**Technical Appendix: GHG emissions reductions ABOR**

The GHG emissions and Criteria Air Pollutants (CAP) reductions associated with the ABOR proposed measures were calculated for all years between 2025-2050 (see attached spreadsheet with calculations).

**eGRID Factors**

Our modeled future GHG intensity of electricity (eGRID factor) may differ from other estimates. Dr. Richard Rushforth developed future eGrid emissions for the City of Phoenix that factors in the planned retirement dates of large fossil fuel power plants – e.g., the 847 MW San Juan Power Plant Operated by PNM in New Mexico has a planned retirement in 2022, the 1,540 MW Four Corners Generating Station operated by APS has a planned retirement in 2031, and the 762 MW Coronado Generating Station operated by SRP has a planned retirement no later than 2032.1,2,3,4,5 The AZNM eGRID factor projection used for this model assumes that as a large fossil fuel power plant is retired, the generation is replaced by a non-GHG emitting power source as per the plans This assumption is based on eGRID data for calendar year 2020, which showed that renewables replaced the generation from the Navajo Generation Station and from regional utility integrated resource plans.6,7,8 The model does not add generation to meet future demand growth. Doing so would decrease the projected eGRID factor if the additional generation was non-GHG emitting or potentially increase grid intensity if the growth was powered by natural gas plants. In this sense, this model utilizes a reasonable conservative model to project the future GHG intensity of the electricity that sub awardees purchase from Tucson Electric, Salt River Project and Arizona Public Service. We utilized the estimated eGrid values developed for the City o fPhoenix 2020-2050 in our calculations for on-site solar displacing grid electricity and emissions associated with charging electric buses and vehicles.

**On-Site Solar and battery**

Solar/ battery project emissions reduction estimates were developed by each of the three universities utilizing third party developer information, indicative pricing, and/or in-house expertise. These estimates included generation and storage capacities, annual energy production, and potential battery dispatch schedules by each project per location.

All solar/battery projects were conservatively assumed to begin operation in 2027 but it is possible some projects may on-line in 2026 if the estimated timeline is accelerated.

For these calculations, all solar production was assumed to replace grid electricity on a 1:1 kWh AC basis. This assumption was used to calculate the MT CO2e reductions per year.

Solar production was assumed to degrade at a level of .6% per year9

To calculate CAP Emission reductions, emission factors were imported from EPAs ‘AVoided Emissions and geneRation Tool’ (AVERT) tool for the criteria air pollutants SO2, NOX, PM2.5, VOC, using inputs in the tool of Southwest Region and reduction of 1 GWh generation to obtain total emissions from fossil generation that was then converted to metric tons per kWh, and this number was multiplied with the total kWh produced by the solar projects to find the reduction in co-pollutants from displacing grid electricity.

We did not try to quantify the battery storage's GHG emissions impact, but we do anticipate that additional energy storage capacity will reduce GHG grid emissions. In the solar and battery measure, batteries play a crucial role in enhancing grid reliability and emissions reduction. They act as a buffer, storing excess energy during periods of low demand and discharging it during peak demand. By providing rapid response capabilities, batteries help stabilize the grid and ensure a steady supply of electricity. We intend to enable carbon reductions through battery management of storage and discharge. The specific quantification of impacts is not available currently because we lack precise numerical measurements of the effects. In the future, we plan to achieve this by leveraging dynamic marginal emissions data and incorporating our battery operations to achieve this goal. This real-time approach provides insights to the impact of load shifting decisions with data now becoming available through organizations like WattTime that provide 5-minute marginal emissions granularity, allowing us to capture rapid fluctuations charge when energy is clean and discharge when the grid is the most carbon-intensive. This enables us to respond swiftly to changes in grid conditions, ensuring that our interventions are timely and impactful.

**Vehicle Electrification**

**GHG Reductions**

Vehicle lists of internal combustion (IC) vehicles to be replaced with electric vehicles were provided by each of the university sub awardees. This list included actual or estimated mileage for 2023. Emission reductions were also calculated for transit buses for NAU and UArizona. For CAP calculation purposes, the vehicles in the passenger vehicle lists were aggregated into light-duty cars, light-duty trucks and diesel buses. Averages and totals were used in the emissions reduction calculations.

For each university’s list of IC vehicles, the annual MTCO2 emitted was calculated for each light-duty vehicle in the list and the average was taken into the column ‘GHG Reductions Per Light-duty [Car/Truck] Vehicle (MT CO2e per vehicle)’ column. This calculation was used to calculate the GHG emissions associated with the removal of these vehicles.

For buses, the baseline was calculated by finding the annual emissions associated with each bus and then calculating an emission factor of MT/mile.

The total sum of kWh necessary to power the planned replacement EVs for the estimated future mileage (based on the 2023 fleet usage data) were used and put into the respective ‘Electricity used Light-Duty [Car/Truck] (kWh)’ Column and then multiplied by the adjusted eGRID factor to get the GHG emissions from electricity from charging.

The emissions from charging the replacement EVs from the grid were subtracted from the emission reductions from the IC vehicles taken off the road to get the Annual GHG Reduction emissions.

For the EV passenger vehicle calculations, the kWh / mile for the replacement EVs information was used and multiplied by the total amount of annual miles of the vehicles to be replaced to get the total GHG reductions for each year.

Due to the university EV purchasing policies, we assume that the vehicles will be replaced in the future (15 years) with better/more efficient zero emissions technology. We did not take increased vehicle efficiency (W/mile) into account but rather used the same electrical consumption numbers throughout the period of analysis. Therefore, the future GHG emission reduction calculations from vehicle charging are presumed to be conservative estimates.

**CAP Emission Reductions**

To calculate the baseline co-pollutant emissions for light-duty IC vehicles, the EPA’s ‘Motor Vehicle Emission Simulator’ (MOVES) tool, was used to estimate criteria air pollutants SO2, NOX, PM2.5, VOC.

For IC buses, Argonne Labs AFLEET tool was used to calculate emissions for the buses in the State of Arizona, with the average amount of miles and fuel economy calculated for each university wanting to replace buses.

For the additional CAP emissions from the charging of EVs from grid electricity, emission factors were imported from EPA’s ‘AVoided Emissions and geneRation Tool’ (AVERT) using inputs in the tool of Southwest Region and reduction of 1 GWh generation to obtain total emissions from fossil generation that was then converted to metric tons per kWh. This number was multiplied with the total annual kWh used by the replacement vehicles and then subtracted from amount of reduction in co-pollutants from not using the IC vehicles.

The emissions reductions from replacing IC vehicles were combined with the additional emissions from the increase load on the electrical grid from charging EVs to get the CAP reduction rate (if negative, it is additional CAP emissions)

**University Vehicle Data Notes**

**ASU**

The data provided only had the gallons of gasoline used for each vehicle, so the grams of CO2 per mile were identified for each vehicle by using the fueleconomy.gov dataset. This was divided into the MTCO2 from each vehicles emission to get an estimate of the miles each vehicle used.

**UArizona**

The data provided only had annual miles so the grams of CO2 for each vehicle were identified from fueleconomy.gov.

**Sources:**  
1 Arizona Public Service (2020). We’re All in for Arizona: Our Clean Energy Commitment. URL: https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Energy-Resources/CleanEnergyReport.ashx

2 Salt River Project (2022). Sustainability at SRP. URL: <https://www.srpnet.com/grid-water-management/sustainability-environment/sustainability-overview>

3 Tucson Electric Power (2022). 2020 Integrated Resource Plan. URL: <https://docs.tep.com/wp-content/uploads/TEP-2020-Integrated-Resource-Plan-Lo-Res.pdf>

4 PNM Resources (2021). 2020-2040 Integrated Resource Plan. URL: <https://www.pnm.com/documents/28767612/31146374/PNM-2020-2040-IRP-REPORT-corrected-Nov-4-2021.pdf>

5 El Paso Electric (2020). 2021 Integrated Resource Plan. URL: https://www.epelectric.com/files/2021-IRP-Public-Presentation-082020.pdf

6 U.S. EPA (2022). Emissions & Generation Resource Integrated Database (eGRID). URL: https://www.epa.gov/egrid

7 Arizona Public Service (2020). 2020 Integrated Resource Plan. URL: <https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Doing-business-with-us/Resource-Planning-and-Management/2020IntegratedResourcePlan062620.ashx?la=en&hash=24B8E082028B6DD7338D1E8DA41A1563>

8 For example, the APS 2020 Integrated Resources Plan states (page 11): We have an extraordinary opportunity to transform our supply portfolio with clean and renewable additions, both to meet our 2030 renewable energy commitment and also chart a path to zero carbon emissions by 2050. Over the next decade, approximately 1,400 MW of APS coal capacity is scheduled for retirement, and another 1,600 MW of medium-term purchases from existing merchant gas plants are scheduled to expire. These resource retirements and contract roll-offs, coupled with the need for additional capacity to serve growth in peak demand, result in new capacity needs of approximately 6,000 MW to reliably serve peak summertime customer demand. Our Action Plan update, which details our plans for the 2020-2024 period, and our IRP portfolios for the period 2025-2035 set out APS's plans to aggressively realize this opportunity for fleet transformation, resulting in a portfolio in 2031 and beyond with no coal and substantial increases in renewable generation, while meeting our reliability obligations and customers' expectations for affordability. As indicated in Table ES-1, our Action Plan relies heavily on renewables, energy storage and demand side management, including demand response and energy efficiency additions.

9 National Renewable Energy Laboratory (2022). PV Lifetime Project - 2021 NREL Annual Report . URL: https://www.nrel.gov/docs/fy22osti/81172.pdf