# UA Crimson Ride Climate Action Plan

## Transition to Zero-Emissions Fleet by 2030

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# Contents

# Executive Summary

The Climate Action Plan presented in this report outlines the University of Alabama (UA) and Tuscaloosa County's joint efforts to replace their current diesel bus fleet with electric buses. The primary purpose of the plan is to reduce emissions of the current all diesel bus fleet, expand public transportation services to better connect the communities, and prepare the workforce for the fleet electrification. In a comprehensive five-year transition plan, UA and Tuscaloosa County will replace over 50 diesel buses with electric buses and develop the charging infrastructure for electric vehicles in the region. The plan's scope also covers ongoing and future regional initiatives to support the project, including a long-term goal of achieving net-zero emissions in the Tuscaloosa region.

The report details ongoing efforts to ensure the effective implementation of the project, including sensor augmentation, data collection, and data analytics for operation assistance, maintaining and monitoring the emission inventory, partnering with local community colleges for sustainable workforce development, and additional opportunities for STEM education.

The report also highlights potential challenges the project team envisions for the electric bus transition project, such as the global competition for raw materials, limited production capacity due to surge in electric bus demand, and limited load capacity in the regional power grid. To mitigate these challenges, the project team has developed a staged deployment plan over 5-years and several smart charging strategies in cooperation with Alabama Power Company.

Looking ahead, the report recommends expanding and maintaining the emissions inventory, exploring and adopting new technologies to advance towards a completely sustainable transportation system, implementing an effective maintenance and repair program, developing and implementing intelligent transportation systems, and integrating sustainable transportation policies and practices.

Overall, the plan aims to guide the implementation of the electric bus transition process and assess the progress of the partner’s goals. With proper execution of the project's long-term goals, the University of Alabama and Tuscaloosa County will contribute to a more sustainable and livable campus community, region, and state.

# 1. Introduction

In this Climate Action Plan, we will provide a comprehensive review for zero-emission transit bus electrification project at the University of Alabama and Tuscaloosa County. This plan aims to set up the goals for reducing emissions and expanding services through the replacement of diesel buses with electric ones. The report details the scope and limitations of the plan, as well as the process for its development. Moreover, the report presents how the agency will use the plan to guide implementation and highlights the long-term goals of the project.

## Purpose of the Plan

The primary purpose of this plan is to provide a vision for zero-emission transit bus electrification in the Tuscaloosa region. The plan aims to replace the current diesel bus fleet with electric buses to reduce emissions and expand services, particularly in underserved areas. Additionally, the plan seeks to develop the charging infrastructure for electric vehicles in the region and to prepare the workforce for the electrification process.

The scope of this plan includes a comprehensive discussion of the details of a five-year transition plan to replace 55 diesel buses with electric buses. The plan will be a joint effort between Crimson Ride at UA and the city of Tuscaloosa. The report also details a workforce transitioning plan to prepare bus operators and maintenance technicians to support the transit bus electrification process. Moreover, the report highlights the ongoing and future regional initiatives that will support the bus electrification project, together with long-term goals to achieve net-zero emission in the Tuscaloosa region.

However, there are also limits to the plan. The first limit is the grid loading and capacity expansion to support ultra-fast charging while maintaining normal grid operation. The second limit is that while the plan seeks to achieve a 100% net-zero emission bus fleet, the electricity to power the buses is not 100% clean, with only 11% of the current electricity generated from renewable sources in Alabama. In the future, the project team also aims to work with regional stakeholders to improve the penetration of renewable energy.

The plan is developed collaboratively by a team of bus operators, university researchers, local policy makers, and industry leaders. The team held several consultations to gather insights on the current state of the transit bus system, the potential for electrification, and the required changes to support the transition. These consultations discussed the plan's vision, which was refined through a series of meetings and research studies. The resulting plan represents a shared vision of the future of electric transit in Tuscaloosa and a roadmap for its realization.

The Crimson Ride campus transit and Tuscaloosa County Transit agencies will use this plan to guide the implementation of the electric bus transition process and monitor the progress of the

project. The plan will be used as a reference for decision-making and to ensure alignment with the project's long-term goals. Besides regular bi-weekly project meetings, the project team will hold annual review meetings to check the progress on the operation of electric buses, the operation of supporting infrastructure, and the preparedness of the workforce, which will guide the project efforts in subsequent years. Additionally, the plan will be aligned with local initiatives to support the overall clean-energy mission for the greater Tuscaloosa area.

# 2. Agency Overview

The Crimson Ride transit agency at the University of Alabama currently maintains a fleet of 39 buses, with 30 of them measuring 40 feet in length and the remaining eight measuring 35 feet. The age of the fleet varies significantly, with some buses dating back as far as 2007 and newer buses added to the fleet as recently as 2020. However, 15 of the 40-foot buses have already reached their projected lifetime of service, and this number is set to increase to include over 60% of the fleet by the year 2024. This situation presents an ongoing challenge to navigate as maintenance and repair costs continue to rise, and in some cases, the proper fitting parts and systems required for repair are not readily available. For instance, the air conditioning systems in 25% of the fleet are no longer manufactured. The eight 35-foot buses are currently within their 12-year replacement cycle, and the agency plans to replace them as needed.

## Service Area Covered

Crimson Ride transit agency provides free-of-charge transportation for the University of Alabama campus, as well as a significant portion of the city of Tuscaloosa, as shown in Figure 1. The transit system also supports a charter operation serving Birmingham and Montgomery.

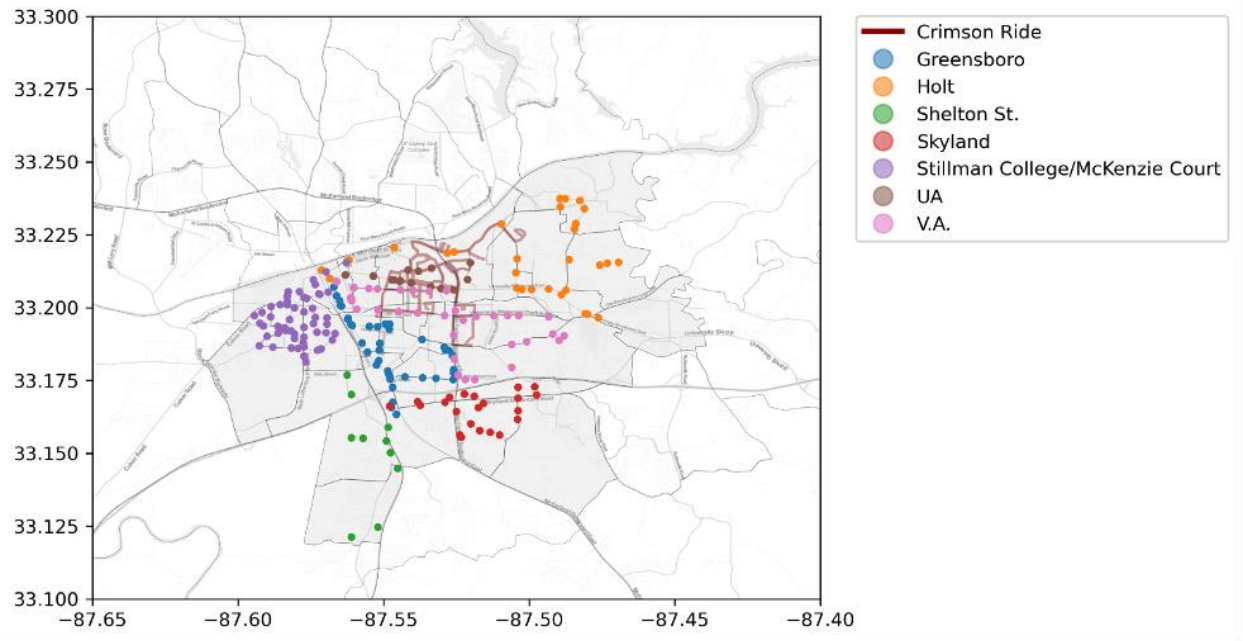


**Figure 1. Public transportation service in Tuscaloosa County including UA Crimson Ride and Tuscaloosa Transit**

## Transit Services Provided

The transit system operates 24 hours a day, seven days a week when the University is open during the academic year. However, the service model is reduced during the summer months due to a significant decrease in ridership. The system provides on-demand services such as the Night Ride program, which operates during late-night hours and serves key locations on campus, and the Paratransit program, which provides curb-to-curb service for passengers with disabilities.

## Facility Types

Crimson Ride operates out of two main buildings. The Bus Hub/Campus Drive Parking Deck is centrally located on the main campus, and the Maintenance Facility/Operations Center is located on the University Services campus, which is on the Eastern edge of the main campus. The Bus Hub/Campus Drive Parking Deck is a multi-level parking deck that also serves as the primary loading and unloading area for buses on the campus. The Maintenance Facility/Operations Center houses the administration offices, maintenance and repair shops, and parking lot offices.

## Financial Information

The Crimson Ride Transit program is centrally funded by the Vice President of Finance & Operations, with an annual budget of around $5M. The buses supporting the campus transportation system are funded with auxiliary funds generated by the campus parking operation. The transit agency is constantly seeking alternative sources of funding to ensure the continuation of its services and to fund future projects such as the transit bus electrification plan.

# 3. Emissions Inventory

The emissions inventory for average operations over the last two years (2021-22) for bus miles and fuel consumption and last three years (2020-22) for facility electrical consumption is used for the baseline data sources. The current inventory includes only facility and vehicle operations as well as vehicle maintenance. Future updates to the emissions inventory will aim to include construction, road maintenance and displaced emissions estimates as well as other emissions converted to $MTCO_2eq$ (e.g. estimated methane emissions)

## Data sources:

Fuel consumption and miles traveled are provided by First Transit, the contracted operations/maintenance provider for Crimson Ride. Facility energy use is provided by UA Energy Management office who maintains these records.

Between 2020 and 2022, UA Crimson Ride operated **39 buses** (model year 2007-2020) with average annual distance traveled and fuel consumed of **14798 miles traveled** and **3990 gallons of diesel** per year per bus.

UA Crimson Ride operates out of two primary facilities, a station/operations hub combined parking deck (estimated enclosed space of **22000 sqft**) and a maintenance building (estimated enclosed space of **13000 sqft**). These two facilities have consumed an **average of 563 MWh and 50 MWh** per year, respectively.

## Non-Revenue Earning Fleet Emissions Estimates

The majority of UA Crimson Ride service is non-revenue and records are not separately maintained for bus operations under revenue service. Therefore, projections of total GHG emissions are based on total usage and not partitioned by non-revenue and revenue generating operations.

### Assumptions:

Estimates of GHG emission from facility and vehicles operations/maintenance are based on two primary sources.

1. Electrical and Fuel Consumption Based Estimations:
    - Electricity Consumption emissions factors – $4.33 \times 10^{-4}$ metric tons $CO_2$/kWh
    - Gallons of Diesel Consumed – $10.18 \times 10^{-3}$ metric tons $CO_2$/gallon of diesel

    Source: EPA's Greenhouse Gases Equivalencies Calculator
    https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

2. Vehicle Miles Traveled and Square Footage based Estimations:

    - GHG Emissions of Diesel Bus Operation per vehicle mile – 1.96 x $10^{-3}$ metric tons $CO_2$/vehicle mile travel (combining upstream and downstream)
    - GHG emissions of Diesel Bus Maintenance – 5 x $10^{-5}$ metric tons $CO_2$/vehicle mile travel
    - GHG Emissions of Maintenance Facility per square footage – 9.12 x $10^{-3}$ metric tons $CO_2$/sqft/ (combined Electrical and heating)
    - GHG Emissions of Station Facility per square footage – 9.04 x $10^{-3}$ metric tons $CO_2$/sqft/ (combined Electrical and heating)

    Source: FTA's Transit Greenhouse Gas Emissions Estimator v 3.0 Excel file and Guide https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/ftas-transit-greenhouse-gas-emissions-estimator

**Emissions Estimates:**

Based on total bus operations (miles/gallons) and facilities (size/electrical consumption) the following total GHG emission estimates are reported.

1. Vehicle Operations estimates
    - 1584 $MTCO_2eq$ based on fuel consumption and EPA sources
    - 1130 $MTCO_2eq$ based on VMT using FTA GHG Estimator
2. Vehicle Maintenance estimate
    - 29 $MTCO_2eq$ based on FTA GHG Estimator
3. Facility Operations estimates
    - 317 $MTCO_2eq$ based on manual sqft calculation using FTA GHG Estimator Guide
    - 281 $MTCO_2eq$ based on FTA GHG Estimator v3.0
    - 265 $MTCO_2eq$ based on kWh consumption from EPA sources

## Total GHG Emissions Inventory for UA Crimson Ride

## 1424 - 1930 $MTCO_2eq$

# 4. Past and Current Initiatives

## Alabama Mobility and Power Center as the Regional Innovation Hub

The Alabama Mobility and Power (AMP) Center is a public-private partnership between the Alabama Transportation Institute at The University of Alabama, Alabama Power Corporation (APC) and Mercedes-Benz US International (MBUSI). The purpose of AMP is to engage in electric vehicle R&D and workforce development activities. Workforce development activities will be centered in a component center of AMP called the National Training Center for Electric Vehicles and Infrastructure (NTC). NTC will coordinate the development of majors, minors and certificate programs designed to provide UA students with the opportunity to develop credentials in the EV space. This approach will mostly be developed by faculty in various disciplines that can contribute content to such programs – most of which are from the College of Engineering, College of Arts & Sciences, and the Culverhouse College of Business.

The NTC will also coordinate the professional and continuing education for industry to support retraining and onboarding of potential employees from non-traditional paths. The signed memo of understanding (MOU) between UA, Alabama Power Company (APC) and Mercedes-Benz U.S. International (MBUSI) solidified the joint desire to establish the National Training Center for Electric Vehicle Infrastructure and Technology. UA has included the National Training Center as one of its highest federal priorities for the next several years.

Therefore, the AMP Center presents a great opportunity to inform both private and government investment on new battery technologies and on securing an efficient EV charging infrastructure.Thus, the AMP Center's research portfolio will be in the areas of efficient and sustainable energy storage, in development of a charging infrastructure, and in management of power delivery to support large scale growth in EVs. Additionally, there is substantial need to support education, training, and workforce development for EVs, as recognized by a national training center for students, multiple state and local officials, and the EV workforce.

The AMP Center provides an interesting backdrop for a transition to electric buses in at least two ways. First, the establishment of a regional innovation hub around this idea will be mutually supportive – as the AMP center thrives, the bus system will receive interest and attention that may help the level of sustainability and investment. The more local interest there is in the AMP Center, the more there will be motivation to invest in green energy for transit. And second, the AMP center serving as an endpoint for workforce development in electric vehicles means that people will be going to the physical location of the center for training and similar activities. Given the investment of the AMP project in promoting diversity, equity and inclusion and Justice40 goals, having an electric transit system in place will reinforce the importance of green energy in the ecosystem.

## Clean-Energy Research Initiatives

The ACTION project is a $16.8M project funded by the FHWA ATCMTD program. The intent of this program is to provide advanced infrastructure technology for Tuscaloosa area roadways, traffic signals and other support for congestion/flow management. The net effect of this project is to create a "connected city" that can provide a demonstration of automated, connected, electric and shared mobility – having connected infrastructure that is also supportive of electric and shared mobility through the proposed evolution to electric buses will support the overall strategic direction of the city.

## Regional Plan for Renovating Public Transit

Tuscaloosa has developed several long-range planning documents that support an expanding emphasis on shared mobility, transit and green transportation (click **Links** for references):

1. City of Tuscaloosa – Existing Conditions Assessment: **Transportation and Mobility** (pages 15-19)
2. Tuscaloosa Area MPO and West Alabama RPO – **West Alabama Coordinated Public Transit Plan** (pages 42-52)
3. Tuscaloosa Area MPO – **2045 Long-Range Transportation Plan** (Transit projects listed on pages ES-10 – ES-11; UA transit system information is detailed on pages 19-20)

The project is well aligned with the Alabama Electric Vehicle Infrastructure Plan (EVIP) that ATI developed in conjunction with Alabama Clean Fuels Coalition in January 2022. The EVIP clearly sets out the strategy for EV charging technology and locations that is cognizant of the geographic and socioeconomic equity issues that must be addressed to insure an inclusive transition to transportation electrification in Alabama.

Additionally, a broad interdisciplinary team from UA was shortlisted on the national Build Back Better grant competition administered by the U.S. Economic Development Administration. The objective of the proposed UA program, entitled Driving Regional Innovation through Vehicle Electrification (DRIVE), is to create a dynamic center of sustainable job creation, innovation, and competitiveness to position the West Alabama region to lead the state and the nation in EV-related education and workforce development. If successful, the DRIVE program will build on and support the momentum created by the several automotive manufacturers located in Alabama as they aggressively transition to an electrified future.

# 5. Emission Reduction Goals and Targets

The Crimson Ride, together with the city of Tuscaloosa, envisions three major goals on emission reduction and fleet electrification by 2030, as detailed below:

## Goal #1 – Transition to 100% net-zero emission bus fleet by 2030.

The Crimson Ride, together within the University of Alabama and the city of Tuscaloosa, is taking a bold step towards a sustainable future. Our commitment is to convert 100% of the current diesel buses to electric buses by 2030, leading the charge towards the university's as well as the regional's goal of reaching net-zero emissions. This initiative has already begun with the support of the Phase I funding from the USDOT FTA, and the team plans to electrify 8 buses in the first phase before 2025, followed by at least 6 more each year after. The city of Tuscaloosa will also be joining the effort, starting in 2024, with plans to retrofit all 15 of their buses into electric vehicles by 2028. This goal represents a collective effort will not only help the University of Alabama and the city of Tuscaloosa achieve the net-zero emission goal but also set an example for other institutions to follow in creating a greener future for all.

## Goal #2 – Improving accessibility, emissions and energy justice for local communities

Tuscaloosa County is home to many underrepresented groups and historically disadvantaged communities who suffer disproportionately from the impacts of air pollution and respiratory diseases. Meanwhile, access to public transportation is an essential mode of transportation for many local residents, making it even more important to address the issue of air pollution from the transportation sector. The electrification project of the Crimson Ride buses and the retrofit of the Tuscaloosa city buses into electric vehicles is a crucial step towards serving the local community with zero-emission transportation options. This effort not only improves transportation equity and energy justice for these communities but also takes a step towards creating a cleaner and healthier environment for all residents. The University of Alabama, as a leading institution, is committed to this mission of sustainability and is working towards moving towards clean energy resources and developing innovative battery storage solutions. By working together, the community, the University, and the city can create a better future for Tuscaloosa County.

## Goal #3 – Building a Comprehensive Eco-System for Electric Vehicle Technologies in Tuscaloosa

The University of Alabama, in collaboration with key industry stakeholders, namely Mercedes-Benz US International (MBUSI), Alabama Power Company, and the state of Alabama, has established two highly successful research and development centers, namely the Center for Advanced Vehicle Technology (CAVT) and the Alabama Mobility and Power Center (AMP). These centers are dedicated to conducting fundamental and applied research on battery electric vehicles, including related areas such as batteries, smart charging, and more. The success of these centers is evidenced by their ability to secure research grants exceeding $20 million over the past two years. Moreover, the Tuscaloosa region has established a robust eco-system for electric vehicle technologies, encompassing battery-pack manufacturing, electric vehicle assembly, and battery pack recycling. These efforts represent the initial steps towards creating a comprehensive electric vehicle eco-system that will include cell manufacturing facilities in Tuscaloosa, as well as anode and cathode battery materials. Additionally, the establishment of a workforce training program will help to build a hub for electric vehicle technologies. The electric bus project is a significant milestone in our vision towards achieving net-zero capital and will serve as a catalyst for future efforts in this area. We remain strongly committed to our goal of establishing a holistic electric vehicle eco-system that will pave the way for a sustainable future.

# 6. Strategies and Actions

The integration of electric buses into our transit system is a critical step in reducing emissions and promoting sustainable transportation. By partnering with Tuscaloosa Transit, we aim to provide a seamless and convenient public transportation experience for our communities. Moreover, by promoting the use of our electric buses to University of Alabama students, we hope to increase ridership and reduce the number of single-occupancy vehicles on the road, thus reducing traffic congestion and improving air quality.

Additionally, the team envisions the integration of electric bus into a smart-city eco-system through the implementation of bus signal prioritization to further improve operational efficiency, reduce the time our buses spend idling at intersections, and achieve even lower emissions. These efforts will not only benefit the environment, but also the overall community in many ways. By offering an alternative to driving, we hope to reduce the financial burden of transportation for individuals, as well as reduce the dependence on fossil fuels and promote energy independence.

Furthermore, the use of electric buses will help create jobs in the manufacturing, maintenance, and operation of these vehicles, and stimulate the local economy. The reduction in emissions will also have a positive impact on public health by reducing the amount of harmful pollutants in the air. With these community benefits in mind, our goal is to create a sustainable and convenient transportation system for the benefit of all.

To accomplish the above strategies, the team has developed an action plan to achieve 100% electric fleet and supporting workforce development for a sustainable electric bus service.

## Fleet Transition Action

1. CY 2022: The project team will hold kick-off meetings and prepare for the detailed energy and ridership analyses of the current diesel bus fleet. A detailed scheduling and operation plan will be developed for operating the mixed electric and diesel bus fleet. Route expansion will be investigated to provide services to Stillman College, Shelton State Community College and underrepresented communities. By collaborating with Alabama Power, the optimal locations and utility costs of the charging stations will also be finalized.
2. CY 2023-2024 (8 electric buses): The project team will acquire 8 electric bus (20% of the current fleet), one overhead charging docks and four pedestal chargers, with two dispensers each, will be deployed. The current maintenance facility will be upgraded to support the operation and maintenance of the electric buses. The operation of the electric bus fleet will be monitored, data will be collected, and benefits and community impacts will be analyzed. These purchases are part of UA Crimson Ride's FY 2022 award under the Low-No program.

3. CY 2023-2025 (12 electric buses): Planning for the expansion of UA campus transit with another 10 electric buses (26% of the fleet, and 55% in total), 1 overhead charging hub and 2 pedestal chargers. A joint planning will be conducted Tuscaloosa County Transit Authority where the experience in stage 1 of the project will be shared. Based on the operating experience of UA campus transit system, a detailed transition plan for the Tuscaloosa County will be developed, including the shared usage of charging and maintenance infrastructure on UA campus. The transition plan will include an additional 2 electric buses to be operated in Tuscaloosa County. The project team will summarize operational experience, lessons learned and prepare for the FY 2023 Low-No application.
4. CY2024-2026 (14 electric buses): At this stage, the project team will plan the expansion of another 10 electric buses. This will achieve the full transit electrification goal for campus transit services. An additional 4 electric buses will be planned for Tuscaloosa County transit service. We envision that there will be a price decrease for battery packs. The electric bus industry will also grow significantly, resulting in the scale of economy effect. These will allow us to acquire more electric buses under a similar budget level. Additional charging infrastructure will be developed at non-campus locations to support the joint operation of UA campus bus and Tuscaloosa County transit services. We will pilot a transit service that connects EV manufactures with local communities.
5. CY2026 and onwards (13 electric buses): The project team plans to reach 100% electrification goal the Tuscaloosa County. This will require the acquisition of another 8 electric buses for UA campus and 5 electric buses for Tuscaloosa County. The team also plans an expansion of service to adjacent rural counties for workforce and healthcare transportation.

## Workforce Development Plan

The workforce plan includes training and development from three distinct dimensions:

### Operation:

The operation of electric buses will differ from diesel buses regarding the routing and scheduling of the timetable. Different operation plan needs to be designed to account for seasonal variations (e.g. temperature) and optimal charging schedules also need to be developed for the effective use of limited charging infrastructure and maximizing charging efficiency. Because of the high number of stops in a transit application, special attention will be necessary regarding recharging during a two-shift operation. Bus operators need to be trained on the efficient driving of electric buses with regenerative braking. They need to be trained in energy management (e.g., cooling and heating) and range of the bus to avoid an empty battery situation. They need also to be trained to address emergencies such as breakdowns and fire hazard.

**Management:**

During the transition period, the staff needs to prepare for the management of a mixed vehicle fleet of both electric and diesel buses, taking into account the different maintenance schedules and the shortage of skilled workers for electric vehicles. The management team needs to develop a comprehensive response plan for vehicle breakdown and electric vehicle fire.

**Maintenance:**

As electric vehicle maintenance and routine inspection are high-voltage applications, we need to train 15-20 workers in topics related to battery maintenance, electric motors and invertors, and the daily operation of charging stations.

Following the above directions, five critical steps will be followed to deliver the workforce development task:

Step 1: Develop the curriculum and the team of instructors for the apprenticeship program based on current training programs at Stillman College, NTI and the University of Alabama.

Step 2: Recruit a subset of existing workers as the initial batch of trainees.

Step 3: Utilize trained workers and the apprenticeship program to facilitate and sustain the training of subsequent batches of workers.

Step 4: In the event of attrition of current workers, hiring and training new workers, primarily from disadvantaged communities such as the Black Belt, for additional workforce development.

Step 5: Develop labor-management program and training programs on transit operations to prepare existing and new workers for the management and operation of electric buses.

During the process, we will engage a small leadership team of 5 workers (2 bus operators, 2 maintenance workers and 1 operation staff) from current workforce to discuss and fine-tune the transition workforce development plan. Following the above 5 steps, the workforce development plan in this project represents a collaboration with the AMP center, Stillman College and NTI for labor-management training programs. Together with Stillman College, an apprenticeship program specifically tailored to electric vehicle safety and maintenance will be developed. Primary candidates from disadvantaged communities (e.g., Black Belt) will be recruited for the program. To the maximum possible extent, traineeship programs will reskill current workers on diesel buses for the operation, management and maintenance of the electric buses.

# 7. Implementation and Monitoring

The project team has developed multiple steps to ensure a smooth and effective implementation of net-zero emission buses and also monitor the benefits bring to the entire community.

## Ongoing Effort #1: Sensor augmentation, data collection, and data analytics for operation assistance

We are working with bus OEM to install sensors on our electric buses to collect valuable data that will allow us to monitor the performance of these vehicles and make informed decisions about their use. The sensors will gather information such as vehicle speed, battery performance, and energy consumption. This information will then be transmitted to a centralized management system where it can be analyzed and used to make informed decisions about our electric bus fleet. With this data, we can identify patterns and trends in performance and use this information to improve route planning, reduce energy consumption, and increase the overall efficiency of our electric buses. Additionally, the data collected from the sensors will be used to track maintenance and repair needs, enabling us to keep our vehicles in good condition and minimize downtime. Overall, the installation of these sensors is a significant step forward in our efforts to provide the best possible electric bus services to our communities and ensure a sustainable transportation future. The data collected from these sensors will be used to optimize routes, synchronizing the operation with traffic signals through C-V2X communication, and improve services for passengers, ensuring that our electric bus fleet is operating at maximum efficiency. With real-time monitoring and analytics, we will be able to identify and address any issues quickly, ensuring that our electric buses continue to provide reliable and sustainable transportation for communities across the region.

## Ongoing Effort #2: Maintaining and Monitoring the Emission Inventory

As the zero-emission transit bus electrification plan progresses, the emission inventory provided in Section 3 will be continuously updated. The updates will reflect the changes in the composition of the transit bus fleet, the deployment of electric bus charging infrastructure, and the use of renewable energy sources to power the electric buses. The emission inventory will be updated in accordance with industry standards and will also be used to inform policy decisions and improve the efficiency of the transit bus system.

One of the key efforts related to maintaining and monitoring the emission inventory is the integration of electric bus energy analysis. This analysis will enable the assessment of the energy consumption and the corresponding emissions of the electric bus fleet, as well as the identification of energy-saving opportunities. Another effort related to maintaining and

monitoring the emission inventory is the expansion of the inventory to cover the entire campus transit vehicle fleet. This expansion will provide a comprehensive view of the emissions generated by the entire transit system and will also facilitate the identification of opportunities for further emission reduction. Finally, monitoring the energy consumption after the deployment of the electric bus charging infrastructure is crucial for updating the emission inventory. This monitoring will also enable the assessment of the performance of the charging infrastructure, the identification of any maintenance issues, and the optimization of charging patterns to minimize grid instability.

## Ongoing Effort #3: Partnership with local community college for sustainable workforce development

One key element for a sustainable electric bus project is the readiness of supporting workforce for both vehicle maintenance and operation. An important component of our project is the initiation of a labor-management training program. This project will enable a closer cooperation between Shelton State Community College, Stillman College and the AMP center at the University of Alabama. The educational program will also have an effect on training of skilled workers for the electric vehicle battery plant of Mercedes-Benz U.S. International and its suppliers in Alabama. The combination of these efforts will contribute to a sustainable workforce development for the electric vehicle eco-system. These collaborative efforts with HBCUs will also provide opportunities for students from underrepresented groups and historically disadvantaged communities to access good-paying job in the EV industry.

## Ongoing Effort #4: Educational opportunity for next-generation students

As the flagship institution in the state of Alabama, UA is also uniquely positioned to introduce significant educational benefits and impacts to the local community. One important effort in this direction is the collaboration with local communities and K-12 schools for early-access and touring of electric bus facilities. The electric bus fleet will expose the next generation community college and university students to new knowledge in transportation electrification including battery technologies, electric vehicle manufacturing, grid integration, renewable power generation, economic growth and regional development. It also offers the K-12 students to experience electric vehicle technology at an early age, cultivating an interest in STEM and contributing to a diverse future workforce preparation and development. All these activities will lead to a more sustainable and equitable transportation system and community life.

## Emerging Challenges

The project team envisions three major challenges for the electric bus transition project. First, the acquisition of raw materials relating to permanent magnets and battery cathode and anode has become a highly competitive global market. This competition creates significant supply chain

shocks in the production of vehicle batteries, affecting the cost of acquiring electric buses. Additionally, the limited production capacity for electric bus manufacturers in the U.S., given the high demand supported by the No-Low project and other green transportation initiatives, presents a significant challenge. As battery electric vehicles increasingly replace conventional combustion-powered cars, a third challenge arises due to the limited loading capacity in the regional power grid. The current grid is insufficient to support the simultaneous high-power charging tasks for electric buses and personal vehicles while maintaining normal grid operation.

To mitigate these challenges, the project team sets up a staged deployment plan over 5-years to avoid acquiring all electric buses at the same time to mitigate the impacts of excessive cost and shortage of supply for electric buses. This also allows for additional time to prepare the regional power grid to support the electric bus operation. In addition, the team has already developed several smart charging strategies, such as peak-shaving, staggered charging schedule with mixed charging infrastructure, and the reuse of second-life batteries, that will adapt to support the charging scheduling and energy-optimal routing for operating a fully-electrified bus and car fleet.

## Looking Ahead

The completion of the transit bus electrification project will mark a significant milestone towards achieving a sustainable, zero-emission public transportation system. However, there are still several potential activities that can be undertaken to further support the electric bus initiative and contribute to a cleaner and more efficient transportation system.

First, efforts can be made to expand the electrification of the entire campus transit system. While the electrification of the bus fleet will be an important step, transitioning to an entirely electric-powered transportation system would require further investments in vehicles, charging infrastructure, renewable energy sources, and the development of advanced energy management systems. By exploring and adopting new technologies, the campus transit system can continue to advance towards a completely sustainable transportation system.

Second, it will be important to ensure the long-term sustainability of the electric bus fleet. This can be achieved by implementing an effective maintenance and repair program that maximizes the longevity and performance of the electric buses. Additionally, the development of workforce training programs will ensure that bus operators and maintenance technicians have the necessary skills and knowledge to support the electric bus transition process.

Third, it will be important to explore the potential for the development of smart transportation systems that optimize the use of electric buses and charging infrastructure. This can be achieved by integrating advanced technologies such as battery monitoring and energy-optimal routing powered by big data analytics and artificial intelligence to optimize the use of the electric buses and minimize the charging infrastructure's impact on the power grid.

Last, there is potential for the development of sustainable transportation policies and practices that can further support the electrification of the campus transit system. This can include incentives for the adoption of electric vehicles, the development of bike and pedestrian-friendly infrastructure, and the implementation of car-sharing programs. By integrating these policies and practices, the campus transit system can contribute to a more sustainable and livable campus community.