**Blueprint to California Energy Commission Clean Transportation Program: Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure**

# Grossmont Union High School District (GUHSD) School Bus Fleet Electrification Blueprint

## Task 4: Essential Electrification of Expanded School Bus Service

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# SECTION 1. PROJECT CONTEXT

## Project Summary

The goal of this project is to develop a blueprint for the full transition of the school bus fleet at Grossmont Union High School District (GUHSD) to a clean, affordable, and resilient electric fleet over the next 20 years. This shift to zero-emission vehicles (ZEVs) will reduce greenhouse gas (GHG) emissions in the communities GUHSD serves, improving overall air quality and eliminating students' exposure to harmful pollutants. This blueprint will also inform the District's efforts to expand bus service in underserved areas, to endorse and support innovation that helps future-proof their electric fleet, to secure financial resources for deployment, and to facilitate meaningful community-learning and workforce-development opportunities.

Notably, the process, findings, and insights from this project can be leveraged and replicated to guide school bus fleet electrification efforts by School Districts across California and across the US, thereby supporting a steady and significant adoption of electric school buses over the next few years.

## Task Goals

This report covers the activities outlined in Task 4 in the original application's Scope of Work.

**Task 4. Essential Electrification of Expanded School Bus Service:** The goal of this task is to evaluate the technical, economic, and environmental impact of extending fleet electrification to add new bus routes over the next five years, especially within disadvantaged and low-income communities. Building on Task 2, this Task determines the incremental increase in total number of electric buses and in capacity of charging and energy supply infrastructure needed to accommodate the new bus routes.

- Task 4.1. Build on the stakeholder engagement process in previous tasks to develop comprehensive understanding and secure alignment on community needs for new school bus routes, especially in disadvantaged and low-income communities. In addition to engaging decision-making and advisory stakeholders, we conduct a dedicated Community Needs Assessment (CNA).
- Task 4.2. Collect all data inputs needed to run a mobility-energy optimization for the expanded bus service, including data from Task 2 and new bus routes data, determined based on the CNA.
- Task 4.3. Rerun the techno-economic optimization analysis (used in previous Tasks) with the new bus routes.
- Task 4.4. Synthesize, document, and report on the results, findings, recommendations, and insights from the optimization analysis, with the new bus routes accounted for.

To meet these goals, this analysis aims to answer two questions:

- Whether, where, and how can GUHSD consider the expansion of bus service to better serve designated disadvantaged communities (DACs) and low-income communities (LICs)?
- What are the technical and economic specifications, as well as environmental impacts, of expanding school bus service?

To answer these questions, we utilize a 3-step approach:

- Conduct a Community Needs Assessment (CNA) to determine neighborhoods where school bus service can be expanded and prioritized. We refer to these areas as "Areas of Interest" (AOIs).
- Design new bus routes to serve the student populations within the identified AOIs.

- Analyze the new routes to determine (a) the optimal technical configuration for the buses and associated charging and energy infrastructure, and (b) the economic and environmental impact of the expanded bus service.

# SECTION 2. COMMUNITY NEEDS ASSESSMENT AND ROUTE DESIGN

## Community Needs Assessment (CNA)

A Community Needs Assessment (CNA) usually refers to a process through which government agencies, planning organizations, or non-profits seek community input and engagement on a range of topics that directly impact their daily lives, such as health, transportation, and housing needs. CNAs are typically conducted through several methods, including but not limited to desktop research, meetings with key stakeholders, and surveys with the broader community.

The CNA for this analysis addresses where the school bus transportation program can be expanded within GUHSD service jurisdiction to better empower students living in DACs and LICs. Specifically, this CNA aims to investigate the unique socioeconomic aspects of the communities served by GUHSD, identify which relevant DACs and LICs currently do not have school bus service, and explore new ways for how future bus expansion efforts may focus on communities that are most in need for service.

### Criteria

To fulfill these objectives, we identify a set of relevant criteria to include in the CNA, to determine the prospective AOIs for potential bus route expansion.

#### DACs and LICs

Students who live in DACs and LICs are the core focus of this CNA. Therefore, it is important to define and determine the DACs and LICs served by GUHSD. To align with definitions adopted by the state of California, "DAC" is defined per California Senate Bill 535 and "LIC" is defined per California Assembly Bill 1550.[1]

Based on these definitions, we map the DACs and LICs (per 2010 census tracts) within the School Attendance Boundaries[2] for GUHSD (Figure 1). As seen in Figure 1, the majority of the DACs and LICs are clustered towards the west in the GUHSD attendance boundary. For the most part, areas to the east in the GUHSD attendance boundary are not designated as DACs or LICs, except for a few rural areas around Alpine and the US-Mexico border.

#### Three School Attendance Boundaries

School bus expansion is deemed feasible at three general-education high schools. Those three schools are chosen based on the relatively high number of census tracts within each School Attendance Boundary that are designated as a DAC or LIC (Figure 1). The three schools to analyze are:

- **Mount Miguel High School**
- **Monte Vista High School**
- **El Cajon Valley High School**

Figure 2 shows each school with its School Attendance Boundary and the DACs and LICs. The analysis only considers DACs and LICs within the School Attendance Boundary for route expansion (except for one additional route considered for El Cajon Valley; see text below for details).

[1] https://webmaps.arb.ca.gov/PriorityPopulations/

[2] The School Attendance Boundary is the boundary around each of the nine public high schools operated by GUHSD, which determines where students will attend school based on their location of residence. The School Attendance Boundary is defined per the demarcations publicly available online by GUHSD.

**School Bus Service Radii**

In addition to the School Attendance Boundary, school transportation services have been historically designed based on specific guidelines regarding the distance between the serviced communities and the school campus. Currently, GUHSD Board Policy 3541[3] states that all students must live at least three miles from their school to be eligible for bus service. This rule is meant to prioritize bus service to students who live farthest from school. However, in order to maximize access by DACs and LICs, we examine lowering this 3-mile-minimum threshold to as low as 1 mile. Therefore, the analysis focuses on areas between 1 and 3 miles of each school. We refer to the 1-mile, 2-mile, and 3-mile boundaries as School Bus Service Radii.

- No service expansion is considered within the 1-mile Radius since those areas are deemed relatively close to the school campus.
- No service expansion is considered outside of the 3-mile Radius since those areas are already allowed service under GUHSD's current school bus service policy.
- We examine separately the areas between the 1-2-mile Radii, and between the 2-3-mile Radii, in order to ensure granular analysis of route design in those areas.

Figure 3 shows the 1-, 2-, and 3-mile "School Bus Service Radii," using Mount Miguel as an example. As seen in the figure, the area within 1 mile and past 3 miles is not considered for the bus route analysis.

**Areas of Interest (AOIs)**

Overlaying the above three considerations – DACs and LICs; School Attendance Boundaries; and School Bus Service Radii – creates distinct AOIs to consider for potential expansion of school bus service. In that sense, AOIs are defined geographical areas that meet the following three requirements:

- They are designated as a DAC or LIC census tract (partially or fully).
- They are within the School Attendance Boundary of one of the three identified schools.
- They are within the 1-3-mile School Bus Service Radii of one of the three identified schools.

For each school, AOIs are counted separately in both the 1-2-mile School Bus Service Radii and the 2-3-mile School Bus Service Radii, to provide more details on their proximity to the schools. Figures 4 – 6 show the maps created with the three overlays and counted AOIs for each school.

## Approach and Process

The CNA analysis is conducted through close collaboration between GUHSD and ENGIE Impact teams, with various input from other external stakeholders and partners on this project, such as the San Diego Workforce Partnership. In addition, we use geospatial software tools to map the various overlays and produce precise AOIs.

## Results

In general, the CNA provides three key findings:

- Each School Attendance Boundary contains LICs, but none contain DACs. Therefore, all the AOIs for all three schools are anchored to LICs.
- The majority of the AOIs are in the School Bus Service 1-2-mile radii. Across all three schools,

[3] https://www.guhsd.net/Departments/Business-Services/Transportation/Routes/index.html#:~:text=GUHSD%20Board%20Policy%203541%20states

21 of the 32 AOIs are within 1-2 miles of the schools and the remaining 11 are within 2-3 miles of the schools. New bus routes would cover the most AOIs if they expand service in the 1-2-mile radii, not just the 2-3-mile radii.

- Mount Miguel has the most AOIs (17), followed by Monte Vista (10) and El Cajon Valley (5).

Mount Miguel High School (Figure 4 & Table 1)

- Mount Miguel has the most AOIs, accounting for 17 of the total 32.
- The CNA indicates multiple locations to expand school bus service, with the largest number of AOIs (12) clustered north and northwest of the school, both in the 1-2-mile (4 AOIs) and 2-3-mile (8 AOIs) School Bus Service Radii.

*Table 1: AOIs for Mount Miguel High School, per DAC and LIC Census Tract Designation*

| Distance from School | DAC Census Tracts | LIC Census Tracts |
|---|---|---|
| 1-2 miles | 0 | 9 |
| 2-3 miles | 0 | 8 |
| **1-3 miles** | **0** | **17** |

Monte Vista High School (Figure 5 & Table 2)

- Monte Vista has 10 AOIs. Most of the AOIs are 1-2 miles west or east of the school.
- Most of the areas within the far north and south of the School Attendance Boundary are not AOIs, since they are not designated as DAC or LIC.

*Table 2: AOIs for Monte Vista High School, per DAC and LIC Census Tract Designation*

| Distance from School | DAC Census Tracts | LIC Census Tracts |
|---|---|---|
| 1-2 miles | 0 | 7 |
| 2-3 miles | 0 | 3 |
| **1-3 miles** | **0** | **10** |

El Cajon Valley High School (Figure 6 & Table 3)

- El Cajon has 5 AOIs, with the largest located to the north of the school, just outside of the 1-mile School Bus Service Radius. Many of the designated LICs within the School Attendance Boundary are within 1 mile of the school and are therefore excluded from the analysis.
- The small size of El Cajon Valley's School Attendance Boundary (relative to the other public schools within GUHSD) limits the AOIs to expand bus service. The area within 1-3 miles of El Cajon Valley includes many communities designated as both DAC and/or LIC, however the majority of those communities lay outside of the School Attendance Boundary (see Figure 6).
  - Given the large number of DACs and LICs that lay just outside the School Attendance Boundary, we provide an additional route design that serves all AOIs within the 1-3-mile School Bus Service Radii, regardless of the School Attendance Boundary (see the below section for more details on this route).

*Table 3: AOIs for El Cajon Valley High School, per DAC and LIC Census Tract Designation*

| Distance from School | DAC Census Tracts | LIC Census Tracts |
|---|---|---|
| 1-2 miles | 0 | 5 |
| 2-3 miles | 0 | 0 |
| **1-3 miles** | **0** | **5** |

## Route Design

Routes are designed to serve the AOIs identified in the CNA. To determine the route specifics, the analysis follows the steps described below. Since route design has to bake in several tangible and intangible considerations related to community needs and constraints, we take a conservative approach to maximize student coverage and minimize travel time.

### Determining the number of new routes

This analysis determines that GUHSD can accommodate up to four new transportation routes, each associated with one school bus that can theoretically fit within spare parking capacity at the newly constructed fleet depot.

Our analysis produces seven alternative bus routes, not just four. These alternative routes provide additional flexibility for GUHSD to determine which routes best fit future operational and economic constraints, but we do not propose that all seven routes be implemented together.

### Designing the routes

The route analysis creates two sets of routes for two potential service areas for each school.

- One set of routes covers AOIs in the 2-3-mile zone from the school.
- One set of routes covers AOIs in the 1-3-mile zone from the school.
- For El Cajon Valley, no part of the School Attendance Boundary is two miles or farther from the school, and thus there are no valid AOIs for bus service in the 2-3-mile School Bus Service Radii. However, many students that attend El Cajon Valley reside outside of the School Attendance Boundary in DACs and LICs (see Figure 15). Since this analysis is dedicated to better serve students from DACs and LICs, a special additional route is created for El Cajon Valley. This additional route provides service to students in DACs and LICs within a 1-3-mile radius of the school, without regard to the School Attendance Boundary.

Each route adheres to the following:

- Each route travels within 0.25 miles from students living in applicable AOIs.
  - The 0.25-mile demarcation is measured as direct distance from the bus route. Actual walking distance might be longer than the direct distance measurement, but the approach remains valid; 0.25 miles is much shorter than the common maximum walking distance of 1 mile (or more) usually adopted by school districts.[4, 5]
- Buses only drive on roads that have suitable space for turning.
- Once the routes' configurations are determined, we calculate the mileage and time.
  - Mileage and timing are calculated for the entire round trip from/to the depot: depot to AOIs; AOIs to school campus; and school campus back to depot.
    - Instead of having full new routes, the AOIs-to-school-campus segment can be added to existing bus routes in the future, if GUHSD determines this useful.
  - Buses complete the AOI-to-school-campus segment within 90 minutes maximum duration, from the time the first student is picked up to the time the bus drops off all

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4 http://guide.saferoutesinfo.org/school_bus_locations/determining_school_bus_stop_locations.cfm#:~:text=Many%20school%20districts,one-half%20miles

5 https://www.vcsedu.org/sites/default/files/department-files/Student%20Transportation/FREQUENTLY%20ASKED%20QUESTIONS_Parents.pdf

students at the school campus. Time includes estimates for moderate traffic, but it does not account for dwell time to pick-up/alight students. By accounting for this idling time, the maximum trip duration should likely be less than 2 hours.

- AM and PM routes are the mirror opposite of each other. In the AM, buses travel from the depot, to pick up students, to the school campus, to the depot. In the PM, buses travel in the opposite direction.

### Results

The seven routes resulting from this analysis represent a range of potential options for GUHSD to consider in future route planning, but they are not intended to be implemented all together. These routes are listed in Table 4 and described in more detail in the subsections below.

*Table 4: The Seven Alternative Route Designs, per High School*

| Mount Miguel | Monte Vista | El Cajon Valley |
|---|---|---|
| 2-3-Mile Route | 2-3-Mile Route | 1-3-Mile Route |
| 1-3-Mile Route 1 (North) | 1-3-Mile Route | 1-3-Mile Route Extended |
| 1-3-Mile Route 2 (South) | | |

<u>Mount Miguel High School</u>

- 2-3-Mile Route (Figure 7): The route starts north of the school near La Mesa, and then travels southwest through the AOIs to the neighborhoods around Chollas Reservoir.
- 1-3-Mile Route 1 (Figure 8): This route follows the same path as the 2-3-mile route to serve the AOIs, and then continues to cover the neighborhoods in Lemon Grove that are 1-2 miles from the school.
- 1-3-Mile Route 2 (Figure 8): This route covers the AOIs south and southwest of the school (all of which are 1-2 miles from the school). The route starts in La Presa, serves the AOIs on both sides of State Route 125, and then travels to the school via the AOIs east of Imperial Avenue.

*Table 5: Mount Miguel High School Bus Route Mileage and Timings*

| | | 2-3-Mile Route | 1-3-Mile Route 1 | 1-3-Mile Route 2 |
|---|---|---|---|---|
| Depot to AOIs | Miles | 2.3 | 2.3 | 8.9 |
| | Minutes | 7 | 7 | 22 |
| AOIs to School Campus | Miles | 16.5 | 19.5 | 9 |
| | Minutes | 61 | 76 | 27 |
| School Campus to Depot | Miles | 6.2 | 6.2 | 6.2 |
| | Minutes | 15 | 15 | 15 |
| Total roundtrip (Depot-AOIs-School-Depot) | Miles | 25 | 28 | 24.1 |
| | Minutes | 83 | 98 | 64 |

*Routes segments depicted in Figures 7 and 8 are highlighted in green.*

<u>Monte Vista High School</u>

- 2-3-Mile Route (Figure 10): This route is relatively short since only three small AOIs are within 2-3-miles of the school. The route starts approximately two miles west of the school, then heads south to serve the AOIs near/in La Presa, and then travels to the school.
- 1-3-Mile Route (Figure 11): This route includes the service provided by the 2-3-mile route, but it

continues through Spring Valley and provides two loops to serve students that live south and southeast of the school.

*Table 6: Monte Vista High School Bus Route Mileage and Timings*

| | | 2-3-Mile Route | 1-3-Mile Route |
|---|---|---|---|
| Depot to AOIs | Miles | 4.2 | 4.1 |
| | Minutes | 15 | 14 |
| AOIs to School Campus | Miles | 8.8 | 16.1 |
| | Minutes | 28 | 47 |
| School Campus to Depot | Miles | 6.5 | 6.5 |
| | Minutes | 14 | 14 |
| Total roundtrip (Depot-AOIs-School-Depot) | Miles | 19.5 | 26.7 |
| | Minutes | 57 | 75 |

*Routes segments depicted in Figures 10 and 11 are highlighted in green.*

<u>El Cajon Valley High School</u>

- 1-3-Mile Route (Figure 13): This route starts service at the northwest corner of the School Attendance Boundary, then serves the communities of Bostonia, the AOIs near the southeast corner of the School Attendance Boundary, and finally travels to the school.
- 1-3-Mile Route Extended (Figure 14): This route covers all AOIs within 1-3 miles of the school. The route starts due west of the school, and then generally travels clockwise to cover neighborhoods north of the school and counterclockwise to cover neighborhoods south of the school. The route includes three major deviations to cover AOIs that extend out to the 3-mile School Bus Service Radius (around Gillespie Field, Winter Gardens, and Granite Hills).
    - The trip duration on this route is estimated at 142 minutes, which exceeds the 90-minute goal. This extended route is designed conservatively to provide maximum coverage for AOIs within 1-3 miles of the school; it is intended as a planning tool to demonstrate all the potential areas to expand service. In practice, GUHSD staff in future planning efforts may reduce this route or divide it into multiple new routes to ensure distance and mileage are operationally feasible.

*Table 7: El Cajon Valley High School Bus Route Mileage and Timings*

| | | 1-3-Mile Route | 1-3-Mile Route Extended* |
|---|---|---|---|
| Depot to AOIs | Miles | 4.5 | 1.8 |
| | Minutes | 12 | 5 |
| AOIs to School Campus | Miles | 8.2 | 43.8 |
| | Minutes | 28 | 142 |
| School Campus to Depot | Miles | 4.2 | 4.2 |
| | Minutes | 12 | 12 |
| Total roundtrip (Depot-AOIs-School-Depot) | Miles | 16.9 | 49.8 |
| | Minutes | 52 | 159 |

*Routes segments depicted in Figures 13 and 14 are highlighted in green.*

**This extended route design is shown as one route for demonstration purposes, however, in practice this route may need to be reduced or divided into multiple routes to ensure timing and mileage are operationally favorable.*

### Further Expansion of Service Based on Student Residential Locations

For each school, some of its students live in DACs or LICs but outside the School Attendance Boundary, rendering them currently ineligible for bus service.

- Figures 9, 12, and 15 show the residential locations of students for each school. These maps illustrate some areas where students at a particular school live outside the Attendance Boundary of that school.
- Based on the route design methodology, these students are not covered by the proposed routes (except for the expanded route for El Cajon Valley, as described above). This may leave a gap in service coverage for some students in DACs and LICs within 1-3 miles from school campus.
- Moving forward, we recommend that future planning consider the tradeoffs associated with expanding routes to reach these additional student populations in DACs and LICs.

*Figure 1: DACs and LICs within GUHSD Service Boundary*

*(Sources: [GUHSD Attendance Boundary Map](), [CARB Priority Populations Map]())*

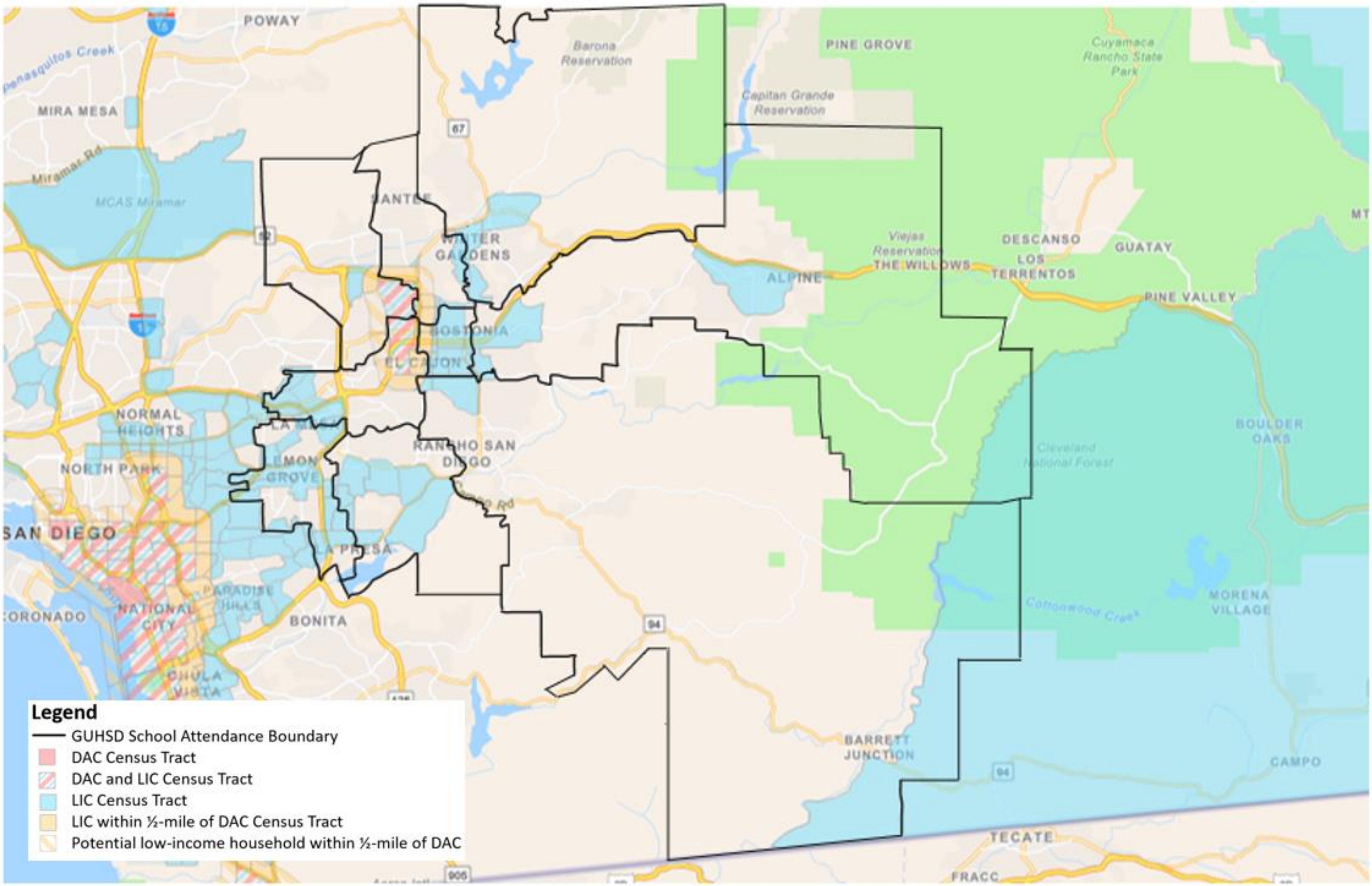


*Figure 2: School Attendance Boundary and DACs and LICs for Mount Miguel, Monte Vista, and El Cajon Valley High Schools*

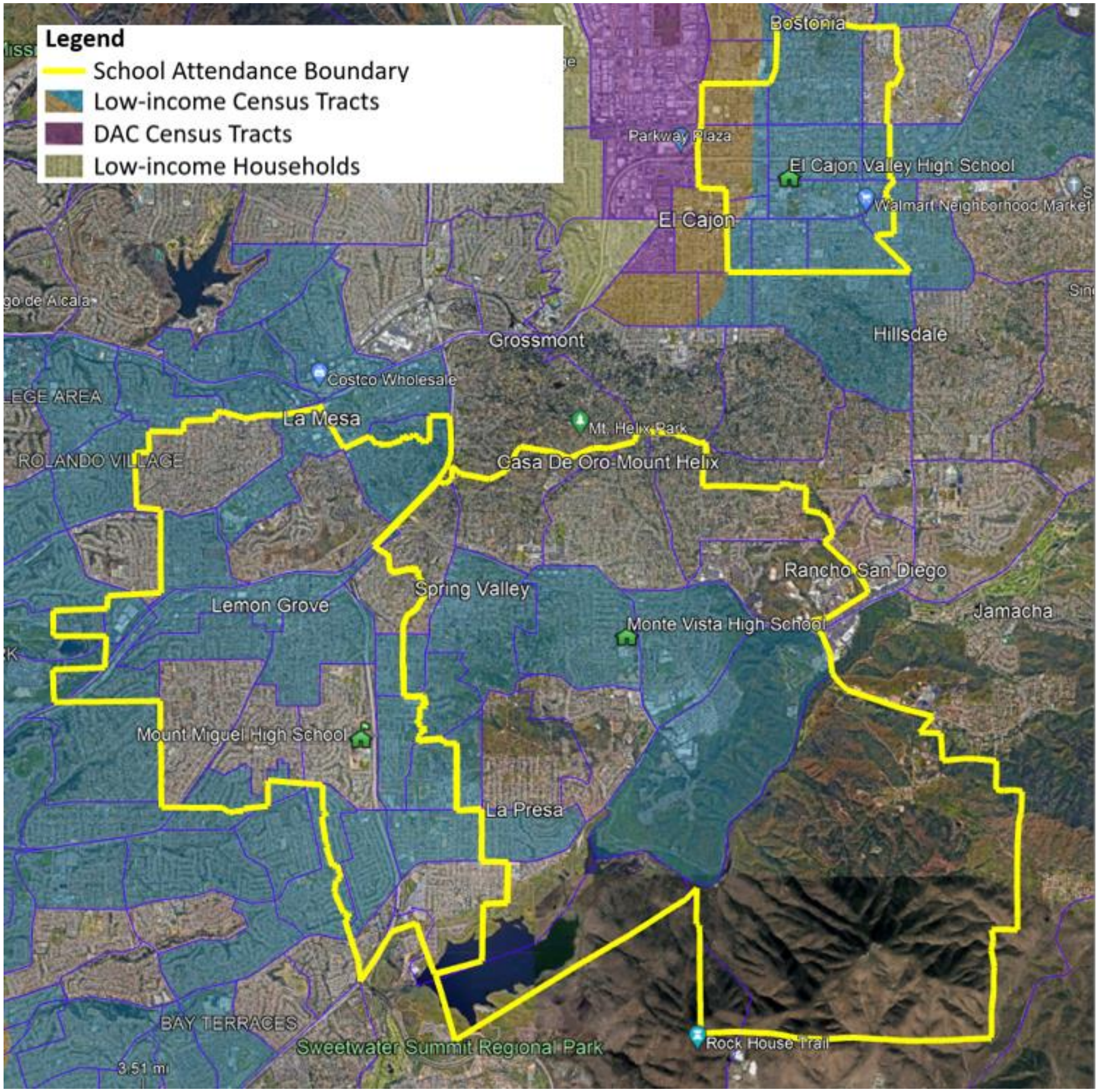


*Figure 3: 1-, 2-, and 3-mile School Bus Service Radii Overlayed with School Attendance Boundary and LIC Census Tracts (Example from Mount Miguel)*

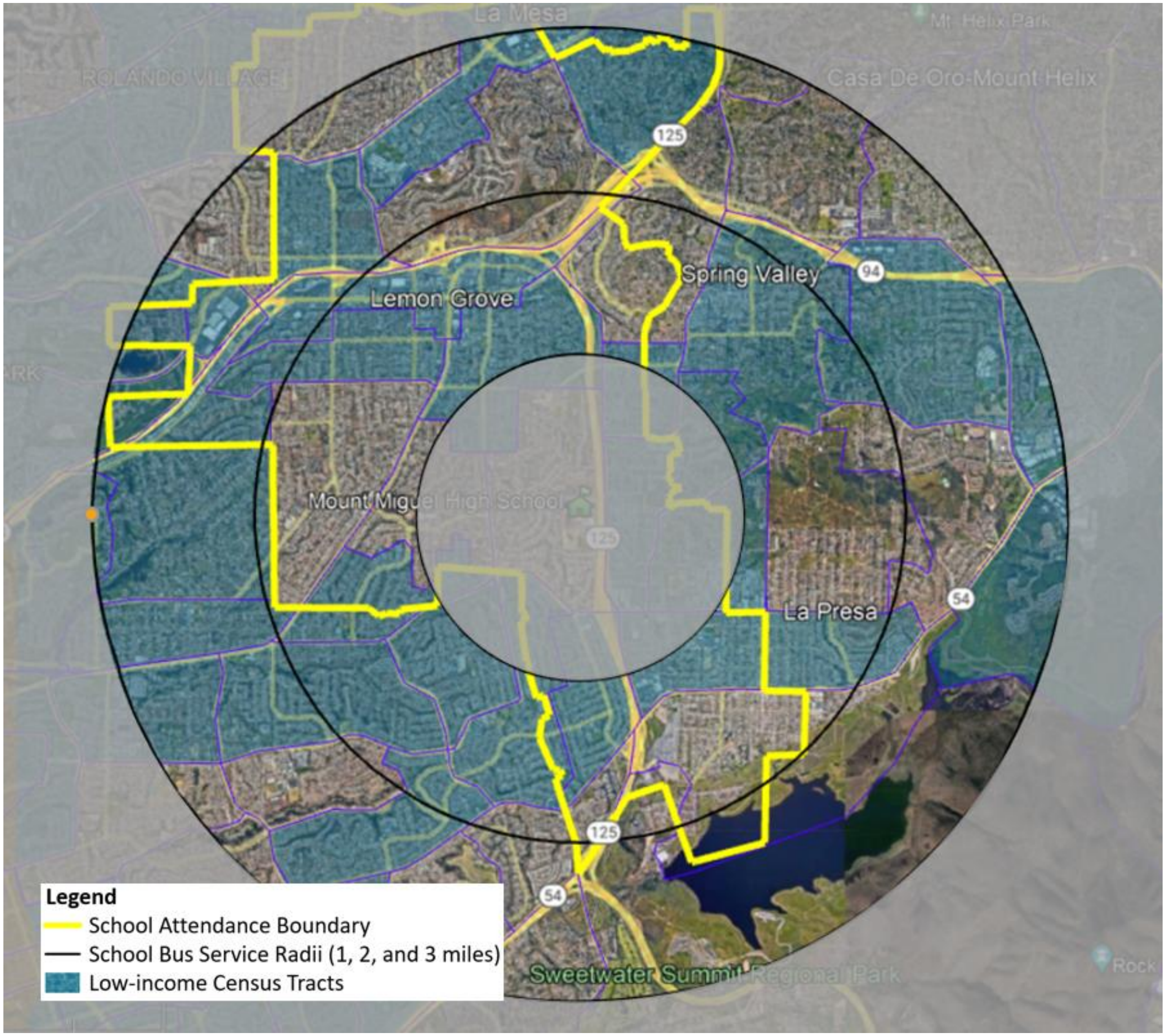


*Figure 4: CNA Map for Mount Miguel High School*

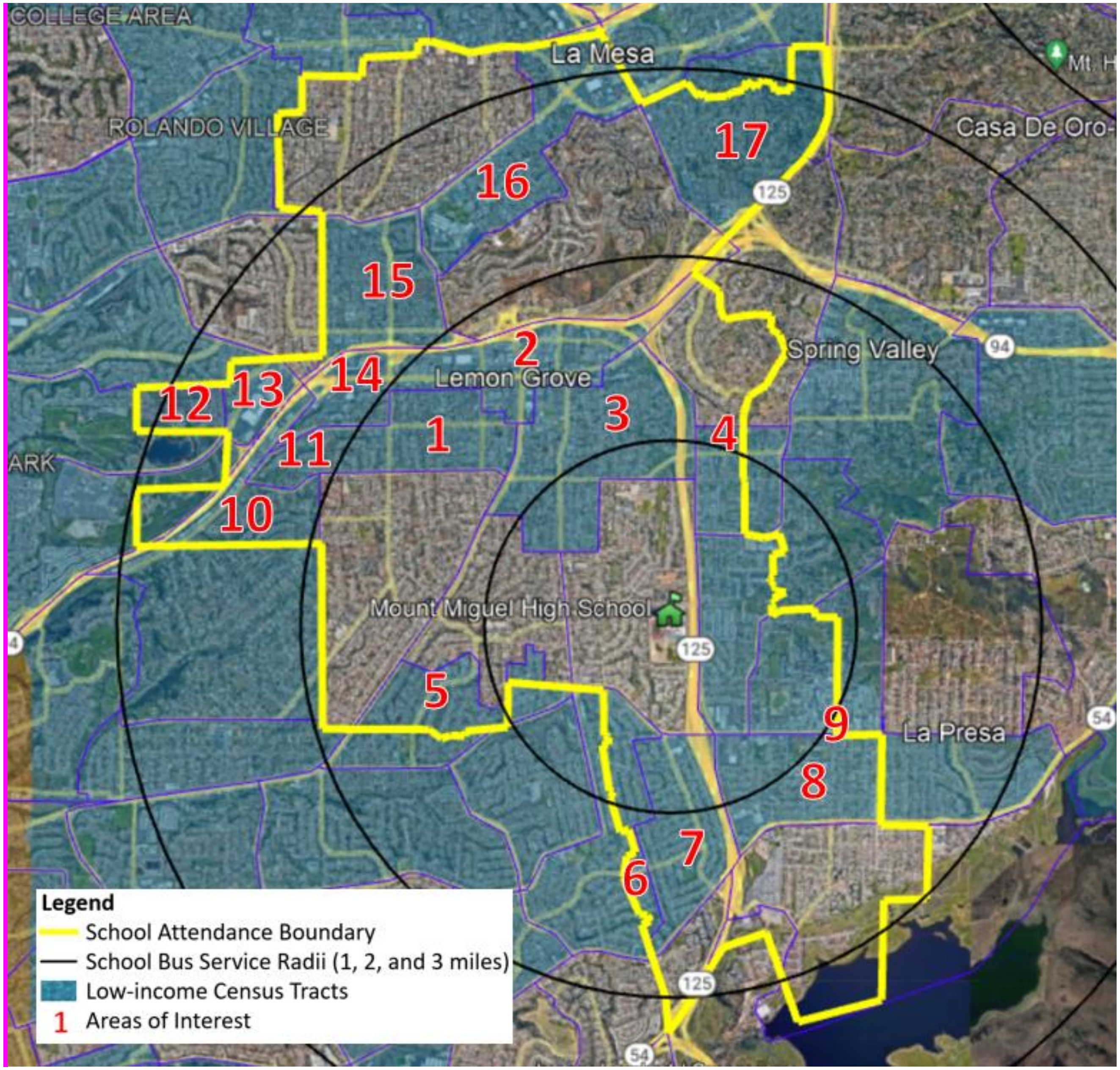


*Figure 5: CNA Map for Monte Vista High School*

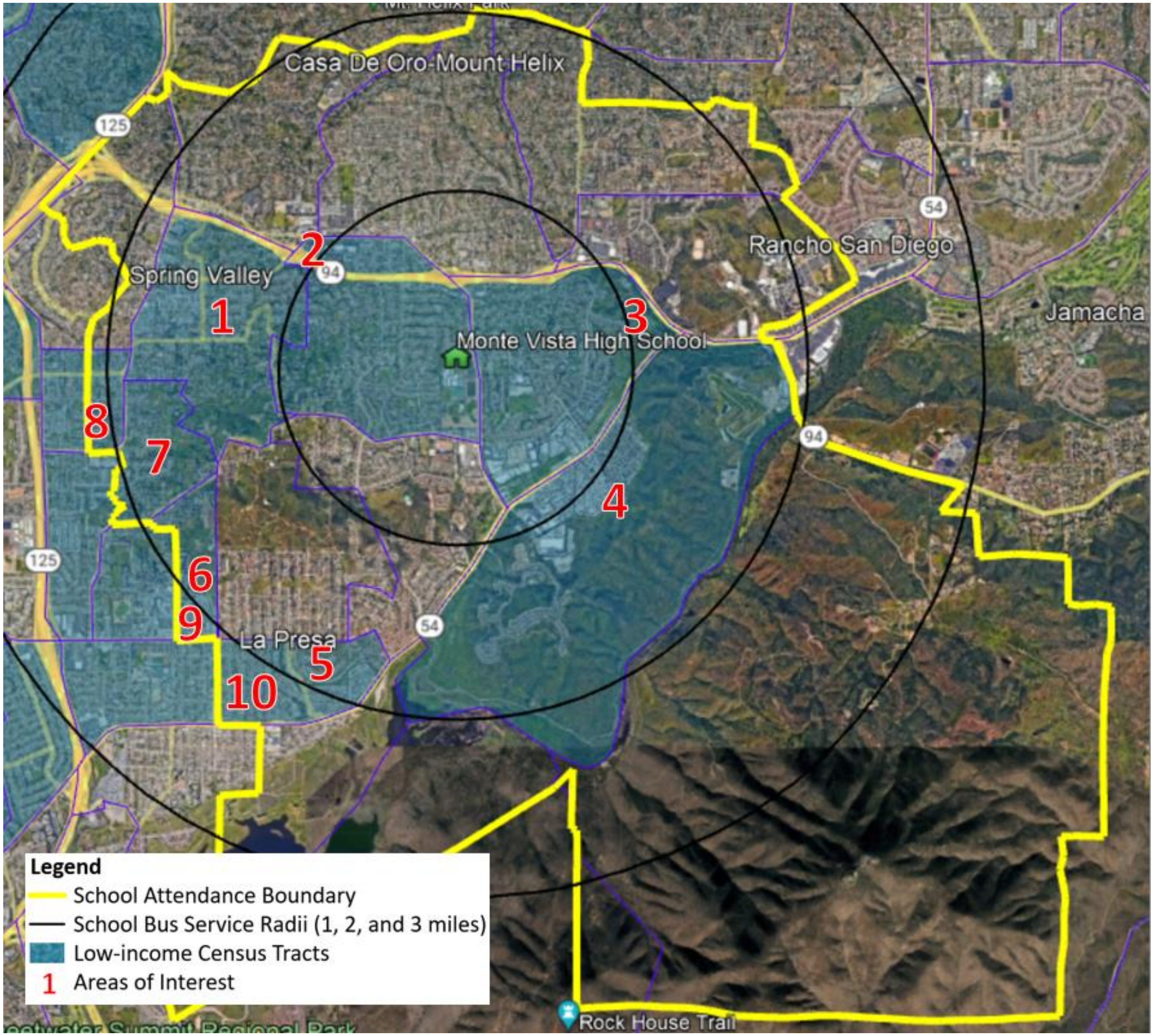


*Figure 6: CNA Map for El Cajon Valley High School*

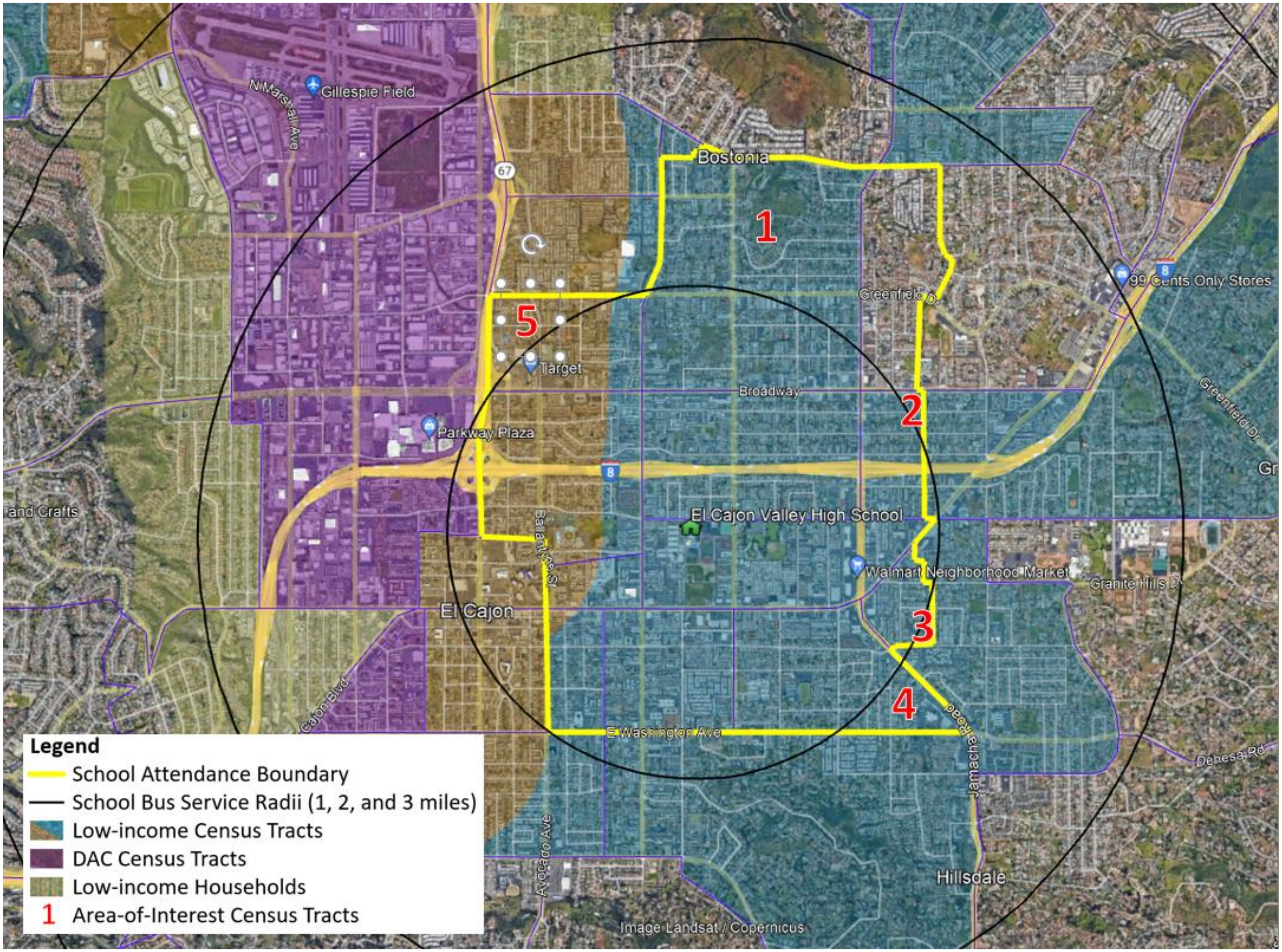


*Figure 7: 2-3-Mile Bus Route for Mount Miguel High School*

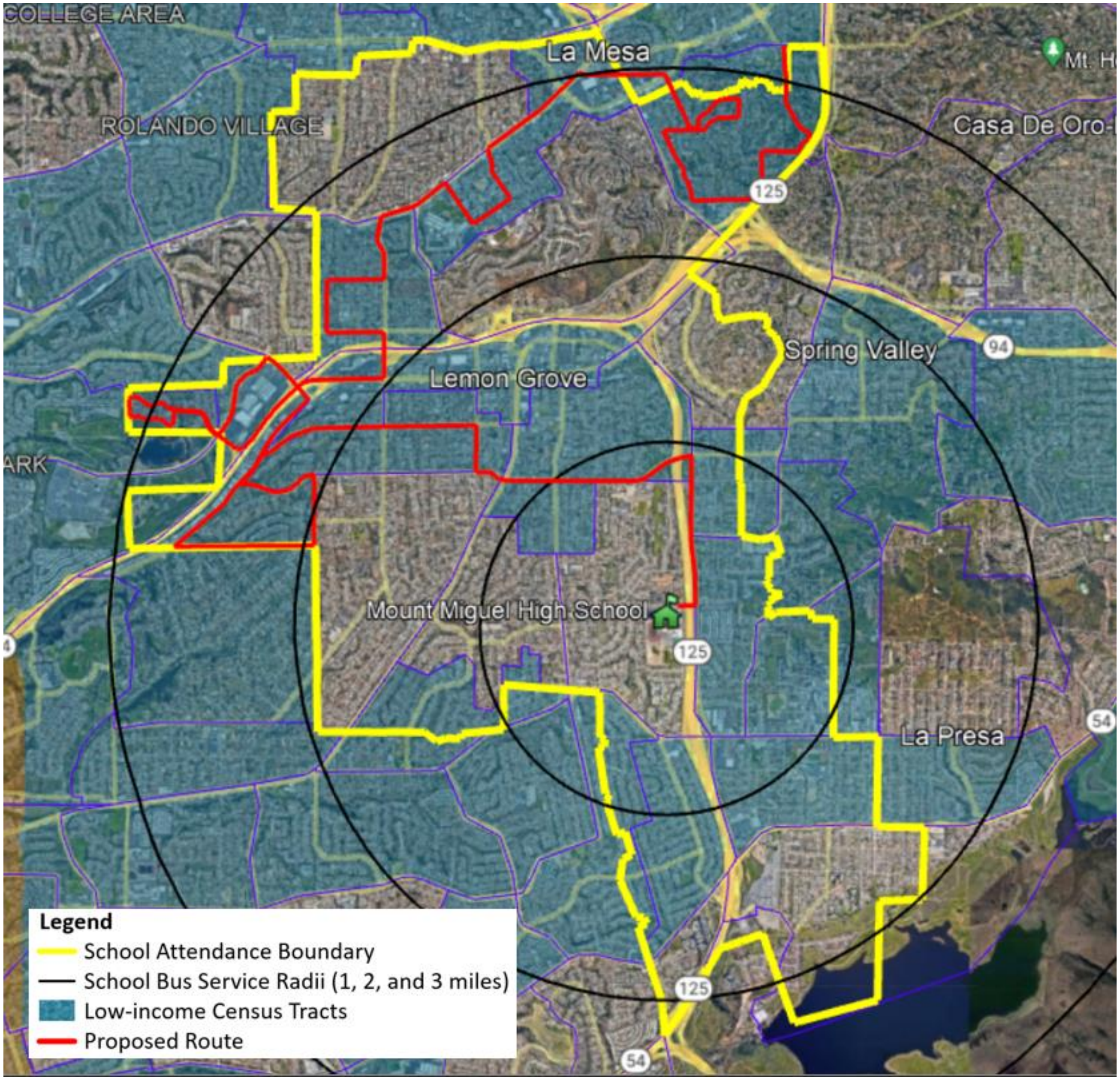


*Figure 8: 1-3-Mile Bus Routes for Mount Miguel High School*

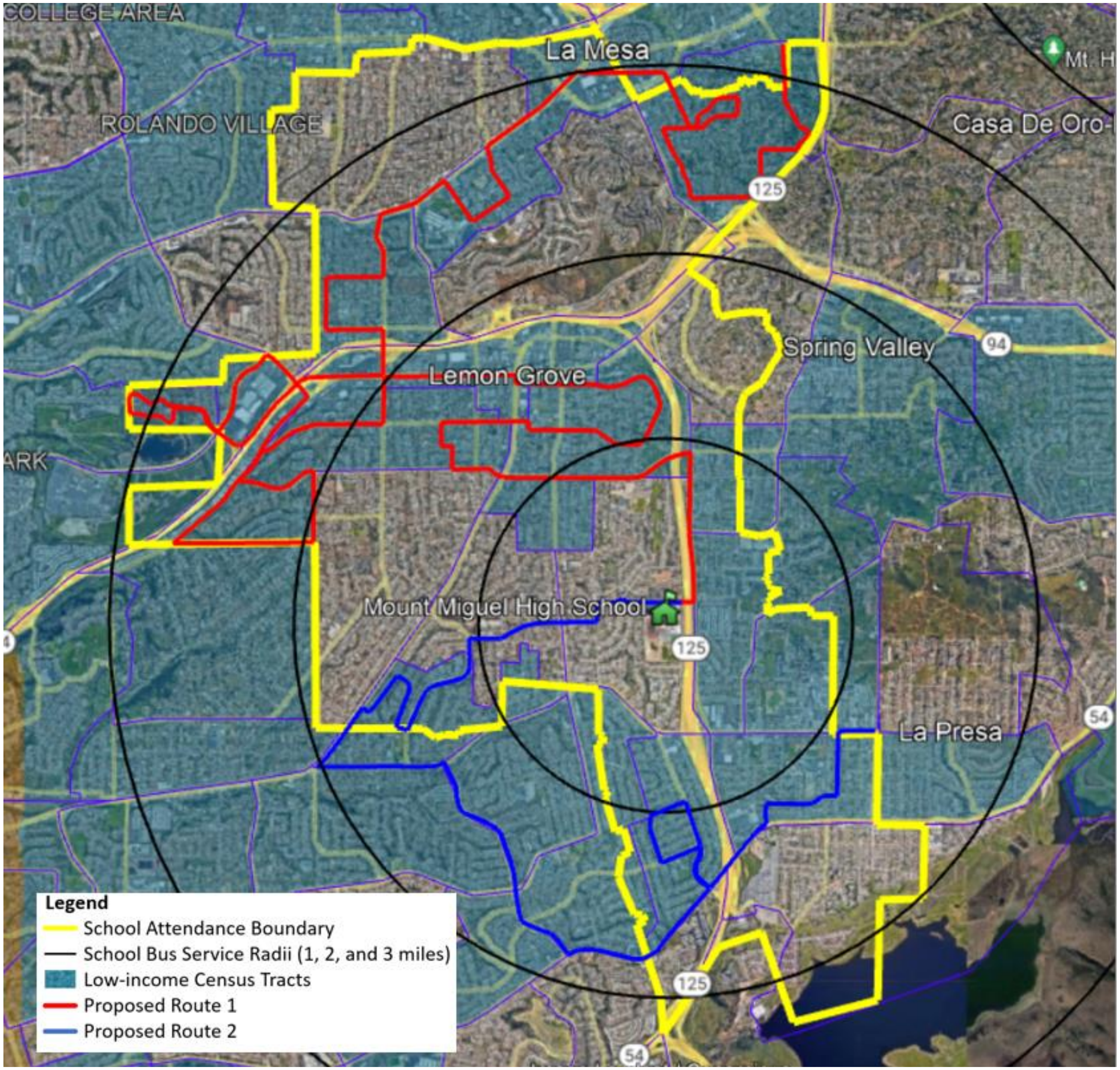


*Figure 9: Student Residential Locations and 1-3-Mile Bus Routes for Mount Miguel High School*

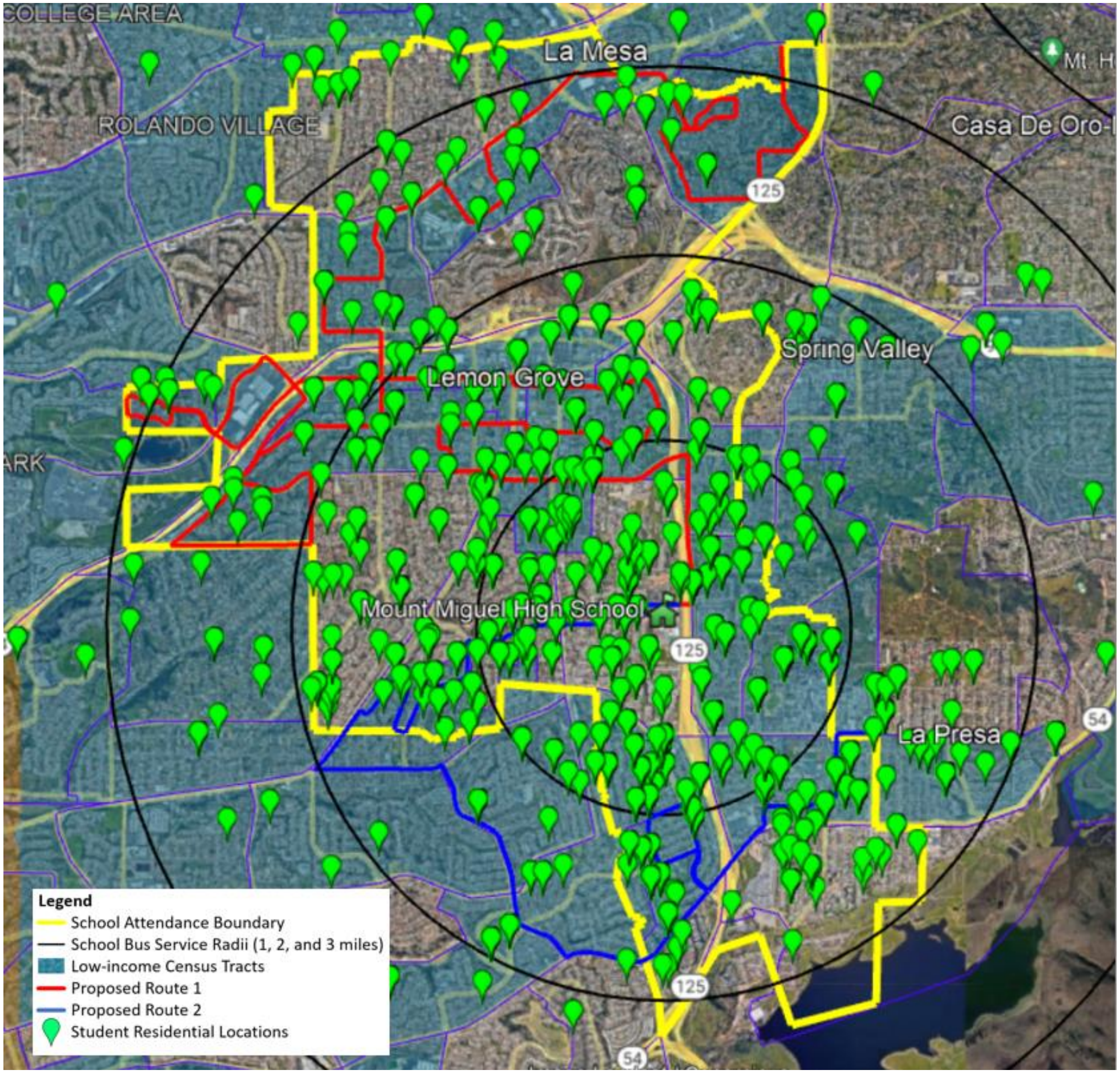


*Figure 10: 2-3-Mile Bus Route for Monte Vista High School*

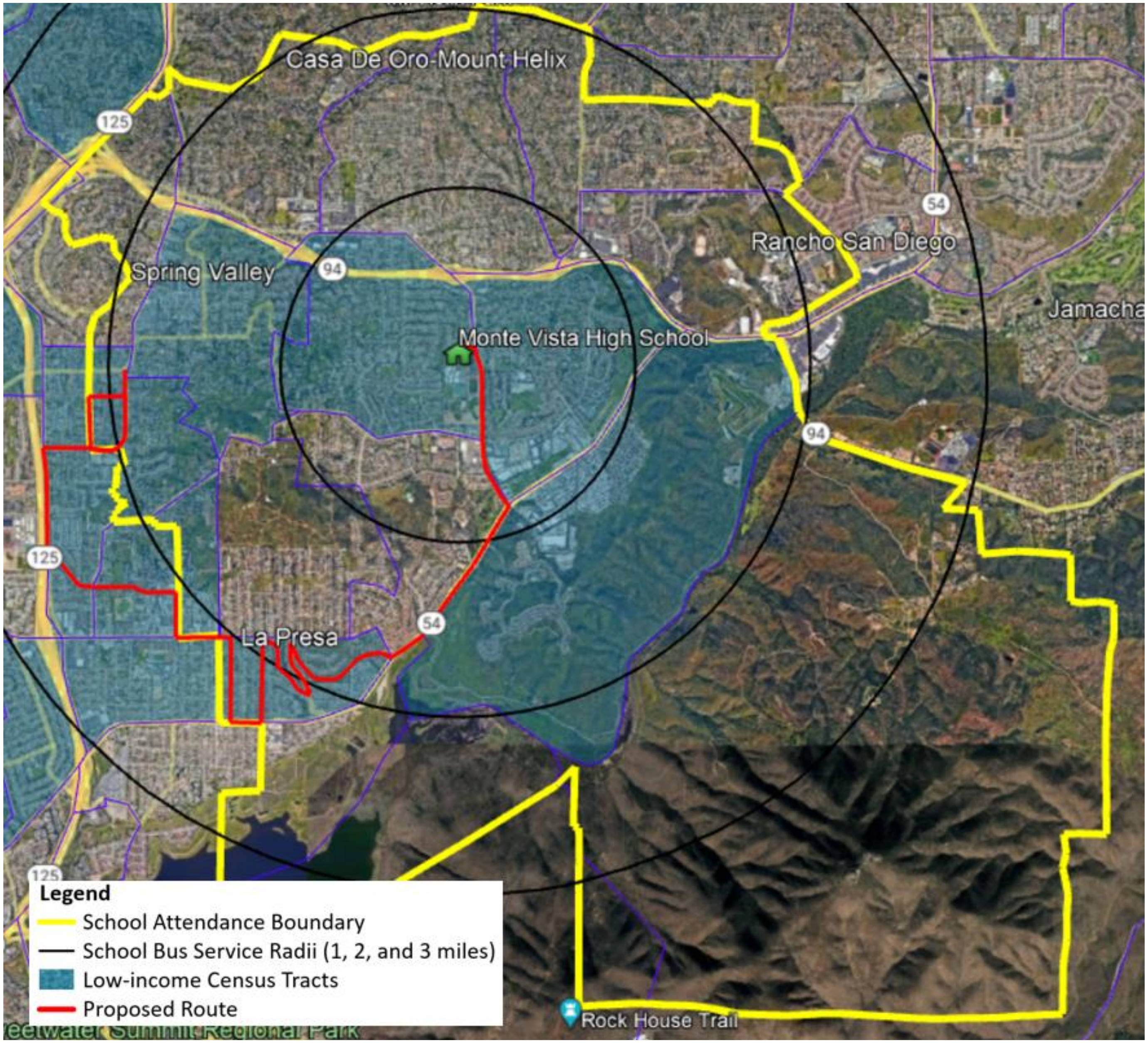


*Figure 11: 1-3-Mile Bus Route for Monte Vista High School*

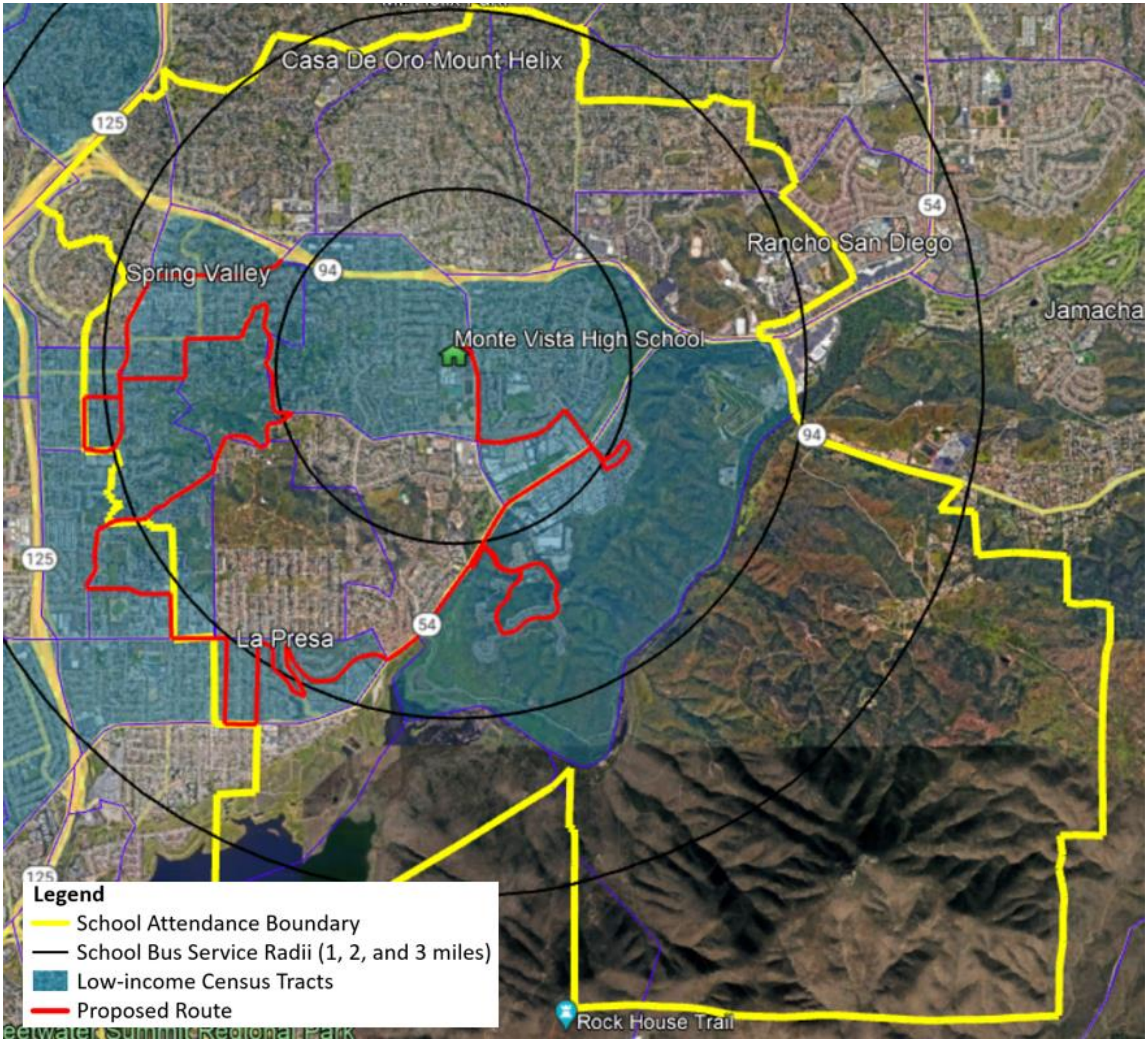


*Figure 12: Student Residential Locations and 1-3-Mile Bus Route for Monte Vista High School*

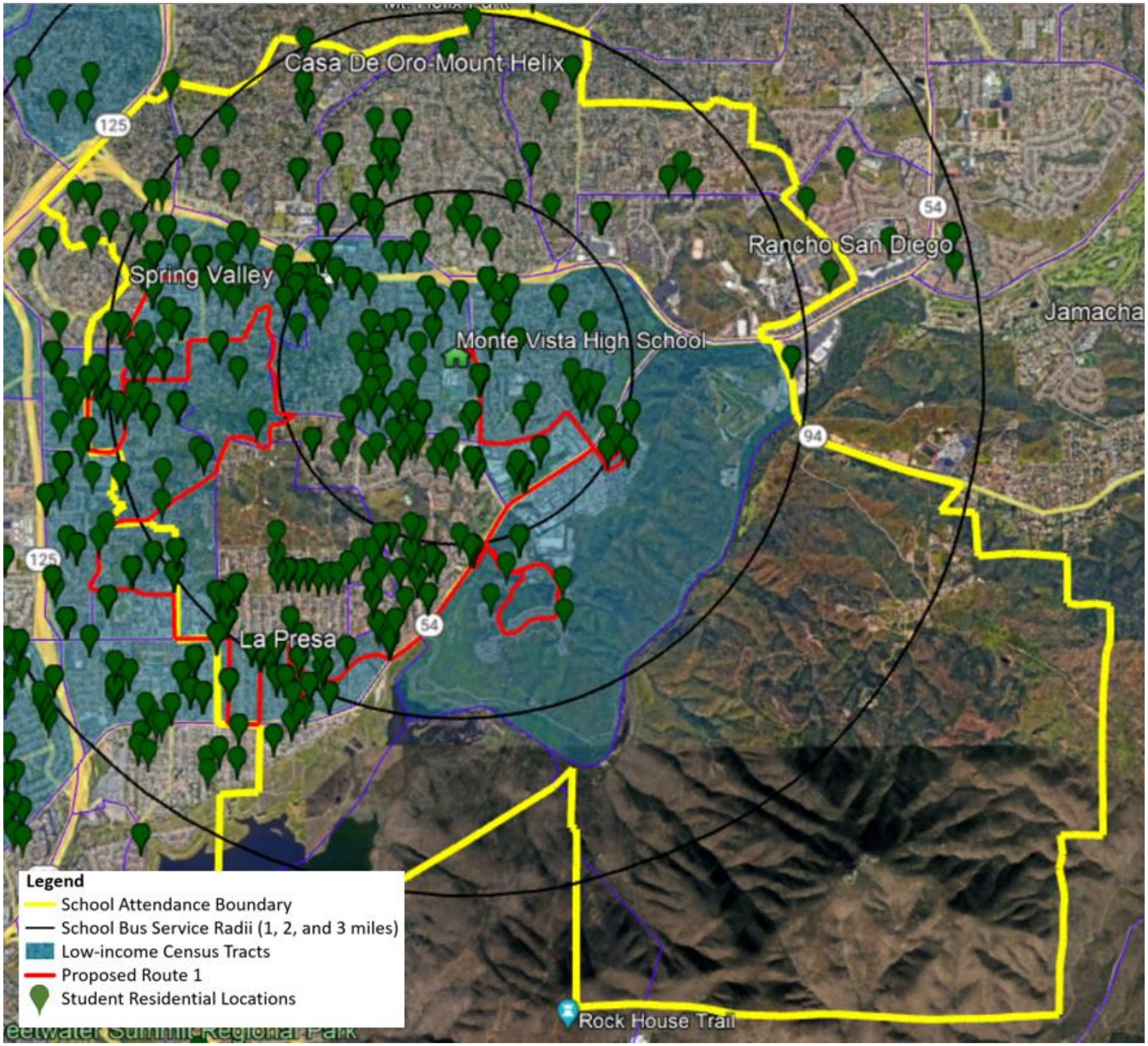


*Figure 13: 1-3-Mile Bus Route for El Cajon Valley High School*

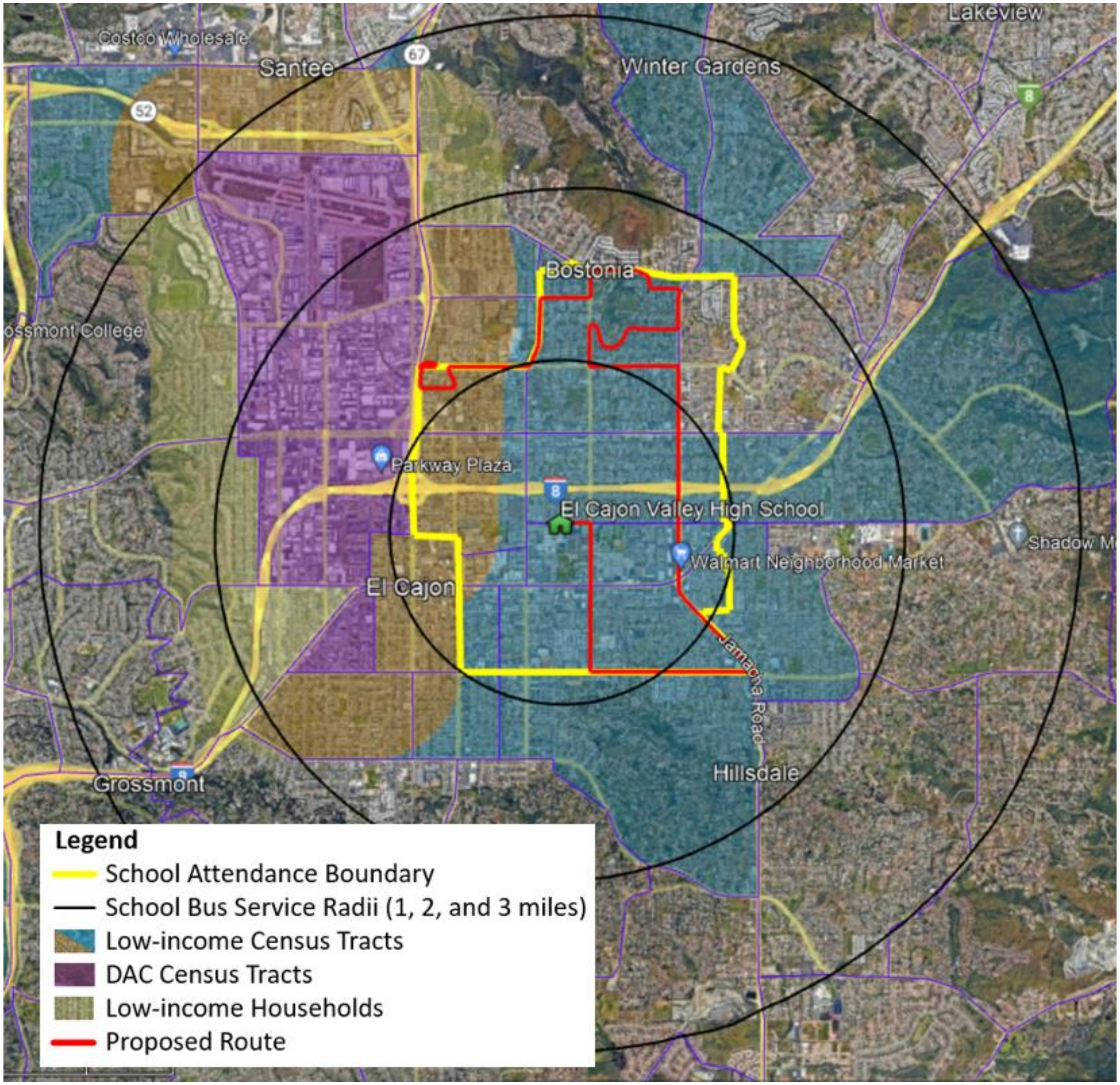


*Figure 14: 1-3-Mile Extended Bus Route for El Cajon Valley High School*

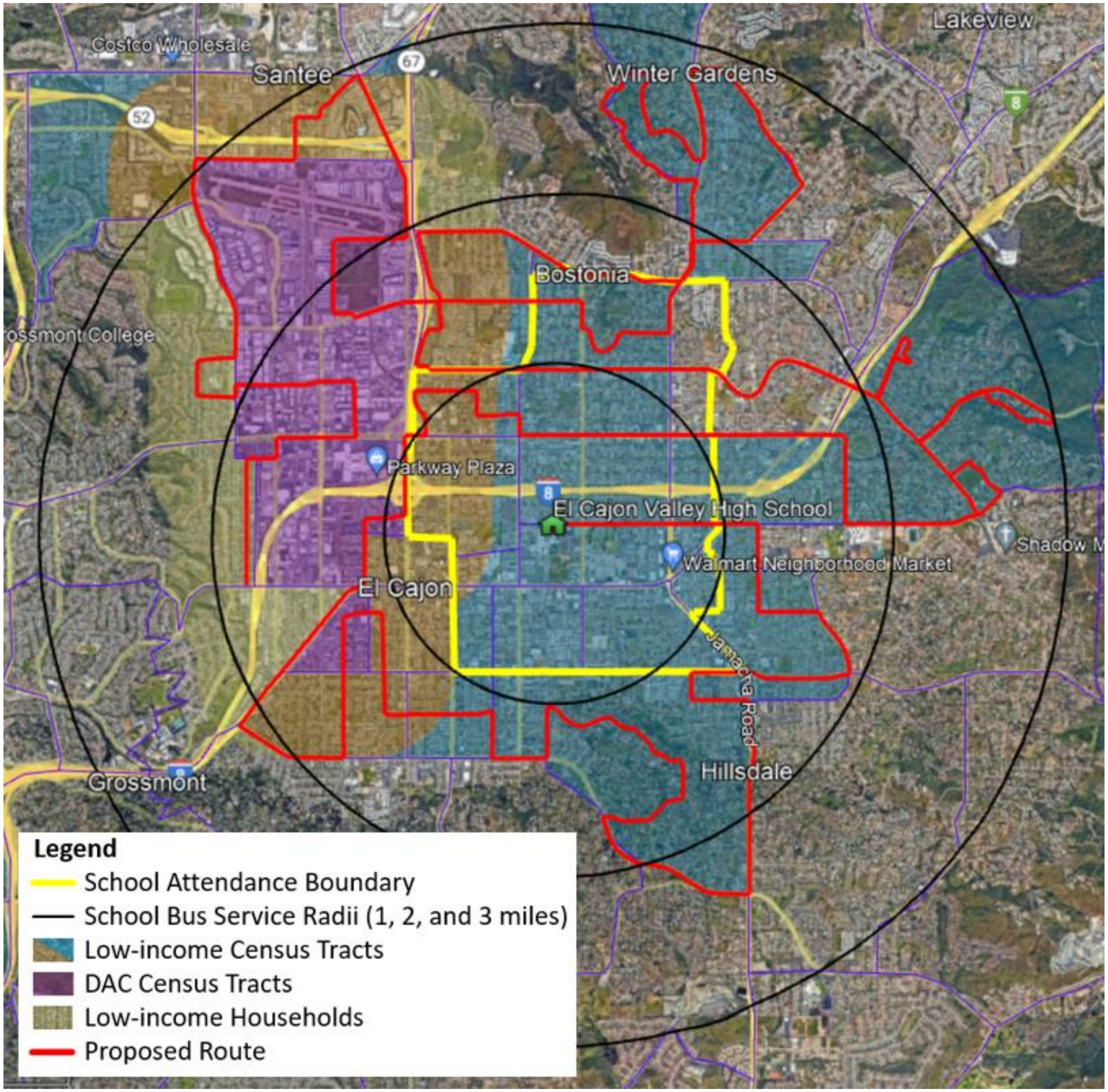
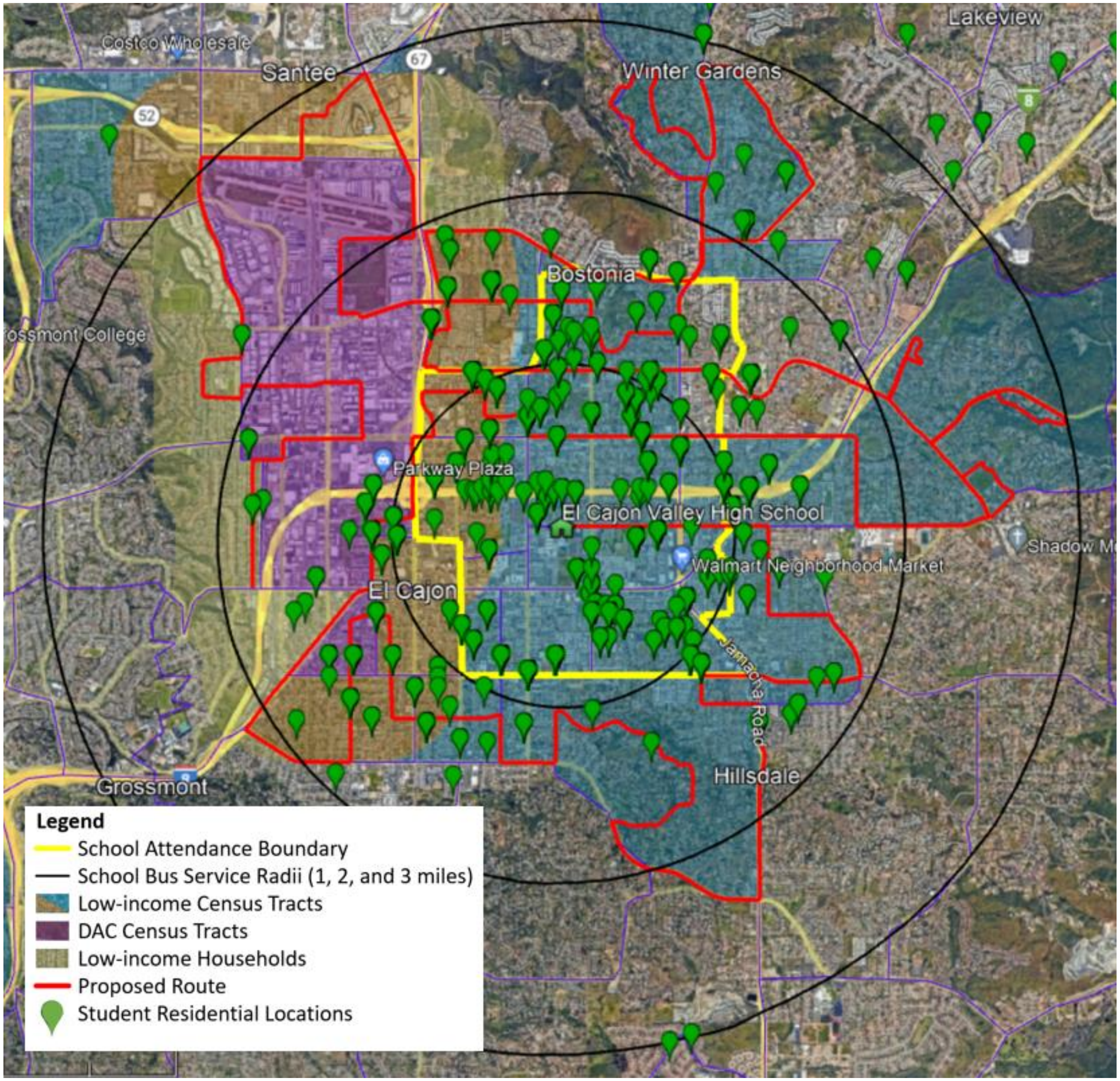


*Figure 15: Student Residential Locations and 1-3-Mile Extended Bus Route for El Cajon Valley High School*



# SECTION 3. OPTIMAL TECHNICAL CONFIGURATION AND ECONOMICS OF EXPANDED ROUTES

## Modeling Approach, Inputs, and Assumptions

### Digital Tools & Modeling Approach: Prosumer

The analysis of potential new routes is conducted using Prosumer, the same digital tool developed in-house by ENGIE Impact and applied for techno-economic modeling in Task 2. Overall, Prosumer seeks to minimize the total cost of ownership and CO2 emissions for the potential new routes over a total project lifetime of 20 years. This means having the optimal number and model of electric buses, as well as the optimal number of chargers, mix of charger types, and integration of charging with energy supply from both the grid and/or DERs. For more detailed information about Prosumer and the modeling approach, please refer to the technical report for Task 2.

### Modeling Scenarios

Expanded school bus service is modeled based on the results of the CNA and route design (Section 2). Because it is unlikely that GUHSD would choose a route that serves *both* the 1-3 and 2-3-mile boundary for the same school *simultaneously*, we model the routes in two separate scenarios:

<u>Scenario 1:</u> GUHSD expands bus service to students who live in the 2-3-mile zone from Mount Miguel, Monte Vista, and El Cajon Valley High Schools.

*Table 8: Routes Modeled in Scenario 1*

| Mount Miguel | Monte Vista | El Cajon Valley |
|---|---|---|
| 2-3-Mile Route | 2-3-Mile Route | N/A |

<u>Scenario 2:</u> GUHSD expands bus service to students who live in the 1-3-mile zone from Mount Miguel, Monte Vista, and El Cajon Valley High Schools.

*Table 9: Routes Modeled in Scenario 2*

| Mount Miguel | Monte Vista | El Cajon Valley |
|---|---|---|
| 1-3-Mile Route 1 (North) | 1-3-Mile Route | 1-3-Mile Route |
| 1-3-Mile Route 2 (South) | | |

As a reminder, we do not model the El Cajon Valley 1-3-Mile Extended Route, which is designed to serve as a planning tool to demonstrate all the potential areas to expand service.

### Inputs & Assumptions

Many inputs and assumptions in this model are identical to those in Task 2; more detailed descriptions of these assumptions can be found in the Task 2 technical report. Other assumptions are updated and customized specifically for this task.

<u>Inputs and assumptions carried over from Task 2:</u>

- EVSE technology
- Solar profile
- Distributed energy resources' technologies
- Utility Time-of-Use (TOU) pricing

*Table 10: Bus Route Schedules*

| Route Information | Scenario 1 | | Scenario 2 | | | |
|---|---|---|---|---|---|---|
| | Mount Miguel 2-3-Mile Route | Monte Vista 2-3-Mile Route | Mount Miguel 1-3-Mile Route 1 | Mount Miguel 1-3-Mile Route 2 | Monte Vista 1-3-Mile Route | El Cajon 1-3-Mile Route |
| **Bus Route*** | **51** | **52** | **53** | **54** | **55** | **56** |
| 12:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 1:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 2:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 3:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 4:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 5:00 am | Buffer | Buffer | Buffer | Buffer | Buffer | Buffer |
| 6:00 am | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 7:00 am | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 8:00 am | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 9:00 am | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 10:00 am | Buffer | Buffer | Buffer | Buffer | Buffer | Buffer |
| 11:00 am | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 12:00 pm | Buffer | Buffer | Buffer | Buffer | Buffer | Buffer |
| 1:00 pm | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 2:00 pm | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 3:00 pm | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 4:00 pm | 6.25 | 4.875 | 7 | 6.025 | 6.675 | 4.225 |
| 5:00 pm | Buffer | Buffer | Buffer | Buffer | Buffer | Buffer |
| 6:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 7:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 8:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 9:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 10:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |
| 11:00 pm | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge | Available to charge |

**Routes are added to the 50 existing GUHSD routes, and so are numbered 51-56.*

*Numbers in blue represent the mileage per hour to complete the total roundtrip (Depot-AOIs-School-Depot)*

- Tiered net energy metering (NEM)
- GHG emissions

Inputs and assumptions specific to Task 4:

**Trip routes and schedules:**

- Trip schedules and route mileage is based on the results of the Community Needs Assessment and route design (Section 2).
- Although the trip for the longest route is estimated to take 98 minutes, trips are conservatively modeled over three hours, with a one-hour buffer on either side to account for potential delays in start and end times. This conservative assumption reduces the time available for bus charging.
- Each route starts the morning segment at 6:00am and the afternoon segment at 1:00pm. These start times are consistent with the average start times used in the analysis for Task 2 & Task 3.
- The routes are repeated in the morning and afternoon, Monday through Friday. Weekly bus schedules are assumed to be the same during winter and summer seasons to remain consistent with the conservative assumptions in Task 2.

**Bus technology:** We only consider Type D school bus models in this analysis, in order to maximize seating capacity and therefore service for students on these routes. From ENGIE's extensive school bus database, this limits the analysis to four potential bus models for each route.

*Table 11: Bus Technology Database for Task 4*

| OEM | Model | Seat Capacity | Range (miles) | Battery Capacity (kWh) | Max L2 Charging (kW) | Max DCFC Charging (kW) | CAPEX | Lifetime (Yr) |
|---|---|---|---|---|---|---|---|---|
| Blue Bird | All American | 84 | 120 | 155 | 19.2 | 60 | * | * |
| Lion Electric Company | LionD2 | 83 | 125 | 168 | 19.2 | 50 | * | * |
| | LionD3 | 83 | 155 | 210 | 19.2 | 50 | * | * |
| GreenPower Motor Company | Beast | 90 | 150 | 194 | 19.2 | 100 | * | * |

** Information redacted for confidentiality*

## Optimization Analysis Results

The analysis identifies the optimal number and sizing of the electric buses, charging stations, and onsite solar PV to fulfil all mobility needs under the lowest total cost of ownership. After modeling Scenario 1 and Scenario 2 of route expansion for GUHSD, a consistent pattern emerges that identifies a small specific subset of buses and charging assets as optimal for GUHSD across all routes.

- For buses, Prosumer selects the Lion D2 bus (83 seats, 168 kWh battery, 125-mile range) to meet the transportation and capacity needs of the district in all six potential routes.
- To power these buses, Prosumer selects either 7.7 kW or 19.2 kW AC level 2 chargers. Routes that are assigned 19.2 kW chargers can maximize solar intake in the middle of the day.

Grid Infrastructure:

In both Scenarios, we see that the maximum peak load from the grid is less than half of the theoretical nameplate capacity from the chosen chargers. This is because Prosumer models the optimal charging behavior of the routes to minimize TCO, including demand charges, so not all buses will be charging at maximum rate at the same time.

Economics:

In both Scenarios, the primary driver of cost is the buses themselves, accounting for roughly 90% of total expenses.

Emissions:

Notably, in either scenario, expanding GUHSD's bus service using electric buses results in an 87% emissions reduction when compared to diesel buses.

Energy Flow and Charging Profiles:

As in Task 2, Tiered NEM shifts some of the optimal charging behavior, to ensure maximum utilization of solar credits and minimum total cost of ownership. The unique impact of Tiered NEM on charging profiles is demonstrated in two primary areas:

- First, the fleet uses the surplus in on-peak NEM credits on weekends to allow occasional charging from the grid during on-peak periods on weekdays (later afternoon and early evening).
- Second, the fleet uses the surplus in off-peak NEM credits to charge from the grid on weekends, even though all charging needs on weekends can be met using onsite solar.
- Overall, optimal charging requires maximum utilization of on-peak and off-peak credits whenever possible; otherwise, they will go to waste at the end of the year.

In the following subsections, we provide a more granular description of the results for both potential Scenarios of route expansion with electric vehicles, with snapshots of the optimal charging behavior of the system on a weekly basis. The graphics for Energy Flows and Charging Profiles are based on data from the 28$^{th}$ week of the year, during the summer season. Data corresponding to the 4$^{th}$ week of the year from the winter season are available in the Appendix.

### Scenario 1: Expansion of routes in the 2-3-mile radius

The first Scenario consists of two potential routes in the 2-3-mile radius for Monte Vista and Mount Miguel High Schools, respectively. The results for optimal technology selection are as follows:

Buses: The analysis shows that the optimal bus option is a Lion D2 bus (83 seats, 168 kWh battery, 125-mile range) for both routes in Scenario 1. The second-best automaker option for GUHSD would be the Green Power Motor Company Beast (90 seats, 194 kWh battery, 150-mile range).

Chargers: To charge the buses in Scenario 1, the optimal options are:

- 1 Blink IQ200 with a maximum charging rate of 19.2 kW
- 1 EVBox BusinessLine with a maximum charging rate of 7.7 kW

*Table 12: Optimal Technology Selection for Scenario 1 Routes*

| Route | Bus Selection | Charger Selection |
|---|---|---|
| Route 51: Mount Miguel 2-3-Mile | Lion D2 | EVBox BusinessLine |
| Route 52: Monte Vista 2-3-Mile | Lion D2 | Blink IQ200 |

Onsite DERs: In Scenario 1, we see the investment in a 19 kW rooftop PV system. The solar system produces about 26 MWh every year. About 17% of the solar energy is directly used for bus charging, while the remaining 83% is fed into the grid and accounted for as NEM credits under the three distinct tiers. Because both buses are only available to charge for one hour between morning and afternoon routes, we see less direct charging from solar PV than in Task 2.

Grid infrastructure: Adding the nameplate capacity of all required charging stations shows that the theoretical grid capacity needed to charge the buses is about 27 kW. However, the maximum peak load on the grid does not exceed 11 kW at any point in time. This is because the optimal charging behavior relies on charging from solar PV in the middle of the day, while spreading charging throughout the remainder of the day to minimize energy costs and demand charges; not all buses charge at the maximum rate at the same time.

Economics: The total cost of ownership for the electric fleet in Scenario 1 over 20 years is detailed in Table 13 below.

*Table 13: Total Cost of Ownership for Scenario 1*

| Cost | Value ($) | Contribution to TCO (%) |
|---|---|---|
| Electric Buses – CAPEX | * | 91.2% |
| Charging Stations – CAPEX | * | 1.9% |
| Charging Stations – OPEX | * | 0.7% |
| Solar PV – CAPEX | * | 3.1% |
| Solar PV – OPEX | * | 0.4% |
| Grid energy supply – OPEX | * | 2.7% |

** Information redacted for confidentiality*

GHG Emissions: The analysis shows that expanding the GUHSD fleet under Scenario 1 with electric vehicles would be 87% less GHG intensive than expanding with diesel vehicles. The total carbon emissions associated with electric bus charging over 20 years is estimated to be 159 MtCO2e, compared to an estimate of 1,244 MtCO2e from diesel. In fact, the GHG emissions from electric buses are probably an overestimate, and the real emissions can be lower, primarily for two reasons. First, the electric bus emissions do not consider the progressive decrease in the carbon intensity of the California grid over time due to higher penetration of renewables. Furthermore, the nearly 159 MtCO2e factors in only 17% of the onsite solar PV generation used to directly charge the buses; it does not account for the solar energy that was generated and fed into the grid.

**Optimal Charging**

Energy flows: Figure 16 shows all energy flows in and out of the system, on a daily basis over the 28$^{th}$ week of the summer season. The results show how the majority of daytime solar generation is fed back into the grid both in the morning and in the afternoon, while the buses are away completing their trips. In the middle of the day, solar is used to charge the buses directly, when the buses are in the depot between their morning and afternoon trips. Grid electricity is used to fulfill remaining charging needs after midnight, and in the evening when needed.

Charging profiles: Figure 17 and Figure 18 focus on the bus charging profiles. Figure 17 shows the stack of charging profiles for both buses in Scenario 1, and Figure 18 shows the sources of electricity used to charge these buses. Some key takeaways:

- Charging is completed to 90% by 5:00 am every weekday, at which point in time the buses may begin their trips. To optimize charging profiles, buses charge during multiple periods on weekdays and weekends.
- During weekdays, bus charging occurs after 6:00pm to about 5:00am, and in the middle of the

day after the morning trips. Throughout the year, the maximum charging rate reaches 24 kW, with peak load from the grid at 11 kW.

  - Between 6:00pm and 5:00am, the buses charge consistently from the grid at a rate of 8 kW. The buses benefit from super-off-peak rates from 12:00am to 5:00am. The model utilizes the Tiered NEM credits to allow on-peak and off-peak charging between 6:00pm and 12:00am. In other words, while this charging pulls electricity from the grid, it does not result in costly energy expense but is rather enabled by the Tiered NEM construct.
  - In the middle of the day, between 11:00am and 12:00pm, significant off-peak charging occurs for the buses to recharge between their morning and afternoon trips. The majority of energy is supplied directly from solar PV. As mentioned, buses are only available to charge for one hour during the day, contributing to a smaller solar system where a higher proportion of solar energy is fed directly to the grid to generate NEM credits.

- On weekends (Saturday and Sunday), the buses continue to charge in the afternoon from both solar and the grid. While all charging can be fulfilled by daytime solar, optimal charging requires that the buses also use grid electricity, during the off-peak period. The reason for that is also uniquely attributed to the Tiered NEM construct. The supply of energy from the grid on weekends allows consuming the surplus in NEM credits during the off-peak period.

<u>Buses' State of Charge:</u> As seen in Figure 19, the state of charge (SoC) for both buses follow a similar pattern.

- As previously noted, charging is completed to 90% by 5:00 am every weekday, at which point in time the buses may begin their trips. Similarly, at no point in time will buses fall between a 10% SoC, providing an energy buffer in case of emergency.
- During the middle of the day, in between the morning and afternoon trips, at least one bus charges using energy from solar PV.

<u>NEM Credit Balance:</u>

- As mentioned before, Tiered NEM shifts some of the optimal charging behavior to ensure maximum utilization of solar credits and minimum total cost of ownership. Of the total 26 MWh of electricity generated by the PV system each year, about 4 MWh are used to directly charge the buses and 22 MWh are fed into the grid to generate NEM credits.
- As shown in Figure 20, those credits fall under the three tiers: 3 MWh on-peak, 14 MWh off-peak, and 5 MWh super-off-peak. Optimal charging requires energy credits to balance energy expense in each tier as closely as possible. The results show that credits and expenses are completely and perfectly balanced for on-peak and off-peak tiers; no net energy expense occurs under these two tiers. The super-off-peak tier is partially balanced, with a credit deficit of about 5 MWh.
- Figure 21 further emphasizes the optimization of solar energy supply and consumption. Within the on-peak and off-peak tiers, all solar energy generated is utilized, with no net grid energy consumed. In the super-off-peak tier, all solar energy generated is utilized, in addition to a substantial amount of grid energy.

### Scenario 2: Expansion of routes in the 1-3-mile radius

The second Scenario consists of potential routes in the 1-3-mile radius for Monte Vista, Mount Miguel, and El Cajon High Schools, based on the results of the CNA and route design. There are a total of four routes modeled, with one bus per route. The results for optimal technology selection are as follows:

<u>Buses:</u> The analysis shows that the optimal bus option is a Lion D2 bus (83 seats, 168 kWh battery, 125-mile range) for all four routes in Scenario 2. The second-best automaker option for GUHSD would

be the Green Power Motor Company Beast (90 seats, 194 kWh battery, 150-mile range).

Chargers: To charge the buses in Scenario 2, the optimal options are:

- 3 Blink IQ200 with maximum charging rate of 19.2 kW
- 1 EVBox BusinessLine with maximum charging rate of 7.7 kW

*Table 14: Optimal Technology Selection for Scenario 2 Routes*

| Route | Bus Selection | Charger Selection |
|---|---|---|
| Route 53: Mount Miguel 1-3-Mile (North) | Lion D2 | Blink IQ200 |
| Route 54: Mount Miguel 1-3-Mile (South) | Lion D2 | Blink IQ200 |
| Route 55: Monte Vista 1-3-Mile | Lion D2 | Blink IQ200 |
| Route 56: El Cajon Valley 1-3-Mile | Lion D2 | EVBox BusinessLine |

Onsite DERs: In Scenario 2, we see the investment in a 41 kW rooftop PV system. The solar system produces about 56 MWh every year. About 16% of the solar energy is directly used for bus charging, while the remaining 84% is fed into the grid and accounted for as NEM credits under the three distinct tiers. Because all buses are only available to charge for one hour between morning and afternoon routes, we see less direct charging from solar PV than in Task 2.

Grid infrastructure: Adding the nameplate capacity of all required charging stations shows that the theoretical grid capacity needed to charge the buses is about 65 kW. However, the maximum peak load on the grid does not exceed 25 kW at any point in time. This is because the optimal charging behavior relies on charging from solar PV in the middle of the day, while spreading charging throughout the remainder of the day to minimize energy costs and demand charges; not all buses charge at the maximum rate at the same time.

Economics: The total cost of ownership for the electric fleet in Scenario 2 over 20 years is detailed in Table 15 below.

*Table 15: Total Cost of Ownership for Scenario 2*

| Cost | Value ($) | Contribution to TCO (%) |
|---|---|---|
| Electric Buses – CAPEX | * | 91.4% |
| Charging Stations – CAPEX | * | 2.3% |
| Charging Stations – OPEX | * | 0.7% |
| Solar PV – CAPEX | * | 3.4% |
| Solar PV – OPEX | * | 0.4% |
| Grid energy supply – OPEX | * | 1.8% |

** Information redacted for confidentiality*

GHG Emissions: The analysis shows that expanding the GUHSD fleet under Scenario 2 with electric vehicles would be 87% less GHG intensive than expanding with diesel vehicles. The total carbon emissions associated with electric bus charging over 20 years is estimated to be 342 MtCO2e, compared to an estimate of 2,675 MtCO2e from diesel. In fact, the GHG emissions from electric buses are probably an overestimate, and the real emissions can be lower, primarily for two reasons. First, the electric bus emissions do not consider the progressive decrease in the carbon intensity of the California grid over time due to higher penetration of renewables. Furthermore, the nearly 342 MtCO2e factors in only 16% of the onsite solar PV generation used to directly charge the buses; it does not account for the solar energy that was generated and fed into the grid.

**Optimal Charging**

Energy flows: Figure 22 shows all energy flows in and out of the system, on a daily basis over the 28th week of the summer season. The results show how the majority of daytime solar generation is fed back into the grid both in the morning and in the afternoon, while the buses are away completing their trips. In the middle of the day, solar is used to charge the buses directly, when the buses are in the depot between their morning and afternoon trips. Grid electricity is used to fulfill remaining charging needs after midnight, and in the evening when needed.

Charging profiles: Figure 23 and Figure 24 focus on the bus charging profiles. Figure 23 shows the stack of charging profiles for both buses in Scenario 1, and Figure 24 shows the sources of electricity used to charge these buses. Some key takeaways:

- Charging is completed to 90% by 5:00 am every weekday, at which point in time the buses may begin their trips. To optimize charging profiles, buses charge during multiple periods on weekdays and weekends.
- During weekdays, bus charging occurs after 6:00pm to about 5:00am, and in the middle of the day after the morning trips. Throughout the year, the maximum charging rate reaches 51 kW, with peak load from the grid at 25 kW.
    - Between 6:00pm and 5:00am, the buses charge consistently from the grid at a rate of 19 kW. The buses benefit from super-off-peak rates from 12:00am to 5:00am. The model utilizes the Tiered NEM credits to allow on-peak and off-peak charging between 6:00pm and 12:00am. In other words, while this charging pulls electricity from the grid, it does not result in costly energy expense but is rather enabled by the Tiered NEM construct.
    - In the middle of the day, between 11:00am and 12:00pm, significant off-peak charging occurs for the buses to recharge between their morning and afternoon trips. The majority of energy is supplied directly from solar PV. As mentioned, buses are only available to charge for one hour during the day, contributing to a smaller solar system where a higher proportion of solar energy is fed directly to the grid to generate NEM credits.
- On weekends (Saturday and Sunday), the buses continue to charge in the afternoon from both solar and the grid. While all charging can be fulfilled by daytime solar, optimal charging requires that the buses also use grid electricity, during the off-peak period. The reason for that is also uniquely attributed to the Tiered NEM construct. The supply of energy from the grid on weekends allows consuming the surplus in NEM credits during the off-peak period.

Buses' State of Charge: As seen in Figure 25, the state of charge (SoC) for all the buses follows a similar pattern, regardless of the size of battery.

- As previously noted, charging is completed to 90% by 5:00am every weekday, at which point in time the buses may begin their trips. Similarly, at no point in time will buses fall between a 10% SoC, providing an energy buffer in case of emergency.
- During the middle of the day, in between the morning and afternoon trips, at least one bus charges using energy from solar PV.

NEM Credit Balance:

- As mentioned before, Tiered NEM shifts some of the optimal charging behavior to ensure maximum utilization of solar credits and minimum total cost of ownership. Of the total 56 MWh of electricity generated by the PV system each year, about 9 MWh are used to directly charge the buses and 47 MWh are fed into the grid to generate NEM credits.
- As shown in Figure 26, those credits fall under the three tiers: 6 MWh on-peak, 30 MWh off-peak, and 11 MWh super-off-peak. Optimal charging requires energy credits to balance energy

expense in each tier as closely as possible. The results show that credits and expenses are completely and perfectly balanced for on-peak and off-peak tiers; no net energy expense occurs under these two tiers. The super-off-peak tier is partially balanced, with a credit deficit of about 11 MWh.

- Figure 27 further emphasizes the optimization of solar energy supply and consumption. Within the on-peak and off-peak tiers, all solar energy generated is utilized, with no net grid energy consumed. In the super-off-peak tier, all solar energy generated is utilized, in addition to a substantial amount of grid energy.

## Procurement Guidelines & Recommendations

- Based on the analysis, the Lion D2 has the lowest cost of ownership of all Type D buses that fit the operational requirements for GUHSD. Likewise, the two charging stations that have the lowest cost of ownership for the expanded fleet are AC L2 charging units EVBox Business Line at 7.7 kW and Blink IQ200 at 19.2 kW. As with the Task 2 report, we recommend limiting the supply of electric buses and EVSE to no more than two manufacturers each, to help reduce service expenses and streamline operations. Therefore, we recommend considering the makeup of the rest of the fleet when deciding which models are best for the new routes.
- Even though expanding service might require some changes to GUHSD transportation program guidelines and rules, it can open new potential funding opportunities for the District's zero-emissions fleet at the state level. Since the CNA expanded routes focus on serving AOIs, the District may be able to access bus and infrastructure grants specifically catered towards DACs and LICs. We recommend exploring additional grants outside of the usual funding avenues to reduce the burden of the bus CAPEX, which is currently estimated at roughly 90% of the TCO.
- Any expansion of the proposed routes, even if partial, will improve service to DACs and LICs. The decision to expand service is not binary (all or none routes); partial expansion of service by including discrete portions of the proposed routes and/or route segments will still provide increased accessibility to students living in AOIs. Running these routes with electric buses also provides environmental benefit to the communities served, compared to expanding service with conventional buses; the analysis estimates an 87% emissions reduction between electric and conventional buses.

*Figure 16: Energy Flows for Scenario 1 – Summer*

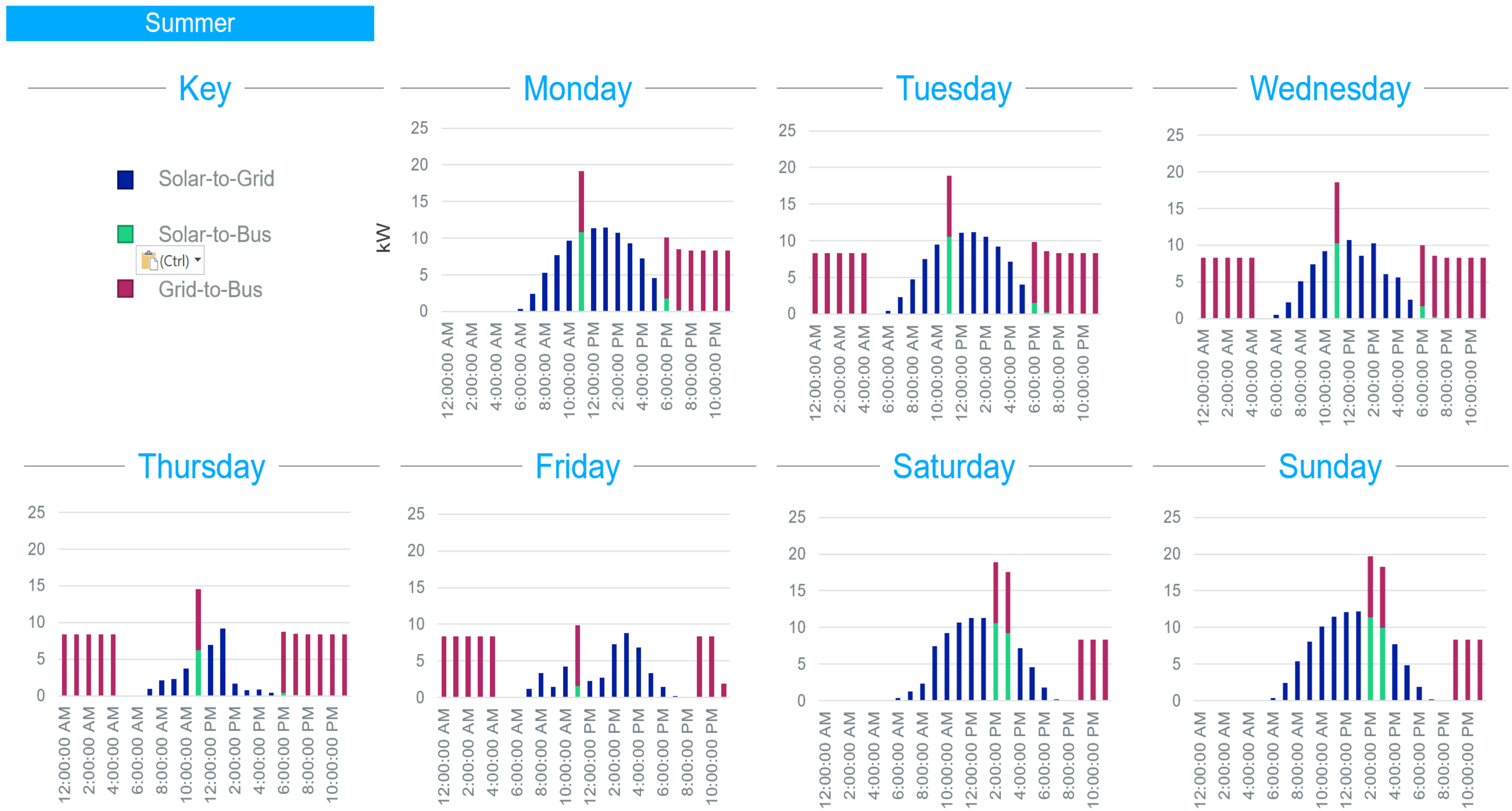


*Figure 17: Charging Profiles for Scenario 1 – Summer*

*Figure 18: Sources of Energy for Bus Charging in Scenario 1 – Summer*

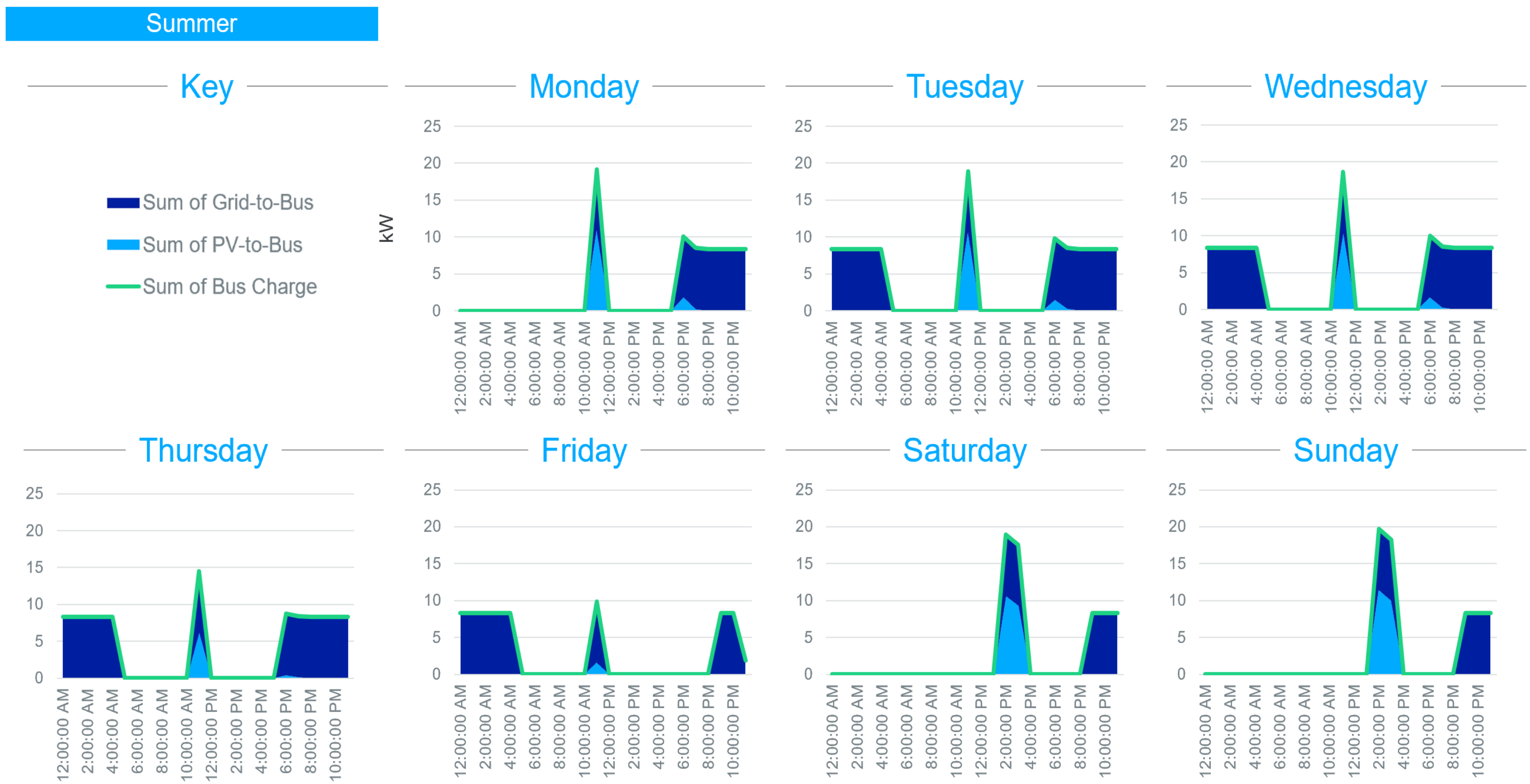


*Figure 19: Weekly State of Charge (SoC) for Scenario 1*

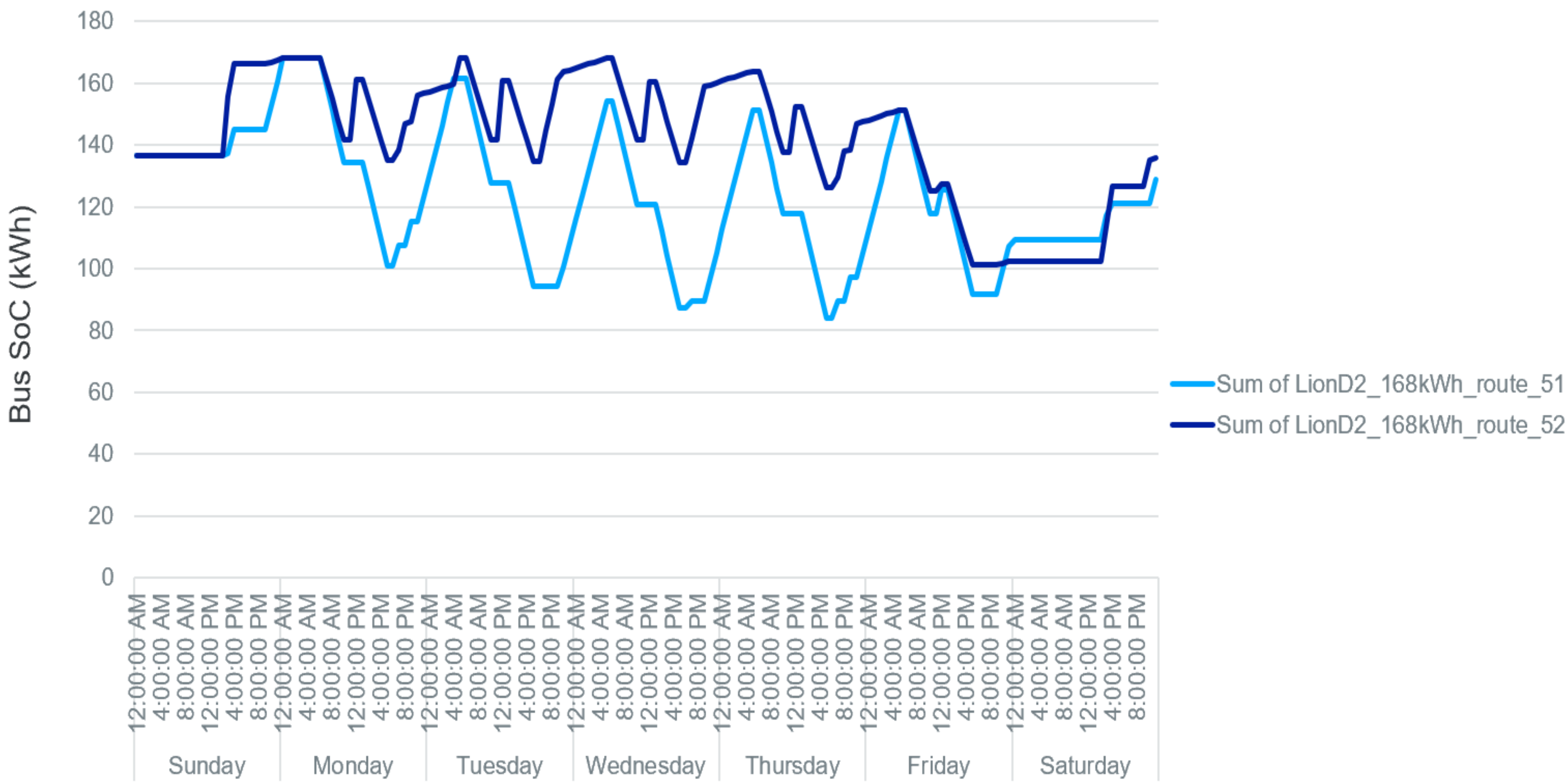


*Figure 20: Tiered NEM Credit Balance for Scenario 1*

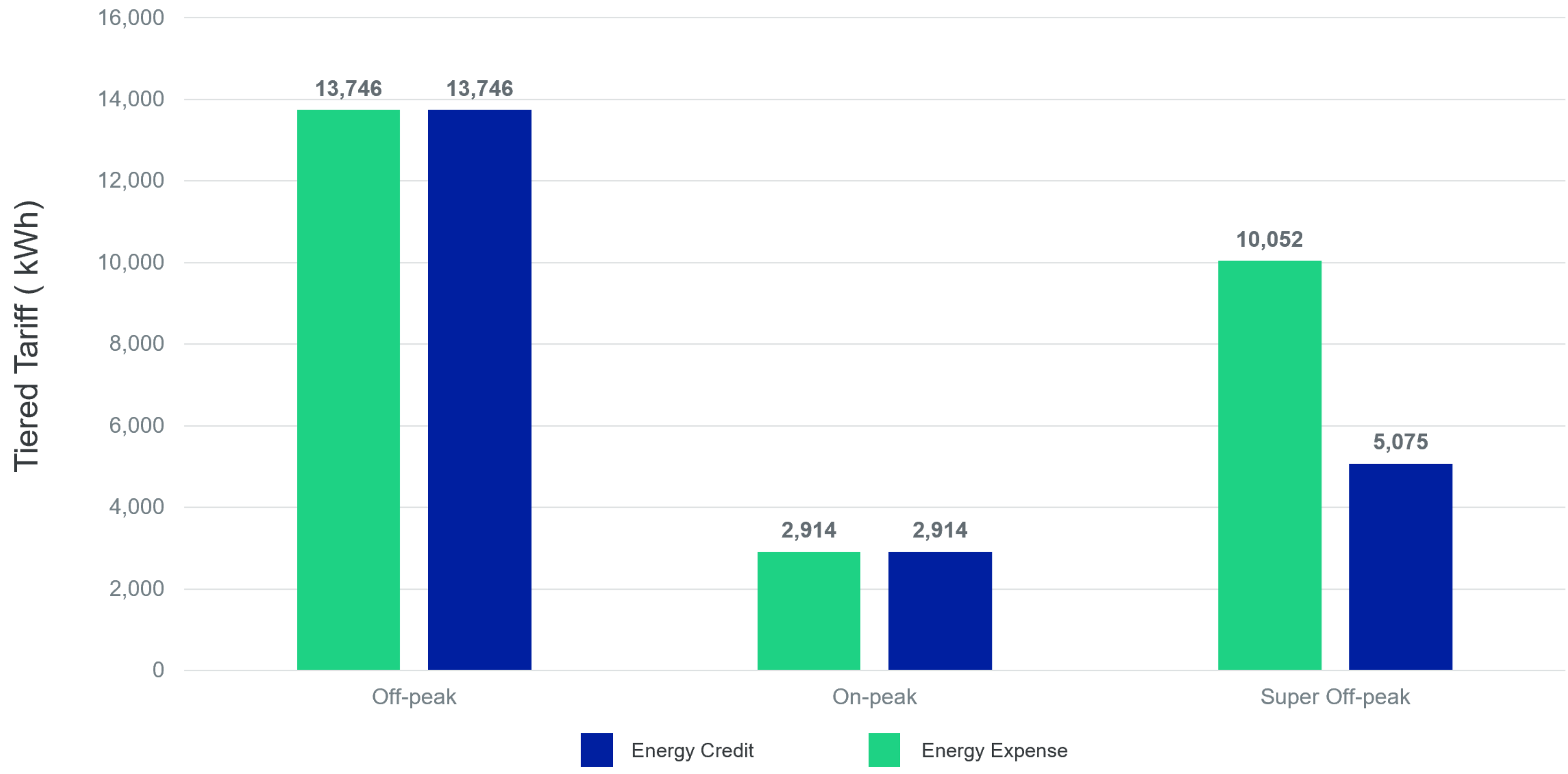


*Figure 21: Solar Energy Generation and Consumption for Scenario 1*

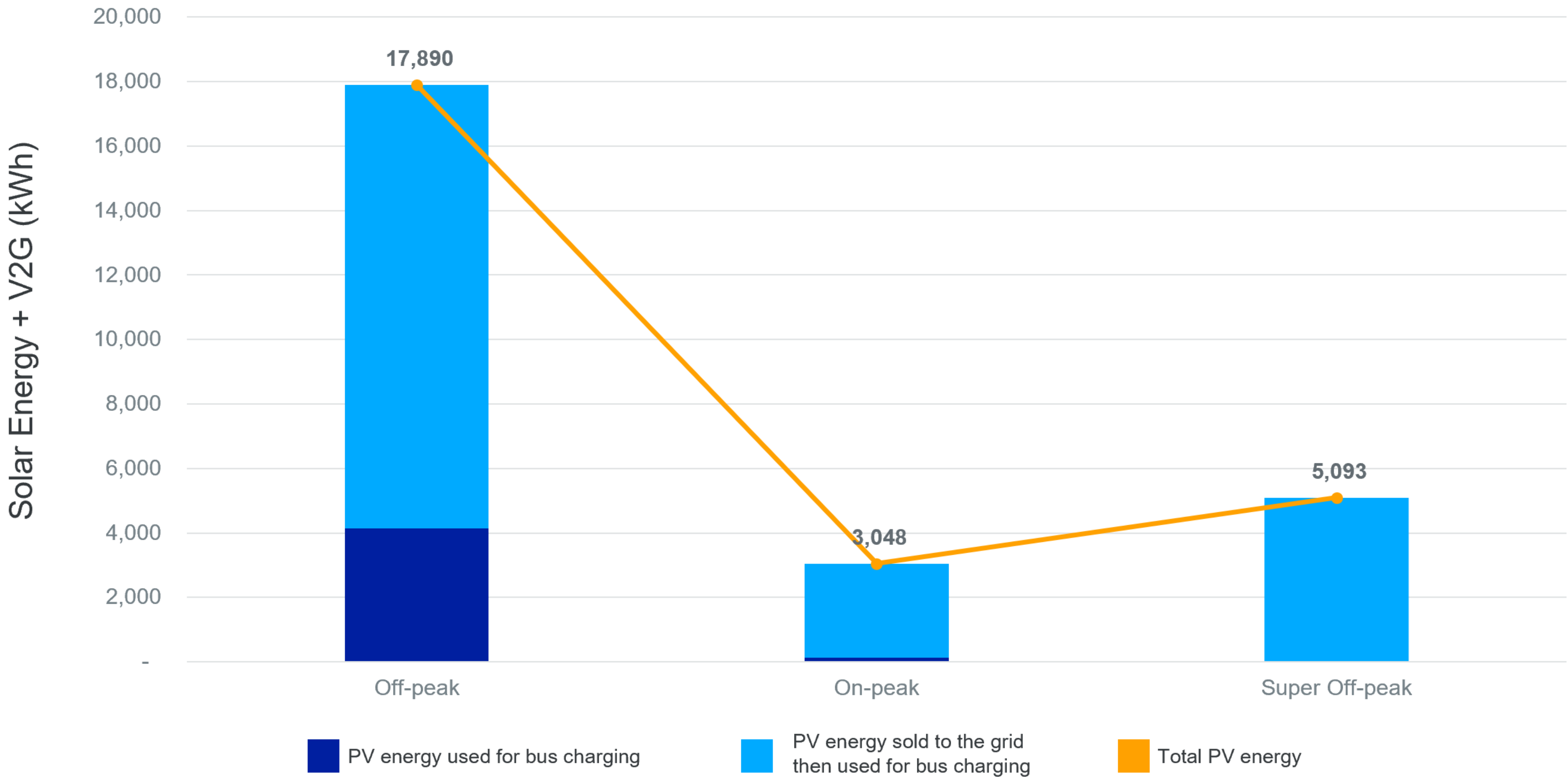


*Figure 22: Energy Flows for Scenario 2 – Summer*

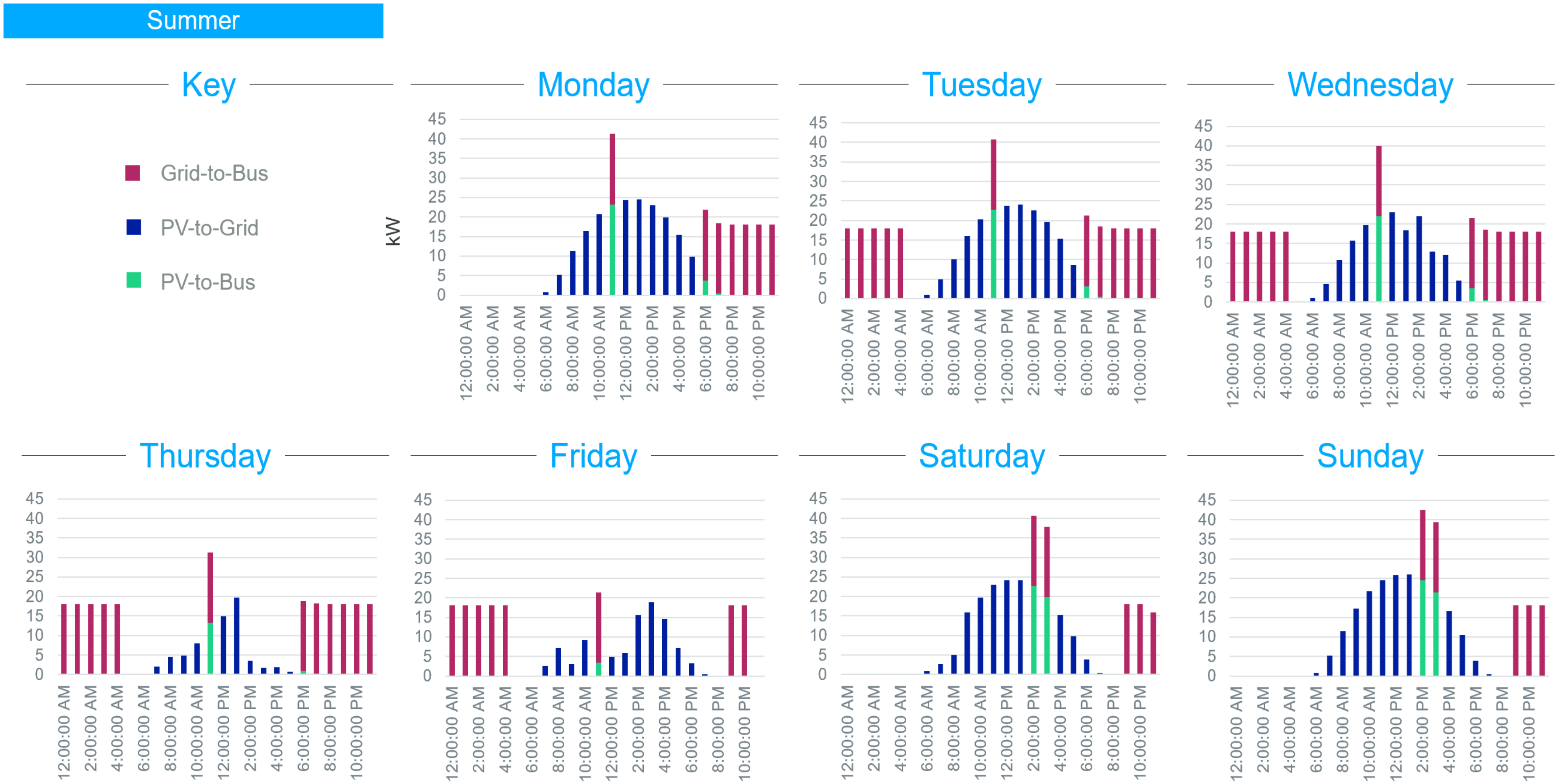


*Figure 23: Charging Profiles for Scenario 2 – Summer*

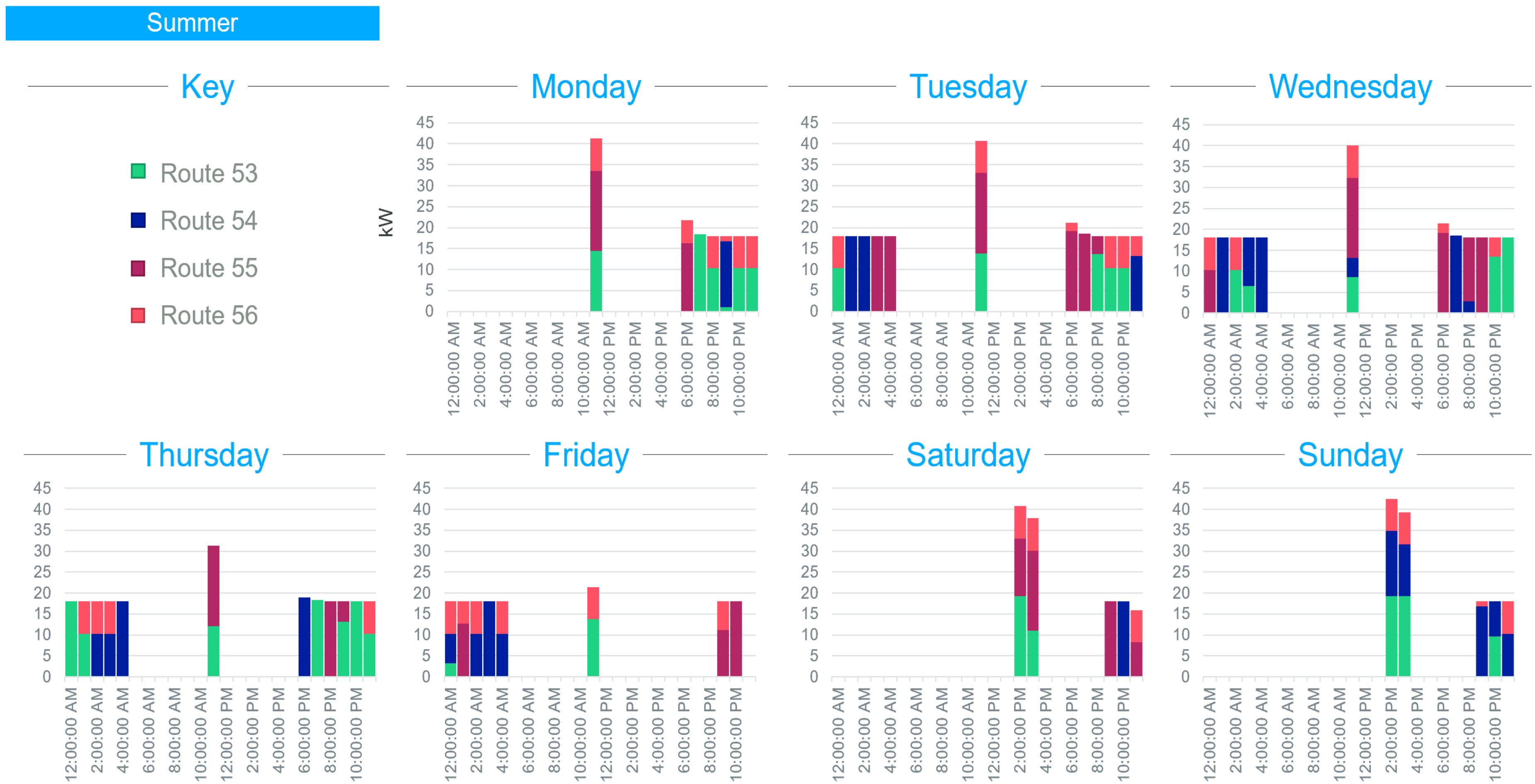


*Figure 24: Sources of Energy for Bus Charging in Scenario 2 – Summer*

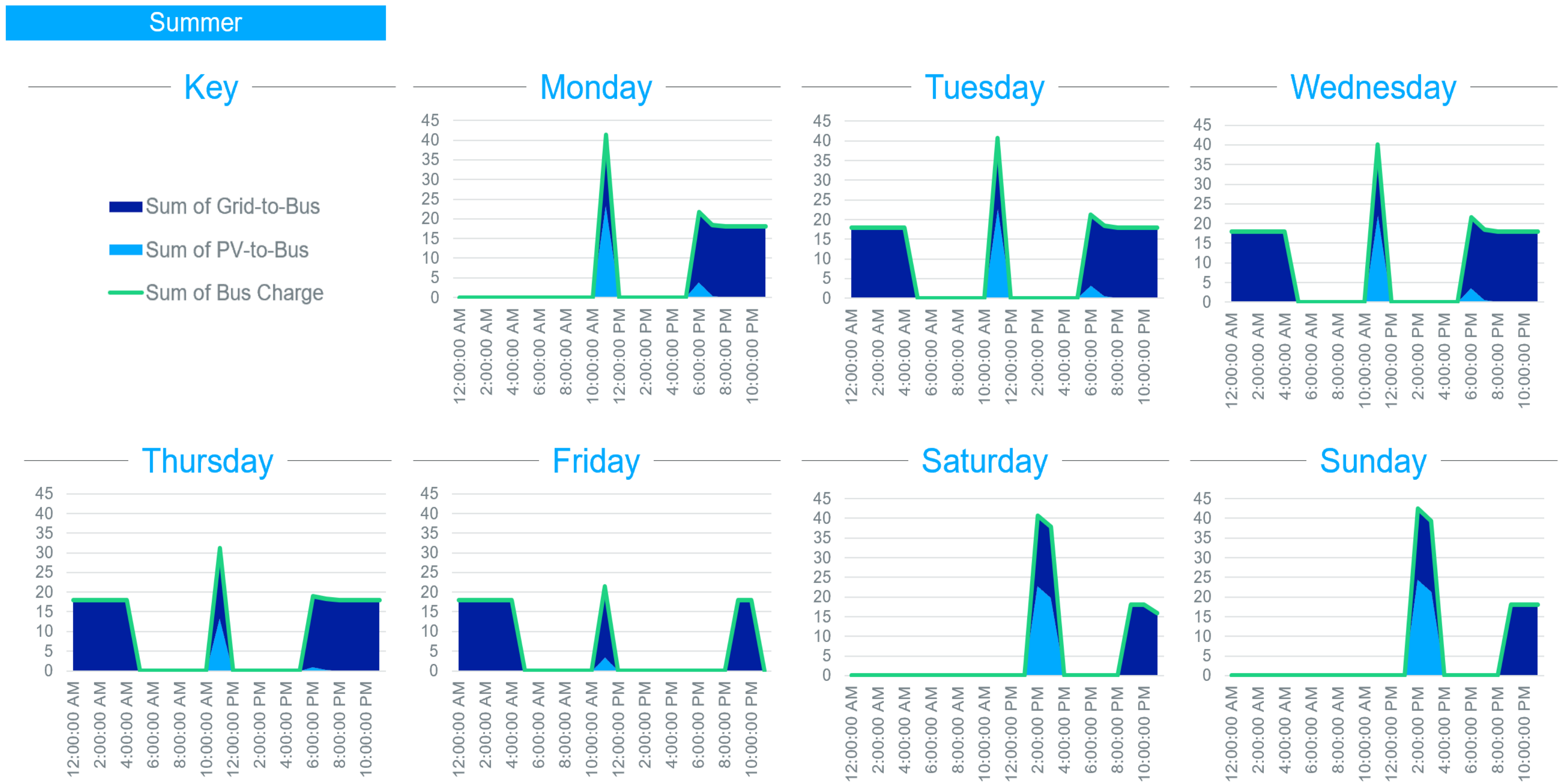


*Figure 25: Weekly State of Charge (SoC) for Scenario 2*

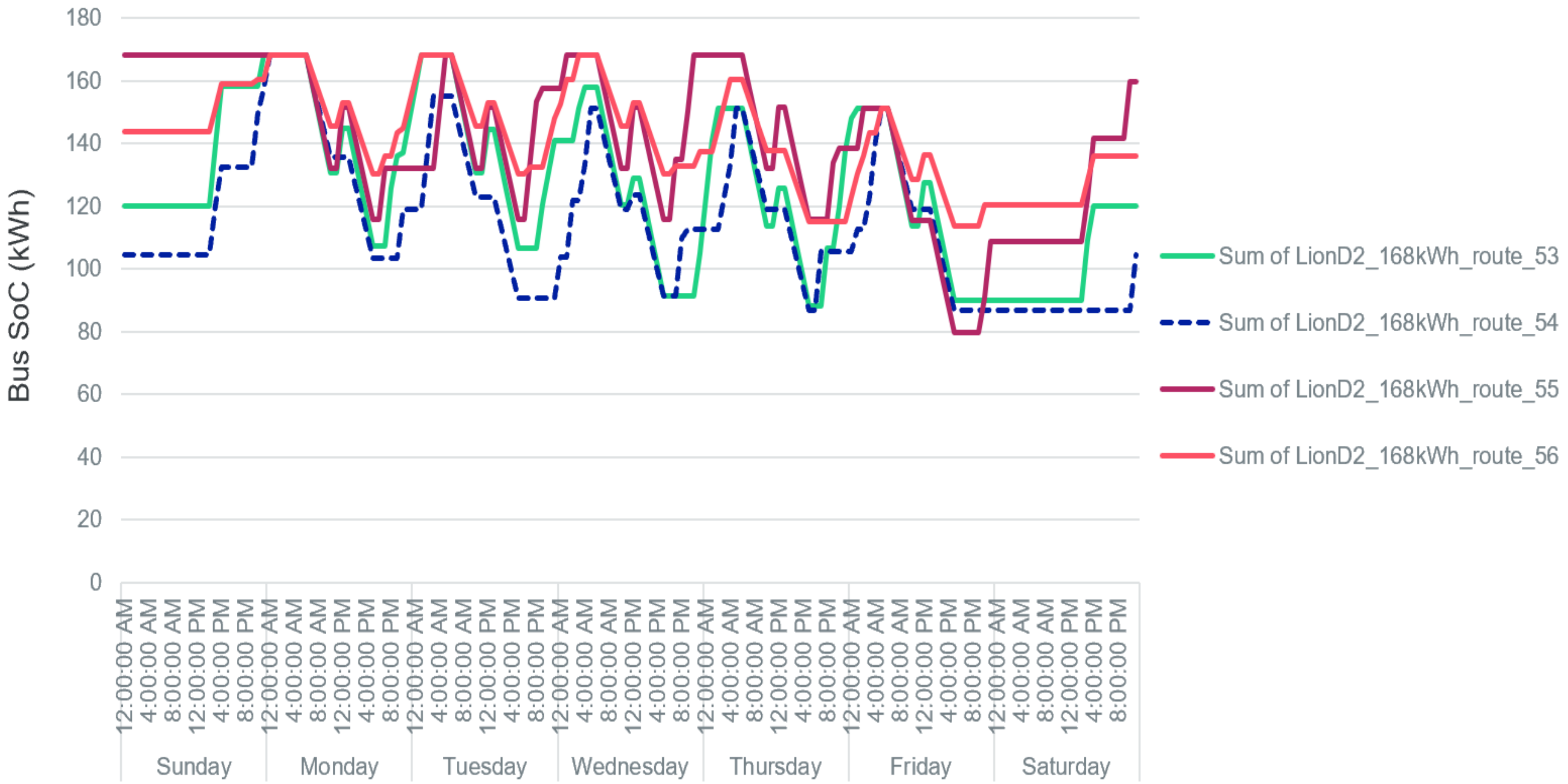


*Figure 26: Tiered NEM Credit Balance for Scenario 2*

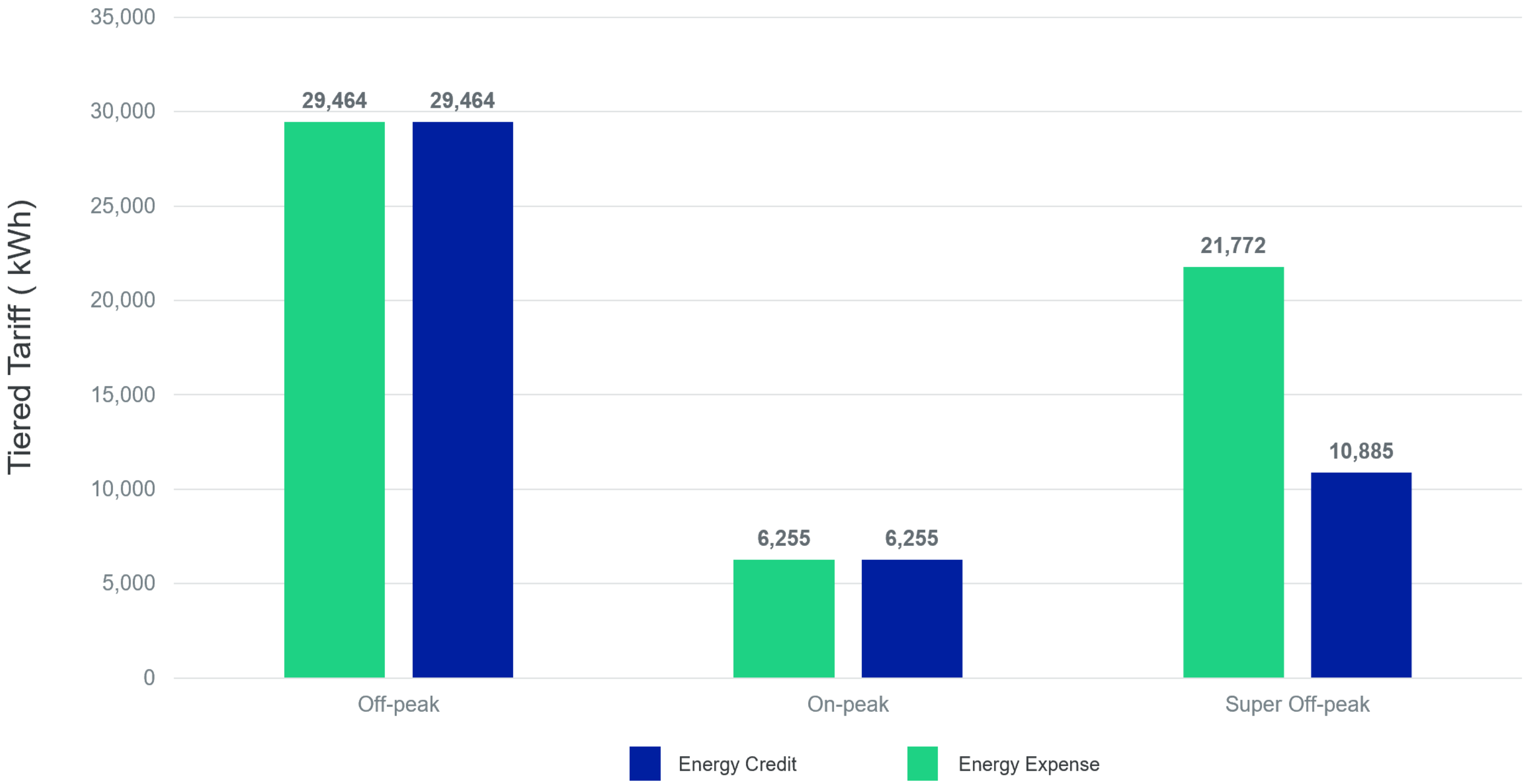
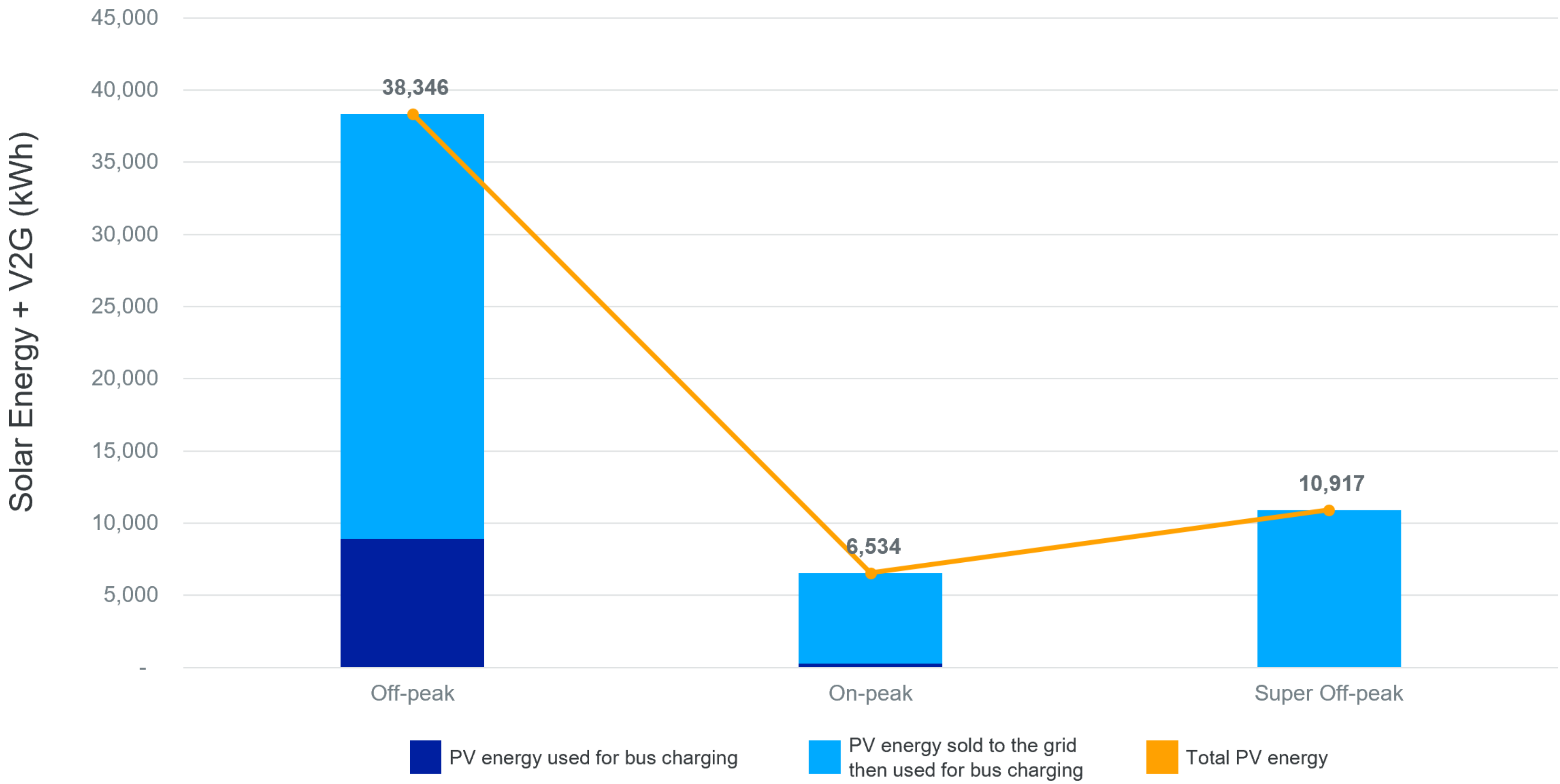


*Figure 27: Solar Energy Generation and Consumption for Scenario 2*



# Appendix

*Figure 28: Energy Flows for Scenario 1 – Winter*

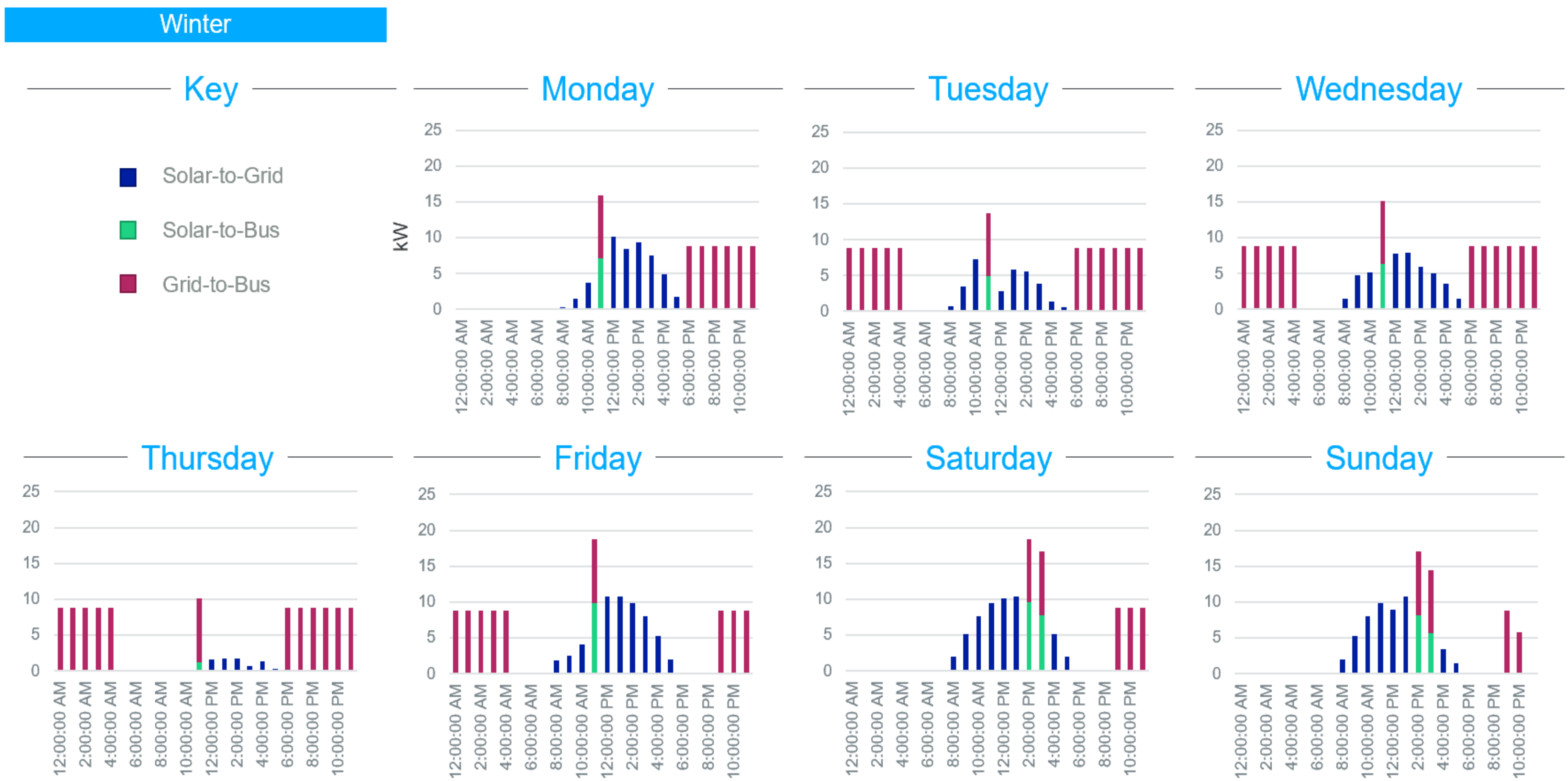


*Figure 29: Charging Profiles for Scenario 1 – Winter*

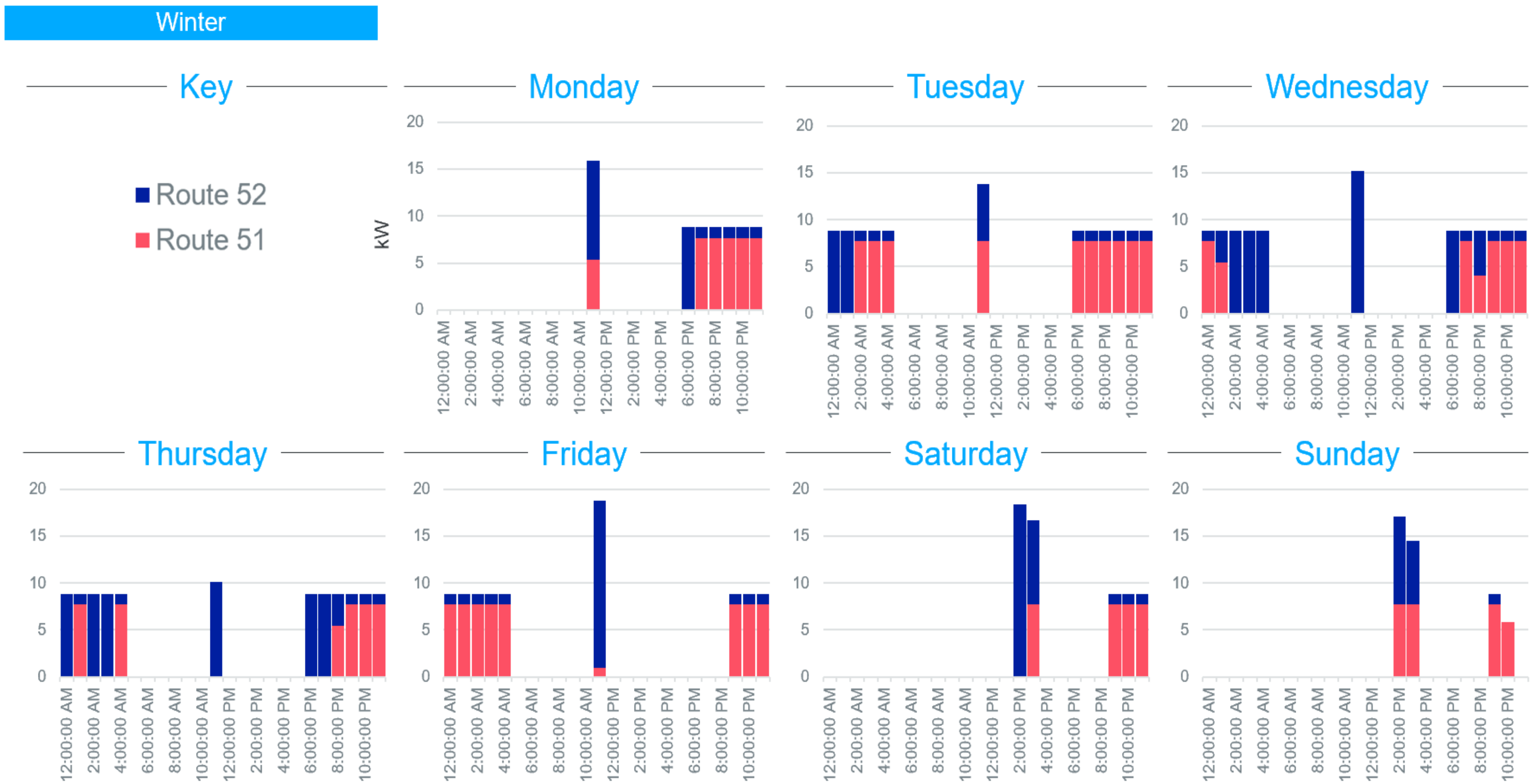


*Figure 30: Source of Energy for Bus Charging in Scenario 1 – Winter*

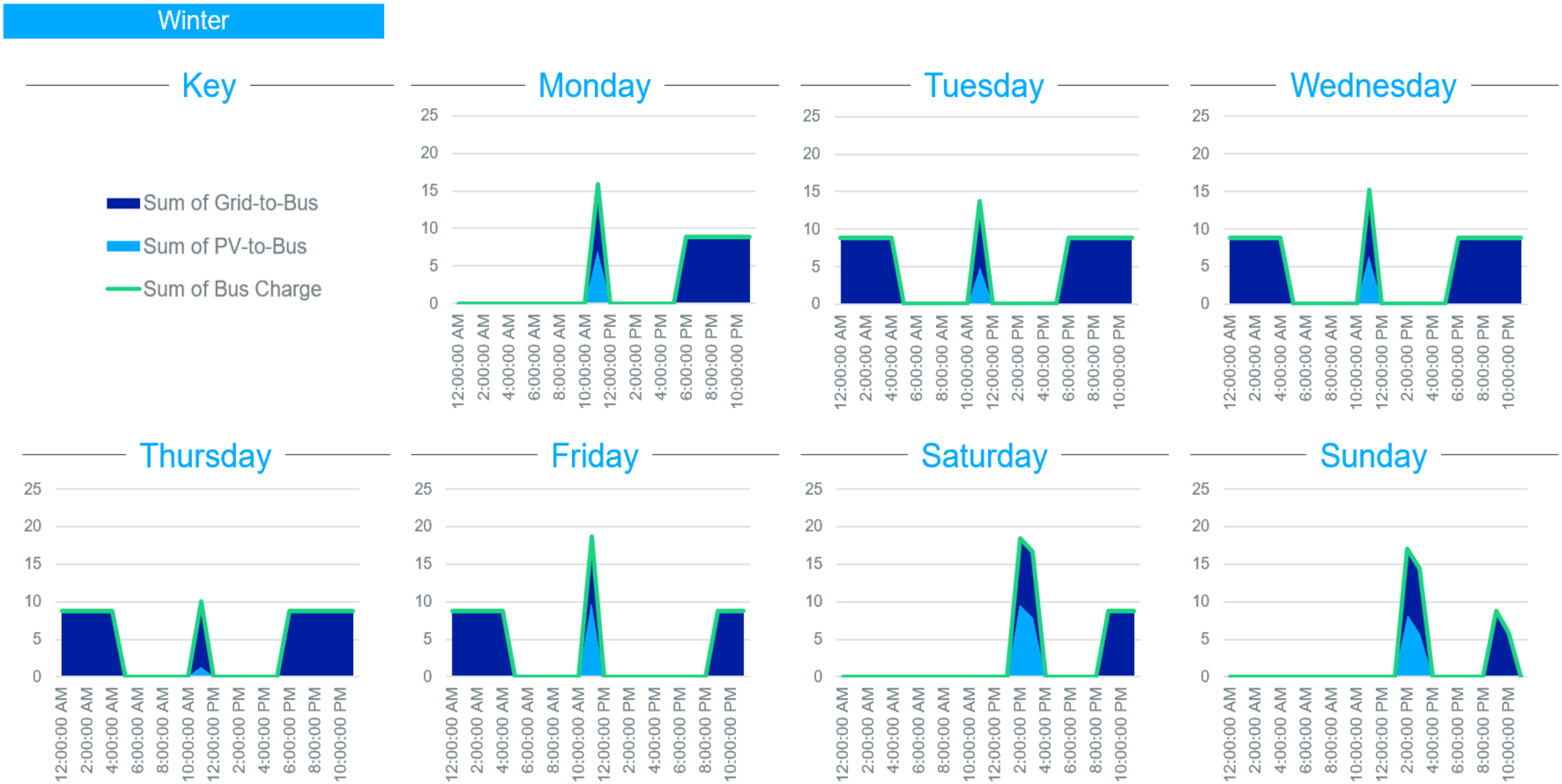


*Figure 31: Energy Flows for Scenario 2 – Winter*

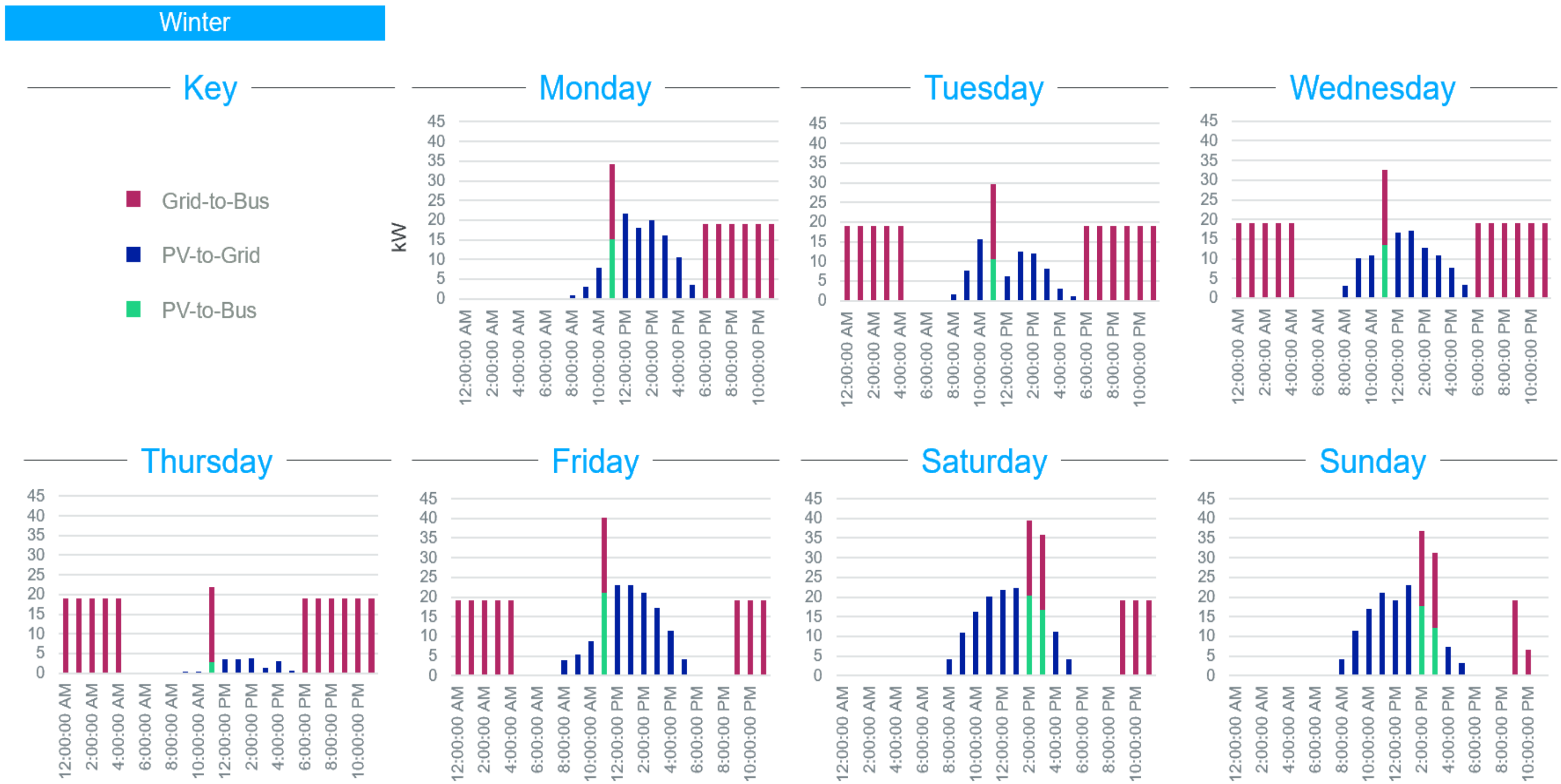


*Figure 32: Charging Profiles for Scenario 2 – Winter*

*Figure 33: Source of Energy for Bus Charging in Scenario 2 – Winter*