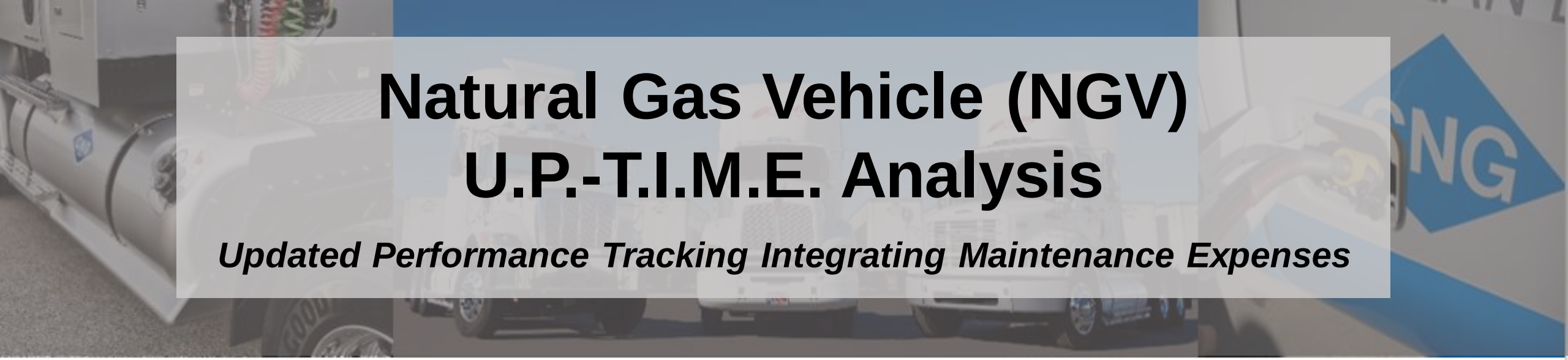


Natural Gas Vehicle (NGV) U.P.-T.I.M.E. Analysis

Updated Performance Tracking Integrating Maintenance Expenses

Principal Investigator: Megan Stein, Chief Operating Officer

Presenter: Timothy Cho, Projects Manager

Organization: Clean Fuels Ohio

Presentation Date: June 23, 2021

Project ID: TI106

CLEAN FUELS OHIO

OHIO'S CLEAN TRANSPORTATION ADVOCATE

NGV UP-TIME

2021 DOE Vehicle Technologies Office Virtual Annual Merit Review

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline:
- Start: October 1st, 2019
- End: September 30th, 2022
- ~60% complete

Partners:
- Project Lead: Clean Fuels Ohio
- Technical Lead: Energetics (Akimeka LLC)
- Technical Partner: National Renewable Energy Laboratory (NREL)
- Clean Cities Coalitions: Central Oklahoma Clean Cities, Clean Communities of Western New York, Dallas-Fort Worth Clean Cities, Empire Clean Cities, Tulsa Area Clean Cities, Virginia Clean Cities, Wisconsin Clean Cities

Budget:
- Total Project Funding: $1,000,000
- DOE Share: $500,000
- Cost Share: $500,00
- Budget Period 1: $473,015
- Budget Period 2: $356,558
- Budget Period 3: $170,427

Barriers Addressed:
- Lack of recent data clearly comparing relative maintenance costs of NGVs and diesel trucks
- Lack of NGV adoption by fleets due to maintenance cost uncertainty
- Validation of NGV lower total cost of ownership (TCO) and potential to improve energy security

Project Objectives

Objectives:

- Quantify the difference in maintenance cost between diesel and compressed natural gas (CNG) freight and goods movement vehicles
- Identify and quantify technology and process improvements between older and newer generation natural gas vehicles (NGVs)
- Assess individual NGV fleets to identify opportunities to enhance operations using newly-generated and legacy NGV and diesel fleet data

VTO TI Goals:

- **National security:** advance knowledge on an alternative fuel that is often produced domestically
- **Economic growth:** proven performance data will generate greater confidence in NGVs and drive greater demand
- **Affordability for business and consumers:** present consumers and businesses with cost comparisons to make informed purchasing decisions
- **Reliability/resiliency:** NGVs provide an alternative transportation option

Impact:

- Multi-dataset analysis detailing NGV and diesel truck maintenance costs to determine cost differences and to improve TCO
- Analyze and document NGVs as a secure, reliable, and cost-effective transportation option
- Document maintenance costs, technology solutions, or best practices capable of reducing maintenance or other related ongoing costs for heavy-duty NGVs used in freight and goods movement

Project Approach

Budget Period 1:
Program Development and Data Gathering

- Program Development
- Develop list of Key Performance Indicators
- Coordinate with Fleets and execute Data Sharing Agreements
- Collect and assemble Fleet Maintenance Data
- Convene the Project Advisory Committee (PAC)
- Initial data quality review

Budget Period 2:
Data Collection & Analysis

- Continue coordinating with additional fleets
- Collect and assemble Fleet Maintenance Data
- Convene the Project Advisory Committee (PAC)
- Complete initial data quality review and assess data gaps
- Analyze collected data
- Develop repair code decoder for all data

Budget Period 3:
Presentations of Findings, Final Report and Dissemination

- Data Cleaning
- Apply quality assurance and quality control techniques to data
- Data Analysis
- Generate specific fleet partner reports
- Develop Final Report and Presentation
- Develop outreach toolkit
- Disseminate Project Results

Milestones

Milestone	Type	Description	Progress
Budget Period 1			
Develop data collection and analysis plan	Technical	Complete data collection plan and gain approval from DOE	**Achieved**
Fleet partners	Technical	Complete list of key regional fleet partners	**Achieved**
Data gathering PAC meeting	Technical	Conduct PAC meeting to obtain feedback on data gathering efforts	**Achieved**
Fleet partnership agreements	Go/No Go	Secure agreements with at least 5 regional partners capable of securing 1041 total project vehicles for data accumulation across at least 383 vehicle months	**Achieved**

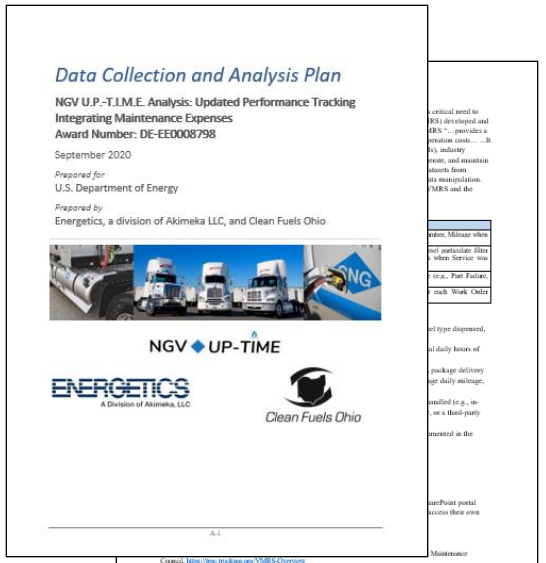
Budget Period 2			
Data Collection	Technical	Data collection complete and meets requirements for analysis	In Progress
Data Cleaning and Analysis	Technical	Conduct PAC meeting to obtain feedback on data cleaning and analysis efforts	In Progress
Repair Code Decoder	Technical	Complete preliminary and maintenance repair code decoder	In Progress
Data transfer	Go/No Go	Complete quarterly transfer of data to DOE	In Progress

Project Accomplishments and Progress (1/3)

NGV Maintenance Data Collection and Analysis Plan Completed & Approved

- Developed a **Data Collection & Analysis Plan** and gained approval from DOE
- Completed a **list of key regional fleet partners** through the Clean Cities coalition partners
- Convened quarterly **Project Advisory Committee meetings** to obtain feedback on data gathering
  - Energetics conducted KPI calls with PAC members
- Secured fleet partnership agreements **totaling at least 1,041 total vehicles accumulated across at least 383 vehicle months** with data from medium-/heavy-duty NGV fleets such as local, regional, and national freight and goods movement providers from different applications

Data Collection and Analysis Plan


Data Collection and Analysis Plan

NGV U.P.-T.I.M.E. Analysis: Updated Performance Tracking Integrating Maintenance Expenses
Award Number: DE-EE0008798

September 2020

Prepared for
U.S. Department of Energy

Prepared by
Energetics, a division of Akimeka LLC, and Clean Fuels Ohio

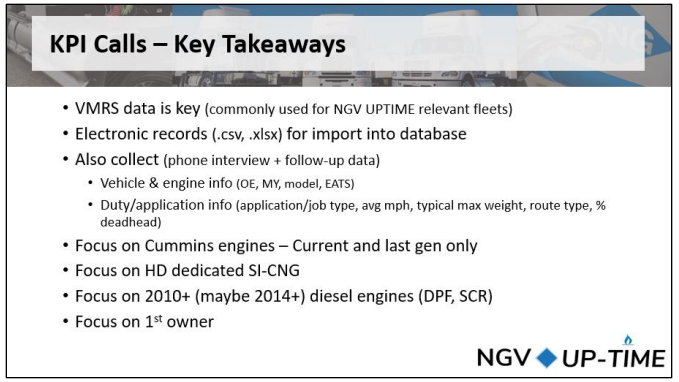
NGV UP-TIME

ENERGETICS
A Division of Akimeka, LLC

Clean Fuels Ohio

Project Advisory Committee Members

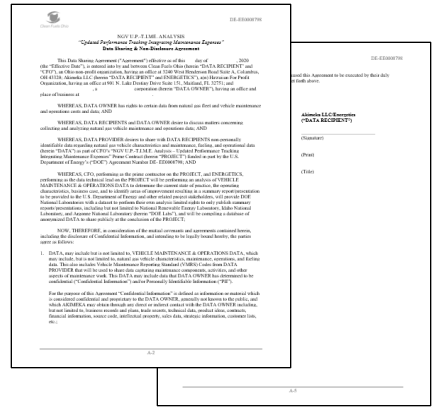
Organization	Point of Contact	Relevance
NTEA	Doyle Sumrall	National association whose members comprise numerous freight and goods movement fleets and NGV end users
GeoTab	Amir Sayegh	Leading telematics company with dataloggers on numerous freight and goods movement fleets
AssetWorks	Marc Knight	Leading maintenance database and fleet management company with dataloggers on numerous freight and goods movement fleets
Yborra & Associates	Stephe Yborra	Former Director of NGV America and current consultant to the natural gas vehicle industry
Energetics	Russ Owens	Energetics Project Manager for NGV UPTIME
Cummins	Patrick Campbell	OEM engine manufacturer whose products represent the largest market share of CNG engines for medium and heavy duty NGVs
ICOM	Albert Venezio	Conversion kit manufacturer specializing in propane autogas and natural gas vehicle technologies
Agility Fuel Solutions	Joe Reisz	Compressed natural gas fuel tank manufactuer and supplier
Clean Energy Fuels	Sandra Ballard	Natural gas station company that operates a large network of natural gas stations nationally
Trillium	Marc Rowe	Natural gas station company that operates a large network of natural gas stations nationally
NREL	Leslie Eudy	Key technical partner providing data analysis, outreach and dissemination support for NGV UPTIME
Columbus State Community College	Steve Levin	Gaseous fuel technician instructor
NREL	John Gonzales	NREL Tiger Team expert on natural gas vehicles


KPI Calls – Key Takeaways

- VMRS data is key (commonly used for NGV UPTIME relevant fleets)
- Electronic records (.csv, .xlsx) for import into database
- Also collect (phone interview + follow-up data)
  - Vehicle & engine info (OE, MY, model, EATS)
  - Duty/application info (application/job type, avg mph, typical max weight, route type, % deadhead)
- Focus on Cummins engines – Current and last gen only
- Focus on HD dedicated SI-CNG
- Focus on 2010+ (maybe 2014+) diesel engines (DPF, SCR)
- Focus on 1st owner

NGV UP-TIME

KPI Calls Takeaways Slide from PAC Meeting


NGV U.P.-T.I.M.E. ANALYSIS
"Updated Performance Tracking Integrating Maintenance Expenses"
Data Sharing & Non-Disclosure Agreement

Fleet Data Sharing Agreement

Project Accomplishments and Progress (2/3)

2,736 Vehicles from NGV Fleet Data Partners Secured and Seeking More

NGV UPTIME: Fleet Partner Engagement		
Fleet Name	**Data Agreement Status**	**# of Vehicles**
Fleet A	**Signed**	**900**
Fleet B	**Signed**	**118**
Fleet C	**Signed**	**1,540**
Fleet D	**Signed**	**62**
Fleet E	**Signed**	**53**
Fleet F	**Signed**	**63**
Fleet G	In Progress	185
Fleet H	In Progress	500
Fleet I	In Progress	40
Fleet J	In Progress	36
Fleet K	In Progress	40
Fleet L	In Progress	378
Fleet M	In Progress	200
Fleet N	In Progress	362
Total Secured:	**2,736 Vehicles**	
Total In-Progress:	**1,513 Vehicles**	
Total Potential:	**4,249 Vehicles**	

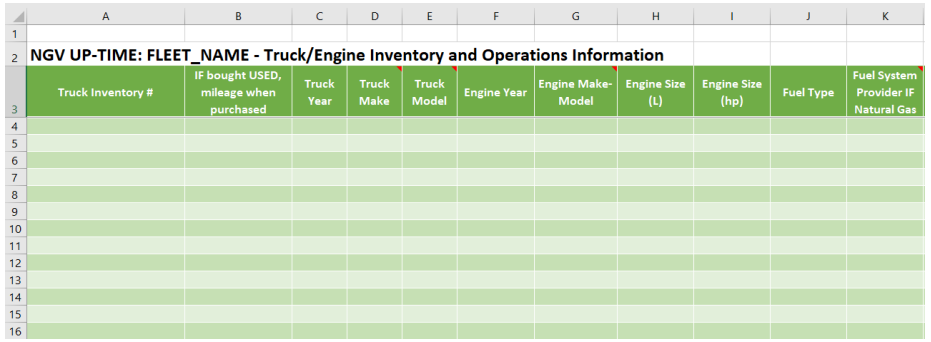
- Secured fleet partnership agreements **totaling 2,736 vehicles to-date**
- Working to secure fleet partnership agreements **totaling 1,513 potential additional vehicles** to round out the dataset with a diversity of additional freight & goods movement fleet types
- **Total potential number of vehicles is 4,249 vehicles** based on all active engagements with fleet partners
  - Goal is to secure as many additional fleet vehicles as possible to finalize the dataset before the end of Budget Period 2 (Sep 30, 2021)

Project Accomplishments and Progress (3/3)

Data Gathering/Collection Process Finalized and Underway

- Constructed **step-by-step process for data collection/transfers** aligning with the Data Collection and Analysis Plan
- Developed and shared **data sharing documents & resources** for fleet partners to follow, review, and complete
  - Fleet Inventory Sheet
  - Fleet Questionnaire
  - Sample Maintenance Data Sheet
  - Data Submission Instructions to secure SharePoint site
- This process will **set us up for success when conducting the multi-dataset analysis** and meeting the deliverables for the remainder of Budget Period 2 and Budget Period 3 that include:
  - Data Cleaning
  - Data Analysis
  - Fleet Partner Reports

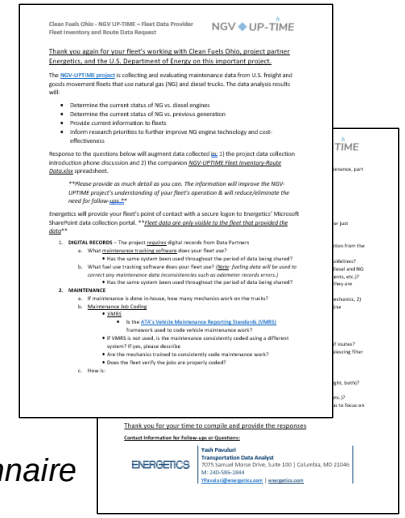
Fleet Inventory Sheet



NGV UP-TIME: FLEET_NAME - Truck/Engine Inventory and Operations Information

Truck Inventory #	IF bought USED, mileage when purchased	Truck Year	Truck Make	Truck Model	Engine Year	Engine Make-Model	Engine Size (L)	Engine Size (hp)	Fuel Type	Fuel System Provider IF Natural Gas

Fleet Questionnaire



Clean Fuels Ohio - NGV UP-TIME – Fleet Data Provider Fleet Inventory and Route Data Request

NGV UP-TIME

Thank you again for your fleet's working with Clean Fuels Ohio, project partner Energetics, and the U.S. Department of Energy on this important project.

The NGV-UPTIME project is collecting and evaluating maintenance data from U.S. freight and goods movement fleets that use natural gas (NG) and diesel trucks. The data analysis results will:

- Determine the current status of NG vs. diesel engines
- Determine the current status of NG vs. previous generation
- Provide current information to fleets
- Inform research priorities to further improve NG engine technology and cost-effectiveness

Response to the questions below will augment data collected in 1) the project data collection introduction phone discussion and 2) the companion NGV-UPTIME Fleet Inventory-Route Data.xlsx spreadsheet.

Please provide as much detail as you can. The information will improve the NGV-UPTIME project's understanding of your fleet's operation & will reduce/eliminate the need for follow-ups.

Energetics will provide your fleet's point of contact with a secure logon to Energetics' Microsoft SharePoint data collection portal. ***Fleet data are only visible to the fleet that provided the data***

1. **DIGITAL RECORDS** – The project requires digital records from Data Partners
   a. What maintenance tracking software does your fleet use?
      - Has the same system been used throughout the period of data being shared?
   b. What fuel use tracking software does your fleet use? *(Note: fueling data will be used to correct any maintenance data inconsistencies such as odometer records errors.)*
      - Has the same system been used throughout the period of data being shared?
2. **MAINTENANCE**
   a. If maintenance is done in-house, how many mechanics work on the trucks?
   b. Maintenance Job Coding
      - DMIS
        - Is the ATA's Vehicle Maintenance Reporting Standards (VMRS) framework used to code vehicle maintenance work?
      - If VMRS is not used, is the maintenance consistently coded using a different system? If yes, please describe.
      - Are the mechanics trained to consistently code maintenance work?
      - Does the fleet verify the jobs are properly coded?
   c. How is

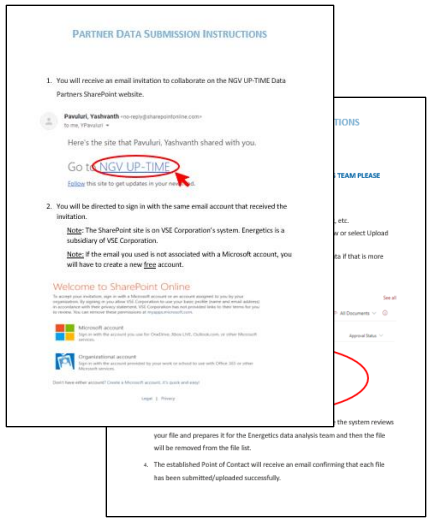
Thank you for your time to compile and provide the responses

Contact Information for follow-ups or Questions:

ENERGETICS

Yash Pavuluri
Transportation Data Analyst
7075 Samuel Morse Drive, Suite 100 | Columbia, MD 21046
M: 240-586-2844
YPavuluri@energetics.com | energetics.com

Data Submission Instructions



PARTNER DATA SUBMISSION INSTRUCTIONS

1. You will receive an email invitation to collaborate on the NGV UP-TIME Data Partners SharePoint website.

Pavuluri, Yashvanth <no-reply@sharepointonline.com>
to me, YPavuluri

Here's the site that Pavuluri, Yashvanth shared with you.

Go to NGV UP-TIME

Follow this site to get updates in your news feed.

2. You will be directed to sign in with the same email account that received the invitation.

Note: The SharePoint site is on VSE Corporation's system. Energetics is a subsidiary of VSE Corporation.

Note: If the email you used is not associated with a Microsoft account, you will have to create a new free account.

Welcome to SharePoint Online

Microsoft account

Organizational account

Legal | Privacy

TIONS

TEAM PLEASE

etc.

or select Upload

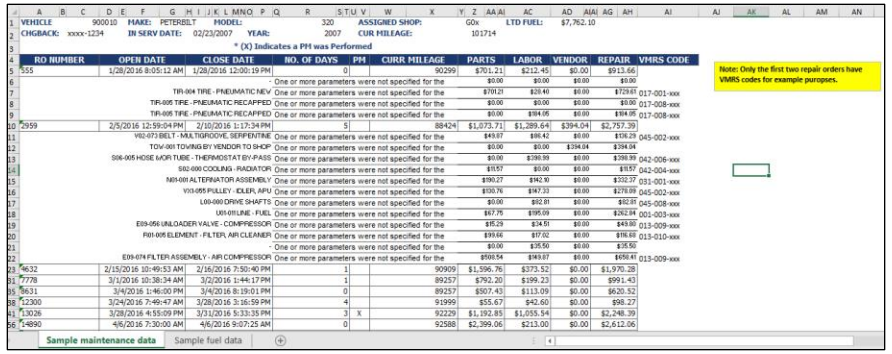
a if that is more

the system reviews

your file and prepares it for the Energetics data analysis team and then the file will be removed from the file list.

4. The established Point of Contact will receive an email confirming that each file has been submitted/uploaded successfully.

Sample Maintenance Data Sheet



VEHICLE	9000 10	MAKE:	PETERBILT	MODEL:	320	ASSIGNED SHOP:	G0x	LTD FUEL:	$7,762.10
CHGBACK:	xxxx-1234	IN SERVICE DATE:	02/23/2007	YEAR:	2007	CUR MILEAGE:	101714		

* (X) Indicates a PM was Performed

RO NUMBER	OPEN DATE	CLOSE DATE	NO. OF DAYS	PM	CURR MILEAGE	PARTS	LABOR	VENDOR	REPAIR	VMRS CODE
555	1/28/2016 8:05:12 AM	1/28/2016 12:00:19 PM	0		90299	$701.21	$212.45	$0.00	$913.66	
		-			One or more parameters were not specified for the	$0.00	$0.00	$0.00	$0.00	
		TIR-004 TIRE - PNEUMATIC NEV			One or more parameters were not specified for the	$701.21	$28.40	$0.00	$729.61	017-001-xxx
		TIR-005 TIRE - PNEUMATIC RECAPPED			One or more parameters were not specified for the	$0.00	$0.00	$0.00	$0.00	017-008-xxx
		TIR-005 TIRE - PNEUMATIC RECAPPED			One or more parameters were not specified for the	$0.00	$184.05	$0.00	$184.05	017-008-xxx
2959	2/5/2016 12:59:04 PM	2/10/2016 1:17:34 PM	5		88424	$1,073.71	$1,289.64	$394.04	$2,757.39	
		V02-073 BELT - MULTIGROOVE, SERPENTINE			One or more parameters were not specified for the	$49.97	$86.42	$0.00	$136.29	045-002-xxx
		TOV-001 TOWING BY YENDOR TO SHOP			One or more parameters were not specified for the	$0.00	$0.00	$394.04	$394.04	
		S06-005 HOSE ASM-TUBE - THERMOSTAT BY-PASS			One or more parameters were not specified for the	$0.00	$299.99	$0.00	$299.99	042-006-xxx
		S02-000 COOLING - RADIATOR			One or more parameters were not specified for the	$9.57	$0.00	$0.00	$9.57	042-004-xxx
		N05-001 ALTERNATOR ASSEMBLY			One or more parameters were not specified for the	$190.27	$142.10	$0.00	$332.37	031-001-xxx
		V03-055 PULLEY - IDLER, APU			One or more parameters were not specified for the	$130.76	$147.33	$0.00	$278.09	045-002-xxx
		L00-000 DRIVE SHAFTS			One or more parameters were not specified for the	$0.00	$92.81	$0.00	$92.81	045-008-xxx
		U01-01LINE - FUEL			One or more parameters were not specified for the	$67.75	$195.09	$0.00	$262.84	001-003-xxx
		E03-056 UNLOADER VALVE - COMPRESSOR			One or more parameters were not specified for the	$15.29	$34.51	$0.00	$49.80	013-009-xxx
		F01-005 ELEMENT - FILTER, AIR CLEANER			One or more parameters were not specified for the	$93.66	$17.02	$0.00	$110.68	013-010-xxx
		-			One or more parameters were not specified for the	$0.00	$35.50	$0.00	$35.50	
		E03-074 FILTER ASSEMBLY - AIR COMPRESSOR			One or more parameters were not specified for the	$360.54	$140.07	$0.00	$496.41	013-009-xxx
4632	2/15/2016 10:49:53 AM	2/16/2016 7:50:40 PM	1		90909	$1,596.76	$373.52	$0.00	$1,970.28	
7778	3/1/2016 10:38:34 AM	3/2/2016 1:44:17 PM	1		89257	$792.20	$199.23	$0.00	$991.43	
8631	3/4/2016 1:46:00 PM	3/4/2016 8:19:01 PM	0		89257	$507.43	$113.09	$0.00	$620.52	
12300	3/24/2016 7:49:47 AM	3/28/2016 3:16:59 PM	4		91999	$55.67	$42.60	$0.00	$98.27	
13026	3/28/2016 4:55:09 PM	3/31/2016 5:33:35 PM	3	X	92229	$1,192.85	$1,055.54	$0.00	$2,248.39	
14890	4/6/2016 7:30:00 AM	4/6/2016 9:07:25 AM	0		92588	$2,399.06	$213.00	$0.00	$2,612.06	

Note: Only the first two repair orders have VMRS codes for example purposes.

Sample maintenance data | Sample fuel data

Collaboration and Coordination Among Project Team

Technical Lead: Data storage, cleaning, repair, anonymization, analysis, visualization, and key reporting functions

Technical Partner: Advise best practices for the data collection and analysis process

Clean Cities Coalitions Partners: identify fleet partners, secure agreements, gather data, and distribute analysis reports

Industry Support: includes associations, OEMs, fuel station providers, industry experts, etc.

energetics
Clean Energy Consulting

NREL
Transforming ENERGY

acog

TULSA AREA CLEAN CITIES

WISCONSIN CLEAN CITIES

VIRGINIA CLEAN CITIES

CLEAN COMMUNITIES OF WESTERN NEW YORK

Dallas-Fort Worth CLEAN CITIES

U.S. Gain
a division of U.S. Venture, Inc.

Clean Energy

AssetWORKS

Trillium CNG

HEXAGON AGILITY

Cummins

NGVAMERICA
Natural Gas Vehicles for America

Overall Market Impact

Achievements to date:

- Data Collection and Analysis Plan
- List of key regional fleet partners
- Project Advisory Committee meetings on KPI's and data gathering
- Fleet partnership agreements (2,736 vehicles to-date)

This study will directly address the lack of maintenance cost data and barrier of NGV adoption uncertainties through a multi-dataset comparison by:

- Reinforcing the total cost of ownership of NGVs as a potential advantage through recent data and analysis
- Documenting maintenance costs, technology solutions, and best practices capable of reducing maintenance costs that will improve the NGV industry

Upcoming:

- Rest of Budget Period 2
  - Data Collection
  - Data Cleaning & Analysis
  - Repair Code Decoder
- Budget Period 3
  - Data Cleaning
  - Data Analysis
  - Fleet Partner Reports
  - Develop Final Report and Presentations
  - Disseminate Project Results
- Key remaining challenges
  - Delay in data collection
  - Unforeseen data analysis misalignments
  - Need for supplemental information

Summary

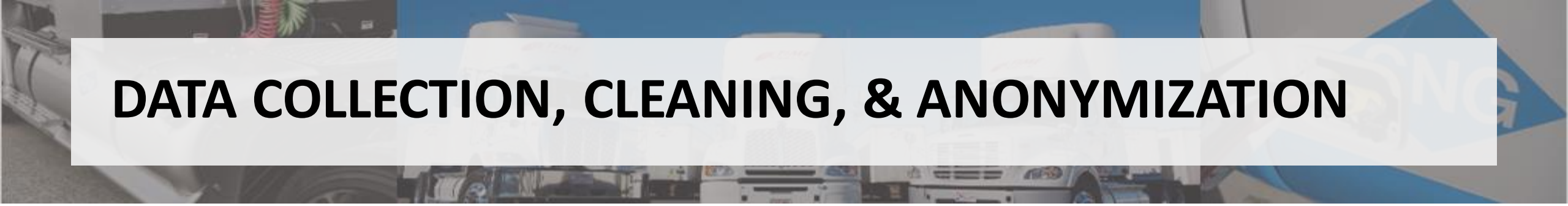
Objectives	• Quantify the difference in maintenance cost between diesel and compressed natural gas (CNG) freight and goods movement vehicles • Identify and quantify technology and process improvements between older and newer generation natural gas vehicles (NGVs) • Assess individual NGV fleets to identify opportunities to enhance operations using newly-generated and legacy NGV and diesel fleet data
Approach	• Program Development and Data Gathering • Data Collection & Analysis • Presentations of Findings, Final Report and Dissemination
Accomplishments	• Developed Data Collection & Analysis Plan • Completed list of key regional fleet partners • Convened Project Advisory Committee and received input on data gathering • Secured fleet partnership agreements totaling 2,736 vehicles to-date
Up Next	• Round out the dataset with a diversity of additional freight & goods movement fleet types • Complete data cleaning & analysis • Develop repair code decoder • Develop fleet partner reports and final report/presentation for dissemination

Technical Back-Up Slides

DATA ANALYSIS GOAL

- Collect, combine, analyze, summarize, and compare the maintenance costs, operating costs, and frequency of repair for freight and goods movement vehicles, specifically focusing on the differences between natural gas vehicles (NGVs) and modern diesel vehicles.
  - Both current and previous generation NGVs
  - Analyze by vehicle application, geography, etc.

NGV UP-TIME



DATA COLLECTION, CLEANING, & ANONYMIZATION

- Microsoft Azure cloud computing platform for data storage, manipulation, analysis (SQL Server and Python)
- Data Partners upload data into secure Energetics SharePoint portal with unique user-specific (username/PW) login
- Review each fleet's data for consistency, completeness, erroneous/outlier data → Resolve issues to create complete fleet dataset
  - Remove PII and business sensitive information (replace with project-defined values)

NGV UP-TIME

DATA ANALYSIS

- Maintenance and fuel records analyzed separately
- **Raw data concatenation.** All cleaned data organized into a single dataframe
- **Repair order level.** Extract repair details for high-level analysis
- **Vehicle application profiles.** Develop summary of vehicle features and performance
- **Repair type.** Includes repair details for subsystem-level analysis

NGV UP-TIME

DATA ANALYSIS

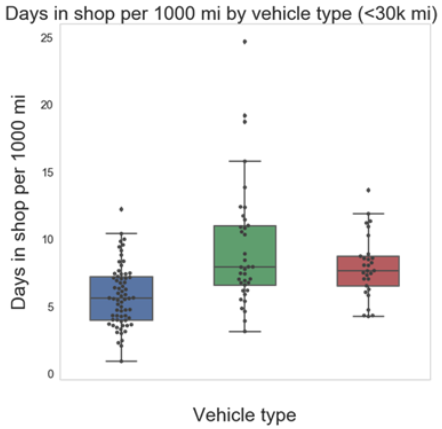
Develop summary data reports to showcase trends and findings by fuel type, application, geography, etc.

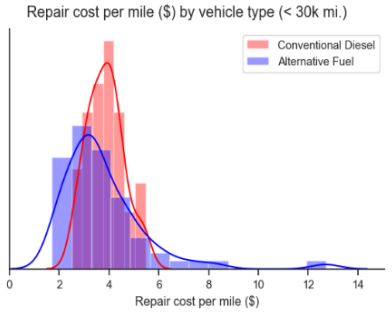
Final outputs may include tables and graphics similar to the following:

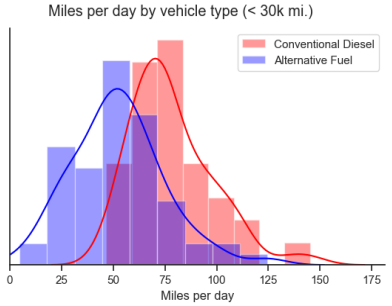
** Sample tables and graphics were produced as examples, so do not represent conclusions for any given fleet or technology*

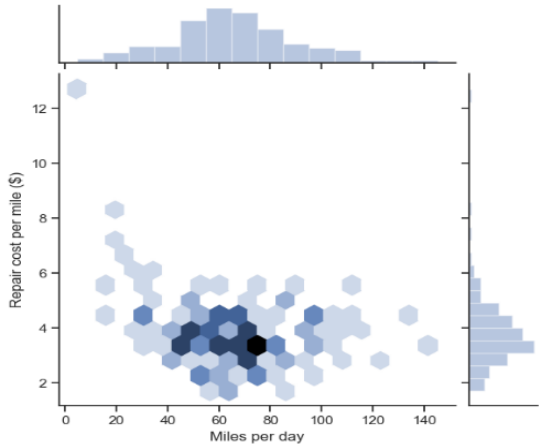
- Miles driven per day by vehicle type
- Repair cost per mile ($) by vehicle type
- Repair orders per 100 mi by vehicle type
- Average repair order length (days) by vehicle type

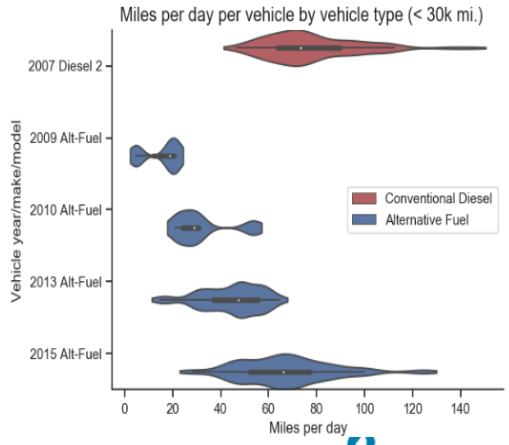
Vehicle Component & Conventional		Pre-2015 Alt-Fuel	2015 Alt-Fuel
Fuel	1.32	0.89	0.89
Tires	1.07	1.55	1.28
Brakes	0.3	0.04	0.07
Engine	0.13	0.07	0.02
Cooling	0.06	0.01	0
Other	0	0.01	0
PM	0.14	0.25	0.13
Body	*1.21*	*1.21*	*0.31*
HVAC	*0.03*	*0.01*	*0.01*
Suspension	*0.02*	*0.01*	*0.01*
Instruments	*0.02*	*0.01*	*0.01*
DEF	*0*	*0.04*	*0.01*
Overall	5.18	5.13	3.68











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DATA ANALYSIS REPORTING

- Project-level shared results will be anonymized using process developed with national labs' feedback
- Share final combined anonymized and cleaned dataset with DOE for further analysis by DOE, national labs, universities, etc.
- Develop Data Provider-specific analyses

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