



USDOT Region V Regional University Transportation Center Final Report

NEXTRANS Project No. 136CESTY2.1

Inventory of Greenhouse Gas Emissions from On-Road Vehicles in Midwestern USA States and Integrated Approach to Achieving Environmental Sustainability in Transportation

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DISCLAIMER

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TECHNICAL SUMMARY

NEXTRANS Project No. 136CEST2.1

Final Report, 29 Dec., 2016

Title

Integrated Approach to Achieving Environmental Sustainability in Transportation; Inventory of Greenhouse Gas Emissions from On-Road Vehicles in Midwestern USA States

Introduction

Nation's emerging need as reflected in the NEXTRANS theme is to address the impacts of high level strategic decisions and policies to boost economic growth, on the quality of life for people. In the transportation sector, this need translates into addressing the aggravating problems of energy insecurities and environmental degradation while maintaining the United States technological leadership and economic competitiveness. The transportation sector accounts for 30% of US emissions that may cause considerable climate changes, if uncontrolled, impacting quality of life. 70% of all U.S. petroleum is consumed by the transportation sector most of it comes from politically unstable/sensitive regions of the world. There is a need to reduce external dependency on petroleum by increasing fuel efficiencies in vehicles, using alternative fuels, harnessing indigenous sources and encouraging changes in travel habits leading to fuel or energy conservation. As innovations are being sought in developing next generation transportation technologies and achieving energy efficiencies, it is imperative that we must ensure environmental sustainability of these solutions and ascertain holistic improvements to the quality of life. We proposed to monitor changes in climate and environmental parameters with concomitant changes in technology enabled integration and other sustainability factors as envisioned in the NEXTRANS center theme.

Two project objectives – one technical and one educational- were laid out in this project. The technical objective was to assess current inventory of greenhouse gases (GHG) in the six Midwestern states of the nation and to estimate improvements as technology enabled sustainable solutions are adopted with the use of alternative fuels. The technical objective was combined with the educational objective that focused on bringing awareness of transportation among middle school and high school students, training undergraduate students in sustainable transportation through curriculum enhancements and summer undergraduate research at the NEXTRANS center.

As a first step, an inventory of current GHG including CO₂, N₂O and CH₄ emissions across six states in the US-Midwest (Ohio, Indiana, Michigan, Illinois, Wisconsin and Minnesota) from on-road vehicles were attempted as a baseline to monitor impacts from the existing traffic data and the emission models such as Motor Vehicle Emission Simulator (MOVES) model and The Greenhouse Gases, Regulated Emissions,

and Energy Use in Transportation (GREET) model. This baseline inventory was used in comparative analysis in studying impact of alternative fuels for on-road vehicles. This helps in developing sustainability and green solution in transportation.

Sustainability of transportation solutions also demands social equity and accessibility. It is known that underserved populations live in neighborhoods in close proximity to areas that are most affected by air pollution. However, their representation in transportation industry workforce, involvement in research and development, or accessibility to education, particularly in transportation or environmental engineering is limited. CeSU contributed to increase the diversity in the workforce development through involving its students in transportation related academic training/research in environmental engineering. Students participated in the center's research activities at CeSU and at NEXTRANS partner institution, Purdue University and also at ODOT (Ohio Department of Transportation) through internship. CeSU also engaged in serving underserved populations through its successful summer transportation institute (STI). Our proposed study was thus aligned with transportation "Links to Energy Security, Environment and Climate Change" of NEXTRANS center.

Findings

Tasks corresponding to Objective 1-Technical Objective to build an inventory of current GHG emissions from on-road vehicles and estimating the impact of using alternative fuels in the GHG emissions

Task 1:

Collection of Traffic Data in the six Midwestern states

The Greenhouse gas emissions from a road are estimated using the US EPA model *Motor Vehicle Emission Simulator* (MOVES2010b and MOVES2014) and *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation* (GREET2015 and GREET2016) with the traffic data. For this study, traffic data from six Midwestern states, Ohio, Indiana, Michigan, Illinois, Wisconsin and Minnesota were collected from the respective state departments of transportation. The core traffic data contain road name, road segment length, road type, county, vehicle type, data collection year and Average Annual Daily Traffic (AADT) count. All the datasets are available in the ArcGIS format. As an example, Figure 1a and Figure 1b show the AADT counts for the passenger vehicles and the commercial vehicles respectively in Indiana for the year 2007.

However, the data collection and presentation methodology was found different from one state to another. For example, while Ohio AADT data contain passenger vehicle and truck data for each highway data collection location, Illinois AADT data contain more passenger vehicle traffic data collection locations than the heavy duty vehicle traffic data collecting locations. Hence, before applying together with MOVES, each AADT data set had to be pretreated.

Also, AADT data were not taken in each of its county by any state for a year. Hence, data for a period of 4-5 years that cover the most of the counties were used to in the Greenhouse Gas (GHG) estimations. In

addition, AADT data for the local roads were not available for all states. Hence, the study at this level was restricted to the GHG emissions on the highways.

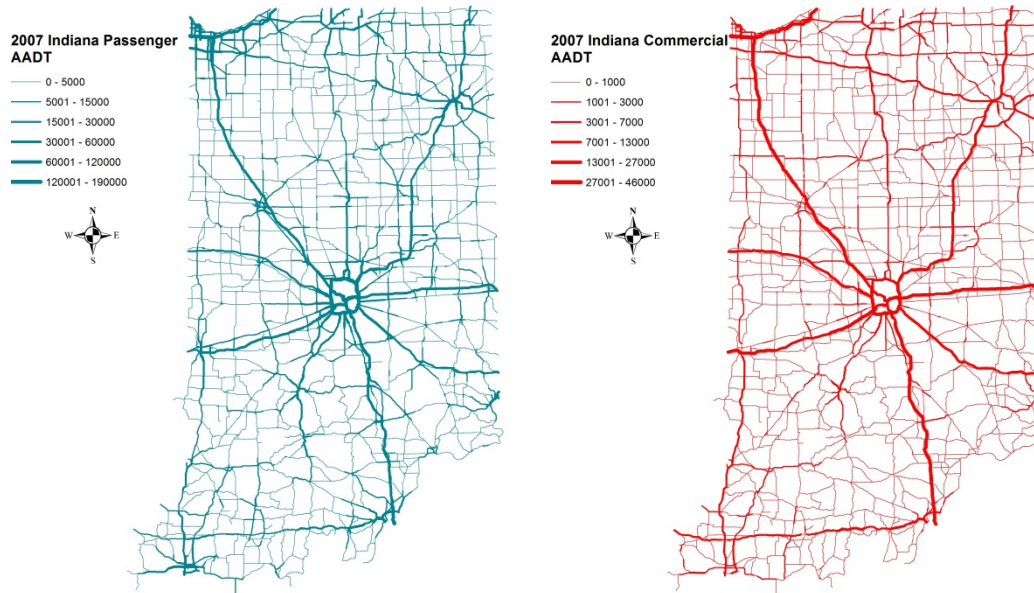


Figure 1a: 2007 Passenger AADT count for Indiana Figure 1b: 2007 Commercial AADT count for Indiana

Task 2:

Training of undergraduate students in research and MOVES

In addition to teaching and demonstrating MOVES in the classroom in the course, *Fundamentals of Air Quality Engineering*, as a part of the project, Central State University environmental engineering students were trained on MOVES in the research. Mr. Christopher Shirkey, Mr. Benjamin Rives and Mr. Ammon Russell had Air Quality Engineering as a part of their environmental engineering curriculum. They were taught concepts in GHG and transportation related pollution (See Objective 2: Task 1). As the undergraduate research students, they were instructed about the specific goal of GHG emission estimation, and literature survey and data collection techniques. Each student was given the task of collecting the AADT data from two states. They installed MOVES2010a in their computers and got initial training instructions on MOVES with the priority pollutant emissions for the 2004-2008 Ohio AADT data. Their progress was evaluated with individual meetings.

Task 3:

Estimation of GHG in the Midwestern states

On-road vehicle emissions of three GHGs, CO₂, CH₄ and N₂O are considered in this study. This study is restricted to the GHGs emitted from the roads in the highway system. AADT data from the state transportation agencies categorized the vehicles as passenger vehicles and commercial vehicles. For the preliminary study, the passenger vehicles are considered as gasoline run passenger trucks and the commercial vehicles are considered as the diesel run long-haul trucks. MOVES, shown in Figure 2, is a complex model solving a set of guiding equations that explain combustion mechanism and emissions by correlating fuel and traffic data with environmental variables such as wind speed, temperature. Hence, it takes significant amount of time to run even a single simulation for a pollutant per vehicle-mile in a county.

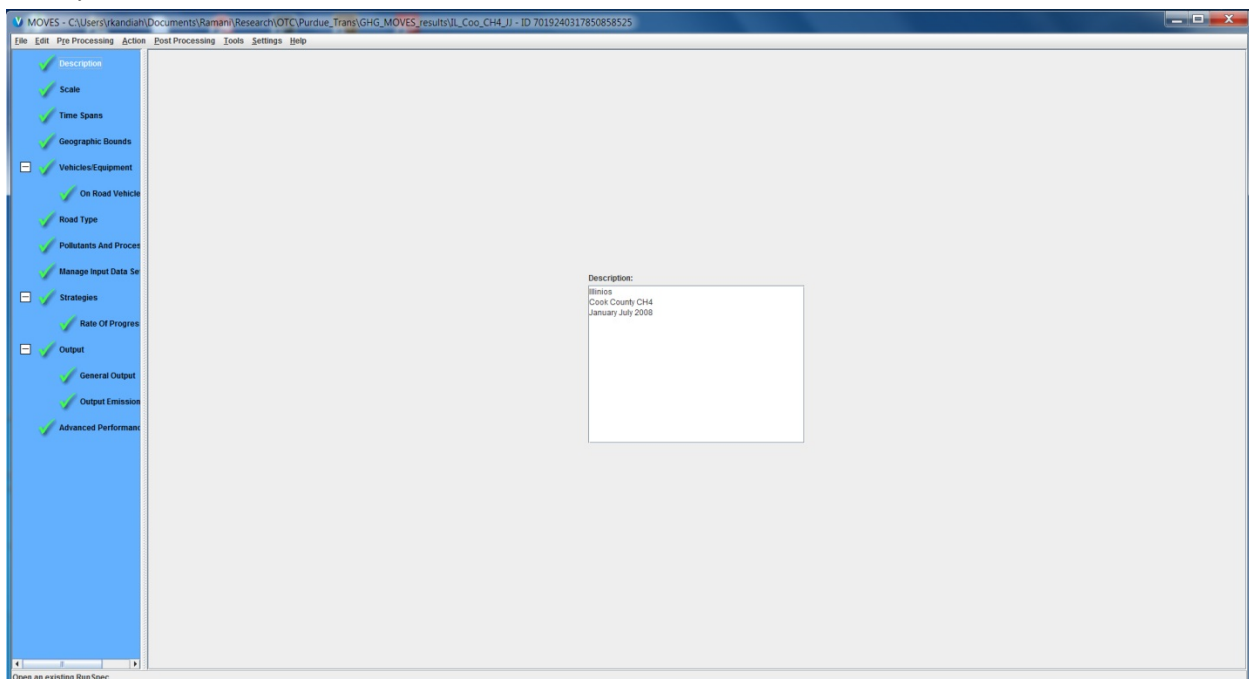


Figure 2. MOVES 2014a Window

Considering this issue, we have decided to select two counties – one in the urban setting and the other in the rural setting- as the representatives for a state. The following counties were selected in each state: Beltrami (Rural) and Hennepin (Urban) in Minnesota, Taylor (Rural) and Milwaukee (Urban) in Wisconsin, Mc Donough (Rural) and Cook (Urban) in Illinois, Mason (Rural) and Wayne (Urban) in Michigan, Carroll (Rural) and Marian (Urban) in Indiana, and Morgan (Rural) and Cuyahoga (Urban) in Ohio. The emissions were calculated for January and July (of year 2008) to get representation of traffic patterns and densities in typical winter and summer months. The final GHG emission rates (*Used_*) that were used in estimating total emission for each states are given in Table 1.

Table 1. Emission Rates of Three GHGs for six Midwestern states

State	Traffic Scenario	Emission Rate					
		CO ₂	N ₂ O	CH ₄	Used_CO ₂	Used_N ₂ O	Used_CH ₄
		g/VMT	mg/VMT	mg/VMT	g/VMT	mg/VMT	mg/VMT
Illinois	Passenger Truck-Rural	535	8.16	12.78	538	8.16	12.78
	Passenger Truck-Urban	538	8.16	8.77			
	Long Haul Track-Rural	2241	2.19	10.27	2241	2.19	10.27
	Long Haul Track-Urban	2232	2.19	10.27			
Indiana	Passenger Truck-Rural	530	8.16	12.59	537	8.16	13.09
	Passenger Truck-Urban	537	8.16	13.09			
	Long Haul Track-Rural	2224	2.19	10.27	2230	2.19	10.27
	Long Haul Track-Urban	2230	2.19	10.27			
Michigan	Passenger Truck-Rural	516	8.16	13.48	532	8.16	13.68
	Passenger Truck-Urban	532	8.16	13.68			
	Long Haul Track-Rural	2166	2.19	10.27	2210	2.19	10.27
	Long Haul Track-Urban	2210	2.19	10.27			
Minnesota	Passenger Truck-Rural	511	8.16	12.15	530	8.16	12.15
	Passenger Truck-Urban	530	8.16	12.07			
	Long Haul Track-Rural	2143	2.19	10.27	2199	2.19	10.27
	Long Haul Track-Urban	2199	2.19	10.27			
Ohio	Passenger Truck-Rural	525	8.16	12.71	527	8.16	12.71
	Passenger Truck-Urban	527	8.16	9.06			
	Long Haul Track-Rural	2200	2.19	10.27	2200	2.19	10.27
	Long Haul Track-Urban	2190	2.19	10.25			
Wisconsin	Passenger Truck-Rural	512	8.16	12.60	530	8.16	12.60
	Passenger Truck-Urban	530	8.16	8.77			
	Long Haul Track-Rural	2147	2.19	10.27	2201	2.19	10.27
	Long Haul Track-Urban	2201	2.19	10.27			

Results on GHG Unit Emissions

The GHG unit emissions were calculated using MOVES on a per vehicle and per mile of road basis within each county for the six Midwestern states. The unit emissions for both vehicle types were estimated. For each vehicle type, MOVES was used to estimate GHG emissions along restricted and unrestricted roads in rural and urban areas. The amount of emission from the vehicles during idling times such as stops at traffic signals and while braking was found using MOVES. CO₂ unit emissions in an urban area from winter to summer months were gone up by 4.35%. There was no change in N₂O unit emissions whereas methane emissions were up by 1.24%. Urban CO₂ emissions were greater than rural emissions by 1.24%. There was no change in N₂O emissions between urban and rural counties where as methane emissions were lower than rural emissions by 19%. MOVES did not predict emissions from rural restricted roads due to significantly lower traffic on these roads compared to unrestricted roads. The

maximum fraction of CO₂ emissions during idling was 0.02% of total emission on all roads within a county. It is 0.7% for N₂O and 2% for methane.

We did not find significant differences in GHG emissions per vehicle mile across the six Midwestern states either in winter or summer irrespective of the type of roads or fuel types.

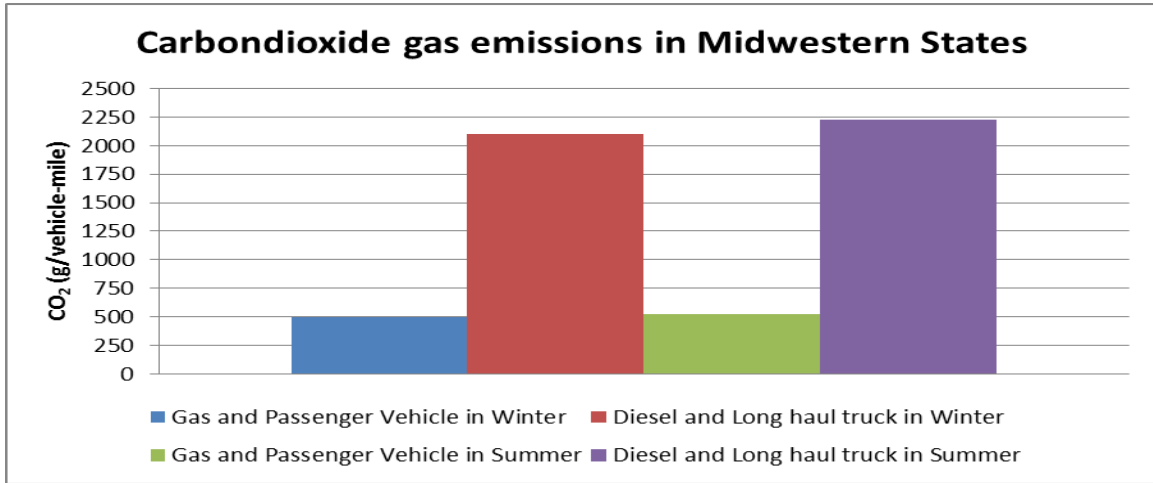


Figure 3: MOVES CO₂ emissions from gas and diesel vehicles in winter and summer

Figure 3 clearly shows that the passenger vehicles emitted less CO₂ than diesel either in summer or winter. Also, emissions in summer were slightly greater than those in winter. This result was same whether the emissions were computed along restricted or unrestricted roads irrespective of whether they were located in rural or urban counties.

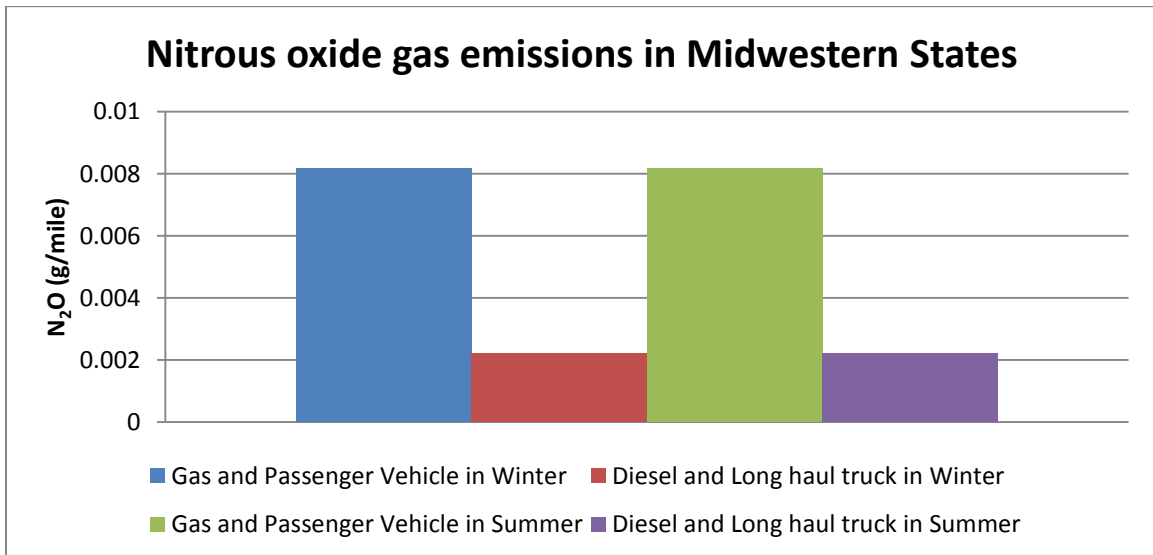


Figure 4: MOVES N₂O emissions from gas and diesel vehicles in winter and summer

Figure 4 shows that the gasoline run passenger vehicles emitted more N₂O than diesel run long haul truck either in summer or winter. There was no significant difference in nitrous oxide emissions from winter to summer. For the practical purpose, this result was same whether the emissions were computed along restricted or unrestricted roads irrespective of whether they were located in rural or urban counties.

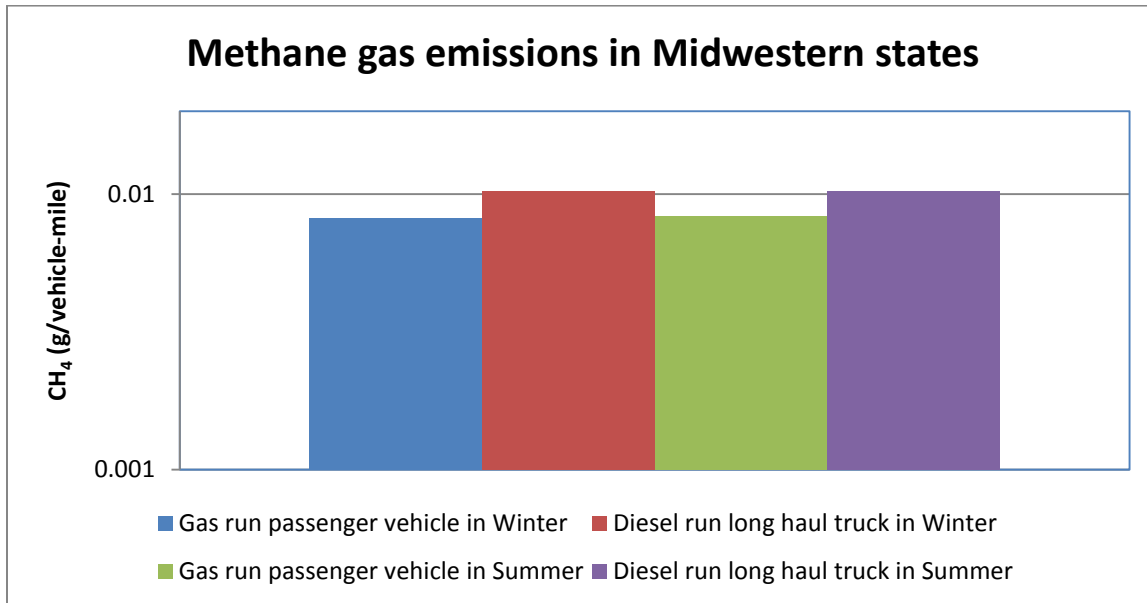


Figure 5: MOVES CH₄ emissions from gas and diesel vehicles in winter and summer

Figure 5 shows a slight increase in methane emission in a gasoline run passenger vehicle from a diesel run long haul truck. The increase was consistent both in summer and winter months. Slight increase in methane emissions was observed from winter to summer months.

Results on county wide total GHG emissions for Ohio

In this section, a detailed GHG emission for one Midwestern state, Ohio is presented. Once the GHG unit emissions were obtained they were used in estimating total GHG emissions in each road segment by multiplying the appropriate GHG emission per vehicle-mile by the vehicle-mile-travelled (VMT) of the segment. In the estimation, model parameters in the National scale were used in MOVES to get GHG estimation per vehicle-mile. Since the AADT count is an average traffic, we used it in two difference seasons -a summer day and a winter day- to evaluate the variation in the emissions. The total GHG emissions were calculated for each county as a cumulative of emissions coming from gas run passenger vehicles and diesel run long haul trucks. The summation also combined vehicle emissions from all types of road segments within each county. While working with the national scale parameters, the GHG emissions per vehicle-mile estimated from MOVES were found close within a state for all six Midwestern states for each GHG. Hence, the total quantity of a GHG emitted was estimated for a state with the respective GHG emission per vehicle-mile multiplied with the total vehicle-miles of the state.

Figure 6 shows total CO₂ emissions across Ohio counties.

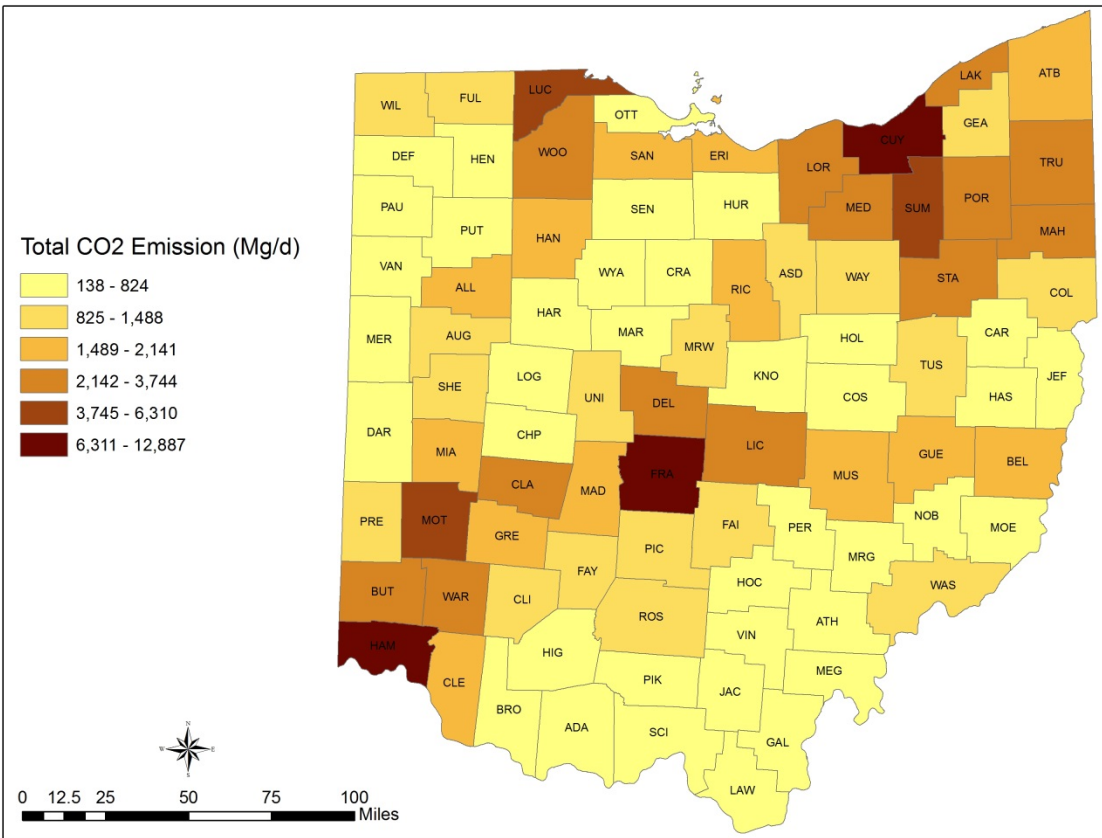


Figure 6: County wide CO₂ emissions for Ohio

As expected Cuyahoga county (Cleveland area), Franklin county (Columbus area) and Hamilton county (Cincinnati area) were found to release maximum emissions in the entire state. Lucas county (Toledo area), Summit county (Akron area) and Montgomery county (Dayton area) came in the next level in emitting greenhouse gases. As also expected, counties surrounding these major transportation hubs also recorded high levels of emissions. As one moves away from the hubs into rural areas, the emission levels came down to lower levels. This study uniquely provided a spatial inventory of estimates of CO₂ emissions for the entire state in a quantitative fashion. This information is crucial for assessing where the states are in terms of meeting the regulatory limits on greenhouse gases and the steps that are needed to be taken in minimizing these emissions through improving efficiencies in fuel types (gas or diesel), restructuring traffic (highways, other roads, and mass transit), or introducing alternate fuels.

Figure 7 shows total N₂O and CH₄ emissions across Ohio counties.

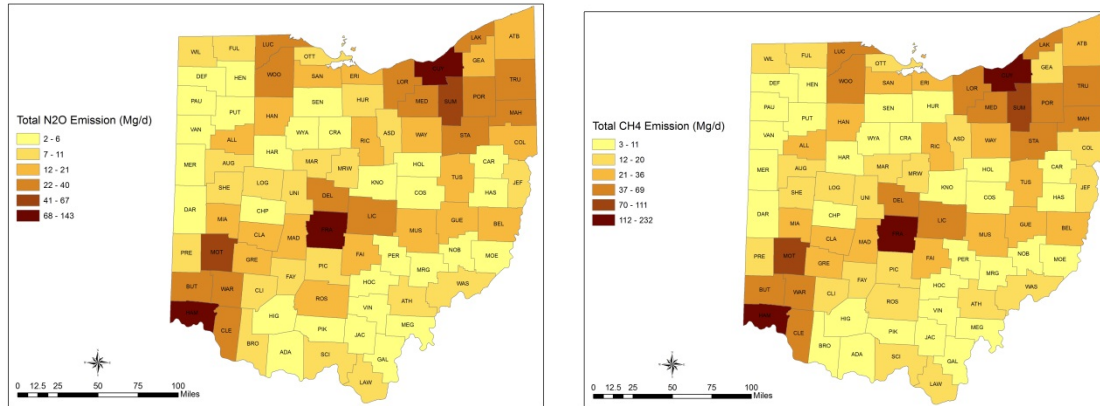


Figure 7: County wide emissions a) N₂O (left) and b) CH₄ (right) emissions for Ohio

While N₂O and CH₄ emissions across Ohio counties followed similar pattern that CO₂ emissions showed but they were in smaller magnitudes.

It was estimated that 153506 metric tons of CO₂, 1453 metric tons of N₂O and 2461 metric tons of CH₄ are emitted in an average day in the state of Ohio in 2008.

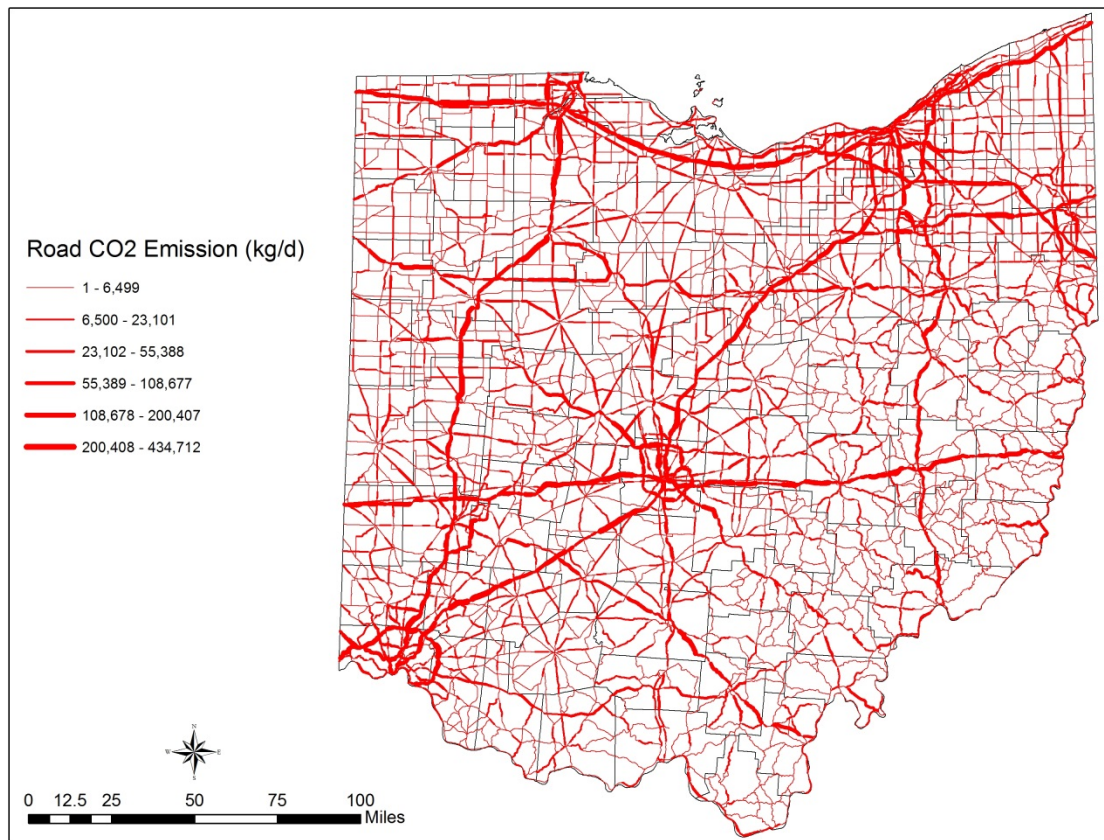


Figure 8: Total CO₂ emissions on road segments in Ohio

Figure 8 describes CO₂ emissions along different roads across Ohio. Major interstate systems I-70, I-75, I-71, and I-80 were maximum contributors to CO₂ emissions. This unique study on arriving at quantitative estimates is also first of its kind and paves way for analyzing traffic patterns taking into account the accumulation of greenhouse gases and considering climate change as an added dimension in designing sustainable traffic systems. This data may be used in conjunction with traffic densities to arrive at alternate routes during peak hours. It will also provide us guidelines on meeting the new air quality standards while designing new routes.

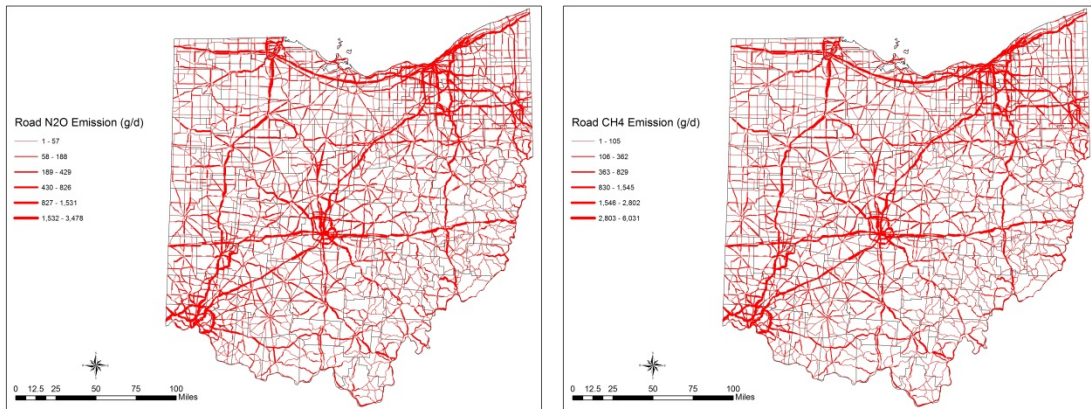


Figure 9: Total emissions on road segments a) N₂O (left) and b) CH₄ (right) emissions for Ohio

N₂O and CH₄ emission patterns shown in Figure 9 are similar to that of CO₂.

Task 4:

Emission Scenarios with Alternative Fuels

Reduction of greenhouse gases can be achieved through various strategies such as advanced efficient technologies that can reduce the GHG emissions in an on-road vehicle, implementation of transportation strategies and use of alternative fuels and energy sources that result in less emissions.

Given the scope, in this study, three alternative scenarios with existing hybrid passenger vehicles were studied.

1. 5% of the passenger vehicles are Ethanol 85 run Spark-Ignition Hybrid Electric Vehicles (SI HEV)
2. 10% of the passenger vehicles are Ethanol 85 run Spark-Ignition Hybrid Electric Vehicles (SI HEV)
3. 5% of the passenger vehicles are Ethanol 85 run Spark-Ignition Hybrid Electric Vehicles (SI HEV) and 5% of the passenger vehicles are Electricity & Ethanol 85 run Spark-Ignition Plug-in Hybrid Electric Vehicles (SI PHEV)

While MOVES2014a has the features to do the emission rate estimation for ethanol (E-85) or electricity run passenger trucks, there is no enough data to run the emission simulations. Hence, we have used

REET 2016 to estimate the emission rates for SI HEVs and SI PHEVs. Figure 10 shows the REET window for estimating emission rates for CO₂, N₂O and CH₄ for SI HEV in the urban environment .

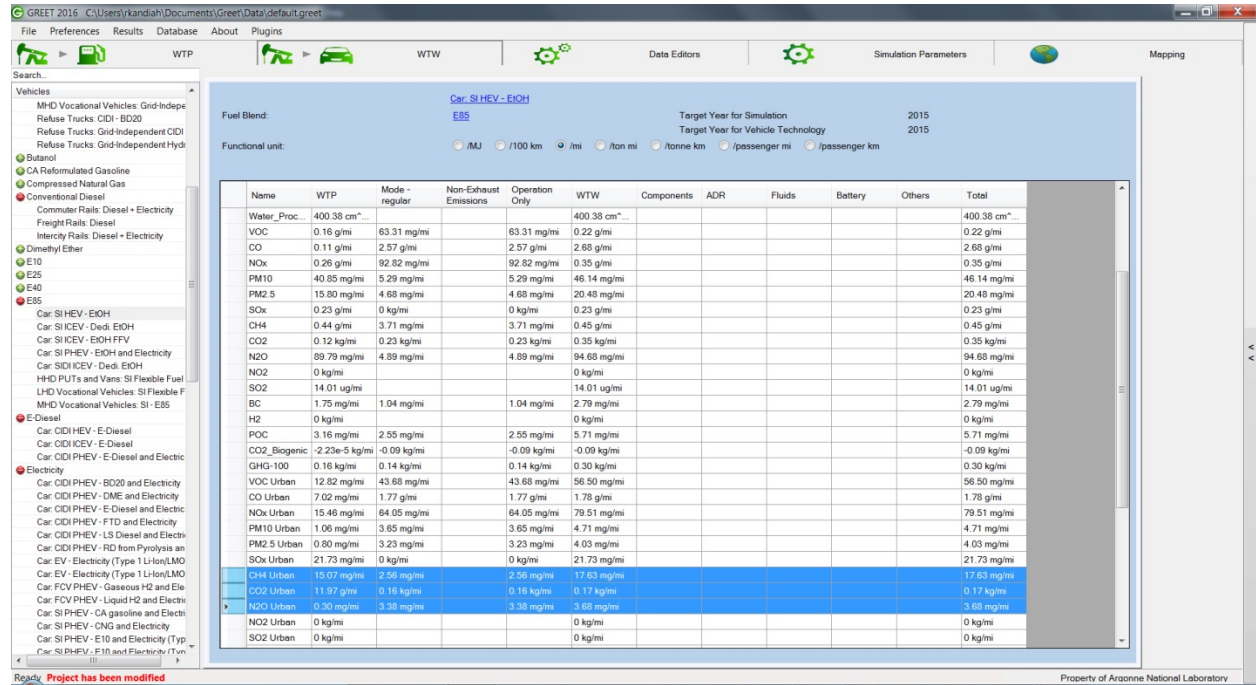


Figure 10: Estimation of Emission Rates for Alternative Fuels with REET

REET provides the estimations for GHG emission rates at production levels (Well-to-Pump) and at both production and operational levels (Well-to-Wheels), here given the objectives of the study, we took only the emissions during the vehicle operations. There are two issues in these estimations. 1. This estimation does not include the non-exhaust emissions such as emissions from brakes, and 2. The emission values are estimated in the national level contrast to the state levels in MOVES. In the future, with the collection of enough data on alternative fuel-vehicle in various spatial and temporal scenarios, these estimations can be improved in MOVES.

Table 2 provides the emission rates for three GHGs for SI HEV and SI PHEV.

Table 2. Emission rates for two alternative fuels

Vehicle-Fuel Type	Emission Rate (Operations Only)		
	CO ₂	N ₂ O	CH ₄
	g/VMT	mg/VMT	mg/VMT
Car-Ethanol 85 (SI HEV) Spark-Ignition hybrid electric vehicle	160	3.38	2.56
Car-Electricity & Ethanol 85 (SI PHEV) Spark-Ignition plug-in hybrid electric vehicle	90.66	1.55	1.18

Table 3 presents the comparisons of the total daily GHG emissions in Ohio in 2008 for three scenarios of alternative passenger cars and their GHG reduction percentages with respect to complete gasoline run passenger trucks.

Table 3. Total Ohio-GHG emissions per day with alternative fuels used instead of passenger trucks

Passenger Vehicle Scenario	Total CO ₂	Total N ₂ O	Total CH ₄	Total CO ₂	Total N ₂ O	Total CH ₄
	Metric Ton/d	Metric Ton/d	Metric Ton/d	% Reduction	% Reduction	% Reduction
100% Gasoline Truck	153506	1453	2461	Reduction from gasoline passenger truck		
5% SI HEV	150379	1412	2375	2.0	2.8	3.5
10% SI HEV	147252	1371	2288	4.1	5.6	7.0
5% SI HEV + 5% SI PHEV	146662	1356	2276	4.5	6.7	7.5

Task 5:

Research collaboration with RAPCA

While the preliminary GHG estimation can be achieved with the National scale parameters using internal data in MOVES, more accurate inventories are expected for State Implementation Plans (SIP) and transportation conformity purposes. However, to achieve this accuracy, we need to have additional reliable data. In such situations, MOVES should be used with the parameters in a smaller scale such as County scale. This also urges for a better traffic classification beyond passenger trucks and long-haul trucks and microclimate data such as wind speed and ambient temperature. Hence, we are working with our collaborators at Regional Air Pollution Control Agency (RAPCA) in Dayton, OH who had worked with county level MOVES for priority pollutants around Dayton.

As the part of the collaboration, Mr. Brain Huxtable of RAPCA provided a case study demonstration on a county scale use of MOVES for priority pollutant inventory. In addition, he performed a test run to estimate CO₂ equivalent in Montgomery, Greene and Miami counties for the projected 2015 July traffic data, Figure 11 shows the CO₂ equivalent emission for a vehicle from three gasoline vehicle types – motor cycle, passenger car and light duty truck- for various speed ranges.

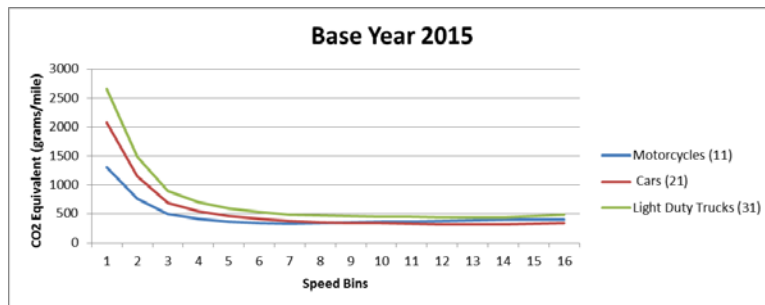


Figure 11: CO₂ Equivalent Emission for three gasoline based vehicles for the projected July 2015 AADT in three Ohio counties

Tasks corresponding to Objective 2-Educational Objective on providing educational outreach

As part of fulfilling this objective, the following tasks have been completed.

Task 1:

Course enhancements in ENE 3315 Air Quality Engineering

ENE 3315. Fundamentals of Air Quality Engineering (II; 3) — Characterization and control of air pollution problems. Analysis of fundamental chemical and physical processes governing pollutant transport and dispersion in air. Combustion chemistry of hydrocarbon fuels. Air pollution control systems. Pollution sources, control techniques with introduction to sensors. Transformations, atmospheric transport, deposition and modeling. Indoor Air quality management. Two one hour lecture/one hour lab.

The course enhancements were made during the thirteenth week of the semester. The course covered topics on transportation related air quality pollution. The current course addressed characteristics, composition, removal and treatment technologies associated with US EPA criteria air pollutants CO, O₃, SO_x, NO_x, PM_{2.5}, and Pb. This course was enhanced to include CO₂, CH₄, and other greenhouse gases.

Schedule of course enhancement

Monday lecture:

A general discussion on greenhouse gases (GHG), different sectors contributing to GHGs was presented to students.

Wednesday lecture:

GHG emissions from transportation and its implications on global climate changes were presented. Sustainability in transportation industry was discussed through presenting alternate modes of transportation, improving fuel efficiencies and using alternate fuels were also discussed.

Friday lecture:

Methodology for the estimation of GHG from on-road traffic using traffic counts data and vehicle (cars and light trucks) and fuel related information was presented to students using MOVES (motor vehicle emission simulator).

Term papers:

In lieu of second week lectures, students were assigned term papers on transportation related GHGs.

1. Benjamin Rives, *GHG from vehicles and global warming*, ENE 3315 term paper, Spring 2014

- a. Discussed GHG emissions and contribution from the transportation industry. Suggested different ways of reducing GHGs through the use of alternate fuels, design of fuel efficient engines and operating practices, use of engines driven by electricity, and reducing the transportation demand using mass transit systems.
2. Christopher Shirkey, *The impact of US EPA regulations in controlling emissions from the transportation industry*, ENE 3315 term paper Spring 2013
 - a. Discussed various US EPA regulations, standards, and newer technologies that have been instrumental in reducing the air pollution while at the same time improving efficiency and handling increased traffic loads.

Reinforcement outside the classroom:

Students worked on problems related to process design of industrial air pollution control systems. Study tables and faculty office hours were used for helping students with extended design problems. Students were assessed on transportation related GHG concepts through mid-term and final exams.

Task 2:

Course enhancements in WRM 4402 Urban Water Problems

WRM 4402. Urban Water Problems (II; 4) — An examination of water problems faced by urban America and solutions to those problems. Urban Hydrology, Wastewater treatment, the supply of quality drinking water, storm water management, flood protection, water for recreation, urban fishing, economic development and infrastructure requirements as pertaining to urban areas and the integrated management. Water infrastructure rehabilitation assessment; Causative water and environmental factors on health Prerequisites: MTH 1750 and WRM 2200.

This course uses a case study approach to covering topics. Some of the individual topics in the course have already been dealt with in courses at 2000 and 3000 levels. Students conduct surveys on major water problems in the U.S. by reviewing newspapers, professional magazines on water, and internet websites. They discuss these problems in light of the concepts that are being taught within the class and suggest solutions based on the knowledge derived from the course content. Students conducted a case study on the effect of transportation run off on storm water quality in urban areas.

Enhancing Environmental Engineering curriculum through educational and research grants such as NEXTRANS was presented at American Society of Engineering Education (ASEE) North Central Section conference-2016.

Task 3:

RAPCA training for students:

Regional Air Pollution Control Agency (RAPCA) provided the students enrolled in ENE 3315 course with real-time monitoring experience using live traffic data. Students learned how to use sensors for analyzing air pollutants from on-road mobile vehicles. They either used MOVES to estimate air quality emissions from cars and light duty trucks in Ohio or be provided demonstrations on using MOVES.

Task 4:

Summer research experiences at Purdue and with ODOT

Mr. Ammon Russell participated in 2013 NEXTRANS summer camp. As part of the summer research, he received training on intelligent traffic control systems, analyzing traffic congestions using algorithms developed by Purdue on a commercially available traffic simulator. Mr. Benjamin Rives participated participating in 2014 NEXTRANS summer camp. Since then, both students graduated from CeSU with BS in Environmental Engineering degrees in 2014 and 2015 respectively. Mr. Trenton Barnes participated in 2016 NEXTRANS summer camp and worked on runoff related issues relevant to transportation.

Though it is not through NEXTRANS program, ENE undergraduate Mr. Aquil Frost did his summer internship in 2016 with ODOT in Lebanon, OH, and currently (December 2016) continues as an intern.

Task 5:

Imparting Education in Transportation to Middle school and High School students

CeSU through its Summer Transportation Institute (STI) mostly supported by ODOT and FHWA with additional support by NEXTRANS brought 30 middle school children across the nation in the project period for four weeks in summer to impart education and awareness of transportation industry – its challenges, solutions and opportunities. The program included different modes of transportation -air, water and land. These students also learned transportation related air pollution issues and climate changes due to GHG emissions. They learned how to monitor air pollutants using sensors that are available in the air quality engineering laboratory. Mr. Brian Huxtable from RAPCA provided an hour presentation to STI 2014 class on air pollution. His presentation included the issues of transportation related air pollution and greenhouse gas emissions. The student presentations at the end of the camp included the issue of greenhouse gas emissions and climate change. In 2014, Ms. Anita Kisanga from the Department of Water resources Management participated as a student counselor for the STI camps. This summer program has so far helped CeSU in recruiting students for STEM fields, especially for ENE program. The case study on STI has been accepted for presentation at the American Society of Engineering Education (ASEE) conference-2017.

Task 6:

Enhancing Transportation Industry, Research and Education at an HBCU

In 2015, CeSU with the collaboration of Clean Energy Ohio held *Waste to Wheels II: Renewable Natural Gas for Transportation* conference at CeSU. In the project period, CeSU has further collaborated with many institutions in the Midwest in submitting transportation related proposals and succeeded in one (*US DOT Regional 5 University Transportation Center* with University of Michigan as the lead institution, 2016).

CeSU acquired an ADR-1500 equipment through this grant that will be used in the classwork and in future research to measure Particulate Matter in the environment. In 2016 December, CeSU has submitted a proposal (*Access to Infrastructure Engineering Education for Underrepresented Minorities (AIEUM)*) to Department of Education through its Minority Science and Engineering Improvement Program (MSEIP) for starting a minor in Infrastructure Engineering with transportation as the main focus in its Environmental Engineering program.

Recommendations

The study shows the technical and financial need

1. for the reduction of the greenhouse gases emitted as the result of transportation mainly in the urban centers and along the state and national highways. This can be done by
 - a. moving from conventional hydrocarbon based fuels to alternative fuels and energy sources in combination with improving the emission reduction technologies (as it was shown in the case of E85 run SI HEV and E85_Electricity run SI PHEV)
 - b. devising and implementing strategies that can reduce traffic
2. for collecting additional regional data on alternative energy-vehicle combinations for MOVES for better estimation of the GHG emissions. This can be done by DoT further research support in collaboration with EPA.

As it showed through our experience with this research, this project showed the importance of supporting and training minority students through minority serving institutions with their niche research areas with the help of large institutions, to bring the equity with respect to demography in the workforce. The accomplishment of the educational objective that was summarized in the previous section (*Objective 2: Tasks*) can be seen as the proof for this statement. However, the non-federal matching support that is expected from the minority institutions as a grant requirement is a tremendous burden for small institutions. This realistic situation has to be addressed in the future funding situations from the Department of Transportation for the institutions that serve the underrepresented groups to participate and perform efficiently.

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