Technical Appendix: Methodology for assessment of climate benefits from combined solar photovoltaic, battery storage, and electric school buses at New Jersey schools.

Areas evaluated are listed in Table 1.

The Argonne National Laboratory (ANL) 2023 AFLEET model was used to estimate emissions reductions from the retirement of individual fossil fuel powered school buses and the amount of electricity that would be consumed by new electric buses.[1] Type A and B school buses[2] were assessed using the model's School Bus vehicle type and shuttle/paratransit vocation. Type C buses were modeled using the School Bus vehicle type and the School Bus vocation. Default fuel efficiencies and energy consumption rates were used, and all vehicles were assumed to travel 15,000 miles per year. Annual emissions estimates for fossil fuel vehicles and annual electricity consumption for electric vehicles were taken from the model's TCO tab and are shown in Tables 2 and 3. For each project, the total annual emissions reductions and energy consumption were found by multiplying per-vehicle annual values by the proposed number of vehicles (Table 4). Cumulative benefits were found by assuming constant annual benefit levels and multiplying by the anticipated number of years the project would remain in operation.

The NJDEP Community Solar Siting Tool was used to estimate the square feet of rooftop or ground area where solar PV installations could potentially be installed (Table 5). The areas evaluated were identified based on conversations with school officials.[3] No attempt was made by NJDEP to physically examine structural conditions or other factors at the individual sites that could affect project implementation.

To assess typical solar module densities (square feet of rooftop per square foot of solar module), aerial photographs of solar PV installations at the NJDEP headquarters at 401 E. State Street, Trenton, NJ, and the Clarkson Fisher Federal Court House at 402 E. State Street, Trenton, NJ, were evaluated. The spatial density at the NJDEP building array was 3.66 sq ft roof/sq ft module, and at the courthouse 3.32 sq ft roof/sq ft module, for an average module density of 3.5 sq ft roof/sq ft module. This corresponds to a spatial occupancy of 29%.

Commercial-sized modules were assumed to have dimensions of 6.5 ft by 3 ft, for a total area of 19.5 sq ft. Capacity was assumed to be 390W, corresponding to 20W capacity per sq ft of module.

Potential solar array capacity was found by multiplying the available rooftop area by the spatial occupancy density (29%) and the capacity per square foot of module (20 W/sq foot) and is shown in Table 5. In one case, Hopewell Valley Regional School District, the amount of area available exceeded what was necessary to meet the needs of the proposed project. In that case, anticipated future demand was used to approximate the array capacity necessary to meet the demand, and that value was used as the maximum allowable array size in later modeling. In another case, Dumont Board of Education, a planned solar PV installation would be augmented by grant-funded storage and EV buses. In that case,

[1] https://greet.anl.gov/afleet
[2] Information on school bus classifications can be found at https://americanbussales.net/seven-different-school-bus-types/
[3] https://storymaps.arcgis.com/collections/a8cb145807ea488db3dc808f96f8ee3b?item=1

the size of the planned array was used for analysis of the storage capacity. The cost and emission benefits of the panels on this site were not accounted for in this grant application.

Electricity billing data was provided by the respective school districts. Billing rates were taken directly from the bills (dollars per kWh usage and dollars per kW demand). For one school district (Belmar Elementary School District), billing rate information was incomplete as billing from a third-party power supplier was missing. For this school district, rates from comparable sites from the same electric distribution company's territory were used. With respect to electricity consumption, when total annual usage was available, that figure was used for later analyses. When only one or two months of billing data was available, the average daily consumption was found and then multiplied by 365 days/year to find the annual amount. The anticipated loading from EV buses that was found using AFLEET was added to the historical billed usage estimate to find total loading under the proposed scenarios. Billing and load data are presented in Table 5.

The 2023 NREL Electricity Annual Technology Baseline (ATB)[4] was used to estimate costs of solar PV and battery storage systems. Solar PV systems were classified as commercial class 8 rooftop installations with construction year 2025. The ATB Solar PV capital cost was $1,731/kW; battery energy capital cost was $209/kWh, and battery power capital cost was $803/kW. ATB estimates were in 2021 dollars and were input into later modeling without additional adjustment for inflation.

Using the above data, the NREL ReOpt screening tool[5] was used to estimate sizes of solar arrays and battery storage systems; capital costs; and grid-based emissions reductions for each site. ReOpt embeds the NREL PVWatts tool for solar analysis,[6] NREL Cambium climate emissions rates,[7] USEPA AVERT air quality emissions factors,[8] and other resources to identify optimal system characteristics for a given scenario. For locations where school buildings would be supplied by the solar PV systems, the Secondary School load profile was used. For the Hopewell Valley Regional School District site, which is located at their administrative building and bus yard, a flat load profile with loading activity between 6 am and 10 pm was used. Calculations of grid emissions were based on the default long-run marginal emissions rates (LRMERs) from the NREL Cambium data set for the RFC East region. Air quality emissions rates were based on the EPA AVERT model's Mid-Atlantic region. Climate and health objectives were included in the optimization routine. Resilience criteria for the battery storage systems were set to meet 100% of load during a 24-hour outage in early October. This period was chosen in light of historic hurricane activity at this time of year. The model was set to consider cost savings, resilience, and clean energy during optimization.

The projected emissions reductions from the solar/storage systems calculated by ReOpt were added to emissions reductions projected by the ANL AFLEET model from retirement of fossil-powered buses to estimate total emissions reductions for each project site. Design and performance details are provided in Table 6. These results are conceptual and do not replace comprehensive analysis and design prior to

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[4] https://data.openei.org/files/5865/2023-ATB-Data_Master_v9.0.xlsx
[5] https://reopt.nrel.gov
[6] https://pvwatts.nrel.gov/
[7] https://www.nrel.gov/analysis/cambium.html
[8] https://www.epa.gov/avert

construction. In the case of Dumont Board of Education, ReOpt was used to analyze the solar-only case, and then the solar + storage + EV bus case. The difference between cases was used to estimate emissions reductions and other parameters.

The lifetime of the solar PV array is expected to exceed the time frame of the analysis. The ten-year default lifetime for storage batteries in ReOpt was used, and replacement is considered to be a routine maintenance expense to be bourn by the school district. Electric bus lifetimes are expected to exceed those of their internal-combustion engine counterparts, but battery replacements may be necessary and would be treated as routine maintenance costs to be bourn by the vehicle owners. Assuming 15 to 20 year lifetimes, it is unlikely the school districts would be able to replace the EV buses with fossil-powered units at replacement due to federal and state initiatives to remove such products from the market. In that case, the emissions avoided by retiring the fossil-powered vehicles would either continue into the future through routine replacement of the EVs, or the school district could forego replacement of the buses altogether. In the latter case, electric loading would decrease due to the absence of the buses, in which case any grid emissions remaining at that time would also decrease. Emissions reductions from the project are therefore considered to be permanent.

The electric school buses are assumed to begin operating in quarter 3 of 2026 while the solar, storage, and microgrid components are operational in quarter 1 of 2028. To determine emissions reductions of these projects through 2030, the first 2 and 3.5 years of the solar/ storage and school bus lifetimes, respectively, were calculated. Once operational, all project components will remain in service through at least 2030. To determine emissions reductions of these projects through 2050, the first 22 years of the solar, storage, and microgrid lifetimes were calculated. The solar panels and microgrid controllers have estimated lifespans of over 30 years and are thus assumed to remain operational through at least 2050. In New Jersey, school buses have a maximum lifespan of 20 years. With these funded school buses going into operation in quarter 3 of 2026, they would reach their maximum lifespan by quarter 2 of 2046, at which point they are assumed to be scrapped. Using the experience they gain with electric school buses through this program, our educational partners will be more confident in the ability of electric school buses to meet their needs. This will allow them to commit to replacing the buses funded under this program with electric buses, rather than returning to fossil fuel powered buses. In this way, the emissions reductions are expected to be durable and continue past 2050.

The emissions outputs described here were used to determine the full scope of emissions reductions from these projects. As described in the attachment Budget_NewJerseyDEP, CPRG funding will be used to support 88 percent of the project’s overall cost, while 12 percent is attributable to federal tax credits. The emissions reductions attributable to CPRG funding were therefore determined using an 88 percent scaling factor.

Table 1: Site Locations

TSchool or School District	Address	Area Evaluated for Solar
Summit High School	25 Kent Place Blvd, Summit NJ, 07901	Central rooftop area.
Hanover Park High School	63 Mt Pleasant Ave East Hanover NJ, 07936	Central rooftop area.
Hopewell Valley Regional School District	425 South Main St Pennington Borough, NJ, 08534	Administration Building and Bus Parking Lot. Empty lot between bus parking lot and Baldwin Court.
French American Academy	209 3rd Street, Jersey City, NJ 07302	School rooftop.
Belmar Elementary School and Board of Education Building	1101 Main St. Belmar, NJ 07719	School and BOE building rooftops and open ground adjacent to school.
Dumont Board of Education	25-31 Depew St. Dumont, NJ 07628	Honnis Elementary School and Administration Building

Table 2: Vehicle Energy Consumption

School Bus Class	Gas MPDGE	Diesel MPDGE	kWh/Year
A/ B	7.7	9.2	19,037
C	5	6	25,285

MPDGE: Miles per diesel gallon equivalent

Table 3: Annual Emissions from Individual Fossil-Powered Vehicles

	Class A/ B		Class C	
Pollutant	**Gas**	**Diesel**	**Gas**	**Diesel**
CO_2e, Metric Tons	24.11	20.29	32.04	26.96
CO, kg	190.01	12.50	190.01	12.50
NO_x, kg	4.03	23.24	4.03	23.24
PM_{10}, kg	1.38	1.81	1.38	1.81
$PM_{2.5}$, kg	0.41	0.36	0.41	0.36
VOC, kg	13.34	1.21	13.34	1.21
SO_x, kg	0.12	0.11	0.15	0.15

Table 4: Proposed Number of Electric School Buses

Bus Class	Summit	Hanover Park	Hopewell Valley	French American Academy	Belmar	Dumont
A				2	3	2
B	6		11			2
C		6				1
Total	6	6	11	2	3	5

Table 5: Electric and Solar PV Parameters

		Units	Summit	Hanover Park	Hopewell Valley	French American Academy	Belmar	Dumont
Electricity	Billing Rates							
	Usage	$/kWh	0.0924	0.0900	0.0910	0.0910	0.0913	0.0892
	Demand	$/kW	7.21	8.91	11.71	11.71	9.69	15.85
Projected Usage								
	Building Annual	kWh	2,034,581	1,487,957	208,066	96,466	591,090	351,886
	EV Annual	kWh	114,222	151,712	209,408	38,074	57,111	101,434
	Total Annual	kWh	2,148,803	1,639,669	417,473	134,540	648,201	453,319
Solar PV	Available Area	sq. ft.	82,406	46,500	> 110,000	9,500	49,500	
	Potential Capacity	W	470,891	265,714	338,000	54,286	282,857	223,200

Table 6: Project Scenario and Performance

			Summit	Hanover Park	Hopewell Valley	French American Academy	Belmar	Dumont (vs.PV-Only)
Design								
	Solar PV Capacity	kW	471	266	338	54	283	0
	Battery Power	kW	521	313	100	33	137	77
	Battery Capacity	kWh	8,371	6,063	1,501	590	2,186	1,013
Performance								
	Power Output	kWh	590,412	323,501	421,831	67,559	366,252	0
	% Renewable	%	26	19	79	49	53	12
	% CO2e reduction	%	21	12	74	41	47	18
Financial								
	Capital Cost (w/o buses)	$	2,983,001	1,978,785	979,267	243,542	1,056,686	273,290
	Avoided Climate Costs	$	124,255	56,910	87,606	15,626	87,701	32,921
	Avoided Health Costs	$	950,626	614,938	263,951	84,516	429,278	113,014
Emissions (Metric Tons Avoided)								
CO_2e avoided								
	25-yr cumulative		6,573.0	5,485.3	8,276.8	1,601.7	4,029.6	4,046.4
	5-yr cumulative		1,314.6	1,097.1	1,655.4	320.3	805.9	809.3

Annual average	262.9	219.4	331.1	64.1	161.2	161.9
NO_x avoided						
25-yr cumulative	7.33	7.09	6.02	0.67	2.73	1.21
5-yr cumulative	1.47	1.42	1.20	0.13	0.55	0.24
Annual average	0.29	0.28	0.24	0.03	0.11	0.05
SO_x avoided						
25-yr cumulative	13.15	8.69	2.48	0.78	4.07	1.37
5-yr cumulative	2.63	1.74	0.50	0.16	0.81	0.27
Annual average	0.53	0.35	0.10	0.03	0.16	0.05
$PM_{2.5}$ avoided						
25-yr cumulative	13.19	0.57	0.41	0.09	0.39	0.15
5-yr cumulative	2.64	0.11	0.08	0.02	0.08	0.03
Annual average	0.53	0.023	0.016	0.004	0.016	0.006