Carbon Accounting in Schools - An Analysis of Emissions in Montgomery County Public Schools

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Carbon accounting is important to understand trends in carbon emissions and to guide initiatives to reduce emissions. However, data underlying carbon accounting is often not available or transparent, making it difficult to identify high carbon emitting activities. This challenge is especially pertinent to schools as school administrators track activities but may lack a common denomination to convert those activities to carbon emisions. In this paper, we ask: How can carbon emissions tracking be applied to a school setting? What are potential environmental, social, and economic implications, and what solutions are there to reduce the emissions? To collect data, we built a dynamic website using quantitative and qualitative self-reported school data on transportation, energy, and waste management. We expect an assessment of this data to highlight the high carbon emitting activities for different types of schools (e.g. elementary, middle, and high schools), at which policy interventions can be targeted. The findings indicate that schools contribute a significant amount of carbon emissions primarily from energy use in buildings and a reliance on old diesel buses for transportation; emissions are partially offset by waste management practices but these practices are not consistently adopted. The paper found no significant correlation between underserved races or low income areas and carbon emissions. We recommend several initiatives to help reduce schools' emissions such as transitioning to electric buses, increasing walk zones and carpooling, and recycling more while decreasing landfill use. Overall, the paper offers baseline emissions and potential solutions that can help MCPS achieve their goal of being carbon neutral by mid 2030s.

Introduction

The Earth is our only home. Yet, humans are destroying it. As we release more carbon dioxide into the atmosphere, the world gets warmer. Glaciers melt, sea levels rise, natural disasters happen more often and more randomly. Not only are natural features impacted, but also people. Negative health effects occur from pollution in the air, land, and water[1].Also, we are not sustainable with our resources whether it is from using too much electricity/water to over-farming land[2].Corporations play a big role in emitting carbon dioxide to the atmosphere[3].To counteract this, these corporations have started to track their carbon emissions using carbon accounting.

Carbon accounting is the data collection of carbon emissions emitted by an entity, which includes hospitals, universities, corporations, and local governments. This is used to track the carbon footprint of the entity over time and is important as it provides insight on the amount of CO_2 emitted by the entity and to what activities these emissions are attributed. Carbon accounting has three scopes, as defined by the Greenhouse Gas (GHG) Protocol[4]. Scope 1 is greenhouse gas emissions directly from the entity. It can be controlled or owned by the organization. Scope 2 is indirect greenhouse gas emission, specifically electricity or natural gas where it is purchased outside the entity but physically used inside the entity. Finally, Scope 3 is another form of indirect emissions but is a consequence of the activities of the entity.

By tracking their carbon emissions, entities can create baselines and trends over a certain amount of time. They can also look at which areas of activities produce the most carbon dioxide emissions and make targeted changes. They can see the positive and negative implications of certain activities, which may influence how they plan certain actions in order to lower their footprint.

So far, mainly governments and corporations have started to track their emissions but schools largely have not. Researchers should begin to direct their attention to the carbon accounting of schools. Schools are an essential place to start reducing climate change and can also educate the next generation. Schools not only have older and less efficient buildings but also have students who can lead the way for the next generation in carbon reduction. Schools can be a place to start reducing these emissions as they have old and less efficient buildings and could easily reduce carbon emissions when environment-friendly changes are made to them[5]. Whether it is from transportation, energy, or waste, schools can find ways to reduce their carbon footprint and to calculate the relevant emissions as a first step.

In this paper, we track carbon emissions from three areas

in schools: transportation, energy, and waste. Transportation falls into scope 1 of carbon accounting as it is directly from the buses that these schools use. Energy is part of scope 2 as schools receive energy from outside sources such as electricity and natural gas. Waste is in scope 3 emissions as waste comes from greenhouse gasses emitted through the decomposition of materials and activities of schools[4].

Transportation is an integral part of the carbon accounting measurement specifically for schools. Buses that run on gasoline or diesel output large amounts of CO_2 into the atmosphere. Electric buses have zero tailpipe emissions and have no negative health consequences (Noel, Lance and McCormack, Regina.[6].However, these other buses emit carbon at high rates. Transportation, specifically, makes up 27% of the total U.S. Greenhouse Gas emissions by economic sector in 2020[7].Transportation clearly has an impact on carbon footprints and should be monitored and tracked during the carbon accounting process.

Energy is also an important factor when calculating emissions and should be addressed for accounting. Studies have been done in carbon accounting to calculate the footprint from electricity. By using a practice of benchmarking (comparing processes and performance of other industries), a study found that there was a 19% reduction in CO_2 emission from electricity[8].Due to counting these emissions from electricity, organizations were able to use the process of benchmarking to reduce these emissions. Also, as of 2020, electricity makes up 25% of carbon emissions in the US[7].

Finally, waste is necessary for not only calculating the negative impacts of waste disposal, but also the positives such as recycling and composting. Different waste treatments cause different volumes of greenhouse gasses. Quantifying and analyzing this data shows that recycling is the most effective method of waste[8].According to the EPA, recycling is a positive when it comes to carbon footprints as it is using materials again rather than taking the energy and resources to create it again. Therefore, in the carbon accounting process, it should have a negative carbon emission as it is beneficial to the environment[9].

A tool can be created to calculate all of these carbon emissions in order to calculate the total carbon emissions. It should allow schools to be aware that their own footprint is important as it educates students. Tools such as a website or a calculator itself will allow for schools to place emphasis on areas that emit the most carbon dioxide and make the necessary changes[10].The primary author created a website, based on calculation information from the EPA, which uses emission data from all three of these sections to calculate the total carbon footprint for each section and the combined results. Even though carbon accounting has been done in other industries, the EPA has not created voluntary disclosure specifically for schools. Thus, to the best of our knowledge, there has been no uniform methodology for schools to report their carbon emissions. The website allows for users to input carbon emission data from their school and save it. They can access it at any time. can input data from any year they want in order to create a baseline and see if there have been improvements towards making a reduction of their carbon footprint.

Results

Based on school data received for the academic year 2018-19, Montgomery County Public Schools contributed to approximately 418 million tons of CO_2 equivalent emissions. The breakdown by school type, emission type and relative contributions are summarized in the Table 1.

To further understand schools' environmental performance, we ran a series of regressions on three categories of emissions: Transportation, Energy, and Waste.

Regression

We ran a regression on transportation emissions with the bus miles and number of students as independent variables. The results demonstrate a statistically significant correlation at the 0.05 level between both independent variables and transportation emissions. Similarly, we ran a regression on the energy emissions using the square footage and population of the school; the results had similar results indicating a statistically significant positive correlation. Finally, a regression on waste emissions with the number of students yielded a statistically significant correlation.

Race and Socioeconomic status

A regression was run with total emissions and these socioeconomic statuses. The first was hispanic and black % (number of black & hispanic students as a % of total students in any school). Then, we rain similar regressions using variables representing students receiving Special Education (students with disabilities from birth through age 21) and Free And Reduced-price Meals (FARMS). Finally, we ran a regression with total carbon emissions as a dependent variable and the percentage of English for Speakers of Other Languages(ESOL) i.e. students who qualify under the ESOL category in schools as the independent variable.

Table 1 Breakdown of CO_2 emission by activity and school type.

MCPS School type	Transport		Energy		Waste		Total		# students	Total lbs CO_2/student
	(lbs CO_2 million)	%	(lbs CO_2 million)	%	(lbs CO_2 million)	%	(lbs CO_2 million)	%		
Elementary School(ES)	101	54%	103	55%	-18	-10%	186	100%	76,195	2,438
Middle School (MS)	49	51%	55	57%	-7	-7%	97	100%	35,841	2,705
High School (HS)	61	45%	81	60%	-7	-5%	135	100%	49,315	2,744
Total	211		238		-31		418		161,351	2,591

MCPS School type	Transport (%)	Energy (%)	Waste (%)
Elementary School(ES)	48%	43%	57%
Middle School (MS)	23%	23%	22%
High School (HS)	29%	34%	21%
Total	100%	100%	100%

Table 2 Best, Worst, and Average emissions and students for all school types.

	School	Total emissions (lbs CO_2)	Transportation (lbs CO_2)	Energy (lbs CO_2)	Waste (lbs CO_2)	Students
Top 2	**Poolesville HS**	3,609,608	1,792,676	1,967,170	-150,238	1,185
	Northwest HS	4,247,772	2,287,192	2,258,967	-298,387	2,586
Average	**All HS**	**5,363,850**	**2,452,360**	**3,223,354**	**-263,236**	**1,973**
Bottom 2	**Paint Branch HS**	6,826,448	3,028,811	4,081,124	-283,487	2,005
	Gaithersburg HS	7,987,261	3,485,554	4,853,775	-352,068	2,352
Top 2	**Loiederman, A. Mario MS**	1,521,150	508,997	1,189,049	-176,896	986
	Newport Mill MS	1,735,267	901,243	962,977	-128,953	675
Average	**All MS**	**2,486,124**	**1,259,668**	**1,404,813**	**-178,357**	**919**
Bottom 2	**Gaithersburg MS**	3,263,692	1,752,159	1,747,907	-236,374	863
	Lakelands Park MS	3,668,429	2,183,290	1,660,671	-175,532	1,121
Top 2	**Cold Spring ES**	350,892	43,955	432,294	-125,357	330
	Highland View ES	556,013	112,456	630,787	-187,230	440
Average	**All ES**	**1,411,107**	**767,659**	**784,149**	**-134,842**	**567**
Bottom 2	**Sherwood ES**	2,421,560	1,730,147	830,010	-138,597	527
	Matsunaga, Spark M. ES	3,137,040	1,521,910	1,743,276	-128,146	728

Discussion

Transportation

For the 2018-19 academic year, MCPS generated 211 Million lbs of CO_2 emissions which accounts for $\sim 50\%$ of all emissions. For transportation, the regression displayed a statistically significant correlation between students and transportation emissions. This suggests that as there are more students in a school, the higher the transportation emissions. This can be attributed for a few reasons such as average travel distances and walk zones.

MCPS has performed a boundary analysis for its school district[11].The analysis studies the spatial relationships between students and schools. Some of the findings from these reports can help explain higher bus miles per day for schools in general. Transportation related emissions are primarily driven by bus miles per day which in turn is determined by average travel distances and walk zones. The average distance to school can provide a good insight into why some schools will need more buses and hence will have higher bus miles per day. Another insight that we can draw from the boundary analysis is population density which is inversely related to bus miles. The denser an attendance area is, the more likely it is to have a lower average distance to school. MCPS studies have shown this negative relationship between density and average distance to school[11].

Walk zones represent the proportion of students who live within the "Walk Zone" defined by MCPS. The walk zone standards as determined by MCPS are as follows:

- Elementary school students: 1 mile walking radius
- Middle school students: 1.5 mile walking radius
- High school students: 2 mile walking radius

Based on the above definitions, MCPS has determined the walk zone score for each school. The lower the walk zone

Table 3 Regression results for Transportation, Energy, and Waste emissions.

x-value	y-value	Pr($>|t|$)	Estimate
Students	Transportation Emissions	2.00E-16	991.46
Bus Miles	Transportation Emissions	$< 2e-16$	5.79E+02
Students	Energy Emissions	0.0298	2.71E+02
Year Renovated	Energy Emissions	$< 2e-16$	8.76E+00
Square Footage	Energy Emissions	$< 2e-16$	1.04E+01
Students	Waste Emissions	$< 2e-16$	-92.414
Site Size	Waste Emissions	$< 2e-16$	-92.414

Table 4 Regression results for Elementary, Middle, and High schools with underserved/socioeconomic statuses.

Pr($>|t|$)	Hispanic/Black %	Special Education	FARMS	ESOL
Elementary	0.946	0.20265	0.975	0.554
Middle	0.3039	0.564	0.3375	0.1593
High	NaN	NaN	NaN	NaN

Table 5 Select Schools vs. Average transport emissions and bus data for all school types.

School	Transportation (lbs CO_2)	Transportation emission / student	Total bus miles per day	#Buses	Miles per bus per day
Poolesville HS	1,792,676	1,513	3,097	18	172
Northwest HS	2,287,192	884	3,952	37	107
All HS Average	**2,452,360**	**1,243**	**4,237**	**44**	**97**
Paint Branch HS	3,028,811	1,511	5,233	56	93
Gaithersburg HS	3,485,554	1,482	6,022	61	99
Loiederman, A. Mario MS	508,997	516	879	13	68
Newport Mill MS	901,243	1,335	1,557	20	78
All MS Average	**1,259,668**	**1,371**	**2,158**	**23**	**94**
Gaithersburg MS	1,752,159	2,030	3,027	31	98
Lakelands Park MS	2,183,290	1,948	3,772	30	126
Cold Spring ES	43,955	133	76	1	76
Highland View ES	112,456	256	194	2	97
All ES Average	**767,659**	**1,353**	**1,317**	**14**	**95**
Sherwood ES	1,730,147	3,283	2,989	29	103
Matsunaga, Spark M. ES	1,521,910	2,091	2,629	22	120

score, the higher is the dependence on school buses which in turn increases bus miles per day[11]. Using the above, collated the statistics for the select schools we are tracking and the averages for the school type in the table below: Based on Table 5 and 6, Paint Branch HS has a walk zone score of 3% (vs. 33% score across all HS) which is extremely low and a contributing factor for higher reliance on school buses. MCPS study on district boundary analysis concludes that Northeast Consortium (NEC) cluster schools such as Paint Branch HS have a lower proximity score. This means the students there live farther away from the HS than other students within MCPS. Although Poolesville HS has a low population density score, it still only uses 18 buses (vs. an average of 44 buses for all HS). On further review, Poolesville is a HS choice magnet school where students from out of the school district usually travel via car. Both Loiderman and Newport Mills MS benefit from a lower average distance traveled by students due to higher population density. They also have a better than average walk zone score of $\sim 2X$ the average of all MS. Cold Spring and Highland View ES have extremely high walk zone scores which directly results in a lower number of buses. On further review, Cold Spring ES may be an anomaly as it is a

Table 6 Statistics explaining bus miles per day.

HS	**Average distance traveled (in miles)**	**Population density (population per square mile)**	**Walk zone(%)**
Poolesville HS	2.01	116	53.08%
Northwest HS	2.25	1,471	47.00%
All HS Average	**2.50**		**33.14%**
Paint Branch HS	2.53	2,479	3.05%
Gaithersburg HS	2.26	2,317	51.70%
MS	**Average distance traveled (in miles)**	**Population density (population per square mile)**	**Walk zone(%)**
Loiederman, A. Mario MS	1.00	7,446	54.07%
Newport Mill MS	1.19	7,440	59.13%
All MS Average	**2.20**		**27.88%**
Gaithersburg MS	2.23	1,280	55.54%
Lakelands Park MS	2.28	1,399	34.82%
ES	**Average distance traveled (in miles)**	**Population density (population per square mile)**	**Walk zone(%)**
Cold Spring ES	0.56	3,802	100.00%
Highland View ES	0.56	6,965	72.15%
All ES Average	**1.20**	**4,444**	**41.41%**
Sherwood ES	2.23	630	Not Available
Matsunaga, Spark M. ES	1.55	1,302	11.80%

magnet school which may explain why it uses only one bus. Students who participate in the elementary magnet program use their home school bus to commute back and forth during the school day. Sherwood and Matsunaga Spark ES have very low population density which increases the average distance traveled. Also, the walk zone score for Matsunaga ES is very low at roughly 1/3rd the average of all ES.

Discussion

Based on the study, the following options may be considered for reducing the transportation related CO_2 emissions.

School district boundary analysis and redistricting are complex topics where many factors are taken into account. From an emission reduction perspective, it will serve MCPS well if future boundary analysis takes into account the geographic area covered by the buses, population density, and walk zone scores.

Electric school buses have a clear advantage over diesel or gasoline buses when it comes to tailpipe emissions as electric buses have zero tailpipe emissions [12].Assuming the current district boundaries, schools with high bus miles per day such as Paint Branch HS, Gaithersburg HS & MS, and Lakeland Park MS should be prioritized when MCPS deploys electric school buses. These schools may offer the highest emission reduction for converting them into electric school buses. MCPS has plans to convert 326 school buses from diesel to electric by 2025. They should consider bus miles/day metric in choosing which schools make the cut.In the past the higher upfront costs of electric buses may have discouraged schools from embracing them. However, in 2022, the Biden Administration passed the Inflation Reduction Act which has incentives for schools to convert to electric buses. For example, the Clean School Bus Program rebates offer up to $285,000 and 375,000$ for class 6 and 7 electric buses [13].

Carpooling, biking, and walking to schools can also lower carbon emissions [14].There are real benefits for carpooling both at a societal level and from a schools perspective. If car pooling, biking, and walking is encouraged, schools can actually reduce their reliance on buses which can also help reduce its carbon footprint. More research on the barriers and opportunities of car pooling may be required to understand its impact to MCPS school redistricting and boundary analysis [15].

Energy

For the 2018-19 academic year, MCPS generated 238 Million lbs of CO_2 emissions which accounts for $\sim$ 57 % of all emis-

sions.

Running a linear regression demonstrated correlation between energy emissions and square feet. It also displayed a correlation with the number of students and energy emissions. The more students in a school, the higher the emissions. The larger the area of the school, the higher the energy emissions because more electricity and heating is needed to disperse the energy throughout the building [16]

The drivers of energy emissions intensity can be better understood by looking into electricity intensity measured by kwh/square feet and therms/square feet [17].

Based on Tables 7 and 8, we can say the following:

Electricity contributes to about 70-75% of the total energy related carbon emissions across all school types in Montgomery County. For many schools including those selected (at top and bottom levels of total emissions), the natural gas consumption data is incomplete. This has the potential to overstate the ranking of the top and bottom schools.

Matsunaga Spark ES has the highest emissions intensity at 19.21 lbs CO_2/square feet which is entirely driven by its electricity intensity at 22.65 kwh/square feet which is more than 2x times the average of all ES. As natural gas data is not available for the full year, its energy related carbon emissions may be understated. More research is warranted to explain what is causing this abnormal level for this elementary school.

In 2015, Northwest HS was presented with The Green Ribbon Schools Award program, sponsored by the U.S. Department of Education. The U.S. Department of Education's Green Ribbon Schools honors schools for excellence in resource efficiency, health and wellness, and environmental and sustainability education. This explains its better than average performance as measured by electricity intensity.

Discussion

Based on the study, the following options may be considered for reducing the energy related CO_2 emissions:

MCPS has a dedicated team called the School Energy and Recycling Team (SERT) which forms a part of the Department of Facilities Management. The SERT currently only tracks electricity consumption for each school and this does not provide a complete picture of the energy related CO_2 emissions. Based on discussions with MCPS staff, natural gas data is not tracked on a consistent basis. With an impact of approximately 25-30% to the energy CO_2 emissions, they should consider adding the heating demand (natural gas consumption) of each school into the SERT tracking plan.

Rooftop solar panels can be an effective way to lower electricity consumption and in turn reduce CO_2 emissions. They may also reduce energy costs which can help schools redirect the money saved into other projects [16].Last year, the Biden Administration passed the Inflation Reduction Act which has many incentives for clean technology and some that support schools to directly collect tax benefits for installing solar panels. This would have schools using clean energy and lower their carbon footprint significantly [13].

MCPS has a robust peak load management program where they curtail air conditioning demand during summer time. However, the impact of this may be limited from a carbon emissions perspective as the demand curtailment lasts for just one hour when schools are usually closed. MCPS may consider adding an energy efficiency program as that may be more effective and offer meaningful reductions in energy consumption. The case study in the citation shows that energy efficiency for the selected schools reduced electricity consumption by 20-37% over a 4-6 year period [11].

An energy audit may reveal which schools have the most potential for energy conservation. This is important as schools could identify certain places such as electricity or natural gas consumption and look to reduce it to lower the carbon footprint [18].

Waste

For the 2018-19 academic year, MCPS generated 31 Million lbs of CO_2 emissions offset which helped lower overall emissions by $\sim$9% . For waste, the linear regression displayed two statistically significant correlations. The more students in a building, the higher the higher negative emissions there are. Similarly, the size of the school displayed a correlation with waste emissions. This can be interpreted by analyzing the different types of waste types and practices that have the highest disposal and carbon coefficients.

If the appropriate waste management techniques are applied to waste disposal, schools can offset their total carbon emissions. MCPS has a robust waste management program across most schools; however their impact on carbon emissions is a net reduction of only 9% across the school district. It is important to understand that based on EPA guidelines not all waste management techniques provide the same emission offset. Using the EPA Waste Reduction (WARM 15) model, the emissions offset for various waste management techniques cis summarized in Table 10. As can be seen in Table 10, recycling cardboard provides the highest carbon emission offsets. Across all school types, it accounts for 84% of the carbon emission offset.

Based on Tables 9, 10 and 11, compared to their peers, Gaithersburg HS and MS have a better than average cardboard recycling metric per student. As this waste management category offers the highest carbon offset, Gaithersburg HS and MS have a better than average carbon emission offset. While this helps with carbon emissions reductions, these schools are still among the highest in total emissions as waste provides a very small offset to their higher than average transportation

Table 7 Select schools vs. Average energy emissions and square feet for all school types.

School	Energy (lbs CO_2)	School Sqft	Energy emission/sqft
Poolesville HS	1,967,170	165,069	11.92
Northwest HS	2,258,967	340,927	6.63
All HS Average	**3,223,354**	**305,856**	**10.54**
Paint Branch HS	4,081,124	347,210	11.75
Gaithersburg HS	4,853,775	426,899	11.37
Loiederman, A. Mario MS	1,189,049	131,742	9.03
Newport Mill MS	962,977	108,191	8.90
All MS Average	**1,404,813**	**149,468**	**9.40**
Gaithersburg MS	1,747,907	157,696	11.08
Lakelands Park MS	1,660,671	153,647	10.81
Cold Spring ES	432,294	55,185	7.83
Highland View ES	630,787	59,210	10.65
All ES Average	**784,149**	**78,724**	**9.96**
Sherwood ES	830,010	81,749	10.15
Matsunaga, Spark M. ES	1,743,276	90,740	19.21

Table 8 Electricity and Natural gas energy intensity for select schools vs. Average for all school types.

HS	**Kwh/square feet**	**therms/square feet**	**share of electricity of CO_2 emissions**
Poolesville HS	9.88	3.86	68%
Northwest HS	8.12	0	100%
All HS Average	**9.38**	**2.93**	**73%**
Paint Branch HS	13.18	1.00	91%
Gaithersburg HS	12.88	0.86	92%
MS	**Kwh/square feet**	**therms/square feet**	**share of electricity of CO_2 emissions**
Loiederman, A. Mario MS	7.91	2.57	72%
Newport Mill MS	7.31	2.94	67%
All MS Average	**8.92**	**2.38**	**76%**
Gaithersburg MS	10.25	2.72	75%
Lakelands Park MS	10.10	2.57	76%
ES	**Kwh/square feet**	**therms/square feet**	**share of electricity of CO_2 emissions**
Cold Spring ES	9.60	0	100%
Highland View ES	8.54	3.68	65%
All ES Average	**9.06**	**2.39**	**73%**
Sherwood ES	11.06	1.13	89%
Matsunaga, Spark M. ES	22.65	0.73	96%

Table 9 Select Schools vs. Average waste emissions and Waste/student ratio for all school types.

School	Waste emissions (lbs CO_2)	Waste emissions / student
Poolesville HS	-150,238	127
Northwest HS	-298,387	115
All HS Average	**-263,236**	**133**
Paint Branch HS	-283,487	141
Gaithersburg HS	-352,068	150
Loiederman, A. Mario MS	-176,896	179
Newport Mill MS	-128,953	191
All MS Average	**-178,357**	**194**
Gaithersburg MS	-236,374	274
Lakelands Park MS	-175,532	157
Cold Spring ES	-125,357	380
Highland View ES	-187,230	426
All ES Average	**-134,842**	**238**
Sherwood ES	-138,597	263
Matsunaga, Spark M. ES	-128,146	176

Table 10 MCPS waste management category mapped to EPA WARM 15 model.

MCPS data received	EPA category	Waste Management Category	Emission offset (CO_2 avoided / MT)
Cardboard	Paper	Recycle	-3.13
Commingled	Plastics	Recycle	-1.01
Yard Waste	Yard	Composted	-0.15
Solid waste	Mixed Materials	Combust	-0.18

and energy emissions. Cold Spring and Highland View ES use double the average cardboard for recycling and this helps with their emission offset per student metric. Both these schools were awarded the SERT quarterly recycling award in 2018-19

Discussion

Overall MCPS and its administrators offer many opportunities for the schools to manage waste in an environmentally friendly manner. Waste management from cardboard recycling offers the highest emissions offset but statistics across school types indicates a wide distribution of this practice. More work can be done here to bring the overall levels higher. Although waste management only offers 9% of the total emissions, more research is required to determine whether this is the highest possible impact. Future research can look into what is the total waste produced by each school and what percentage of that waste is converted into waste management practices.

Emissions vs. Underserved races, special needs and socio-economic status

Climate change has a disproportionate impact on people of color and those suffering from socio-economic inequalities[19].While this claim may be true for the study, we did a regression analysis as shown in Table 4, which looked across each MCPS school type using race, special education, ESOL and FARMS. The results did not show any correlation. One reason for this may be the diverse demographic of the county. As shown in Table 12 below, MCPS belongs to a diverse community with multi ethnic races.

Table 11 Select Schools vs. Average, waste category by type normalized for students for all school types.

HS	**Cardboard (lbs/student)**	**Commingled (lbs/student**	**Yard Waste (lbs/student)**	**Solid Waste (lbs/student)**
Poolesville HS	32	6	6	111
Northwest HS	29	5	6	110
All HS Average	**35**	**6**	**6**	**112**
Paint Branch HS	34	13	6	112
Gaithersburg HS	39	5	6	114
MS	**Cardboard (lbs/student)**	**Commingled (lbs/student**	**Yard Waste (lbs/student)**	**Solid Waste (lbs/student)**
Loiederman, A. Mario MS	47	9	7	112
Newport Mill MS	52	7	7	114
All MS Average	**54**	**8**	**6**	**112**
Gaithersburg MS	79	5	5	115
Lakelands Park MS	43	4	6	112
ES	**Cardboard (lbs/student)**	**Commingled (lbs/student**	**Yard Waste (lbs/student)**	**Solid Waste (lbs/student)**
Cold Spring ES	107	27	7	114
Highland View ES	120	25	5	115
All ES Average	**67**	**17**	**6**	**112**
Sherwood ES	71	17	4	113
Matsunaga, Spark M. ES	51	12	0	0

Table 12 MCPS Demographics [11]

Race	**%**
Hispanic/Latino	33.4
White	25.3
Black/African American	21.9
Asian	14.1
Two or more races	5.0

Materials and Methods

In our paper, we evaluate the environmental performance of schools using three broad categories - transportation, energy consumption and waste (including disposal mechanisms).In order to determine what factors influenced the carbon emissions for each of the three types, we ran multiple linear regression models. A $\Pr(>|t|)$ value less than 0.05 indicated strong correlation between the two variables tested and justified emissions. The regression coefficient reports the amount of carbon emissions produced when the x-value is increased by 1 unit. For example, if the coefficient is -0.4, then an increase in one unit of the x variable leads to a decrease by 0.4 units of the y variable (here, carbon emissions).

Transportation

School buses

Schools use buses to transport students to/from schools and over any academic year; buses also take multiple trips a day depending on the route they cover. Using data provided by the Montgomery County Public Schools (MCPS) sustainability team, we derived the number of school buses used by each school per academic year. Although MCPS has aspirations to use electric vehicles, at this time the vast majority of the school buses are diesel based. The website has the ability to categorize school buses into diesel, gasoline or electric anticipating a gradual shift in the fuel type. We also received and summarized the miles traveled by all the school buses related to any particular school.

Using US Department of Energy [20] data, the primary author was able to determine the fuel mileage for each bus type to arrive at gallons of fuel consumed (diesel or gasoline) per year:

$$\text{Gallons of fuel consumed} = \text{Miles driven/MPG fuel type} \quad (1)$$

From the data derived from the U.S. Environmental Protection Agency[21].I derived the CO_2 emissions factor for diesel fuel. First the primary author converted kg CO_2/gallon to lbs CO_2/gallon ($10.21 * 2204.62 = 22.5091$) using standard conversion metric (1 kg = 2.20462 pounds (lbs). A similar calculation for gasoline buses can be performed if the school bus uses conventional gasoline as a fuel. Although the carbon content of diesel is higher, it will result in lower gallons of fuel consumed as it is much more efficient than gasoline. Once we have the gallons of fuel consumed and the lbs of CO_2 emissions per gallon, we can derive the lbs of CO_2 emission from all the school buses for a particular school in an academic year.

Carpool and Walkers

To make sure we are accounting for all students of each school, we have included students who carpool and those who walk. In further analyses, it's important to understand how the mix of students using different transport options changes. While data for carpool students may not be readily available, any increase in carpool or walker students that may reduce the reliance on the current number of buses can help bring down the carbon emissions of the school.

Energy

Electricity

School building cooling demand is one of the main indirect drivers of CO_2 emissions. To accurately determine the underlying emission source, it is important to know the fuel mix that is used to generate electricity. Using data collected by MCPS sustainability team, we compiled electricity consumption for an academic year for each school. The next step would be to identify based on the zip code where the school is located, the lbs/Mwh CO_2 emission for schools located in that zipcode. The EPA website[22].

In case electricity consumption is not readily available, we can also use the dollar amount to convert bill data to equivalent consumption. This involves an extra step which to convert $/month to kWh by using the price/kWh of electricity for commercial business[23].

Electricity based CO_2 Emissions = (2)

- If input is dollars, then, (average monthly electric bill / price per kWh) * electricity emission factor * months in a year
- If input is kWh, then, average number of kWh consumed per month * electricity emission factor * months in a year.

Natural Gas

School building heating can be done using either natural gas or electricity. In case it's done using electricity, data included in the electricity section will represent both cooling and heating demand. However the website is able to handle calculations for natural gas heating and this section looks at CO_2 emissions where natural gas is used for heating.

Once we get school data on heating demand in therms or thousand cubic feet (ccf), we use conversion factors of 11.6889 lbs of CO_2 per therm of natural gas or 119.58 lbs of CO_2 per thousand cubic feet of natural gas.

In case natural gas consumption is not readily available, we can also use the dollar amount to convert bill data to equivalent consumption. This involves an extra step which the website calculates by converting $ /month to ccf by using the price/ccf for natural gas for commercial business[24].

Natural Gas based CO_2 Emissions = (3)

- If input is dollars, then, (average monthly gas bill per month / price per thousand cubic feet) pounds of CO_2 per thousand cubic feet of natural gas * months in a year
- If input is thousand cubic feet, then, (average number of thousand cubic feet consumed per month * pounds of CO_2 per thousand cubic feet of natural gas * months in a year
- If input is therms, (average number of therms consumed per month * pounds of CO_2 per therm of natural gas * months in a year

Propane

The use of propane in a school setting is fairly limited however for the sake of completeness, the website takes into account this source of CO_2 emission using an emission factor of 12.61 lbs/gallon[23].

Propane based CO_2 Emissions = (4)

- If input is dollars, then, (average monthly propane bill / price per gallon) * propane emission factor * months in a year
- If input is gallons, then, (average gallons of propane consumed per month) * propane emission factor * months in a year

Fuel Oil

The use of fuel oil in a school setting is also fairly limited, however for the sake of completeness, the website takes into

account this source of CO_2 emission using Emission factor of 22.51lbs/gallon[23].

$$\text{Fuel Oil based } CO_2 \text{ Emissions} = \quad (5)$$

- If input is dollars, then, (average monthly fuel oil bill / price per gallon) * fuel oil emission factor * months in a year
- If input is gallons, then, (average gallons of fuel oil consumed per month) * fuel oil emission factor * months in a year

Waste

Schools generate a tremendous amount of waste and it's important to understand not only the type of waste but also what are the current waste disposal practices. The EPA has done an extensive study here and has made available a Waste Reduction Model (WARM) to help quantify it[25].WARM provides a convenient way to quantify potential GHG emissions from different waste types and waste management practices. In a school setting, these waste types have been summarized as:

- Paper
- Food Waste
- Yard Trimmings
- Mixed Plastics
- Electronics
- Metals
- Glass
- Construction Materials
- Tires
- Mixed Materials

Based on my discussions with MCPS sustainability team, the waste management practices at schools can be summarized as:

- Recycle
- Landfill
- Combust
- Composted
- Anaerobically Digested

Since MCPS schools all employ waste management practices, I was able to use the WARM (version 15) file to derive what are the GHG emission factors associated with each combination of waste and waste management practice[25].Using the WARM emission tables and data from individual schools about their waste type and waste management practices, we can derive the lbs of CO_2 of emissions:

$$\text{Lbs of } CO_2 \text{ emissions} = (\text{MT of waste x } CO_2 \text{ emission factor for waste type/waste management combination})^* 2204.62 \text{ lbs/MT} \quad (6)$$

Conclusion

Carbon accounting is beneficial to schools to determine where they are in the carbon reduction journey. Calculating and accounting for their carbon emissions is the first step of the carbon reduction process to have a 'greener' and more just future. This project can be expanded across other counties in order to broaden the sample size and create a richer data set that encompasses more geographic regions and their social, economic, and political status. MCPS did not impact these socioeconomic groups as there was no correlation found between total emissions and these groups. Some solutions to reduce a schools carbon footprint is by converting to electric buses, installing solar panels, and by recycling paper and cardboard.

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