DRAFT SMUD IRP

Scenarios Summary Report

July 2018

SMUD®

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1 Introduction

Sacramento Municipal Utility District (SMUD) is a community-owned, not-for-profit electric utility. Our purpose is to enhance the quality of life for our customers and community.

SMUD's Integrated Resource Plan (IRP) is a living document that is intended to guide efforts to supply reliable electricity in an environmentally responsible and cost-effective manner through the study of planning strategies that achieve high-level policy goals. SMUD's IRP is updated annually to address staff recommendations for additional study and to reflect legislative, regulatory, market and technology changes. Every five years, SMUD conducts a full IRP refresh that will be approved by our Board of Directors following a public process and filed with the California Energy Commission, as required by the Clean Energy and Pollution Reduction Act of 2015 (Senate Bill 350, SB 350).

This IRP relies on numerous planning assumptions that help model SMUD's electricity system under various scenarios. While these assumptions and scenarios are plausible and simulated using the best available modeling techniques, the results are illustrative, not deterministic of near-term budgets and plans, and show how different planning targets affect operations, revenues, reliability, and costs from a policy perspective.

Given the policy-level approach of an IRP, staff emphasizes that this study is not forecasting or predicting outcomes. Periodically, staff will update SMUD's IRP to reflect market trends allowing for careful determination of resource planning investments during shorter-term decision-making windows.

SMUD's IRP process informs long-term strategic development by the various business units within SMUD and efforts are made to ensure the assumptions align with short-term 5-year and 3-year plans as well as SMUD's annual budget and enterprise metrics. The IRP should not be treated as a business plan, budget recommendation, customer program choice or design, or as a commitment to procure any immediate resource. Rather, an IRP provides broad direction and goals that guide the strategies developed and implemented by staff with specific program design and project implementation done during 1- and 3-year planning cycles.

1.1 Purpose: Advancing SMUD's Environmental Leadership

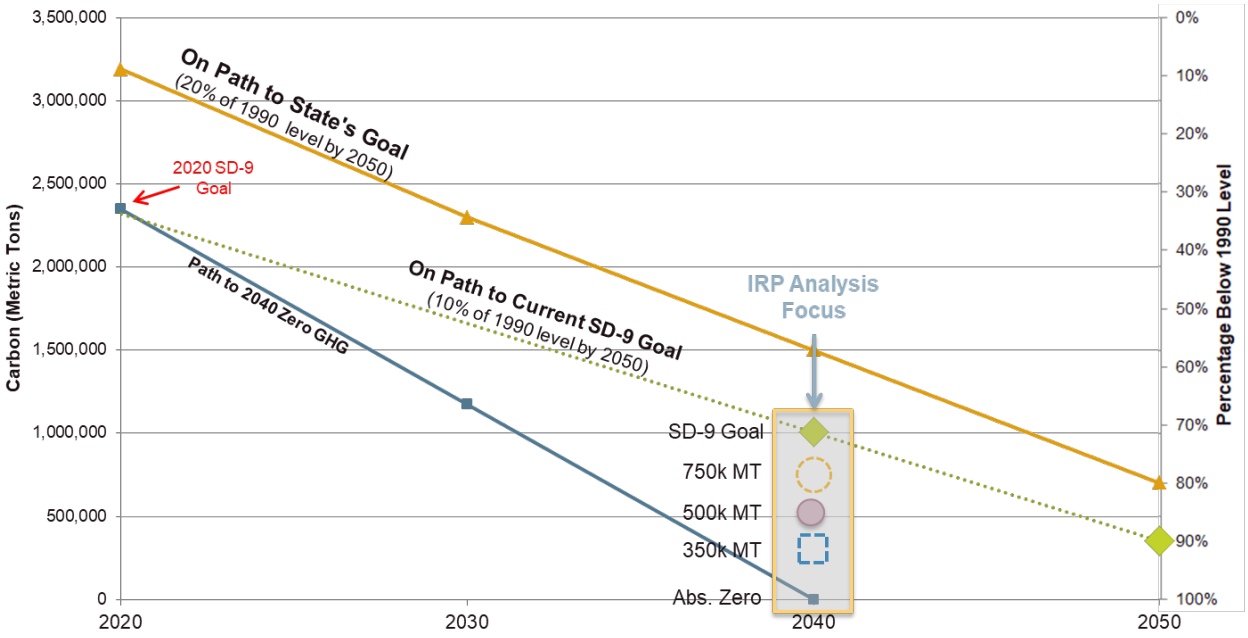
It is a core value of SMUD to provide our customers and community with a sustainable power supply through the use of an integrated resource planning process. A sustainable power supply is currently defined in Strategic Direction-9 (SD-9) as one that reduces SMUD's net long-term greenhouse gas (GHG) emissions to serve retail customer load to 350,000 metric tons (MT) by 2050 (equivalent to a 90% reduction below 1990 levels), while assuring reliability of the system, minimizing environmental impacts on land, habitat, water quality, and air quality, and maintaining a competitive position relative to other California electricity providers. SD-9 was established by SMUD's Board of Directors in 2004 and has provided the road map for SMUD's ongoing environmental

leadership. The GHG emission reduction target was established in 2008 with refinements to the policy continuing over the years based on market and regulatory conditions. SMUD's GHG emission reduction target is more aggressive than targets established by the State of California.

SB 350 requires that most utilities in California undertake a comprehensive planning process that incorporates multiple state mandates and goals. SB 350 requires SMUD, as well as 15 other publicly-owned utilities (POUs) to adopt IRPs by January 1, 2019, that show achievement of California's long-term climate goals and renewable procurement requirements by 2030, while considering cost effectiveness, reliability, impacts to disadvantaged communities, and various additional statutory mandates.

Additionally, SMUD's Board of Directors directed that staff use this planning cycle to study additional steps to increase SMUD's environmental leadership, particularly with respect to GHG reductions. Accordingly, SMUD staff looked at various GHG trajectories out to 2040 as illustrated in Figure 1. These scenarios included SMUD's SD-9 goal path to reduce GHG emissions 90% below 1990 levels by 2050, and an absolute zero emissions scenario in 2040.

Figure 1: Current policy benchmarks and scenario targets



As directed, the objectives of this planning cycle are to analyze the maximum level of grid decarbonization achievable at a reasonable cost without sacrificing reliability, while taking into account the grid impacts of electrification, and the economy-wide carbon savings. Key questions include the long-term role of SMUD's existing thermal fleet, how

quickly SMUD can achieve GHG reductions both within the electric sector and across the local economy, and the overall cost of various alternatives.

As a community-owned utility, SMUD is uniquely positioned to holistically consider and balance both utility-specific carbon reductions plus SMUD investments in local community measures that may achieve greater carbon reductions overall. This study focuses on procuring renewable generation and accelerating local vehicle and building electrification to achieve significant carbon reductions over the planning horizon. These strategies, renewable generation and electrification are most directly within SMUD's core competencies and represent promising areas to achieve additional GHG reductions above and beyond efforts that SMUD, or other state actors, are already undertaking. These broad strategies also include targeted energy efficiency programs, investments in disadvantaged communities, and other customer renewables and storage resources.

The key metrics used to evaluate these options within SMUD's IRP include impacts on:

- SMUD's resource portfolio
- System reliability and reserves
- Costs and rate impacts

SMUD contracted Energy and Environmental Economics, Inc. (E3) to use their California PATHWAYS model to develop a long-term, carbon reduction scenario. This scenario is designed to be consistent with other state plans and California's long-term climate goals and estimate SMUD's contribution to community-wide carbon reductions.

SMUD worked with E3 to develop and evaluate plausible carbon reduction scenarios using the PATHWAYS model. Through this model, electric vehicle adoption, building electrification, and other economy-wide carbon reduction strategies were modeled for each year between 2020 and 2050, such that SMUD would achieve a minimum 90% reduction in electricity sector GHG emissions by 2050, while supporting high levels of energy efficiency and electrification economy-wide.

This report is a summary of key findings and includes recommendations for 2040 GHG reduction targets. SMUD's preferred scenario identifies options and aggregate costs to achieve this 2040 carbon reduction plan. The planning targets adopted by SMUD's Board will be used to develop an SB 350-compliant IRP for submittal to the California Energy Commission in April 2019.

2 Decarbonization Scenario Analysis in PATHWAYS

The PATHWAYS model is a long-term economy-wide energy and GHG accounting model, taking user-defined scenario input assumptions to evaluate changes in total resource costs, electricity demand, and GHG emissions, among other metrics. The PATHWAYS model is used in California by state agencies for scenario planning

purposes, including by the California Air Resources Board in California's 2017 Climate Change Scoping Plan.[1] Most recently, the California Energy Commission published a report detailing several long-term energy scenarios through 2050 which use E3's PATHWAYS model to evaluate strategies that achieve the state's climate goals.[2]

2.1 SMUD's Climate Commitment and California's Climate Goals

SMUD has committed to achieving a 90% reduction in our electricity portfolio GHG emissions by 2050, relative to 1990 levels. In addition, SMUD is also committed to help the Sacramento region more broadly reduce GHG emissions outside of the electricity sector.

California, through Executive Orders S-3-05 and B-30-15, established a goal of reducing total statewide GHG emissions 80% below 1990 levels by 2050 ("80x50"). Senate Bill 32 also established an interim requirement of at least 40% reduction below 1990 levels by 2030. These ambitious goals are commensurate with the intent of the 2015 Paris Agreement aiming to limit global mean climate change to less than 2°C.

SMUD's programs that contribute to reducing GHG emissions outside of the electric sector include investments in energy efficiency and electrification, cross-agency efforts to mitigate high global warming potential gases, and tree planting and land stewardship to increase the sequestration of carbon in trees and soils.

Reducing GHG emissions in the Sacramento region will require transformation of the local energy economy in ways that expand beyond current state policies and mandates. SMUD is poised to enable and facilitate critical pieces of this transition. Furthermore, SMUD expects to be a major partner, with other local, regional and state players in ensuring that Sacramento is on a path to achieving the state's ambitious climate goals.

2.2 Greenhouse Gas Emissions in Sacramento and the SMUD Service Territory

Today, GHG emissions in the Sacramento region are highest in the transportation sector. Cars, trucks and other vehicles represent approximately 45% of the total regional GHG emissions. Direct emissions from homes and businesses represents about 19% of total regional GHG emissions, while the electricity sector, including imports used to serve SMUD's load, represents about 18% of the region's total, which is

[1] Available at: https://www.arb.ca.gov/cc/scopingplan/scopingplan.htm
[2] "Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model", CEC publication number: CEC-500-2018-012. Available at: https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

about 2.5 million metric tons (MMT) in 2015. Industry and agricultural emissions make up the remaining 17%. [3]

Overall in the Sacramento region, GHG emissions are estimated at approximately 14 MMT of CO_2-equivalent in 2015, or about 3% of the statewide total. With a population of 1.5 million people in 2015, this means that the per capita emissions in Sacramento are 9.5 MT. This is slightly lower than the statewide average (11 MT per capita), largely due to the lower prevalence of industry, as well as SMUD's lower GHG emissions intensity of electricity.

To achieve an 80% reduction in GHG emissions by 2050, emissions in the Sacramento region must fall to 2.6 MT per capita by 2040 and 1.3 MT per capita by 2050. This dramatic reduction in GHG emissions is reflected in the SMUD IRP analysis, as well as SMUD's role in enabling this transition.

2.3 SMUD's Role in Meeting Climate Goals and Benefits to the Sacramento Community

SMUD is making significant investments to reduce GHGs on many fronts across our service territory. SMUD is investing in energy efficiency programs in both commercial and residential buildings to reduce electricity and natural gas consumption. SMUD and our customers are investing in renewable generation, including community and rooftop solar PV. To further reduce GHG emissions in buildings, SMUD has recently launched a gas-to-electric conversion incentive program through our Home Performance Program. This first-in-the-state program is particularly beneficial to SMUD's customers with rooftop solar PV and is likely to be expanded in the coming years to enable higher levels of building electrification and greater carbon savings in buildings.

SMUD is also helping to achieve carbon reductions in the transportation sector through our electric vehicle programs and by investing in vehicle charging infrastructure. Finally, SMUD is working with city and county agencies on many fronts. We are partnering to phase out and replace equipment capable of emitting high global warming potential gases. We are also working to increase soil and tree carbon sequestration through better stewardship of our region's lands and forests tree planting programs.

Reducing GHG emissions in Sacramento through energy efficiency, electrification and renewable energy will also improve local air quality, reduce criteria pollutant emissions and improve local health. Sacramento sits at the crossroads of some of California's major interstates (Highways 99 and 50 and Interstates 80 and 5), and as a result is impacted by the local air pollution and criteria air pollutants associated with vehicles and trucking along these interstates. Electrification of the transportation sector will reduce both GHG emissions as well as local air pollution, improving health outcomes in Sacramento communities in tangible ways. By reducing or eliminating the combustion of

[3] As estimated in the PATHWAYS model.

natural gas in buildings, electrification in buildings will improve both indoor air quality and safety, in addition to the potential for bill savings and improved comfort.

2.4 The California PATHWAYS model

To incorporate an economy-wide perspective on GHG mitigation in the SMUD IRP process, E3 used their California PATHWAYS model to develop a SMUD-specific outlook for a long-term, carbon reduction scenario that is consistent with achieving a 90% reduction in SMUD's electricity sector emissions by 2050, and an 80% reduction in economy-wide GHG emissions in the region.

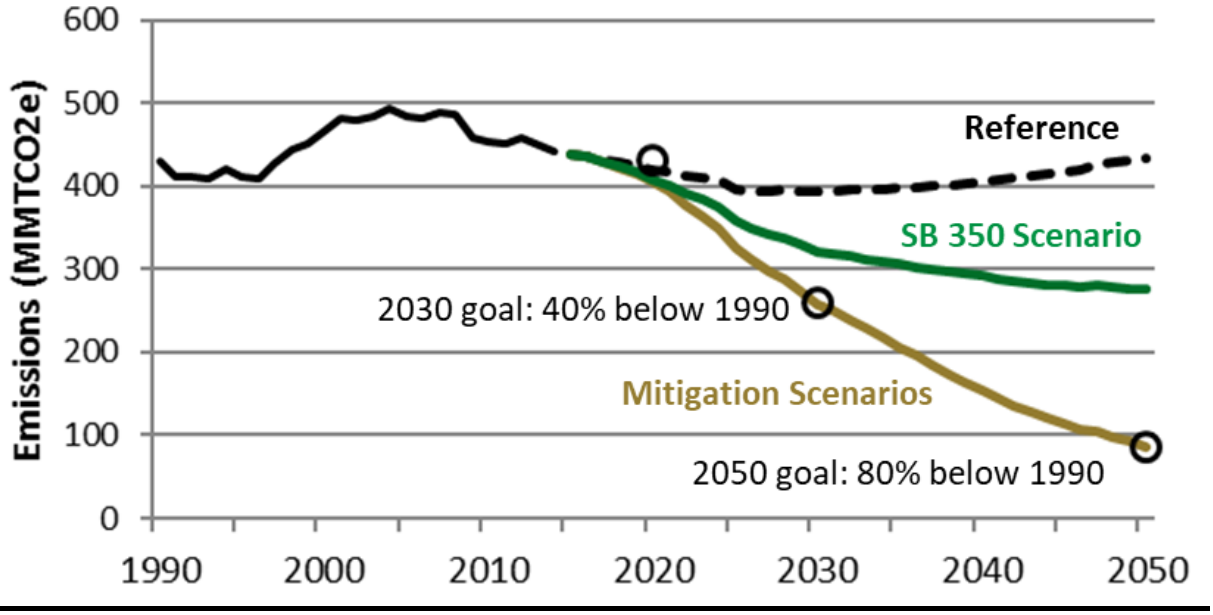
Within the context of SMUD's IRP, the PATHWAYS model is used to forecast demand-side electric load assumptions in buildings and the transportation sector that are consistent with achieving a low-carbon future in the SMUD service area. The load assumptions are used to populate the electric resource planning tools RESOLVE and PLEXOS used by the IRP modeling team.

E3 analyzed three kinds of scenarios (Figure 2):

- "Reference" or business-as-usual scenario,
- Senate Bill 350 scenario incorporating most existing policy commitments through 2030 and excluding the effects of cap-and-trade, which is not directly modeled in PATHWAYS, and
- Mitigation scenarios that achieve the state's 2030 and 2050 goals.

E3 found that large emission reductions, either from cap-and-trade or other complementary policies, will be needed beyond those achieved by existing policies in the Senate Bill 350 scenario. This gap, between current policy and the state's climate goals, is illustrated by the difference in GHG emissions in the green "SB 350 Scenario" line and the gold "Mitigation Scenarios" line shown in Figure 2. SMUD is planning for a future along the gold "Mitigation Scenarios" line but getting there is not a foregone conclusion. Achieving this low-carbon future will require significant new efforts at the local, regional and state level and can be facilitated and helped by SMUD's own actions and programs, as discussed below.

Figure 2: California GHG emissions, historical and projected in PATHWAYS



2.5 The California 80x50 Scenario

Through their scenario analysis, E3 has identified four "pillars," or key strategies that are needed to reduce GHG emissions across the economy. These include:

1) Energy efficiency and conservation across all sectors of the economy -- in buildings, transportation and industry.
2) Electrification of fossil fuels, and switching to cleaner electricity, while
3) Deploying low-carbon fuels, including sustainable biofuels and low-carbon, renewable electricity.
4) Non-energy and non-combustion sources of GHG emissions must be mitigated, including through the prevention and elimination of methane leaks, fugitive methane, and high global warming potential gases while carbon sequestration in soils and lands must be enhanced.

Electrification of the transportation sector is a critical component of any scenario that meets the state's long-term climate goals. Electrification of buildings will be needed, and electrification of industry may also be needed. The "High Electrification" scenario is one of the 10 mitigation scenarios E3 developed for the CEC and includes a high level of energy efficiency across sectors, renewable electricity, and electrification of transportation and buildings. This scenario was used as a basis for developing the electrification assumptions for the SMUD IRP.[4] We refer to this scenario here as the "California 80x50" scenario.

[4] For the SMUD IRP, the High Electrification scenario was modified somewhat to exclude hydrogen fuel cell cars and trucks, and to instead include more battery-electric vehicles and some electrification of

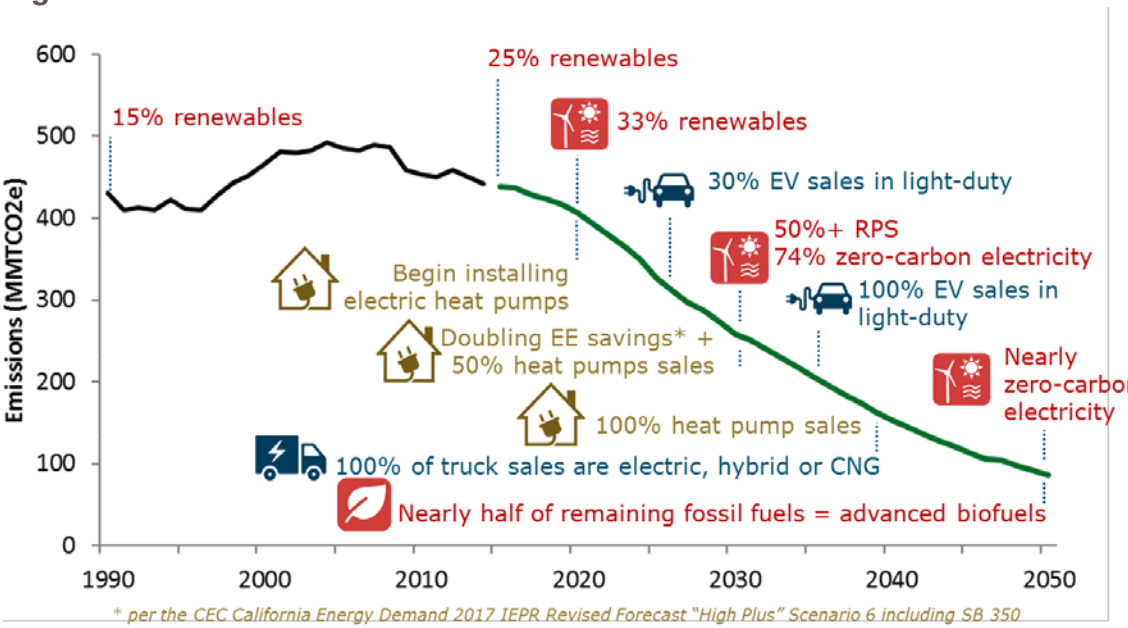
The California 80x50 scenario entails profound transformations of how energy is consumed and generated across all sectors, as illustrated in Figure 3. Notable landmarks include:

- 100% of new car sales are zero-emission vehicles (ZEV) by 2035. This represents a level of ZEV adoption that likely exceeds Governor Brown's ambitious goal in Executive Order B-48-18 to get 5 million ZEVs on the road by 2030.
- 100% of new water and building space heater sales are electric heat pumps by 2040. This represents a fundamental change from the current practice in the state and the Sacramento region where natural gas water and space heating continue to represent the majority of equipment sales.
- 74% of electricity is generated from zero-carbon resources by 2030 and nearly 100% is zero-carbon by 2050. This is more aggressive than is required under current state mandates.

For Sacramento to achieve this 80x50 scenario, SMUD, as well as state, local and regional partners, will have critical roles in enabling and speeding the adoption of electric vehicles, building electrification and renewable electricity. It is not a foregone conclusion today that these ambitious climate goals will be achieved absent significant new decarbonization efforts and investments by many stakeholders.

industrial end uses. This modification is intended to reflect the greater confidence in electric vehicle technology relative to hydrogen vehicles, which would also require a large amount of new infrastructure to support centralized hydrogen electrolysis and a fuel distribution network.

Figure 3: Timeline of GHG Reduction Measures in the California 80x50 Scenario

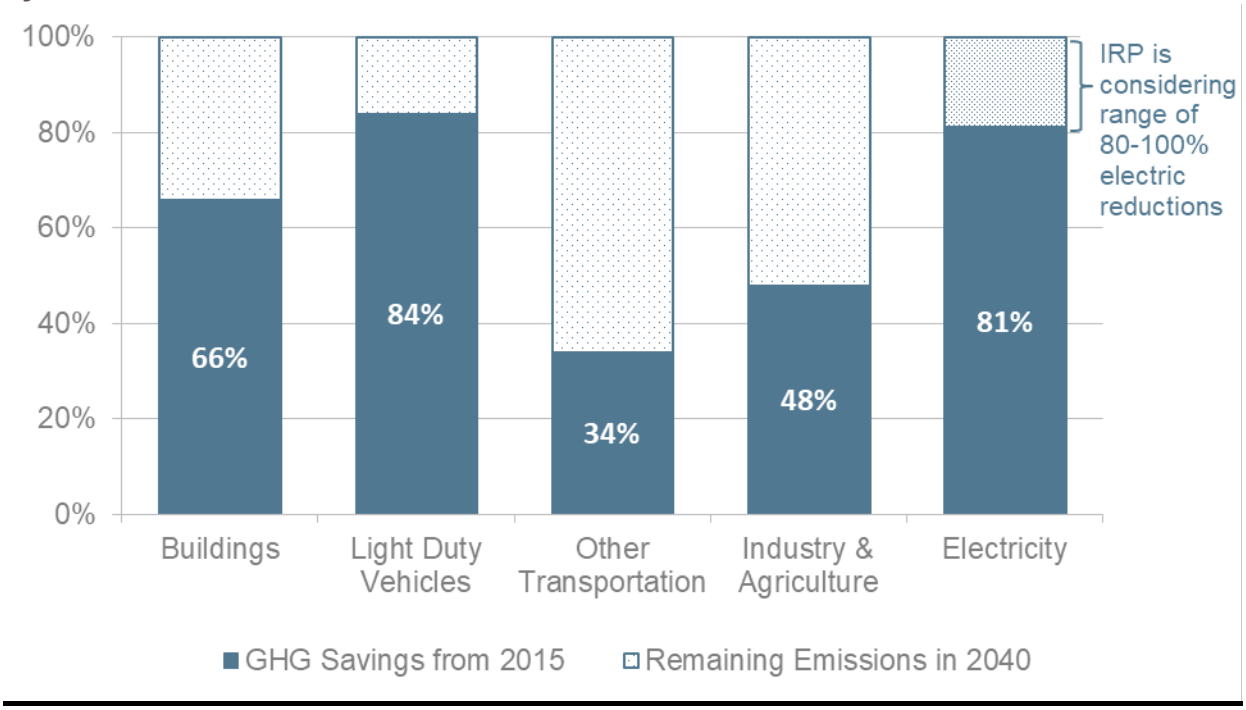


2.6 GHG Emissions and Savings in Sacramento and the SMUD Service Territory

For SMUD's IRP, the statewide California 80x50 scenario was downscaled to SMUD's service territory using SMUD-specific energy demand data and building stock information. When SMUD-specific information was not available, scaling factors were applied based on SMUD's share of the Sacramento region's population, households, commercial square footage, and vehicle miles traveled. The resulting present-day GHG emissions were benchmarked to the Sacramento County 2005 GHG emissions inventory and found close agreement with emissions modeled for 2015 in PATHWAYS. The future trajectory of GHG emissions reflects the SMUD territory's contribution to the state's 80x50 goals.

The model results indicate that by 2040, the largest share of emissions reductions in Sacramento would come from new renewable electricity and the electrification of light-duty vehicles. In this scenario, 100% of light duty vehicle sales are zero-emission by 2035. In the 80x50 scenario, Sacramento area GHG emissions from electricity and light duty vehicles are both reduced by over 80% relative to 2015 levels by 2040. The next largest source of emissions savings are expected to come from energy efficiency and electrification in buildings. In this scenario, direct GHG emissions from buildings are reduced by over 65% relative to 2015 by 2040 (Figure 4).

Figure 4: Sacramento Region GHG Savings, Percent Reduction below 2015 Levels by Sector in 2040



2.7 Implications for SMUD Demand-Side Programs

The levels of increasing energy efficiency and electrification in the 80x50 scenario contemplates a significant increase in SMUD-led investments in energy efficiency and other distributed energy resources. These investments would benefit both SMUD customers as well as the environment, and would use SMUD funding to leverage private investment in clean energy resources. For example, a SMUD incentive to install a high-efficiency electric water heater can encourage a customer to also bring their own investment dollars to the table, reducing both carbon emissions and their energy bills over the long-run.

In the California 80x50 scenario, total incremental SMUD investments in clean-energy distributed energy programs are assumed to increase nearly ten-fold between 2020 and 2040, expanding from $10 million per year in 2020 to nearly $100 million per year by 2040 as part of an effort to unlock deeper levels of carbon savings through 2040.

In this scenario, starting in 2020, an increase of $10 million per year SMUD investment in distributed energy resources is assumed to be split nearly evenly between energy efficiency, building electrification, and transportation electrification programs. This mix, as well as the total level of SMUD-driven distributed clean energy investments (DER), is assumed to change over time through 2040, as SMUD's DER programs support higher levels of carbon reductions across the region.

Also in this scenario, by 2040, nearly 65% of this estimated $100 million per year investment would fund energy efficiency programs, including incentives for building upgrades in homes and businesses. Approximately 20% of these investments are assumed to fund building electrification efforts across the SMUD service territory, including incentives to replace natural gas space heating and water equipment with high efficiency electric alternatives.[5] The remaining 15% of these investments are assumed to be used to enable and encourage the electrification of vehicles across the Sacramento region, above and beyond the levels of vehicle electrification funded with Low Carbon Fuel Standard credits.

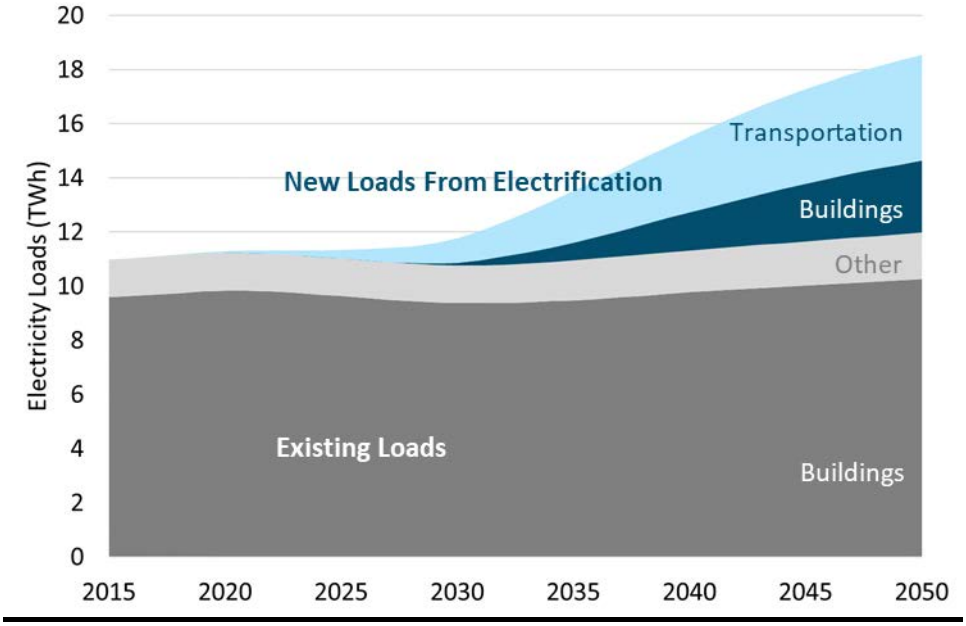
2.8 Implications for SMUD: Electricity Demand

Electrification in the transportation and building sectors will lead to higher electricity demand in the Sacramento region, necessitating additional procurement of renewable resources to meet increasing loads while also meeting the RPS and carbon reduction obligation. SMUD's IRP analysis is designed to reflect and incorporate these effects on both loads and resource procurement needs, consistent with meeting or exceeding the state's RPS and climate goals and SMUD's Strategic Directions.

In the California 80x50 scenario, SMUD's investments in DERs combined with the potential impacts of other state and regional policies to support energy efficiency and electrification result in a significant transformation of SMUD's electricity demands over time. High levels of energy efficiency are offset by new electrification loads from transportation, buildings and industry, especially after 2030 (Figure 5). This electrification reduces GHG emissions by displacing internal combustion engines with electric and hybrid-electric vehicles, and gas space heaters with more efficient electric heat pumps.

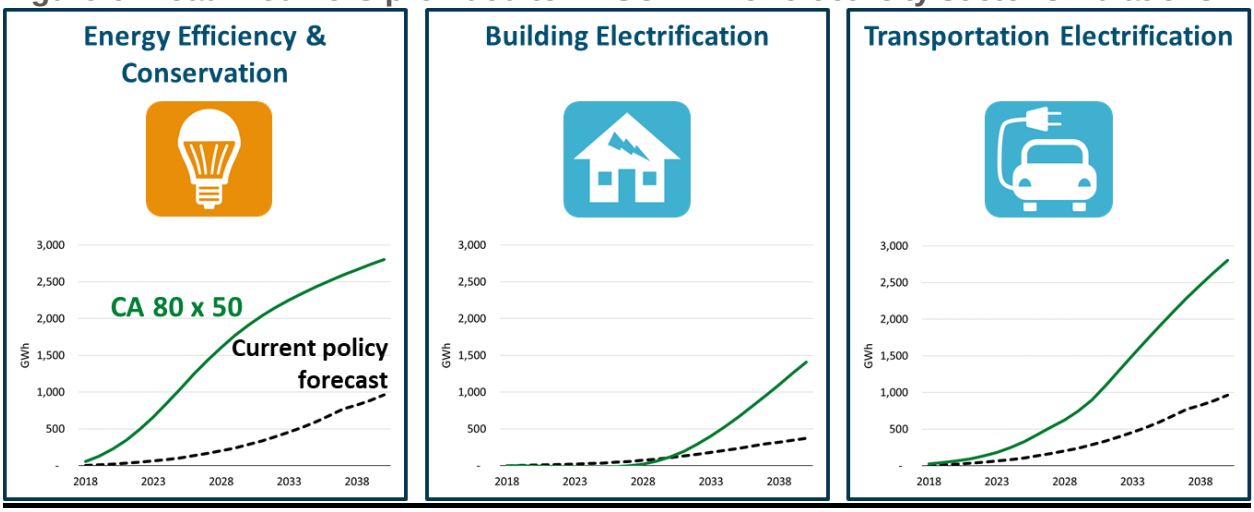
[5] Funding in this category will be dependent on the implementation of local and state codes that are consistent with electrification as a fuel substitution. If the code changes are not made, the investment share will need to be greater.

Figure 5: SMUD total electricity loads projected in PATHWAYS 80x50 Scenario



Electric load modifiers from the California 80x50 scenario are used in the IRP electric generation portfolio analysis described in the next section. Relative to current projections, large increases in energy efficiency, building electrification, and transportation electrification are necessary to meet the 80x50 goal. The annual energy demand projections from these load modifiers are illustrated in Figure 6.

Figure 6: Load modifiers provided to RESOLVE for electricity sector simulations



The "current policy forecast" in Figure 6 also illustrates the levels of energy efficiency savings and electrification in buildings and vehicles that might be achieved with current policies and programs. This "current policy forecast" is unlikely to be sufficient to

achieve the California 80x50 scenario or the state's long-term carbon goals. In order to accelerate the transition to a significantly lower carbon future, SMUD is planning for a more ambitious deployment of energy efficiency, building electrification and transportation electrification in Sacramento, driven by SMUD programs and new local, regional, and state policies and programs. This accelerated deployment of energy efficiency and electrification is represented by the California 80x50 trajectories in Figure 6.

3 SMUD Electricity Portfolio Optimization Analysis

To further examine SMUD's role in facilitating a deep decarbonization future for our customers and community and to link the state's decarbonization goals to our IRP, SMUD undertook a detailed analysis of its long-term generation portfolio options, at a level consistent with achieving a minimum of 90% reductions by 2050, relative to 1990 levels, as articulated in SD-9. To explore the investments needed to decarbonize our electricity supply as well as the associated costs and average customer retail rate impacts, SMUD developed a range of long-term scenarios tied to future GHG reduction goals. The analysis of these scenarios provides SMUD's customers and Board with actionable information on the relative viability of potential electricity sector GHG emissions goals, in the context of a high energy efficiency and high electrification future.

3.1 Scenarios Analyzed

SMUD examined multiple scenarios representing a range of long-run electricity sector GHG trajectories and infrastructure goals. Each of these scenarios is consistent with the California 80x50 scenario, including high levels of energy efficiency and electrification. These scenarios included:

- SD-9 Goal Scenario: a scenario that is consistent with SMUD's existing SD-9 GHG goal of 350,000 MT by 2050. This scenario achieves GHG emissions equal to 1.0 MMT by 2040 while preserving SMUD's existing gas generation resources, and is consistent with a trajectory to achieve a 90% reduction in GHGs (or 350,000 MT) by 2050, relative to 1990 levels.
- SD-9+ Scenarios: a range of scenarios exceeding the SD-9 trajectory that test meeting alternative GHG reduction targets— ranging from 350,000 to 750,000 MT in 2040—while preserving SMUD's gas generation resources.
- Absolute Zero Scenario: a scenario that requires SMUD to retire all existing gas generation resources and to serve its load exclusively with carbon-free resources.

The key assumptions that define each of these scenarios are shown in Table 1. Each of these scenarios is consistent with a future in which SMUD, the Sacramento region, and the state as a whole are assumed to undertake a significant new effort to enable higher levels of energy efficiency, building electrification and vehicle electrification. These

demand-side assumptions are represented in the table below as "80x50" on the Distributed Energy Resources category.

Table 1: Key Scenario Assumptions in 2040

	SD-9 Goal 1,000k MT	SD-9+ Scenarios			Absolute Zero
		750k MT	500k MT	350k MT	
GHG Emissions (MT)	1,000,000	750,000	500,000	350,000	—
RPS+ Level*	86%	91%	96%	98%	137%
Distributed Energy Resources	80x50	80x50	80x50	80x50	80x50
Existing Gas Generation	Maintained	Maintained	Maintained	Maintained	Retired
Balancing	Internal/ Market	Internal/ Market	Internal/ Market	Internal/ Market	Internal

** The shorthand reference to "RPS+" used in this report represents the share of SMUD's retail sales served by RPS-eligible renewable generation and carbon-free large hydro resources.

In the SD-9 and SD-9+ scenarios, SMUD's thermal fleet continues to operate through 2040 and provides needed energy and capacity for reliability. Within this scenario framework, the Absolute Zero scenario stands apart from the other scenarios not only because of its GHG target, but also because of the stringent exclusion of thermal gas-fired generation resources in the portfolio. All other scenarios allow SMUD significantly more flexibility in its effort to integrate incremental renewables while ensuring system reliability.

- The SD-9 Goal and SD-9+ scenarios allow SMUD to maintain its existing natural gas generation resources to meet reliability needs, whereas these resources are retired in the Absolute Zero scenario; and
- The SD-9 Goal and SD-9+ scenarios allow SMUD to continue to import unspecified power to meet reliability needs from wholesale markets—taking advantage of a broader and more diverse pool of loads and resources to facilitate renewable integration—whereas the Absolute Zero scenario functionally islands SMUD from these wholesale markets, requiring SMUD to supply and balance carbon-free electricity in all hours throughout the year.

These two factors significantly drive differences between the Absolute Zero scenario and the others considered in this IRP.

3.2 Modeling Methodology

E3 used RESOLVE to develop a generation portfolio to meet the policy goals in each scenario. RESOLVE is designed to inform long-term electricity system planning when high penetrations of renewable generation are considered. RESOLVE co-optimizes investment and dispatch—in this case, between 2020 and 2040 solving for the optimal investments in renewable resources as well as complementary resources such as energy storage and demand response subject to multiple constraints:

- An annual constraint on delivered renewable energy that reflects the RPS policy;
- A resource adequacy constraint to maintain reliability;
- Simplified unit commitment and dispatch constraints; and
- Scenario-specific constraints on the ability to develop specific renewable resources

RESOLVE is also used by the California Public Utilities Commission (CPUC) for development of its long-term "Reference System Plan" for the service area covered by the utilities regulated by the CPUC. E3 and SMUD worked jointly to create a version of the model designed to optimize SMUD's future generation portfolio that reflects both SMUD's unique system characteristics and its position as part of the broader electricity system in California and the Western Interconnection.

3.3 Key Assumptions

The following assumptions are common to all scenarios:[6]

- SMUD's demand forecast is consistent with a transition towards California's "80x50" climate goals (discussed in Section 2), which include high levels of energy efficiency as well as building and transportation electrification;
- DER costs assume new local and state mandates are enacted consistent with the state's long-term objectives and that Low Carbon Fuel Standard (LCFS) incentives continue;
- Wholesale market prices in the California Independent System Operator (CAISO) and at the California-Oregon Border are based on fundamentals modeling of the loads and resources within each region; [7]
- Natural gas prices reflect market forward curves in the near term (through 2021), then linearly transition to the fundamentals forecast of Energy Information Administration's 2017 Annual Energy Outlook by 2040;[8]
- SMUD's existing resource portfolio is assumed to remain online throughout the course of the modeling analysis while taking into consideration expiring renewable contracts;[9]
- Renewable supply costs and projections of CAISO charges and tariffs; and
- Operational reserves assumptions for load and variable renewables.

[6] Planning assumptions and technology costs will change over time and need to be monitored closely and revised in future IRPs.
[7] Fundamentals models develop market clearing prices based on optimal dispatch and operation of resources (e.g. thermal, hydro, renewables) to serve hourly load forecasts.
[8] https://www.eia.gov/outlooks/archive/aeo17/
[9] The Absolute Zero scenario, which assumes the retirement of all of SMUD's existing gas resources by 2040, is an exception to this assumption.

Optimized portfolios in each scenario are constructed by adding new resources to SMUD's existing resource base. The resources considered in the optimized portfolio include:

- **Solar:** The study assumes 1,000 MW of local solar could be built in SMUD territory, and up to 180 GW of solar resources could be developed elsewhere throughout the state of California and delivered to the CAISO.
- **Wind:** In-state wind potential available to SMUD is limited to 1,200 MW. An additional 900 MW of out-of-state wind resources are included as potential wind resource options.
- **Geothermal:** The study assumes approximately 650 MW of geothermal resources from out-of-state regions (Pacific Northwest and Southern Nevada) were available for SMUD.
- **Energy Storage:** Battery storage has been added to absorb renewable oversupply. The maximum contribution toward SMUD's capacity need is 560 MW based on a "rule-of-thumb" assessment of SMUD's load shape. Future technology advancement may increase the maximum level of support battery storage could provide for local renewable integration.
- **Demand Response:** the study relies upon SMUD's forecast for available DR in SMUD territory, which starts at 85 MW in 2018 and increases to 179 MW by 2040.
- **Unspecified Capacity Resource Purchases:** As available, market resource adequacy purchases are made to meet SMUD's reliability targets. Local capacity resources could be added if cost effective or required.

Cost and performance assumptions for each resource option were determined from a combination of sources, including:

- Public technology cost estimates used in the California Public Utilities Commission 2017 IRP proceeding; [10]
- National Renewable Energy Laboratory's 2017 Annual Technologies Baseline; [11]
- Internal SMUD forecasts; and
- Energy storage costs were updated based on Lazard's Levelized Cost of Storage 3.0 analysis. [12]

[10] Page 34 http://cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/RESOLVE_Inputs_Assumptions_2017-09-15_redlines.pdf
[11] https://atb.nrel.gov/
[12] https://www.lazard.com/perspective/levelized-cost-of-storage-2017/

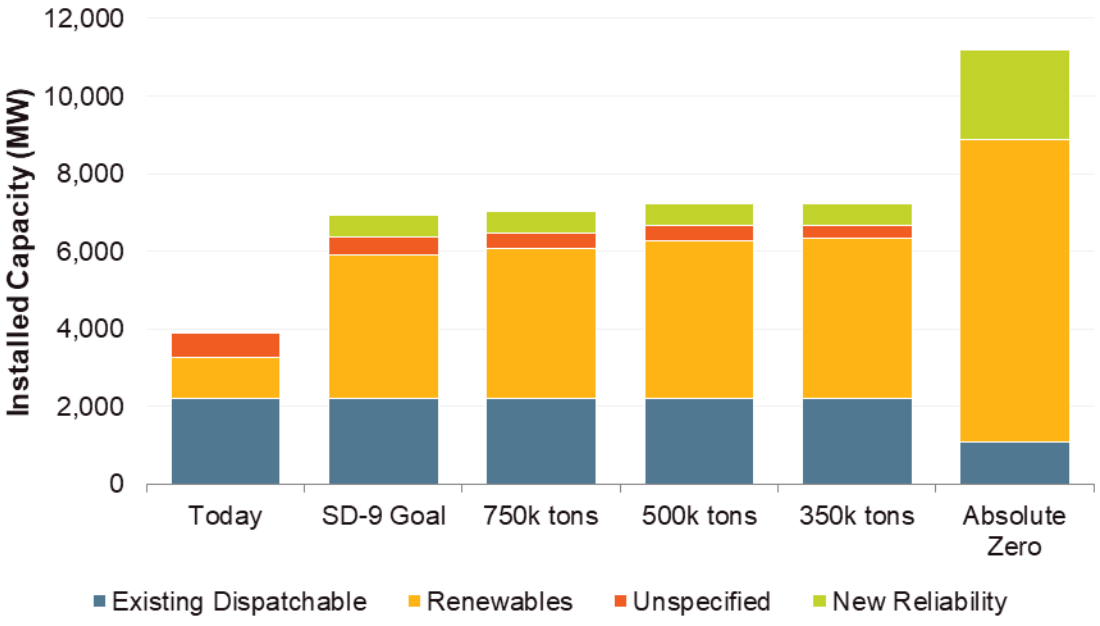
4 Portfolio Analysis

RESOLVE was used to create a portfolio of resources to meet the specific emissions targets for each scenario. The existing and new resources were categorized into one of four broad categories:

- SMUD existing dispatchable generation, including SMUD's existing natural gas resources, the UARP hydro resource, and SMUD's long-term contract for WAPA hydro;
- SMUD renewable generation, including all existing and new renewable resources;
- Unspecified capacity, representing generic capacity needed to meet reliability needs that may be supplied through market purchases or development of new capacity resources; and
- Additional reliability resources, which includes both energy storage capacity and demand response.

The selected resource portfolios for each scenario are shown in Figure 7.

Figure 7: Snapshots of 2040 SMUD resource portfolios in each scenario



Several observations can be made for these portfolios:

- Meeting SMUD's SD-9 goal by 2040 under the high levels of energy efficiency and electrification needed in the California 80x50 scenario will require significant investment in additional renewable generation capacity, including a mix of wind, solar, and geothermal resources. Whereas SMUD's existing portfolio includes

roughly 1,000 MW of renewable generation capacity, a total of roughly 3,700 MW of renewable capacity is needed by 2040 to maintain a trajectory towards achieving the SD-9 goal in 2050.

- Incremental reductions in SMUD's GHG footprint in the SD-9+ scenarios can be achieved with limited additions of renewable generation capacity beyond those needed to achieve the SD-9 goal.
- The Absolute Zero scenario requires substantial investments to double the renewable capacity and more than three times the storage capacity relative to the SD-9 goal and SD-9+ scenarios. In addition, the duration of storage resources needed in the Absolute Zero scenario is substantially longer (48 hours) than the storage resources in the other scenarios (4 hours). This very long duration is added to mitigate reliability risks in the absence of SMUD's existing dispatchable gas resources.

4.1 Reliability Implications

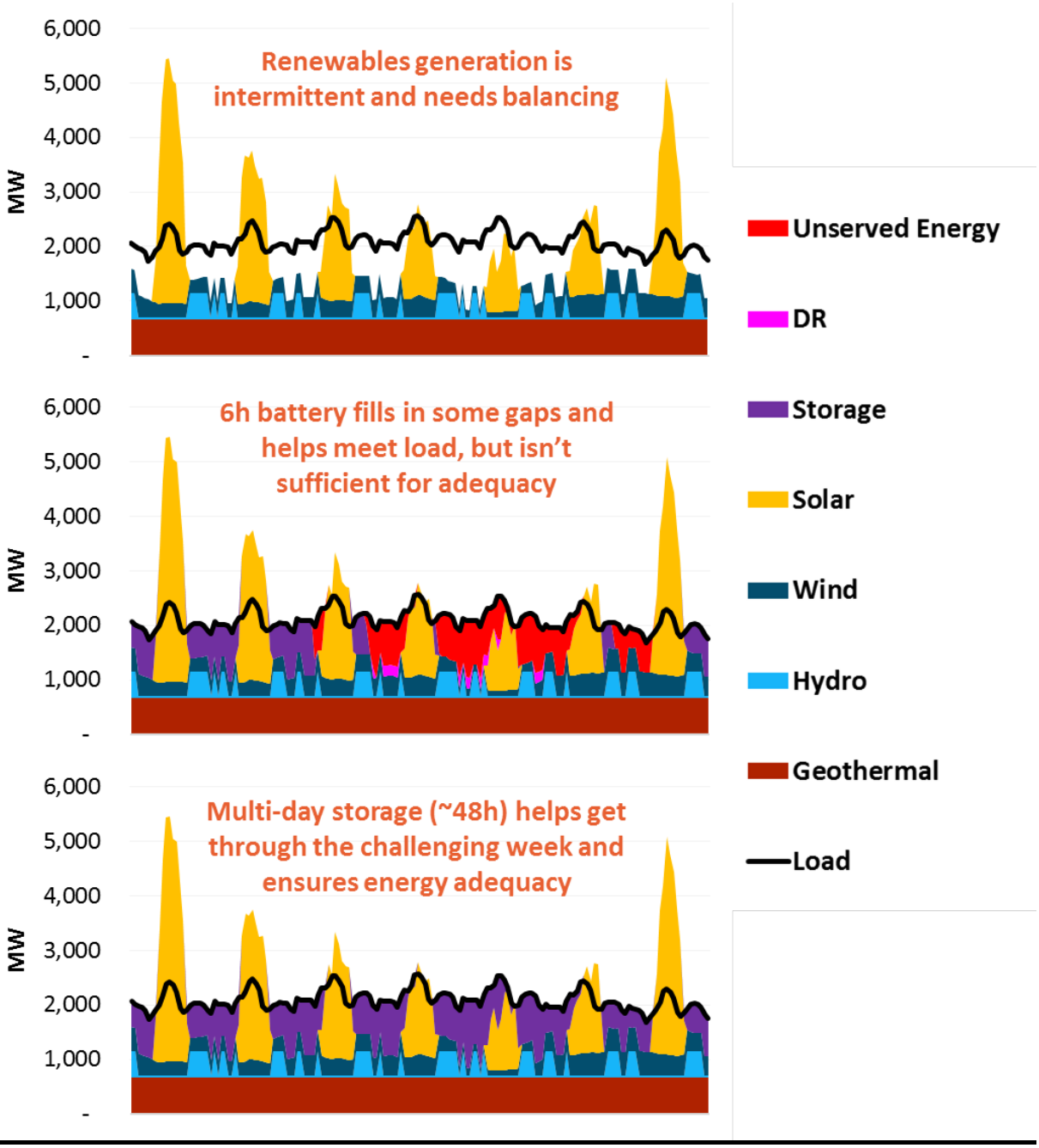
Each portfolio in this analysis is designed to achieve the high standard of reliability expected by SMUD's customers. In the SD-9 Goal and SD-9+ scenarios, SMUD satisfies its reliability obligations by adding capacity resources to meet annual peak demand plus a 15% planning reserve margin to account for extreme weather, operating reserves, and unexpected outages.

In the Absolute Zero scenario, a 15% planning reserve margin is not sufficient to ensure that load can be met during all hours. Evaluation of energy adequacy becomes increasingly important in portfolios that rely upon renewables and storage resources to meet reliability needs, as the capability of energy storage to meet demand across extended periods of need is limited by its duration and is dependent on availability of surplus system power to charge.

In systems with a high penetration of intermittent renewables and little to no dispatchable generation, the ability of storage to contribute to reliability is contingent on intermittent renewable energy production. In extended periods with low solar and wind production, ensuring we meet our customers' energy needs becomes challenging despite large investments in additional amounts of renewables and storage on the system. The problem is addressed in the Absolute Zero scenario by adding multi-day energy storage (48+ hours) at considerable cost to the system since battery technologies that are commercially available today are sized to meet a 4 to 6 hour need. This phenomenon and the need for substantial storage capacity to meet reliability needs are shown in Figure 8. In addition, this example doesn't cover the array of different anomalous weather events that SMUD's system currently experiences. Even the substantial additional investment in 48-hour storage would be insufficient to ensure reliability during anomalous weather events. Consequently, it is doubtful that SMUD could meet our customers' reliability expectations under certain anomalous circumstances.

In the future, new technologies may emerge to help solve this challenge, however, in the absence of such technologies this scenario becomes prohibitively expensive for our customers and calls into question our ability to meet SMUD's reliability metrics.

Figure 8: Resource adequacy analysis for a challenging period in the Absolute Zero scenario.



4.2 Cost & GHG Impacts

For each scenario, SMUD's overall revenue requirement and average annual retail rates were estimated. The revenue requirement includes costs in a number of categories. Across the scenarios, it was assumed that a number of costs would remain constant in real terms.[13] These include costs associated with maintaining SMUD's existing generation resources and transmission and distribution systems, customer costs, and public goods charges. In addition to these costs, the revenue requirement includes the fixed costs of new investments in generation, transmission, and distribution as well as the costs to operate SMUD's system, comprising fuel and variable costs and the costs and revenues associated with market purchases and sales. The revenue requirement is also used to calculate an average retail rate in each scenario. These metrics are summarized in Table 2.

Table 2: Portfolio cost metrics across scenarios[14]

	SMUD 2018 Budget	2040 Scenarios Results				
		SD-9 Goal 1000k MT	750k MT	500k MT	350k MT	Absolute Zero
Revenue Requirement (2016 $B)	$1.36	$2.04	$2.07	$2.10	$2.12	$5.13
Average Retail Rate (2016 cents/kWh)*	12.8	13.6	13.9	14.1	14.2	34.4
Average Residential Monthly Bill Impacts** (2016 $)	$103	$178	$182	$185	$186	$451

*Average bills may rise faster than rates because of increasing loads from electrification and the costs associated with decarbonizing SMUD's electric supply and the Sacramento economy.
** Average Residential Monthly Bills compare current average monthly bill for a single family gas/electric customer with potential future average monthly bill for all electric single family residential customer with an EV.

For the SD-9 and SD-9+ scenarios, revenue requirements increase as SMUD reduces its GHG emissions. Emissions reductions to achieve the SD-9 emissions pathway are achieved mainly through a combination of distributed resources, new renewables, and local reliability investments. Emissions reductions to achieve the SD-9+ scenarios are assumed to be achieved through the addition of new renewable generation. To achieve the 2040 goals for SD-9, new renewables and reliability investments mostly occur after 2030 while additional expenditures for local, clean distributed resources, including vehicle and building electrification efforts, begin in the early 2020's and continue to increase until about 2030 after which annual investment in local resources levels off.

[13] The IRP analysis does not incorporate non-IRP related costs that are likely to increase, and would result in potentially higher rate increases than those reflected in the analysis. Rate and bill impacts will be higher due to additional costs necessary for normal SMUD operations, which typically require some level of annual rate increases to cover increases in operating costs and fund investments.
[14] All dollars are in 2016 values throughout this report. Costs shown do not include impacts of inflation. Assuming 2% inflation, a multiplier of 1.6 would apply to convert to 2040 values.

Under the 80x50 scenario load forecast, achieving SD-9 (with incremental GHG reductions beyond 2018) means revenue requirements increase by more than $600 million over the 22-year period. While that is a modest average increase of about 1.75% per year, with increasing loads due to electrification of transportation and buildings customer bills may rise by a higher amount each year. Customer bills may increase faster due to greater electricity demand per customer.

For illustrative purposes, SMUD's current all-electric single family residential customers with EV's have average monthly single family residential bills that are nearly 63% higher than SMUD's current single family residential customers with a natural gas/electric mix. This illustrates that customer electric bills are likely to rise as a result of deep decarbonization of the Sacramento economy and SMUD's electric supply, which will both increase SMUD costs and customer electricity usage. Offsetting this increase to electric bills will be a reduction to customers' gasoline costs and natural gas bill as well as significant expansion of our investments in energy efficiency. Future bills will also be affected by technological change and efficiency as well as future rate design and strategy. Specific rate design, cost allocation, and customer retail rate strategy are the subject of rate proceedings not the IRP. While final impacts to customer bills will be determined by a combination of factors, it's likely there will be relatively larger electric bill increases because of electrification and decarbonization, which will be offset by lower natural gas and gasoline costs.

In addition, reducing SMUD's GHG footprint from the SD-9 goal to 350,000 MT requires an additional $80 million of spending in 2040, which equates to an average abatement cost of $123/ MT. In the SD-9 and SD-9+ cases, emissions reductions are achieved at lower cost relative to the Absolute Zero case due to the preservation of SMUD's gas fleet and the addition of low cost regional renewables to achieve the lower net emissions.

In all scenarios except absolute zero, significant increases in electric sales in the 80x50 scenario moderate impacts on the system average rate. For the Absolute Zero scenario, costs increase dramatically due to the retirement of existing gas resources and the need to overbuild renewable and storage resources to meet reliability needs as discussed previously in section 4.1.

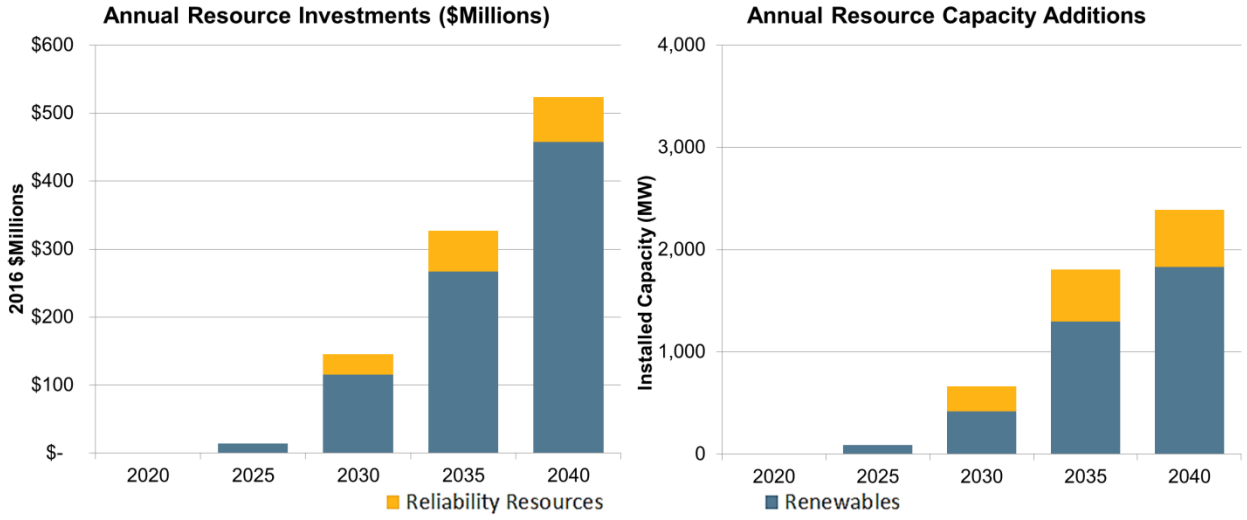
4.3 SD-9 Goal Path is Aggressive

This analysis indicates that SMUD's current Strategic Direction to reduce emissions beyond the state's goals will require numerous investments by SMUD. Additionally, enabling the greater Sacramento region to transition to a low-carbon future will also require SMUD commitments and investments that are not limited to SMUD's generation portfolio, such as consumer incentives and distribution system upgrades.

Shown below in Figure 9 (right) are the capacity additions in new renewables and local reliability resources to achieve an SD-9 pathway. Figure 9 (left) shows the annual costs

of these additional resources. Together, new investments in renewables and reliability resources add over $500 million to the revenue requirement in 2040.

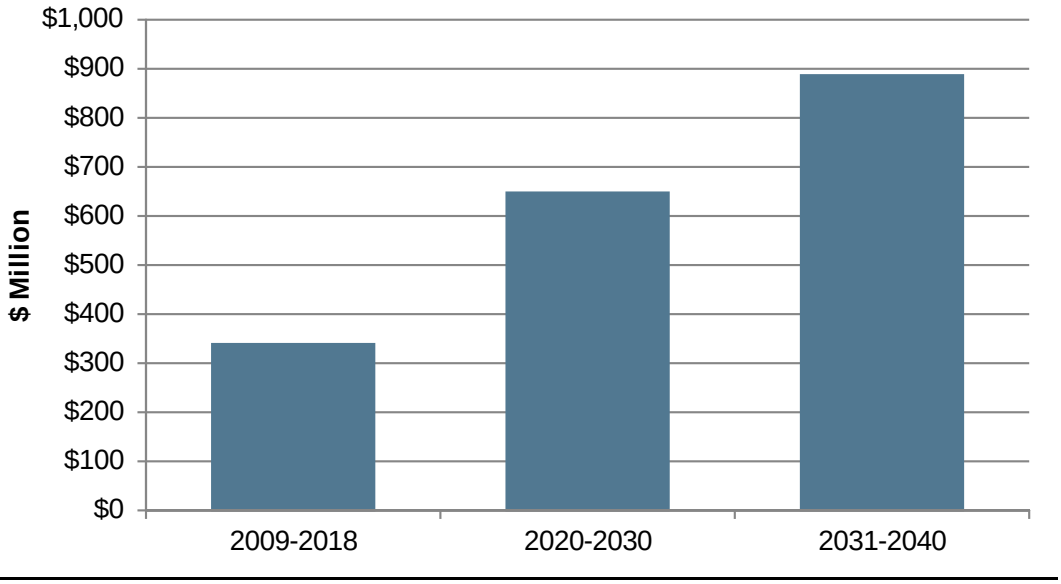
Figure 9: Annual resource capacity and investments



Renewable capacity additions to follow the SD-9 pathway require a tripling of SMUD's renewable portfolio in 2020. Expansion of local capacity to support the increase in renewable generation represents the largest local capacity expansion since the construction of Cosumnes Power Plant in 2006. Much of the increase to renewable capacity is required to continue to reduce SD-9 emissions in the face of significantly increased loads caused by electrification of transportation and buildings. Continuing along the SD-9 emissions pathway in the face of a nearly 50% expected increase in electric sales represents a far greater commitment to GHG reduction than was envisioned when the SD-9 goal was originally adopted in 2008.

In addition to renewable and capacity expansions, SMUD is also making very significant investments in local electrification and distributed resources over this time frame. Figure 10 shows the planned local expenditures for building and vehicle electrification every ten years through 2040. These local investments coupled with the new renewable and reliability capacity represent substantial, new spending to achieve a lower GHG footprint for both the local economy and for SMUD's electric portfolio. From 2020 to 2040, investments total over $1.5 billion in electrification and energy efficiency to achieve the 80x50 goal and represent a tripling of the spending SMUD made on these efforts from 2009-2018.

Figure 10: Building and Vehicle Electrification and Energy Efficiency 10-year Program Costs



As rates and customer bills rise to achieve decarbonization goals, there is a crucial balance that SMUD must consider in its resource planning, procurement, and long-term strategy development. If rates and bills rise too quickly, higher costs for SMUD's customers will begin to undermine the economic viability of much of the electrification foundation to achieving local and state economy-wide decarbonization. Recent consumer surveys have found that fuel cost savings is just as important as other factors (such as local or home charging, $7,500 tax rebate, state EV rebates, and battery warranties) in supporting the purchase or lease of an electric vehicle. On the other hand, low rates and bills will support and encourage the rapid transition necessary toward electrification envisioned in the IRP scenarios. Keeping rates affordable and competitive to ensure there is a strong local incentive to switch to clean, low carbon electricity benefits the local economy and ensures SMUD can support and enhance the region's efforts to significantly reduce local GHG emissions.

Finally, California's 80x50 goal is not a requirement on any local entity and there are no mandates in place to achieve these targets economy-wide. High levels of electrification sales in the California 80x50 scenario will need support from local and state policies and regulations. Early action by SMUD can help the Sacramento region successfully achieve these targets without overly burdening the community. SMUD's resource plan will need to be frequently reviewed and updated to insure investments and strategies remain cost-effective and prudent in an uncertain and competitive market. However, achieving the SD-9 pathway in conjunction with the local electrification investments made to achieve the 80x50 objectives will significantly reduce GHG emissions in the local community and support decarbonization of the local economy and transportation

networks.

5 Achieving 80x50, a Local Net Zero Approach

While the cost to achieve a portfolio that adheres to the standards of the Absolute Zero scenario would be prohibitively expensive to SMUD's customers, an alternative is to look at SMUD's role in enabling economy-wide carbon reductions. The economy within the greater Sacramento region will need to undergo a significant transformation to achieve the State's climate goals, as discussed in Section 2: Decarbonization Scenario Analysis in PATHWAYS. State and regional mandates alone may not be sufficient to enable this market change. Local incentives and infrastructure investment will also be needed. Under this paradigm, SMUD may consider targeting local, economy-wide emissions reductions through investments enabling the decarbonization of buildings and transportation. A Net Zero approach would consider the emissions reductions associated with SMUD's investments in decarbonization of buildings and transportation as a strategy to reduce the emissions associated with an SD-9 pathway.

Within this strategy, SMUD can reduce emissions in Sacramento through investments in emissions reductions in other sectors, including local investments in decarbonization of transportation and buildings. These local investments to support the State's decarbonization pathway will significantly lower Sacramento area overall GHG emissions. However, absent the substantial, new renewable investments envisioned in this IRP and articulated in Section 4.3, SMUD's own emissions would increase as a result of continued electrification of transportation and buildings. SMUD's investments to support a transformation of local transportation and building use, coupled with the significant expenditures and resource growth to maintain an SD-9 pathway in the face of electrification, together significantly reduce local GHG emissions. A Net Zero approach would both recognize the investments SMUD is making to achieve an SD-9 emissions pathway along with the investments SMUD is making to reduce Sacramento area emissions overall. One challenge of the Net Zero approach will be measuring the impacts of local measures relative to other statewide and regional efforts to reduce GHG emissions through electrification of transportation and building uses.

5.1 Local Net Zero

As proposed, "Local Net Zero" would complement SD-9 emissions reductions with the emissions reductions associated with transportation and building electrification. SMUD's investments in local electrification, taken together, would be targeted toward reducing Sacramento's local GHG emissions by an amount equivalent to SMUD's SD-9 pathway emissions by 2040. For the SD-9 scenario, SMUD determined that local investments in electrification required to achieve the 80x50 scenario can result in a Net Zero portfolio for SMUD.

It is estimated that for every additional electric vehicle on the road in SMUD's service territory, 2 to 5 metric tons of CO_2e from gasoline consumption are avoided each year. SMUD's own GHG emissions increase because of producing the electricity for the

electric vehicle, but these increased emissions are expected to be much smaller than the avoided emissions from gasoline due to the greater efficiency of electric drivetrains and the lower emissions intensity of electricity. Similarly, displacing natural gas appliances in buildings with electric appliances such as heat pumps can reduce overall household emissions by between 1 and 3 MT per year. However, SMUD does not currently count emissions reductions from transportation or building electrification within SD-9, despite the significant investments SMUD makes to encourage local electrification efforts.

For the purposes of this IRP and the SD-9 scenario discussed in this report, SMUD is assumed to invest in enough additional new renewables to reduce SD-9 GHG levels to offset the additional electric sector emissions caused by electrification of transportation and buildings assumed in the 80x50 pathway. SMUD's investment in renewables to offset the emissions associated with transportation and building electrification was not reduced to reflect the local emissions reductions from electrifying transportation or buildings. If SMUD were to count these local emissions reductions, SMUD can achieve a "Local Net Zero" portfolio by 2040 through our local investments made in transportation and building electrification. These SMUD investments would significantly benefit the local community by reducing emissions of harmful co-pollutants associated with fossil fuel combustion, particularly in disadvantaged communities, which are disproportionately exposed to these co-pollutants.[15]

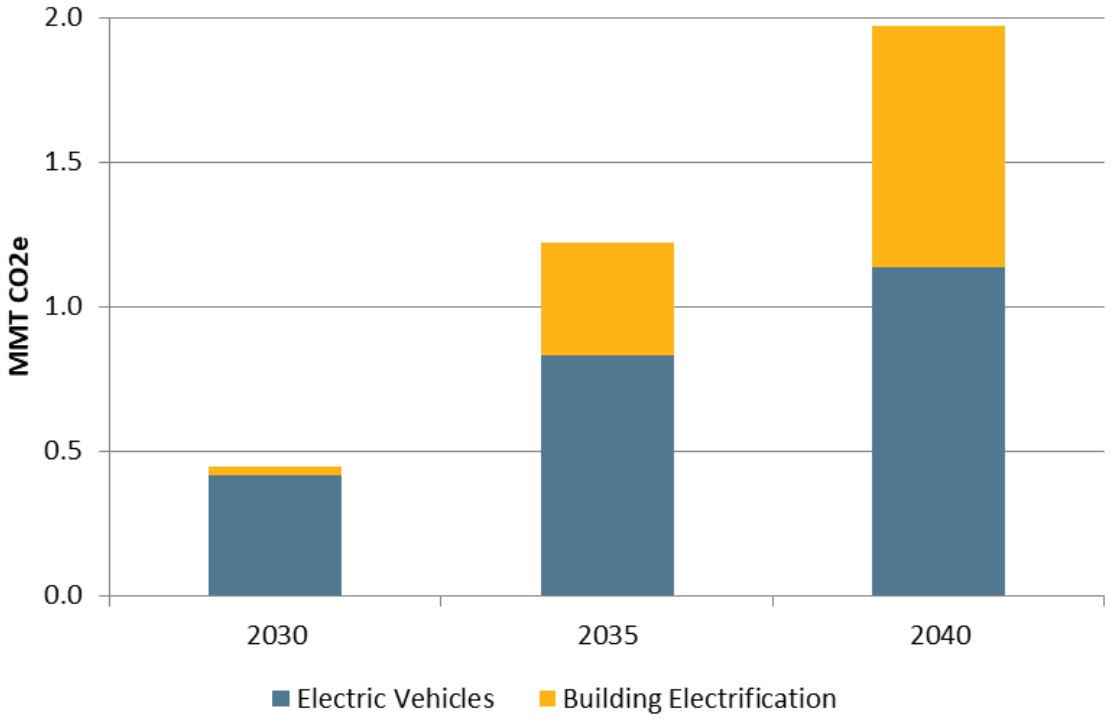
Avoidance of natural gas for heating, clothes drying, and cooking and displacement of gasoline use in the transportation sectors are the primary sources for emissions reductions due to electrification in SMUD as shown in Figure 11. This figure represents an estimate of the GHG emission savings in the SMUD region associated with the high building and vehicle electrification trajectory, relative to zero electrification, in the California 80x50 scenario. As shown in the figure, avoided GHG emissions through electrification of transportation and buildings reach almost 2 million MT of GHG emissions annually by 2040.

These emission reductions were estimated relative to zero electrification of buildings and vehicles, assuming continued increases in efficiency for gasoline vehicles and natural gas furnaces over time.

To enable this market transformation, SMUD must invest in projects and programs designed to enable and encourage adoption of these new technologies. These include, but are not limited to, distribution system upgrades, electric vehicle charging infrastructure, education and outreach, and customer incentive programs.

[15] See https://doi.org/10.5194/acp-18-4817-2018

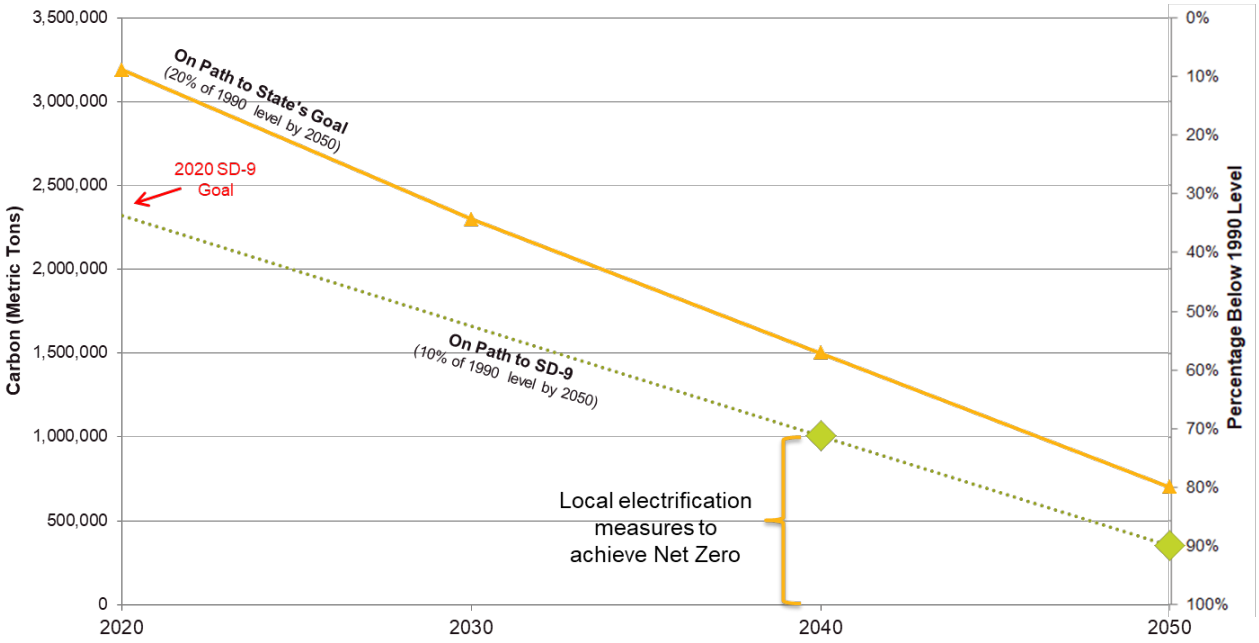
Figure 11: Maximum GHG Emissions Avoided in the Sacramento Region due to Local Electrification



Quantifying SMUD's effect on the adoption rate of electric vehicles and heat pumps, relative to statewide efforts, will require understanding of how effective programs are at enabling customer adoption and influencing customer choice. This is an initial attempt to assess the magnitude of the local GHG reductions associated with SMUD's electrification efforts. As part of implementing this IRP, SMUD plans to create an accounting methodology to address how our electrification efforts translate into local GHG savings. The State and its regulatory bodies do not currently have an approach that adjusts the utility GHG footprint for the GHG savings associated with carbon reductions in transportation or buildings, despite the State needing significant support and investment from utilities to encourage this transformation. The California Air Resources Board does have the Low Carbon Fuel Standard (LCFS) program that provides incentives for emissions reductions in the transportations sector, but does not directly address GHG emissions increases associated with increased loads in the electric sector due to electrification nor does the LCFS program credit electrification GHG reductions against a utility's GHG footprint. Additionally, the California Air Resources Board, as part of its AB398 proceedings, is currently considering additional allowance allocations to Electrical Distribution Utilities to account for increased carbon obligations resulting from transportation electrification. SMUD will develop a methodology to count emission reductions from electrification and will work with the State and regulatory bodies to recognize our approach.

SMUD's local investments in support of decarbonization of transportation and buildings creates significant reductions in local GHG emissions. If these reductions are counted toward offsetting SMUD's SD-9 GHG footprint, SMUD could potentially achieve a Net Zero portfolio as early as 2040. This study finds that the investments SMUD plans to make in local carbon reductions coupled with the significant efforts to increase renewables and decarbonize its own electricity supply while maintaining local reliability expected by SMUD's customers, will allow SMUD to achieve a Net Zero carbon portfolio by 2040 as show in Figure 12.

Figure 12: SD-9 Pathway with Local Net Zero emissions in 2040.



5.2 Accelerating Regional Net Zero to 2035 and 2030

In addition to the Net Zero options considered by 2040, the Board directed staff to consider accelerating the 2040 carbon reduction target to 2035 or 2030. Based on an initial assessment by E3, staff is able to provide a high-level assessment of the minimum costs to achieve these goals.

- Using local measures only (including transportation and building electrification) will require early retirement/turnover of vehicles and building appliances which substantially increases the costs to achieve a Net Zero GHG goal earlier than 2040.
- Annual costs to accelerate achievement of a Local. Net Zero is estimated to be on the order of $500 million per year if achieved by 2030 or $200 million per year by 2035. These cost estimates reflect a conservative assessment of carbon

reductions available to be achieved and measures to achieve carbon reductions through early adoption of electrification (available at a higher cost than achieving 80x50). Expenditures to maintain a net-zero portfolio would decrease over time as SMUD's resource mix includes more carbon-free resources.

- Retail rate impacts for these scenarios were not analyzed in this study, however, they are expected to be higher than the SD-9 case due to the need for additional dollars to pay for early retirements.
- Along with additional costs of moving Net Zero to 2030 or 2035, there is also concern about the pace of achieving the Net Zero goal as it would require reaching 100% adoption of electric vehicles and heat pumps in this time frame. It is unclear whether this will be enough time to allow complete market transformation in these two sectors. By focusing on a 2040 timeframe to achieve net zero, technologies will have longer to mature and become more widely adopted as well as, allow for natural turnover of appliances (avoiding early retirement). This will make achievement of the goal less risky and less expensive for SMUD and its customers.
- Future technology performance and costs are uncertain and will evolve over time. Over the next five to 10 years, more information will be available about costs and market acceptance for zero-carbon building technologies and zero-carbon vehicles within SMUD's service territory. Staff plans to continue to assess technology options as they emerge to further reduce GHG emissions over time.

6 Discussion

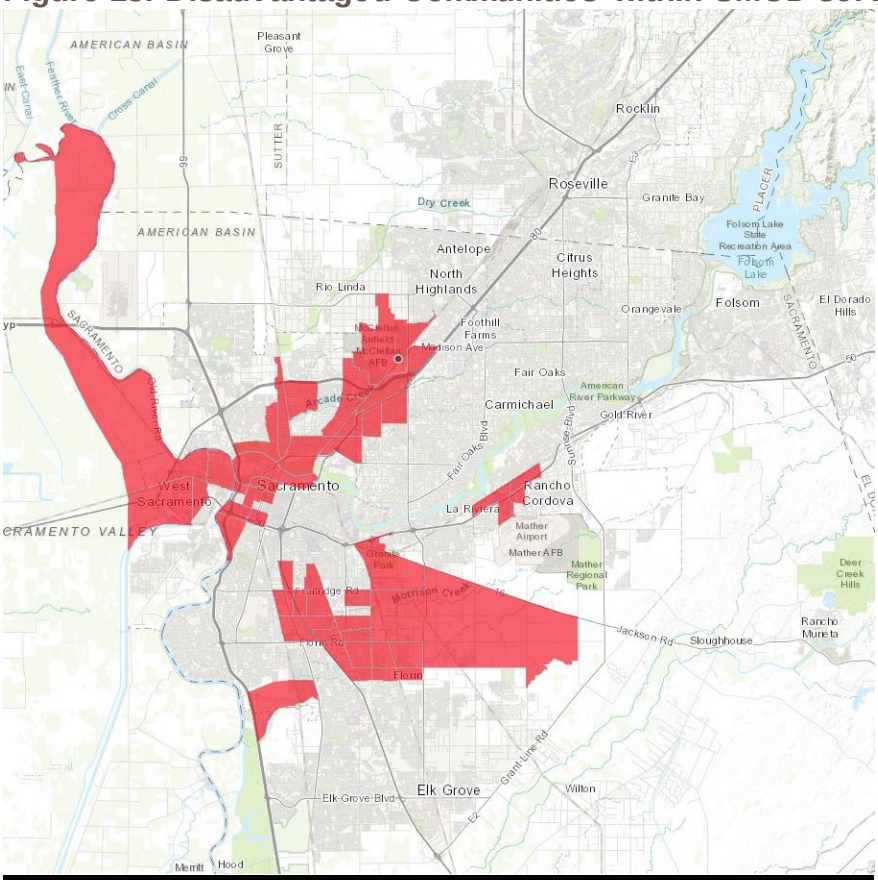
The findings of this study indicate that SMUD will need to increase spending significantly to achieve any target adopted by SMUD's Board, including maintaining the existing SD-9 pathway with significant load growth associated with electrification. Staff took a high-level look at the effect of these scenarios on power plant operations in disadvantaged communities and the potential for new jobs in Sacramento's clean-energy economy.

6.1 Economic Development and Disadvantaged Communities

SB 350 requires that utilities look at programs targeting not just low-income communities, but disadvantaged communities. CalEPA used the CalEnviroScreen 3.0 tool to inform the designation of these communities. [16] Figure 13 illustrates the disadvantaged communities within SMUD's service territory.

[16] See the following for more information: https://oehha.ca.gov/calenviroscreen/sb535

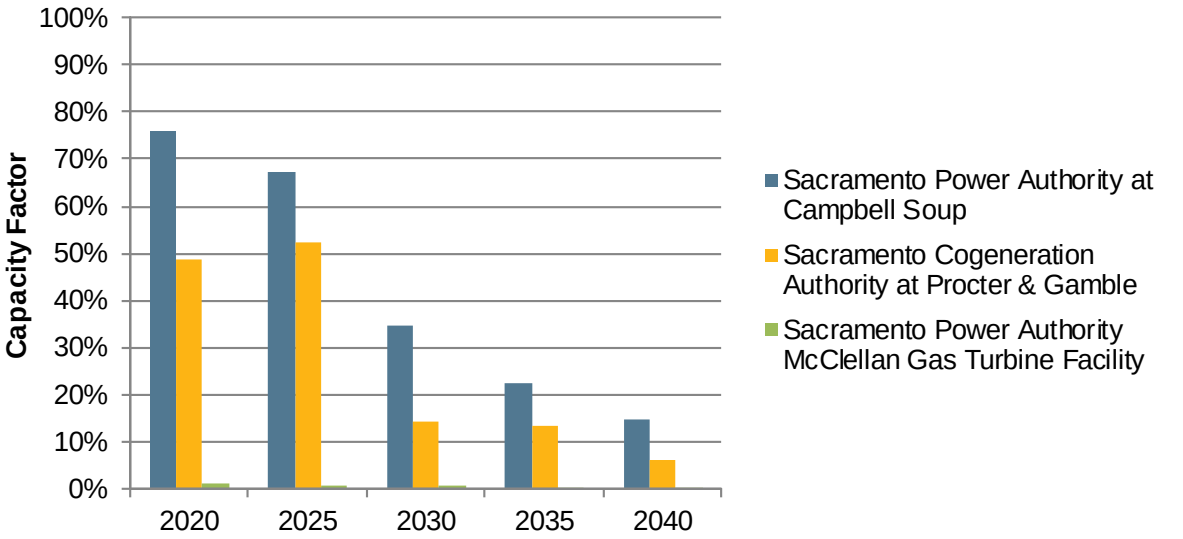
Figure 13: Disadvantaged Communities within SMUD service Territory



There are three thermal natural-gas power plants within SMUD's service territory that fall within the state's defined disadvantaged communities. [17] This analysis assumed that these plants would continue to be utilized to maintain system reliability. In all cases, reliance on these plants declines due to increased renewables and other economic factors. Consequently, criteria air pollution emissions from these plants are also expected to decline. See Figure 14 for details.

[17] Disadvantaged Communities are defined by California Environmental Protection Agency as California communities that are disproportionately burdened by, and vulnerable to, multiple sources of pollution. More information is available at : https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

Figure 14: Change in dispatch of Power Plants in SMUD's Disadvantaged Communities



SMUD currently provides incentives to low-income residential customers, including energy efficiency upgrades and discounted electricity rates. While program design was beyond the scope of this study, SMUD will continue to develop and administer programs targeting low-income customers, including initiatives needed to achieve SMUD's SD-9 goals to support sustainable communities and insure that all customers benefit from SMUD's local investments in carbon reduction.

Under each of the scenarios, funds are spent to increase building efficiency and enable electrification of vehicles and buildings. These efforts will deliver environmental and health benefits to the Sacramento region. As previously stated, building electrification can provide indoor air quality improvements. Vehicle electrification can help improve Sacramento's overall air quality, particularly in disadvantaged communities located near freeway corridors. Furthermore, it is likely that money spent on program incentives will encourage job growth/creation in the local economy. Recent studies indicate that investments in energy efficiency programs can result in 5 to 10 job-years per million dollars spent.[18] [19]

[18] A job-year is defined as one full-time job for one year.
[19] More information can be found at the following links
http://edfclimatecorps.org/sites/edfclimatecorps.org/files/the_growth_of_americas_clean_energy_and_sustainability_jobs.pdf
http://www.energy.ca.gov/2009publications/CEERT-1000-2009-022/CEERT-1000-2009-022.PDF
http://www.labormarketinfo.edd.ca.gov/contentpub/GreenDigest/CaliforniaGreenEconomy-070910.pdf
https://www.epa.gov/statelocalenergy

6.2 Risks and Uncertainties in the Decarbonization Strategy

As mentioned previously, the analysis demonstrates the relative viability of achieving a deep decarbonization future for the Sacramento region. It is important to recognize that the projections and assumptions are many years in the future with significant uncertainty. Cost assumptions could diverge substantially as technology advances or new mandates and regulations are adopted. For this reason, the findings and recommendations are intended to provide an initial roadmap for SMUD policy makers and planners.

Some examples of key assumptions that will need to be monitored closely to mitigate potential risks include:

- Renewable costs: Solar and wind costs have steadily decreased in recent years to historic lows and may increase with renewable goals for all utilities in California. These resource costs are susceptible to land value and environmental regulation. Resources such as battery storage used to balance renewables are projected to decrease significantly over the next 10 years which would allow for lower cost deployment of these valuable balancing resources when needed.
- New technology advancements: New technology will likely emerge that could make deeper decarbonization easier and less costly.
- Regulatory uncertainty: Environmental regulations in California are continually evolving as the state pushes towards its low-carbon goals. Higher than forecasted carbon prices would drive up cost and rate projections, even in low-carbon systems. RPS goals through 2030 may be revised higher than the current 50% standard and likely will be extended past 2030. Mandates to procure baseload renewables, such as biomass and geothermal, would replace assumed procurement of the lower cost renewable resources.
- Market uncertainty: Higher than forecasted increases in market prices will drive up cost and rate projections beyond those assumed and dampen the adoption of transportation and building electrification. Market value of renewables in the CAISO may decline with increasing solar penetration along with increasing charges and tariffs.
- DER program implementation: Converting the Sacramento region to electric transportation and space heating will require significant collaboration statewide and locally.
- DER costs: The cost of distributed resources will require local and state mandates and LCFS incentives to provide customers the necessary motivation to convert to electric and keep utility costs reasonable.
- Retail Sales: The timing and magnitude of future sales influenced by transportation and building electrification has the ability to offset infrastructure investments costs. However, electrification is still highly speculative and the magnitude of load increases is uncertain. Additionally, if load does not increase as expected, investment costs will be applied to a smaller sales base, magnifying the retail rate impact.

- Third-party competition for sales: The plan assumes increasing electric sales to cover growing costs of electrification. However, with new policy mandates, improving technology and expanding rooftop solar beyond those assumed in our analysis would dampen sales and could increase retail rates.
- Stranded investments: Ensure that appropriate off-ramps exist in the project review, approval, and implementation processes before significant capital outlays or commitments are made in case the project economic benefits erode, or the associated benefits are placed at risk.

SMUD will need to frequently update its IRP action plan as technology, markets, and regulations evolve. SMUD will likely need to update its SD-9 goals in the future to deliver resources at a reasonable cost and manageable risks, in order to maintain its core commitments to customers (safety, cost, reliability, and environmental stewardship).

7 Staff Recommendations

SMUD has a long history of strong environmental leadership in its resource planning and procurement activities. This includes voluntary programs, such as Greenergy and SolarShares, early renewable adoption, strong energy efficiency mandates, and existing GHG reduction goals that exceed the state's aggressive goals.

RESOLVE analysis indicates that SMUD's SD-9 goal of reducing GHG emission to 1.0 MMT by 2040, while more aggressive than the state's goals, is still achievable at a reasonable cost to customers. In 2018, average rates are estimated to be 12.8 cents per kWh and expected to increase to an estimated 13.6 cents per kWh in 2040, or 6.3% over SMUD's 2018 rates (in 2016 dollars and in real terms), under the SD-9 scenario. This assumes that, compared to SMUD's portfolio today, in an 80x50 world, SMUD will need to increase its renewable generation portfolio by 270% and invest in distribution system upgrades to allow for a significant increase in DERs. While rate impacts are shown to be relatively modest under the SD-9 scenario, the significant amount of new capacity investment necessary to achieve the 80x50 goal as depicted in Figure 7 should not be discounted. As noted above there is considerable uncertainty around the technology, market and policy environment.

In addition, if higher electricity sales fail to materialize as assumed in this analysis, average annual rates could increase more quickly than shown in this report. While it is expected that rates will increase at a moderate pace, with increased costs offset somewhat due to increases in sales, customer bills could increase at a faster pace as a result of increased sales and increased costs associated with decarbonization. Overall, Customer energy costs, including natural gas and gasoline, are anticipated to be lower, despite increases in electric bills. This is based on the significant efficiency improvements of electrification technologies compared to incumbent transportation and heating solutions. Bill impacts will depend on the pace of technology change, cost

allocation and rate design strategy over the next 20 years, all of which will be the subject of future rate proceedings and to Board consideration and approval.

The analysis also indicates that additional carbon reductions beyond the SD-9 goal appear to be feasible. Achieving a carbon goal of 350,000 MT in 2040 results in a 2040 average system rate increase of up to 11% over SMUD's 2018 rates (in real terms). Achieving a "local net zero" emissions target is also feasible with additional investment in local measures such as incremental local electrification or renewables. This analysis shows that SMUD is making significant early investments that support the transition to the State's 80x50 objectives. This not only helps the State achieve its carbon reduction goals but it also represents a significant reduction to local GHG emissions. If these emission reductions are counted to offset electric sector emissions along the SD-9 pathway, SMUD can achieve a Local Net Zero emissions target by 2040.

From a reliability perspective, maintaining a variety of options for renewable balancing, including CAISO, BPA purchases and internal SMUD resources within a large regional grid is a key to low-cost carbon reductions. Fewer balancing options will require less efficient dispatch of SMUD resources – such as running multiple thermal generators at minimum operational level and may require new, significant local investments in flexible resources. Also based on this study, staff notes that meeting load entirely with renewables, hydro and storage is prohibitively expensive with current technology and may not be reliable during long-duration adverse weather events. Retaining gas generation ensures reliability and moderates cost increases and rate impacts under all of the SD-9 scenarios, allowing SMUD to pursue lower carbon scenarios without causing undue reliability obstacles. [20]

In summary, SMUD's SD-9 goal is already more aggressive than California's economy-wide GHG reduction policy. This results in SMUD being a strong contributor to California's low-carbon energy market. SMUD's environmental leadership thus far has set the groundwork for decarbonizing the Sacramento region. Sacramento's regional GHG emissions savings modeled by PATHWAYs, as shown in Figure 4, demonstrates that SMUD, as a provider of low-carbon electricity, will be a key player in reducing GHG emissions in the building and transportation sectors. While loads are expected to increase, SMUD's portfolio emissions are expected to decline.

The current SD-9 policy is focused on decarbonizing SMUD's portfolio without considering how SMUD can enable a similar transformation of Sacramento's economy. This study has demonstrated that there are opportunities for utility action outside traditional resource procurement decisions. SMUD investments in DER-enabling technologies will lower economy-wide carbon emissions while maintaining SMUD's current approach to reducing portfolio emissions and maintaining system reliability. These investments will also have beneficial effects on jobs, the environment, and disadvantaged communities. Local reductions in emissions with electrification of

[20] Does not apply to the Absolute Zero scenario. Albeit, under the SD-9 scenarios, SMUD's utilization of gas-fired generation declines over time.

transportation and buildings can offset the SD-9 emissions remaining in SMUD's GHG footprint to achieve a Net Zero portfolio by 2040.

Based on this study and the findings presented here, SMUD staff recommends the following language be adopted and added to Strategic Direction- 9, Resource Planning:

> *It is a core value of SMUD to provide its customers with a sustainable power supply through the use of an integrated resource planning process. A sustainable power supply is defined as follows:*
>
> - *2020 GHG emissions goal: 2.318 million metric tons*
> - *2030 Power Supply GHG emissions goal: 1.65 million metric tons*
> - *2040 Power Supply GHG emissions goal: 1.0 million metric tons offset by investments to achieve Net Zero*
> - *2050 GHG emissions goal: 350,000 metric tons offset by investments to achieve Net Zero*
>
> *Beginning in 2040, SMUD will achieve a Net Zero GHG footprint. A Net Zero footprint is defined as achieving emissions reductions that offset SMUD's 2040 and 2050 GHG emissions. GHG reductions may come from vehicle and building electrification, energy efficiency, clean distributed resources, renewables, large hydro, biogas, and offsets. Local resources will have priority over regional resources while assuring reliability of the system, minimizing environmental impacts on land, habitat, water quality, and air quality, and maintaining competitive rates.*
>
> *To guide SMUD in its energy efficiency evaluation and investment, SMUD shall achieve Energy Efficiency equal to 15% of retail load over the next 10-year period. On an annual basis, SMUD will achieve energy efficiency savings of 1.5% of the average annual retail energy sales over the three-year period ending with the current year. To do this, SMUD will acquire as much cost effective and reliable energy efficiency as feasible through programs that optimize value across all customers. SMUD shall support additional energy efficiency acquisition by targeting one percent (1%) of retail revenues for above market costs associated with education, market transformation, and programs for hard to reach or higher cost customer segments. The market value of energy efficiency will include environmental attributes, local capacity value and other customer costs reduced by an efficiency measure.*
>
> *To guide SMUD in its renewable procurement, SMUD will procure renewable resources to meet 33% of SMUD's retail sales by 2020, and 50% of its retail sales by 2030, excluding additional renewable energy acquired for certain customer programs. In acquiring renewable resources, SMUD shall emphasize local and regional environmental benefits.*

7.1 Next Steps

Following Board direction on revisions to SD-9, staff will complete the development of the 2018 Integrated Resource Plan for filing with the CEC in April 2019.

SB 350 requires a statewide doubling of energy efficiency achievements by 2030, including savings resulting from utility programs as well as building codes and standards and other state energy efficiency programs. SB 350 directs the California Energy Commission to set energy efficiency targets based on a doubling of the additional achievable energy efficiency contained in the *California Energy Demand Updated Forecast, 2015-2025,*[21] extrapolated to 2030. While the CEC has provided their view of a statewide shortfall, work remains to be done on creating a fuel substitution carbon accounting mechanism.

This analysis incorporates SMUD's initial understanding of how to account for these savings, however, questions remain, and therefore staff is not recommending an update to SD-9 energy efficiency targets at this time. Implementation of the doubling goal requires a new accounting methodology that incorporates both traditional energy efficiency programs and energy efficiency resulting from building electrification. Staff will develop this methodology, along with the methodology for accounting for electrification reductions driven by SMUD investments in electrification, and recommend updates to SD-9 in the spring of 2019.

[21] Jones, Melissa, Michael Jaske, Michael Kenney, Brian Samuelson, Cynthia Rogers, Elena Giyenko, and Manjit Ahuja. 2017. Senate Bill 350: Doubling Energy Efficiency Savings by 2030. California Energy Commission. Publication Number: CEC-400-2017-010-CMF.