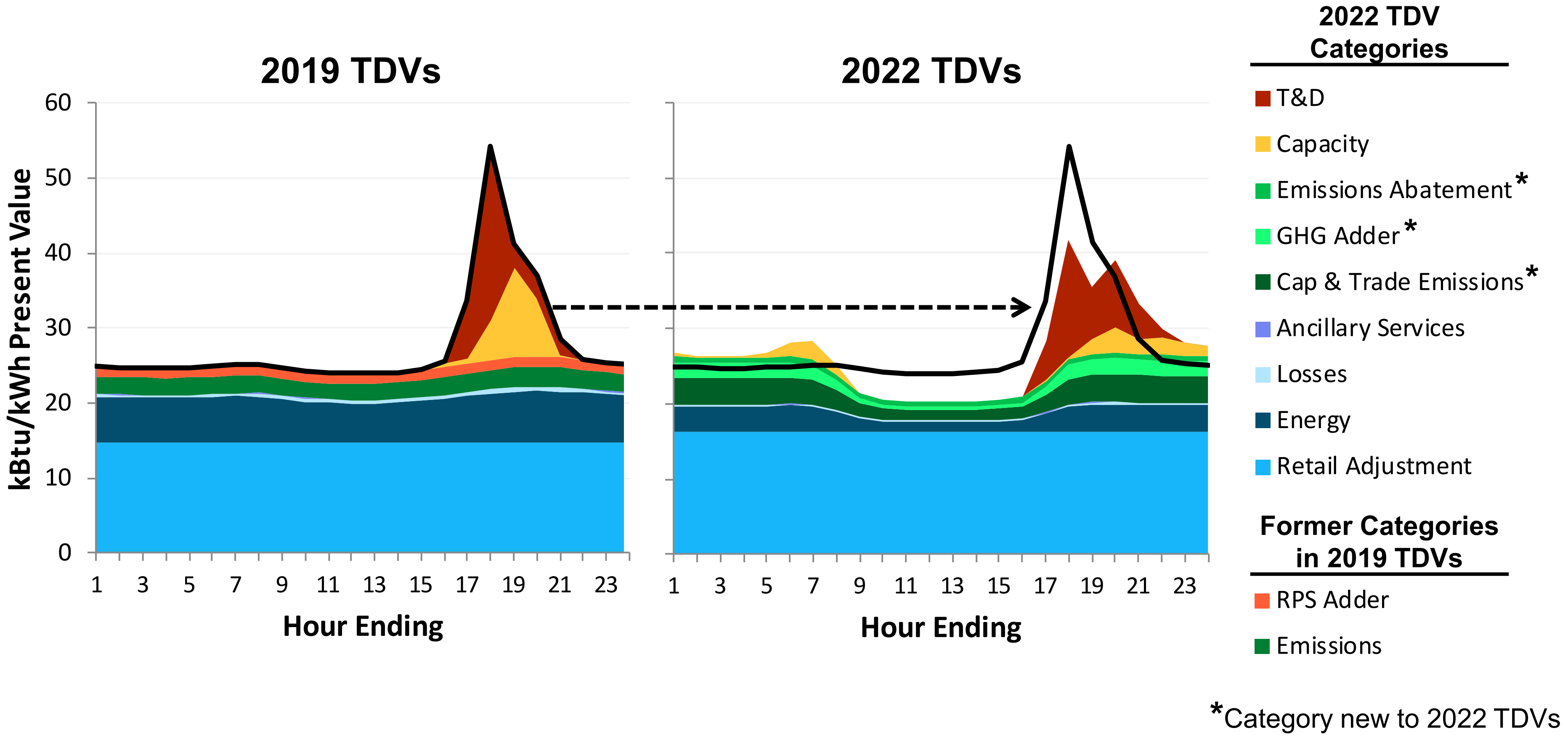


Updates for 2022 TDVs

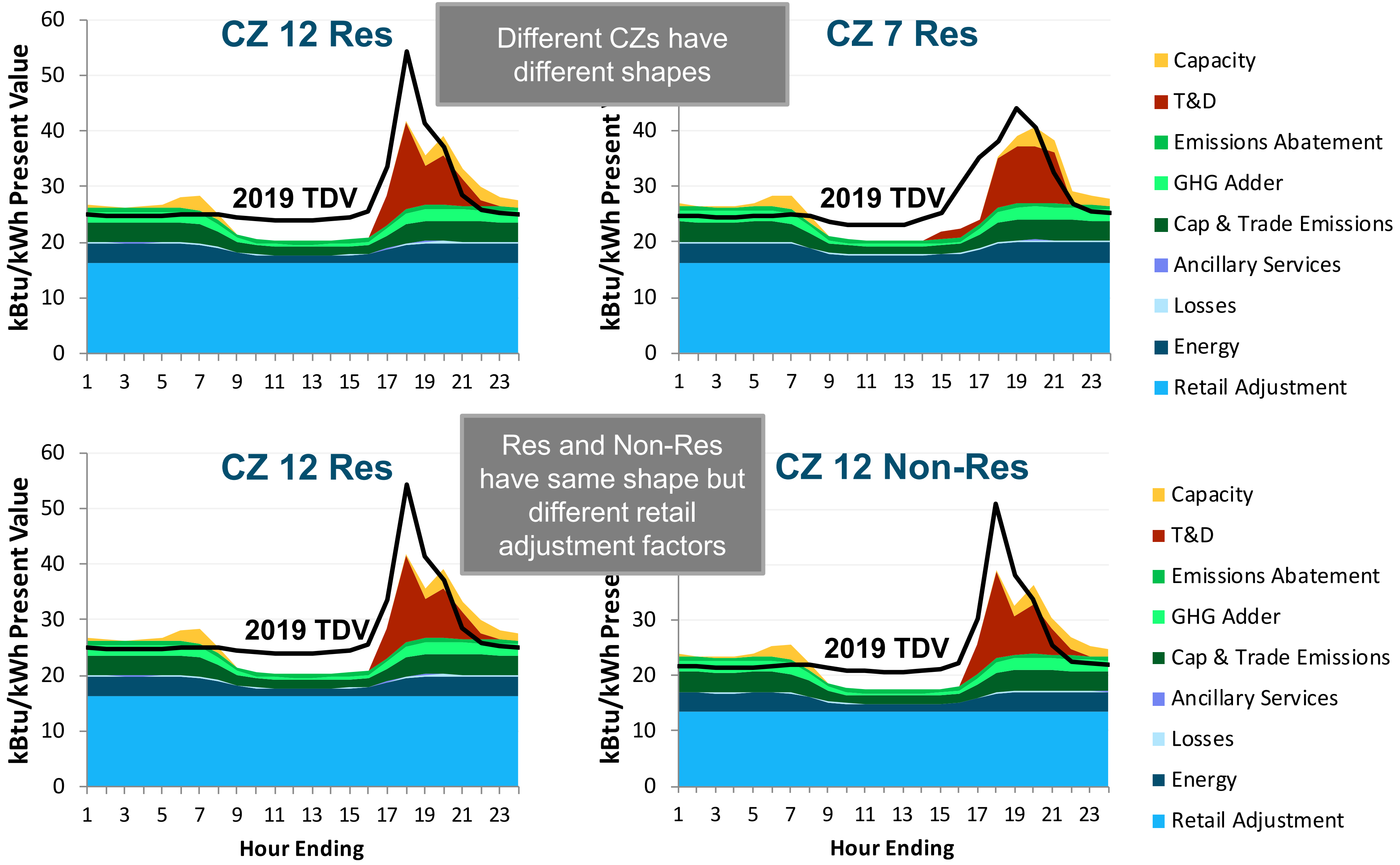
- Resource balance year, marginal capacity resource
- T&D costs, CTZ weather, distributed PV % and profile
- Carbon price forecast, economy-wide abatement costs to hit 80x50
- GHG-based procurement of integrated renewables to reduce electricity GHGs
- Carbon allowance price forecast
- Ancillary services costs
- Same loss %'s → new value
- PLEXOS simulation with SB100 resource portfolio, loads with CTZ weather and electrification
- Electric retail rate forecast

Electricity TDV Changes from Last Cycle

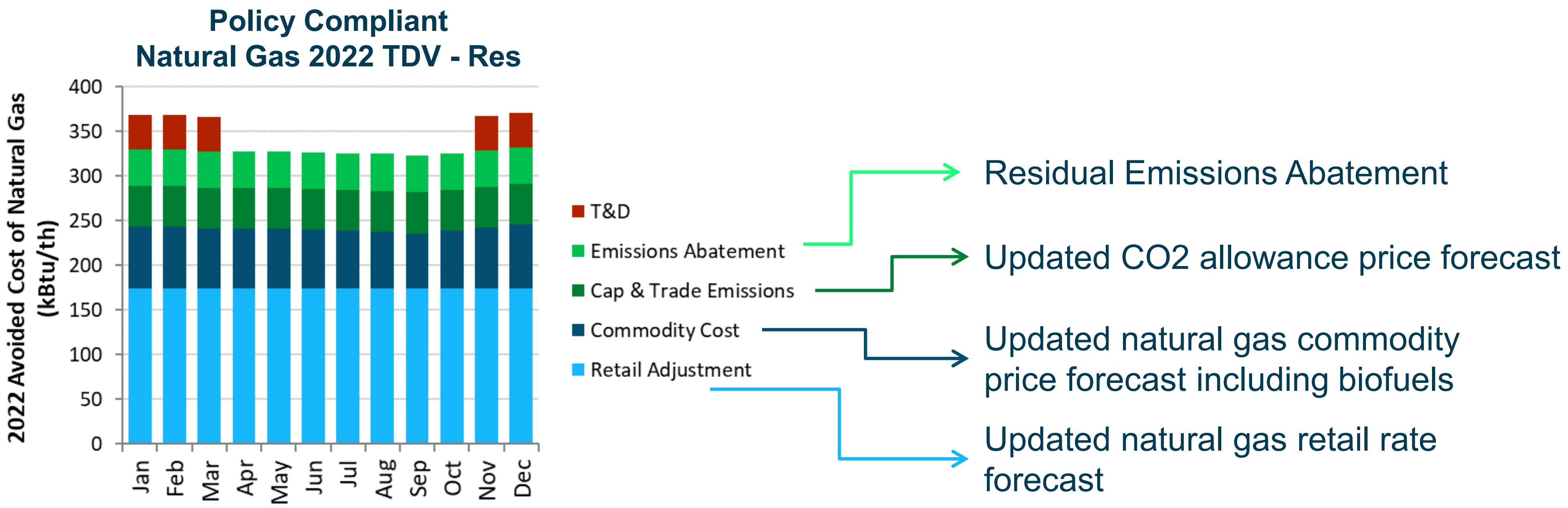
- **Increase in renewable generation, decrease in natural gas commodity cost drive down wholesale energy costs**
  - Decrease in volumetric costs is supplemented with fixed costs through retail rate adder
- **Decrease in TDV in middle of day**



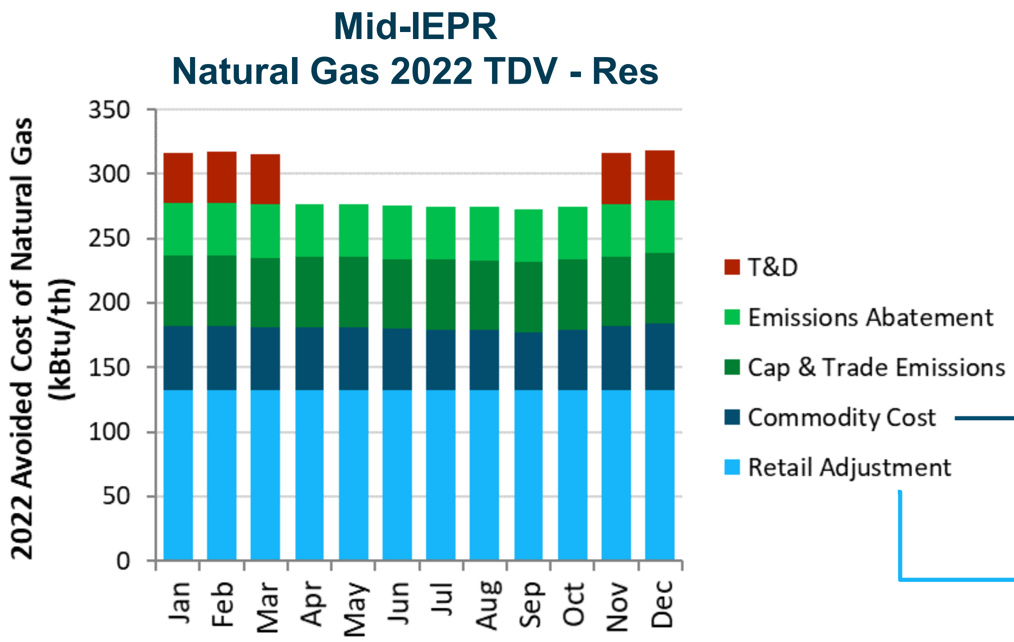
Comparisons between TDVs



Updated inputs to Natural Gas TDV - Policy



Updated inputs to Natural Gas TDV – Mid-IEPR



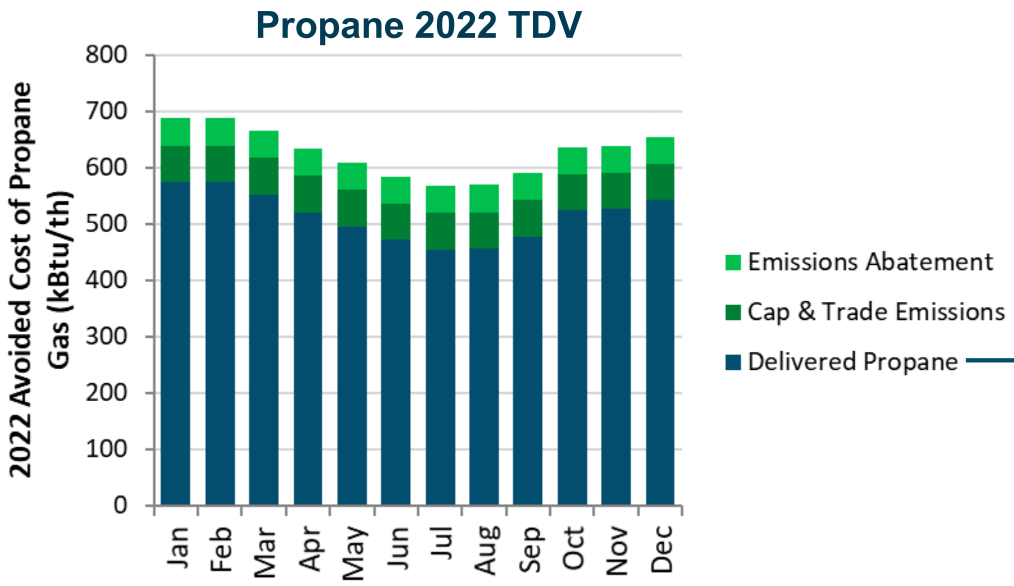
Added Emissions Abatement

Updated CO2 price forecast

Updated natural gas commodity price forecast

Updated natural gas retail rate forecast

Updated inputs to Propane TDV



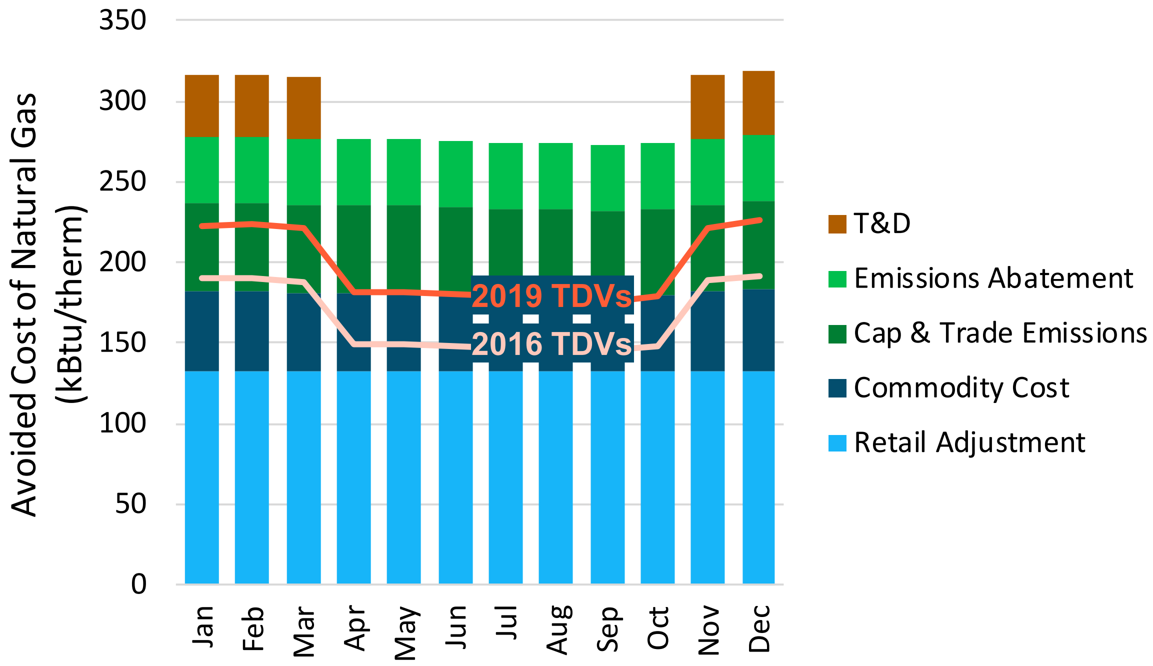
Added Emissions Abatement

Updated CO2 price forecast

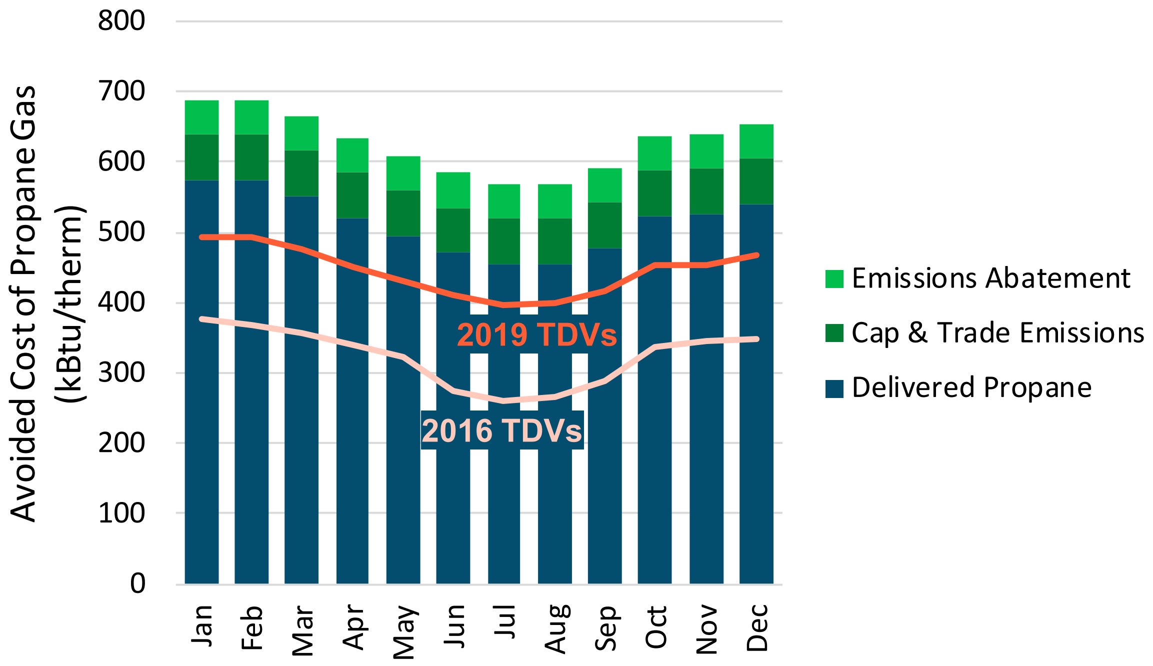
Updated propane retail rate forecast (2019 EIA AEO)

Natural Gas and Propane TDVs Comparison

Natural Gas TDV
30-year NPV Residential, CZ12



Propane Gas TDV
30-year NPV Residential, CZ12



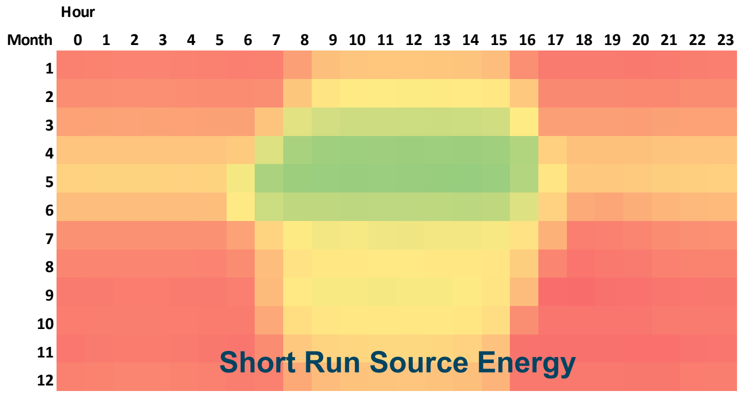
Source Energy Metric

Source Energy Metric

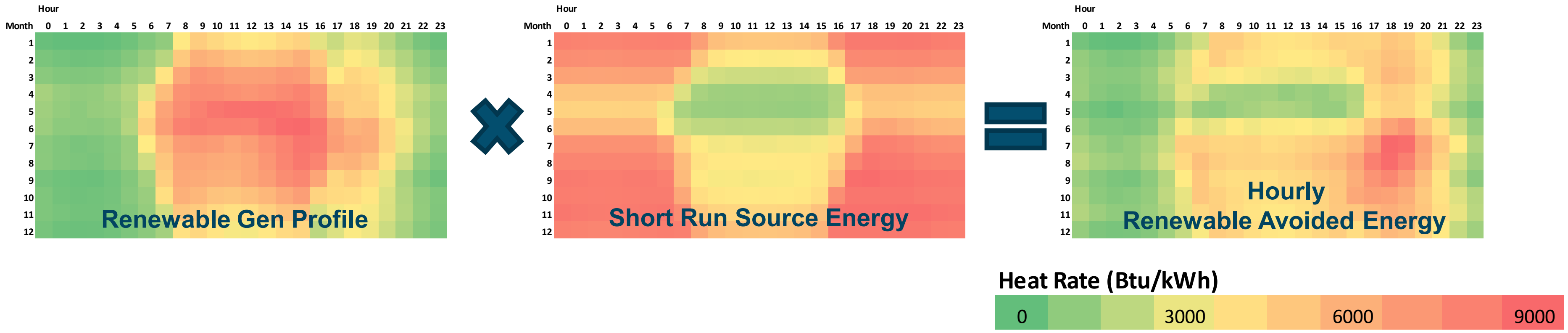
- **Secondary evaluation metric to encourage efficient consumption of input fuels, by calculating the total input fuels for a unit of end-use consumption**
- **Defined as Btu of depletable fuels, averaged over the lifetime of a building or measure**
  - Renewable energy (ex: wind, solar) and renewable fuels (ex. biogas, hydrogen) are defined as having zero marginal source energy in this definition
- **As natural gas is the only thermal generation that could be on the margin, the source energy metric correlates with emissions**
- **For electricity end-uses, long run marginal source energy is used**
  - Factors in supply-side interventions that will occur as a result of incremental load
    - Ex. given a 50% RPS, if 1,000 MWh of new annual load is added, a corresponding 500 MWh of new renewable energy must be procured and delivered
    - The new renewables will offset some of the initial increase in generation

Formulation - Electricity Source Energy

+ Implied short run marginal source energy calculated based on hourly wholesale energy price forecast (from PLEXOS)

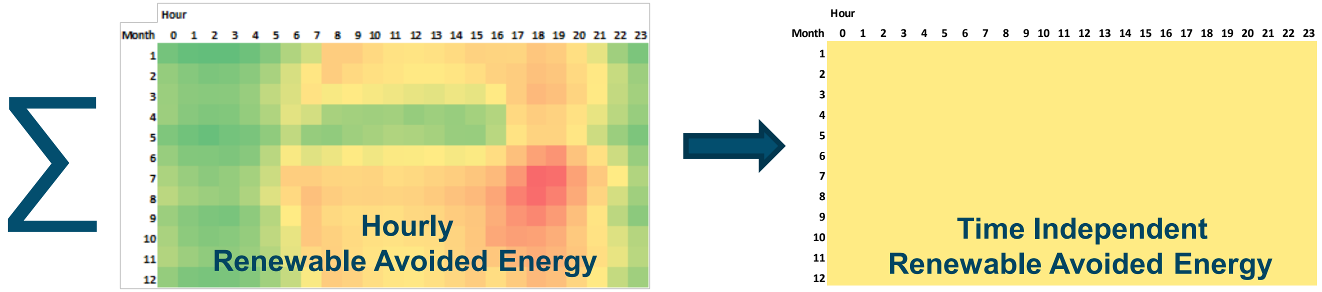


+ Avoided source energy from incremental renewable generation is calculated based on hourly profile of new renewable portfolio and short run source energy

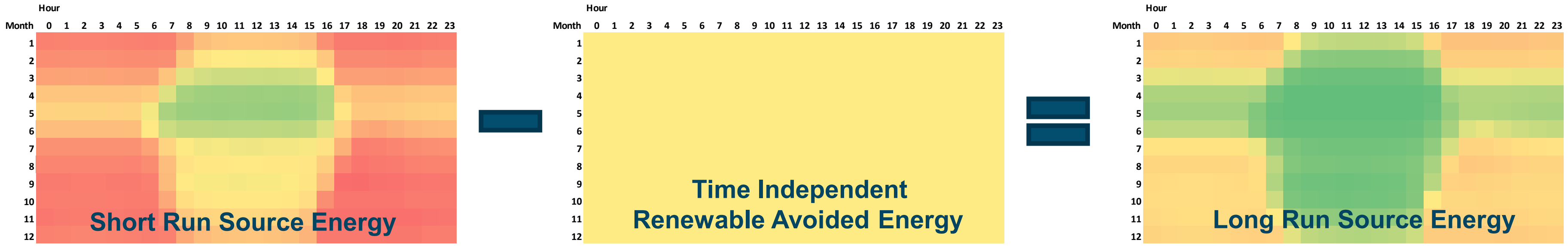


Formulation – Electricity Source Energy (2)

- Renewable avoided source energy is generalized to an annual number (renewables integration does need to occur in same hour as new load)



- Avoided source energy from incremental renewable is calculated based on hourly generation of incremental renewables and short run source energy



8760 Long-run Source Energy Factors

+ **Based on achieving an RPS Portfolio over time consistent with SB100**

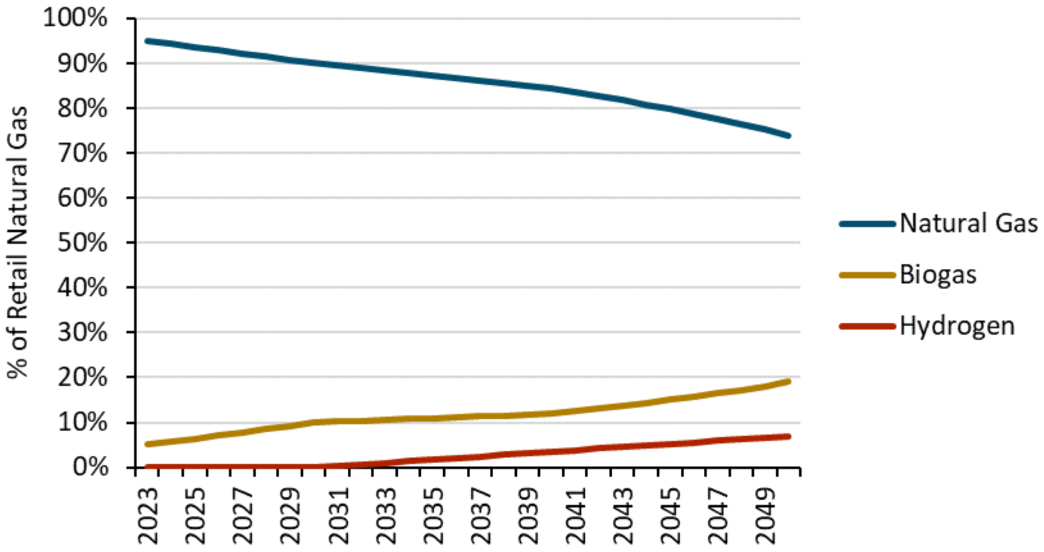
+ **Average of month and hour, Btu/kWh**

Source Energy with minimum @ zero

	Hour																							
Month	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1	4282	4245	4229	4231	4269	4314	4333	4336	3239	2087	1787	1717	1694	1725	1816	2024	3537	4399	4399	4398	4397	4395	4379	4357
2	3719	3704	3694	3698	3713	3730	3739	3736	1590	734	625	603	600	617	647	736	1391	3757	3759	3758	3757	3757	3751	3735
3	2751	2743	2738	2740	2754	2764	2768	1701	477	223	188	179	178	182	190	250	776	2668	2720	2721	2720	2716	2710	2703
4	1271	1268	1267	1268	1271	1274	1220	402	76	15	4	0	0	0	0	8	112	1097	1320	1321	1318	1300	1288	1283
5	853	850	849	849	851	853	469	90	25	7	4	5	2	1	4	23	132	643	1075	1074	1051	988	936	924
6	1560	1545	1543	1542	1545	1529	645	172	92	72	63	60	61	61	71	121	313	980	2022	2323	2009	1849	1716	1645
7	3412	3409	3408	3407	3409	3411	2712	939	375	193	169	156	156	162	178	270	614	1510	3780	3894	3740	3591	3472	3449
8	3994	3982	3976	3977	3990	3995	3751	1370	415	237	212	212	213	224	256	409	939	3291	4227	4222	4193	4095	4043	4031
9	4591	4548	4506	4506	4545	4595	4566	1758	298	145	116	70	123	162	238	522	1475	4672	4732	4725	4694	4643	4619	4601
10	4439	4416	4402	4409	4433	4458	4466	2622	578	371	309	305	306	321	362	631	3321	4540	4534	4533	4525	4508	4491	4477
11	4803	4749	4722	4718	4751	4809	4842	4479	1614	1143	1123	1076	1072	1106	1212	1700	4836	4900	4901	4901	4901	4900	4886	4833
12	4354	4312	4290	4296	4321	4384	4416	4420	2980	1918	1648	1551	1526	1611	1769	2068	4455	4463	4463	4462	4461	4458	4431	4400

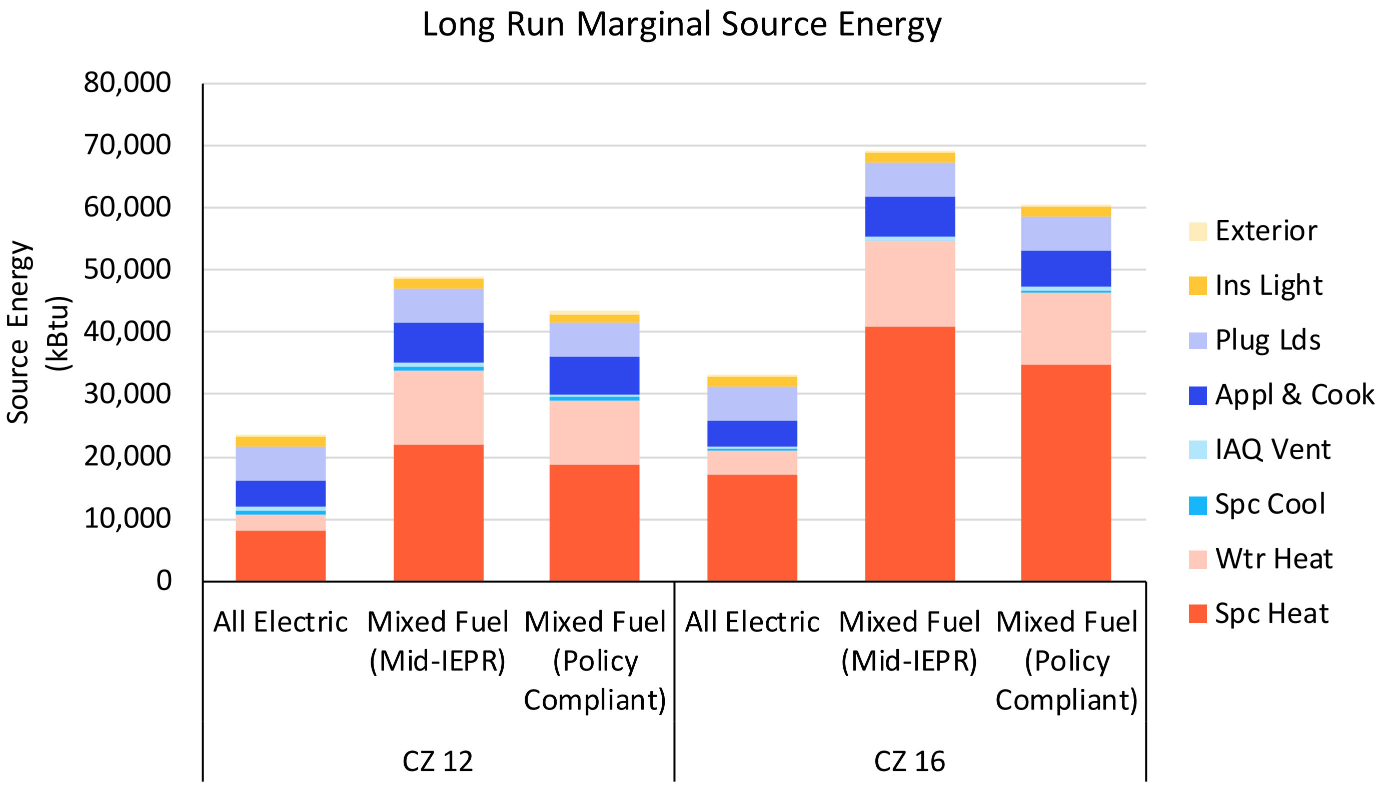
Natural Gas and Propane Source Energy

+ **Propane source energy is simple unit conversion (100 kBtu/th)**
+ **In retail natural gas – blended biogas and hydrogen are counted as 0 Btu/th**
  - Blended RNG assumption results in lifetime source energy of 86-88 kBtu/th
  - Includes compression losses + LUAF



Source Energy Comparison

- All electric end uses, especially heat pumps, have lower source energy than analogous natural gas end uses in mixed fuel home



Non-Combustion Emissions

Background on including High GWP emissions

- **All heat pumps have refrigerants, and nearly all refrigerants in use today are very potent greenhouse gases– up to ~2000x stronger than CO_2**
  - This comparison to CO_2 is known as the Global Warming Potential (GWP)
- **These refrigerants only contribute to global warming when they leak, but leakage is inevitable, and can account for a significant portion of lifecycle emissions from an all-electric building**
  - Air conditioners use refrigerants too, so mixed-fuel buildings have leakage as well
- **Including these emissions in the TDV framework will allow us to compare the true lifecycle emissions between all-electric and mixed-fuel buildings, and more importantly, <u>incentivize the use of lower-GWP refrigerants</u>**
  - Lower-GWP refrigerants are available, but are not widely used in the US, and often require different installation practices as they can be mildly flammable

Background on including High GWP emissions

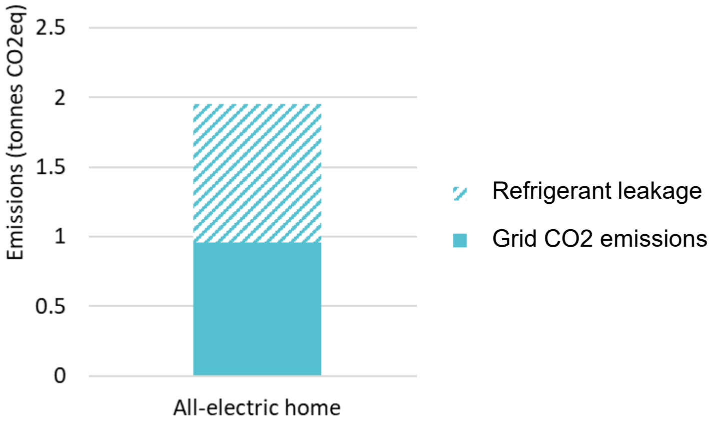
+ **On the natural gas side, it is also important to account for the potential for <u>avoided methane leakage</u> through building choices**
  - It is well-known that the natural gas system has leaks, particularly during the production and storage stages
+ **Methane has a 100-year GWP of 25, so leaking methane causes significantly more global warming than burning it**
+ **The difficult question is: how much methane leakage could we avoid through electrification?**

Proposed Mechanism for Non-Combustion Emissions Accounting

+ **Establish for the baseline building types the CO2e for both of the non-combustion emission sources in consideration; refrigerants and methane**
+ **In CBECC-Res and CBECC-Com:**
  - Compute the CO2e of lifecycle refrigerant and methane emissions
  - Multiply by the GHG Abatement factor for TDV
  - Add to the TDV score based on electricity, natural gas, and propane energy use
+ **Reduction from the baseline non-combustion emissions would then count as a TDV trade-off so that lower non-combustion emissions would be considered in building design tradeoffs**

Refrigerant leakage is a significant portion of the GHG emissions from an all-electric home

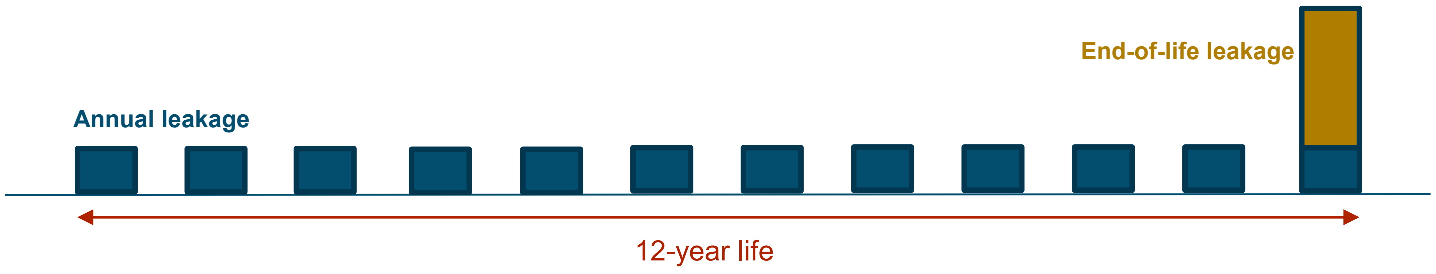
Example:



Refrigerant leakage

+ **The California Air Resources Board has compiled data on average leakage rates for appliances that use refrigerants**
  - Leakage happens both during operation and at end-of-life
+ **This allows us to calculate <u>lifecycle refrigerant leakage emissions</u> for any building**
  - These numbers are of course average, as some buildings will leak more than others

Appliance	Typical refrigerant	Refrigerant GWP	Average refrigerant charge	Average annual leakage	Average end-of-life leakage
Central A/C	R410A	2088	7.5 lbs	5%	80%
Air-source ducted heat pump	R410A	2088	8.2 lbs	5.3%	80%
Heat pump water heater	R134A	1430	2.4 lbs	1%	95%
Heat pump clothes dryer	R134A	1430	0.88 lbs	1%	100%



Annualized leakage = (Annual leakage rate) + (End-of-life leakage)/lifetime

Lower-GWP refrigerants

- Lower-GWP refrigerants are available, but not yet commonly used in the US
- The most promising near-term low-GWP refrigerant for use in residential HVAC heat pumps is lower-GWP HFCs, such as HFC-32
  - These refrigerants are generally mildly flammable, so different installation practices are required.
  - Fire Code and Mechanical Code currently don't allow mildly flammable HFCs
- For other, smaller heat pumps such as water heaters, the most promising option is HFOs, which are similar to HFCs but have a very low GWP
- Another option being used in some places, such as Europe and India, is hydrocarbons such as propane– but flammability is an obvious issue
- CO2 can be used as a refrigerant, but requires much higher system pressures, so is currently only viable for smaller systems such as automobiles and heat pump water heaters

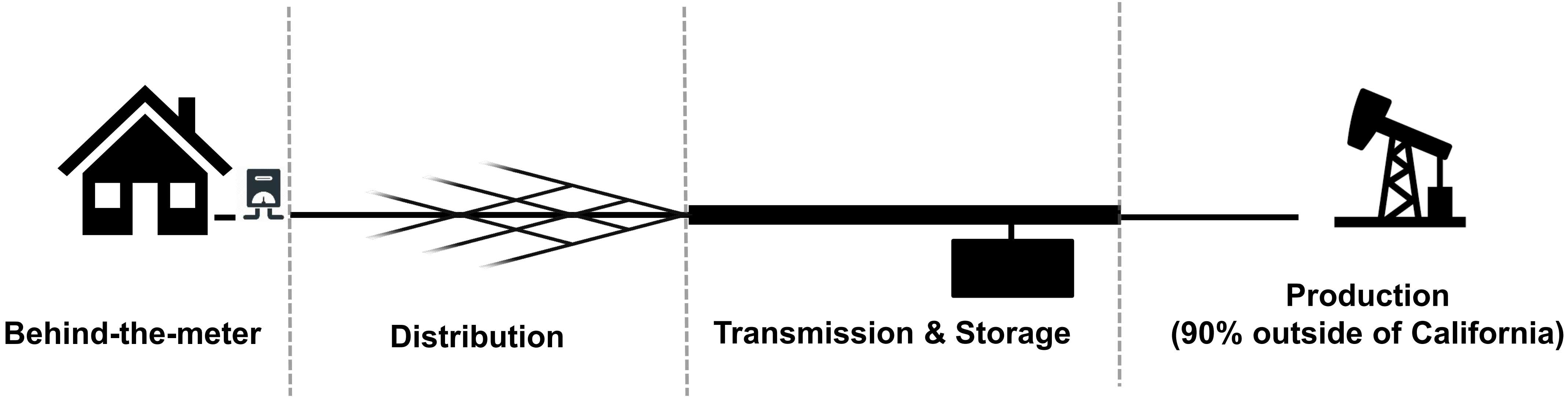
Low-GWP refrigerant alternatives

Refrigerant	GWP	Appropriate for…
HFC-32	675	HVAC Heat Pumps
HFO-1234yf	4	All heat pumps except HVAC
R-290	3	All
R-744 (CO2)	1	All heat pumps except HVAC

Methane leakage

+ Key question: how much do changes in building natural gas consumption change methane leakage?

Sources of leaks in the natural gas system



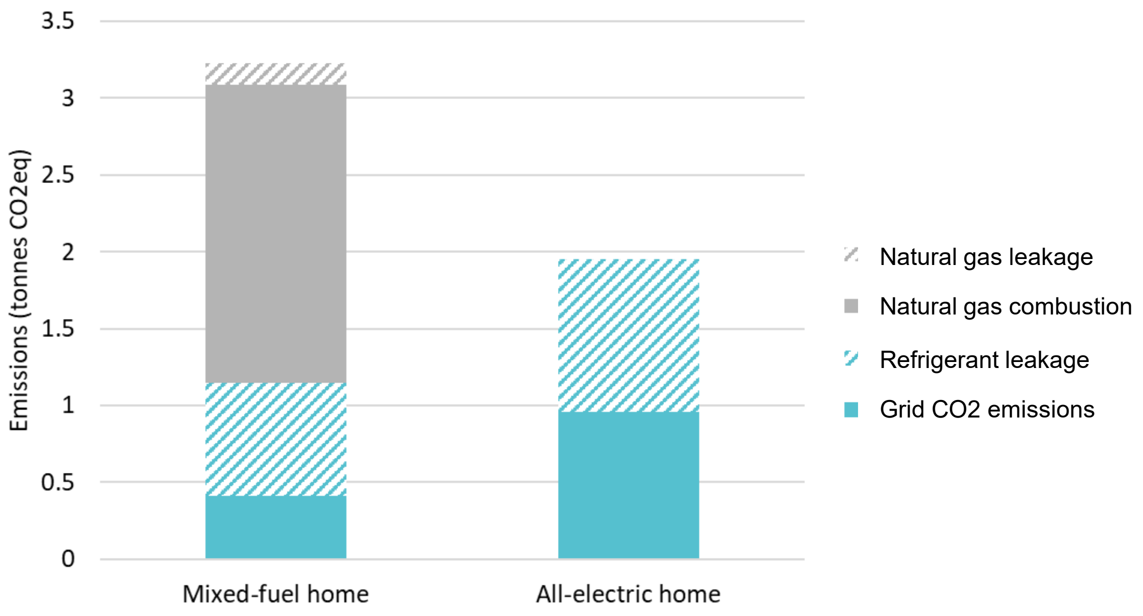
Estimating methane leakage

- We looked at a broad range of studies on methane leakage
- None of them answer exactly our question: how much leakage could be avoided by electrifying an appliance or home in California?

Source	Description	Leakage rate
CARB Inventory- behind-the-meter only	Includes both new and existing homes	0.5%
CARB Inventory	All leakage sources in CA	0.7%
LA Basin Study (He, 2019)	LA Basin only; attempts to quantify correlation with consumption	1.4%
Alvarez (2018)	US-wide estimate including production emissions. Not all of this leakage will be marginal.	2.3%

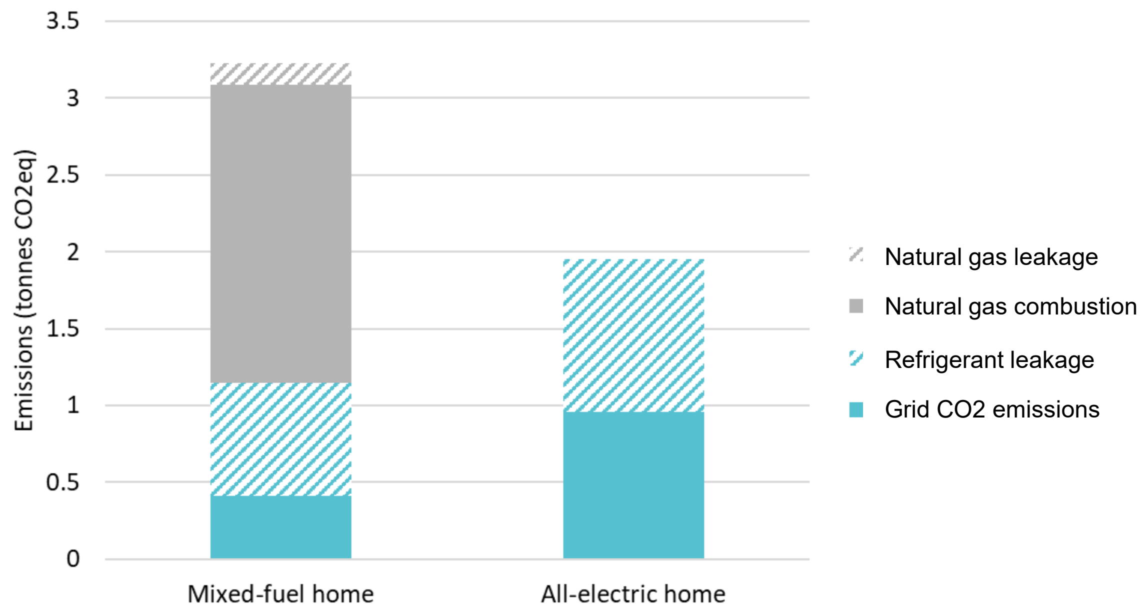
Sample calculation of emissions using leakage rates

- We examined sample CBECC results for a single-family home in CZ12 (Sacramento), to compare the emissions from all-electric and mixed-fuel homes when leakage emissions are included
- Air conditioners in mixed fuel homes also have refrigerant leakage
- Overall, the all-electric home in this example emits about 40% less GHGs, once leakage emissions are accounted for.



Key takeaways

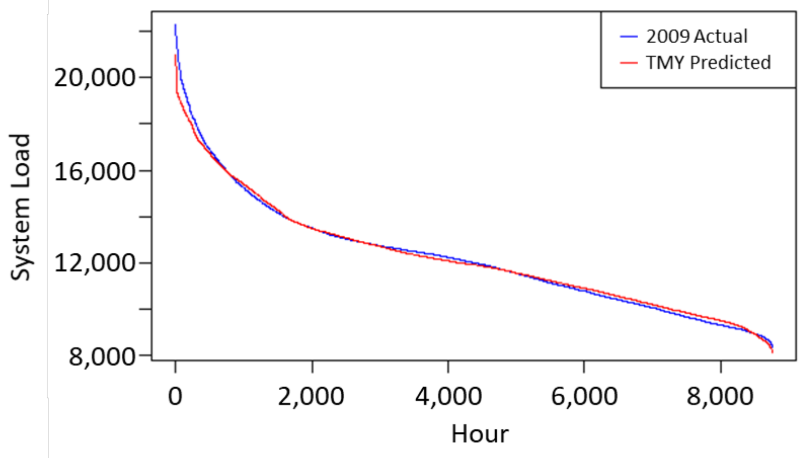
- All-electric homes emit significantly less GHGs, even when refrigerant and methane leakage is accounted for
- Low-GWP refrigerants have a significant potential to reduce lifecycle emissions, and therefore could be significantly incentivized through TDV
- We will further investigate the potential for electrification to reduce leakage in new homes; the CARB leakage rate of 0.7% is our starting point

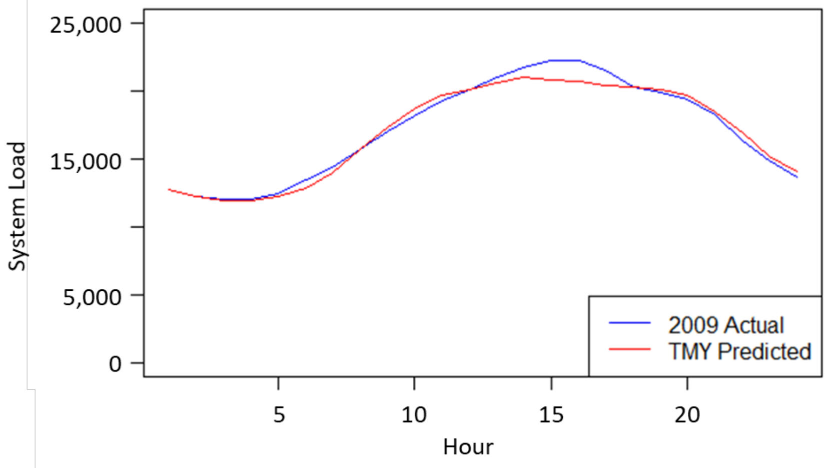


Appendix

Baseline Load Weather Matching Algorithm

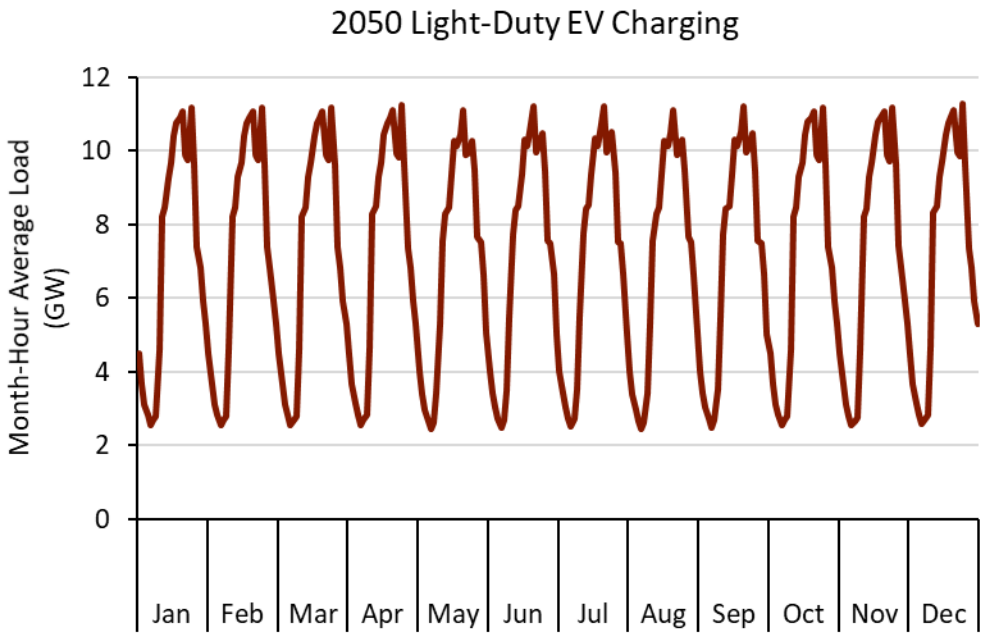
- Weather/load prediction algorithm updated from previous code cycles
- Regression model for each balancing authority is trained using historical weather data and load data
- New weather year characteristics are used to predict hourly load for each balancing authority
- Load profiles are normalized and scaled up by annual baseline load



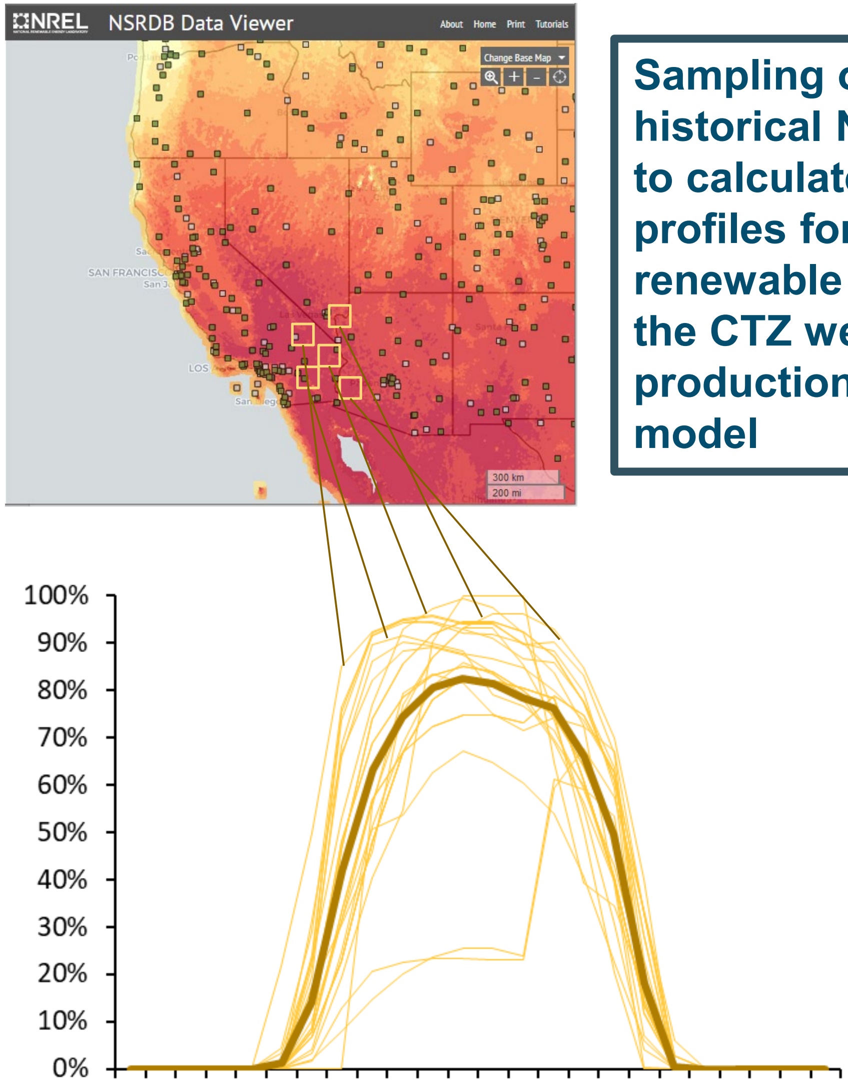


Electric Vehicle Charging Load Profile

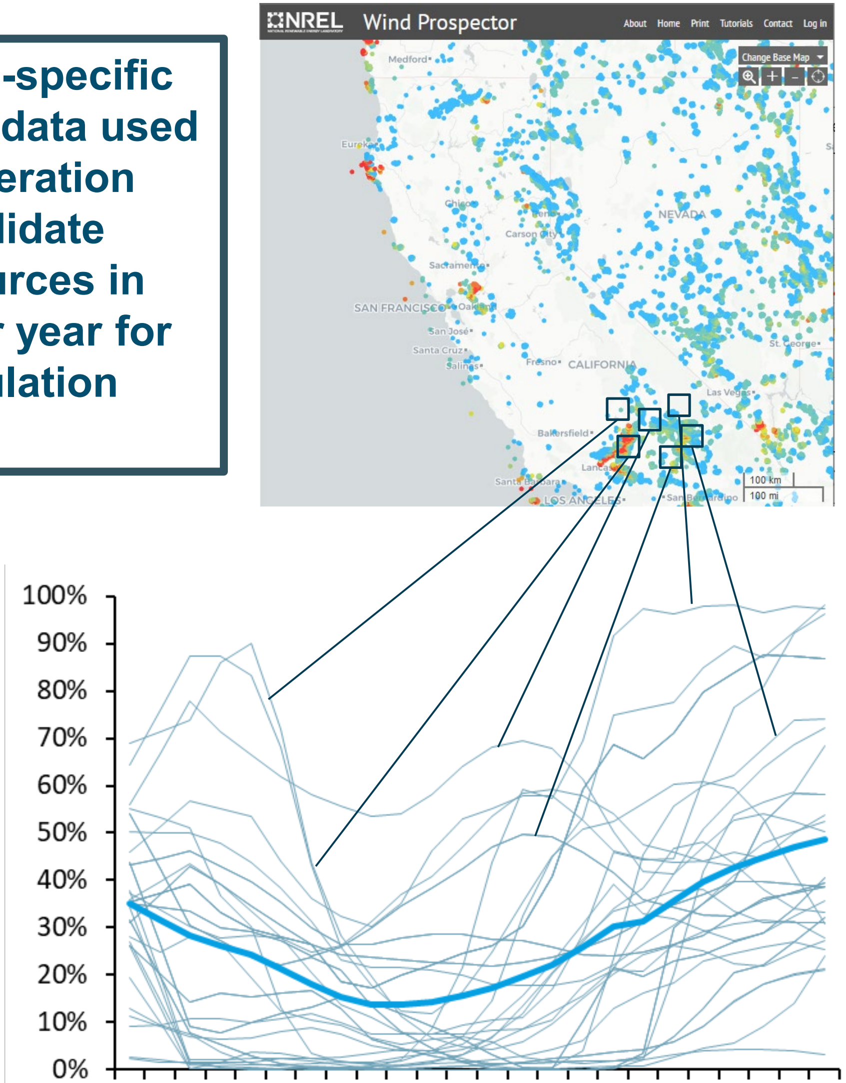
- Load shape generated by E3 EV Load Shaping Tool, scaled up to PATHWAYS annual average loads
- Assumes distribution of EV types (BEV, PHEV, etc), and models driving behavior with historical trip data from the National Household Travel Survey (NHTS)



Weather-Matched Renewable Generation

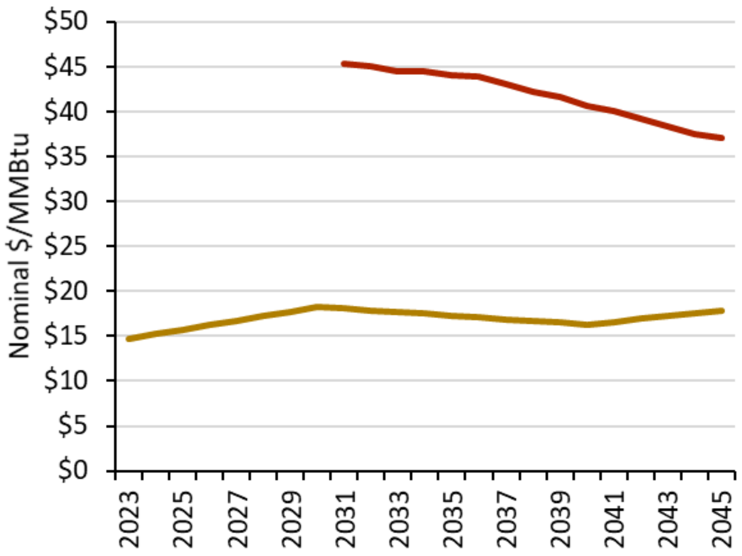


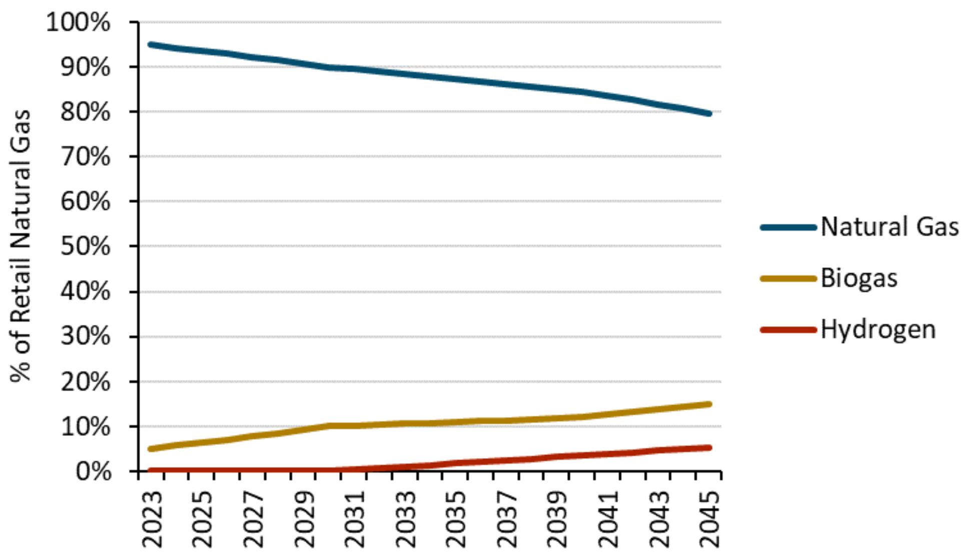
Sampling of site-specific historical NREL data used to calculate generation profiles for candidate renewable resources in the CTZ weather year for production simulation model



Policy Compliant RNG Costs

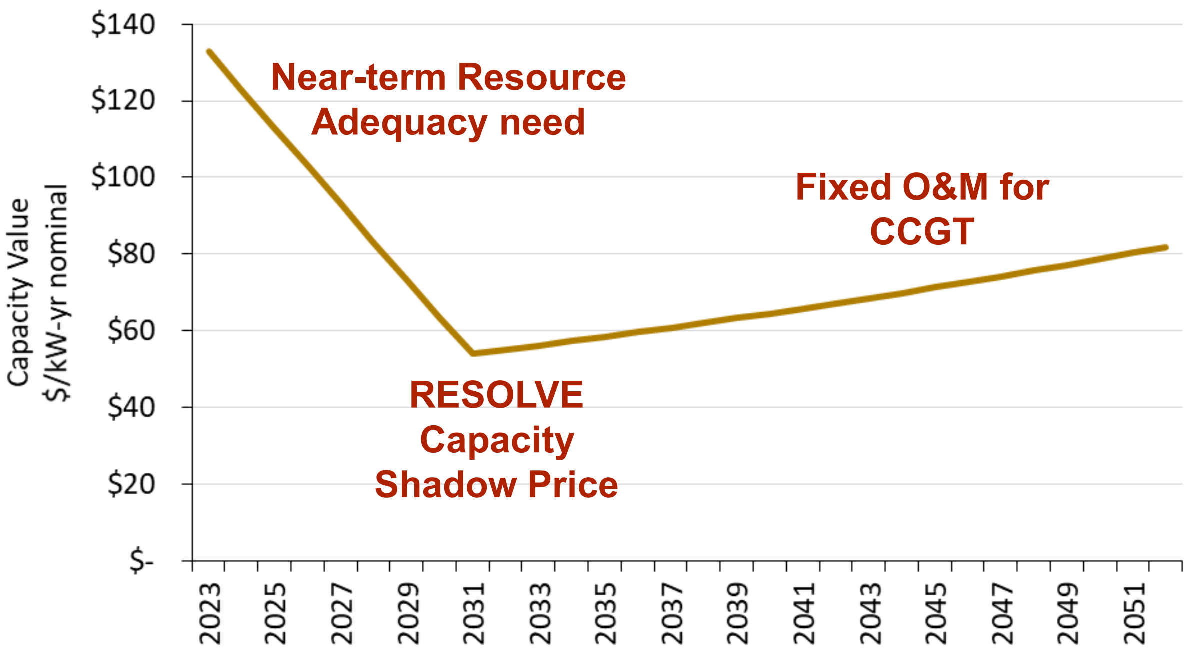
- **To decarbonize retail natural gas, biogas and hydrogen are blended in**
  - 10% biogas by 2030
  - 7% hydrogen by 2045 (assumed off-grid renewable generation for hydrogen)
- **The renewable natural gas blend is reflected in both commodity cost and emissions**





Generation Capacity (2)

+ **Marginal capacity price tracks with transition system net peak**
  - 2023 resource balance year, based on new CT
  - 2030 based on RESOLVE capacity shadow price
  - Beyond 2030 transitions to the cost to keep CCGTs operating to meet winter energy constraints



Ancillary Services, Losses

+ Ancillary Services

- Continue to use 0.5% of energy

+ Losses

- Continue to use utility-specific loss factors retained from 2019 TDV analysis

Description	PG&E	SCE	SDG&E
Summer Peak	1.109	1.084	1.081
Summer Shoulder	1.073	1.080	1.077
Summer Off-Peak	1.057	1.073	1.068
Winter Peak	0.000	0.000	1.083
Winter Shoulder	1.090	1.077	1.076
Winter Off-Peak	1.061	1.070	1.068
Generation Peak	1.109	1.084	1.081
Transmission Peak	1.083	1.054	1.071
Distribution Peak	1.048	1.022	1.043

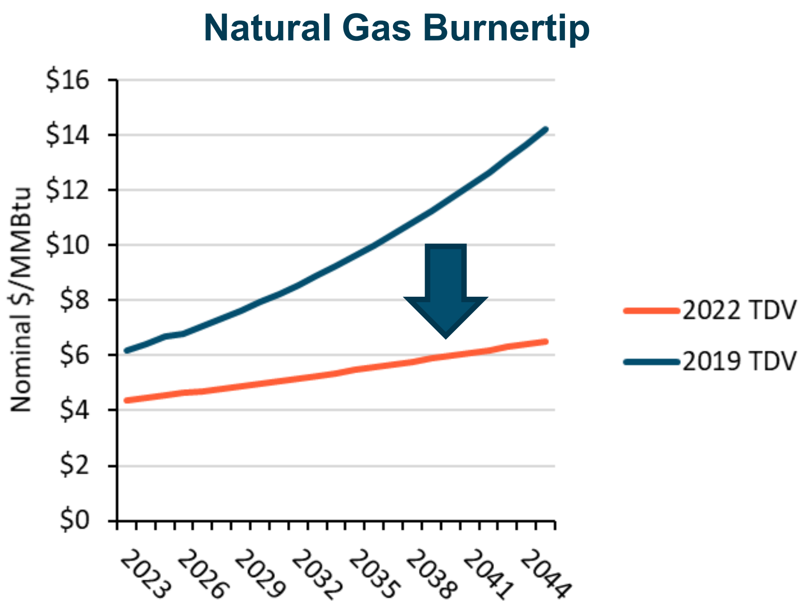
Natural gas retail rate forecasts (Policy Compliant Scenario)

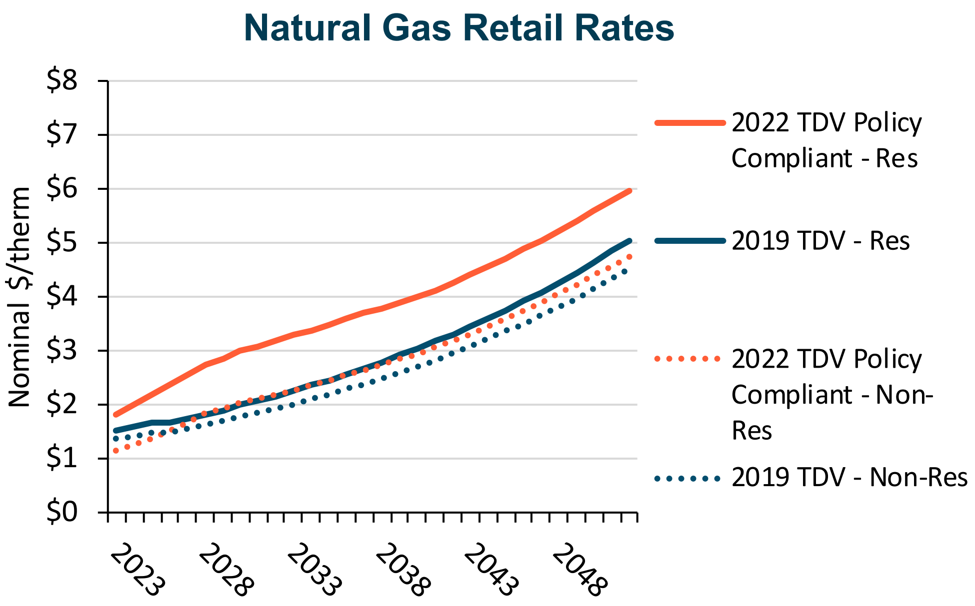
Natural gas commodity price has decreased since 2019 Code Cycle

- Natural gas commodity and burnertip price forecast from 2019 Preliminary IEPR (average of PG&E Backbone and SCG Needles)

Natural gas retail rates based on 2019 CEC Future of Natural Gas study – Multi-Prong with Slower Building Electrification scenario

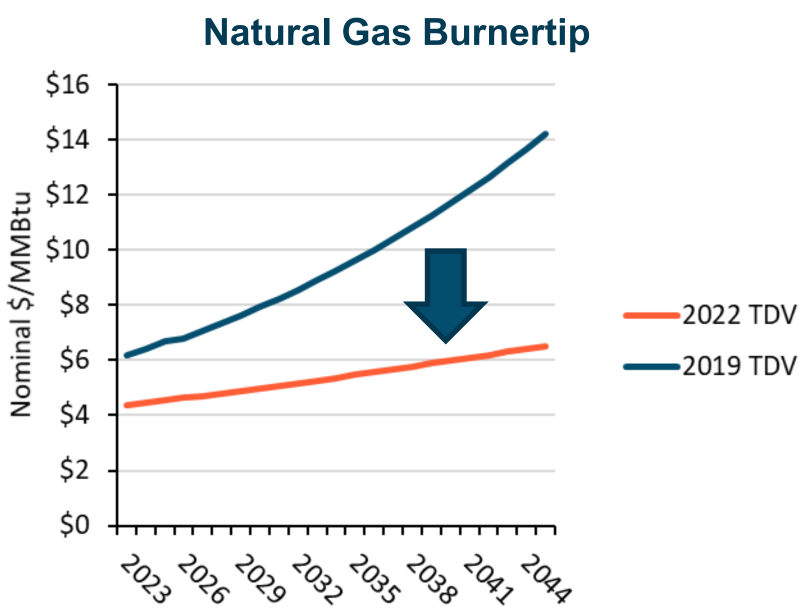
- Retail rates increase compared to 2019 code cycle due to recently approved safety upgrade costs, somewhat decreased throughput, some blend of biogas and hydrogen

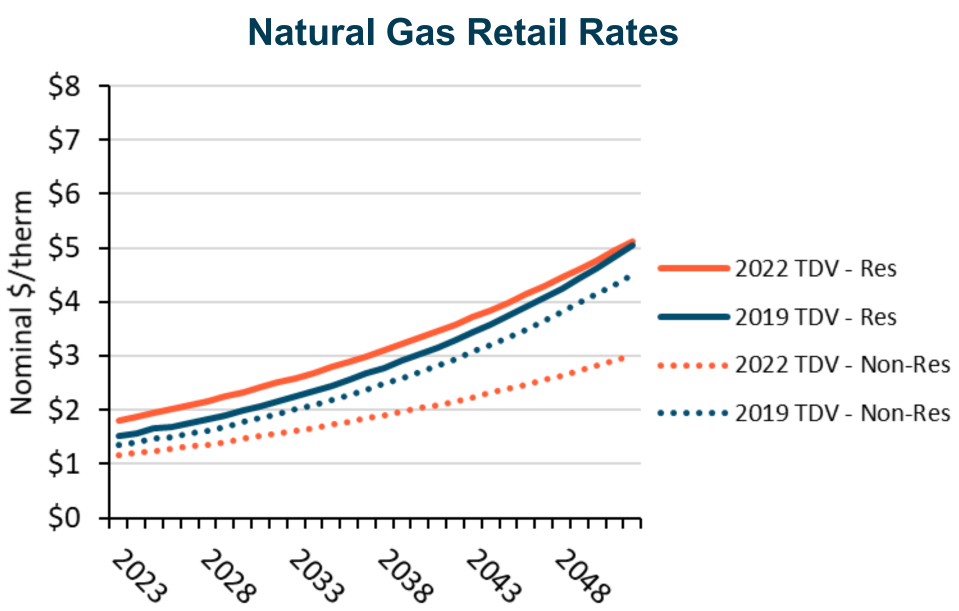




Natural gas retail rate forecasts (Mid-IEPR Scenario)

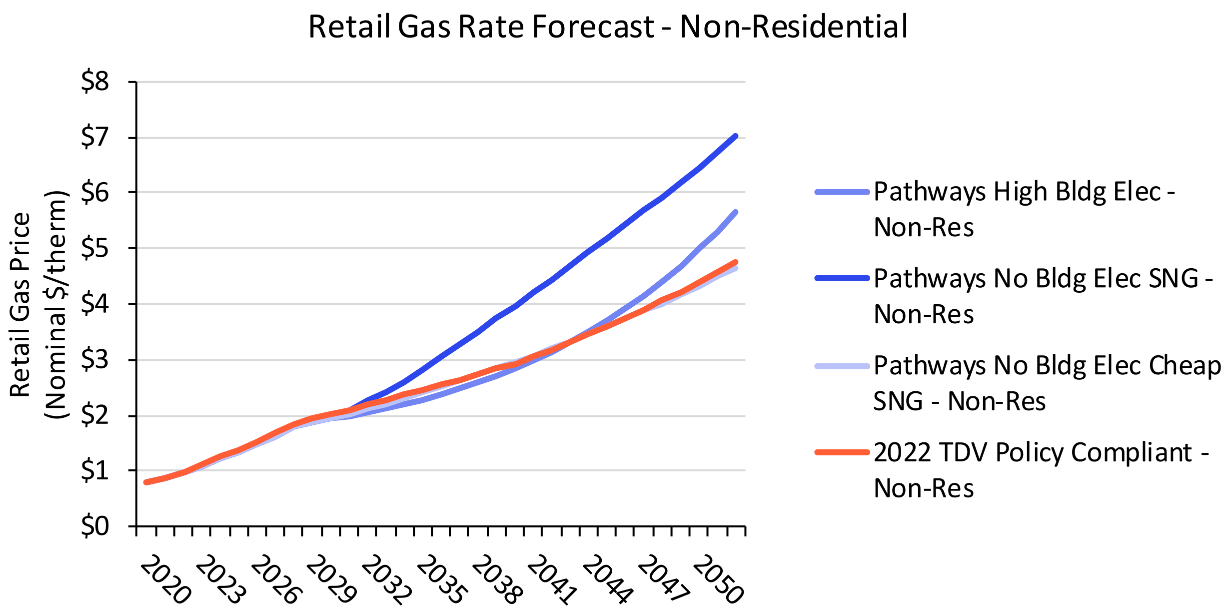
- **Natural gas commodity price has decreased since 2019 Code Cycle**
  - Natural gas commodity and burnertip price forecast from 2019 Preliminary IEPR (average of PG&E Backbone and SCG Needles)
- **Natural gas retail rates based on 2019 Preliminary IEPR Mid-Demand Retail Rate Forecast**
  - Residential retail rate forecast has increased compared to 2019 code cycle
  - Non-residential retail rate forecast has decreased compared to 2019 code cycle





Retail Rate Forecast Comparison

+ **Retail Rate forecast scenario is conservative compared to other PATHWAYS scenarios that meet emissions targets**
  - Alternatives are increased synthetic natural gas, or high building electrification, both of which are expensive
  - This scenario compensates for less decarbonization in the building sector with larger, more expensive reductions in other sectors



Natural Gas Scenario Comparison

- Policy Compliant yields higher retail gas rates, which translates to higher TDVs
- The difference between scenarios is larger for Non-Res