Project ID #EEMS027

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

National Scale Multi-Modal Energy Analysis for Freight

P.I.: Kevin Walkowicz
National Renewable Energy Lab
June 19, 2018

Yi Hou, Adam Duran, Lijuan Wang
(National Renewable Energy Lab)
Victor Walker (Idaho National Lab)
Yan Zhou (Argonne National Lab)

Timeline

- Project start date: 10/01/2016
- Project end date: 9/30/2019
- Percent complete: 58%

Budget

- FY 2018 project funding (all Labs)
  - DOE: $130k (new)
  - Carryover from FY17: $53,286 (NREL)
- FY 2017: 100k (NREL)

Barriers

- Computational models, design, and simulation methodologies
- Constant advances in technology

Partners

- DOE Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium members:
  - Argonne National Lab (ANL)
  - Idaho National Lab (INL)
  - Oak Ridge National Lab (ORNL)
- Industry Partners:
  - United Parcel Service (UPS)
- Other Institutions:
  - Mid-Ohio Regional Planning Commission (MORPC)
- Indirect Data Providers:
  - U.S. Department of Transportation (DOT)
  - U.S. Federal Highway Administration (FHWA)
  - U.S. Department of Homeland Security (DOHS)
  - INRIX

PROJECT OBJECTIVE:

- Provide framework to quantify benefits and impacts from optimized inter-city freight due to mode shifts and advanced technology deployment and inform private and public sector decision-making
- Develop an understanding of new technologies while also assessing their efficacy through analysis of existing inter-city delivery behavior and modality
- Quantify impacts of inter-city freight movement due to modal shifts combined with advanced technology improvements expected by 2040 and compare to current scenarios through tour-based modeling
- Leverage existing data to baseline actual inter-city freight model attributes and modalities.

FY18 MILESTONES

- FY 2018 Q2: Provide at least one case study of national energy use changes based on the application of technology and methodology adoptions/mode shifts on inter-city freight (platooning, full automation and electric vehicle [EV] truck scenarios)
  - ANL/INL
  - Status = Complete

- FY 2018 Q4 (Annual): Demonstrate initial integrated algorithm + TransCad framework and perform initial analysis for at least three scenarios (including estimated or assumed adoption rates) of technology and mode shift to quantify energy and time impacts
  - INL/NREL
  - Status = Pending

- Go/No-Go: FY 2018 Q4: Analyze completed case studies to determine if there are sufficient data and adoption information on technology changes and mode shifts to project impacts.
  - Status = Pending

APPROACH

Identify

Identify mode shift and efficiency improvement scenarios due to automation (all levels), connectivity, and advanced vehicle technologies

Qualify

Work with industry partners and research institutions to qualify scenario assumptions and technologies

Quantify

Quantify advanced technology efficiencies in British thermal unit (BTU)/ton-mile

Quantify

Quantify/estimate penetration rates of advanced technologies and define impacts on modal share shift

Refine Models

Refine route + mode optimization algorithms developed for Multi-Modal task 3.1 and develop inter-city freight optimization capability in TransCad

Identify Impact

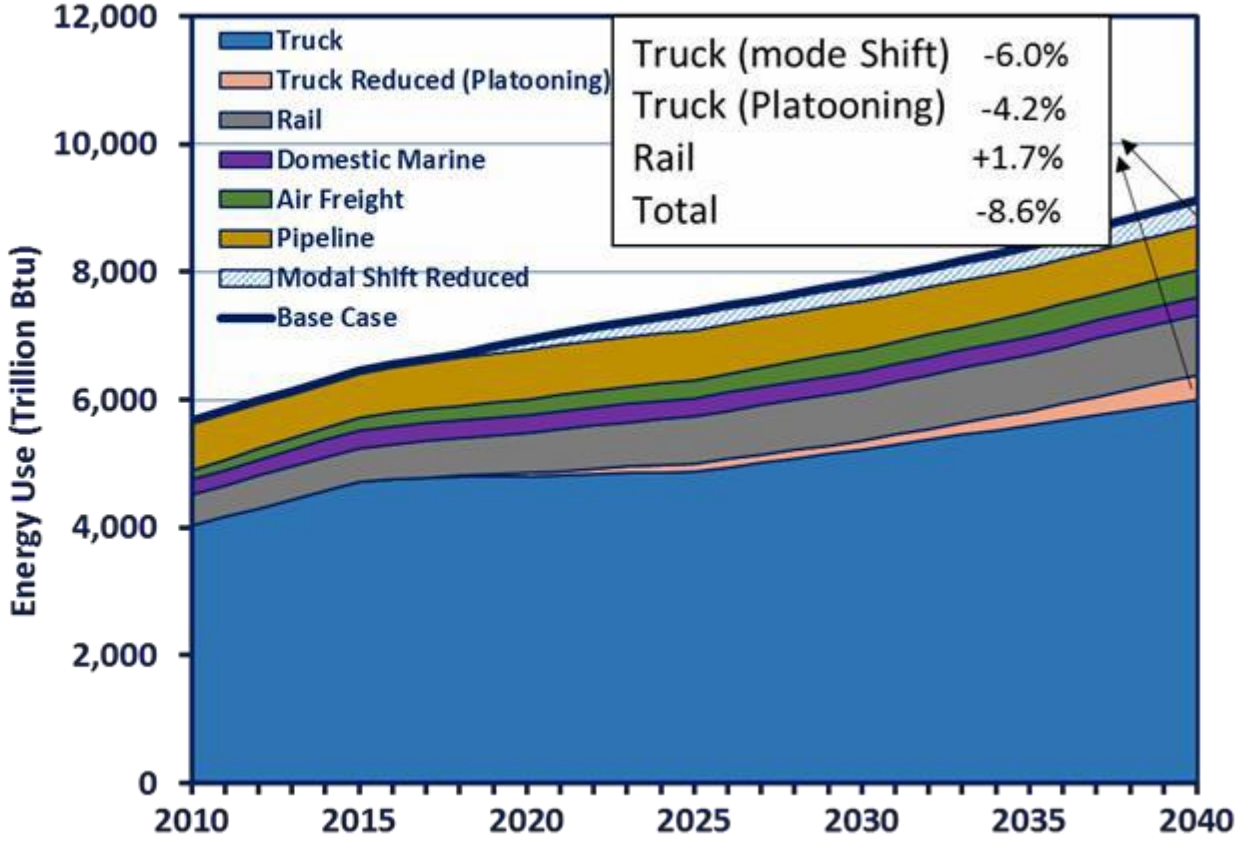
Estimate and optimize potential time and energy impacts of new technologies and mode shifts using Origin-Destination routing and technology scenarios

TECHNICAL ACCOMPLISHMENTS - Summary

- Examined Platooning National Impact
- Examined Electric Class 8 truck opportunities
- Created O-D optimization model for 3.1 and adapting it to 2.1 to create 'Inter-city' Analysis Model / Framework
- Scenarios Identified
- Technology Energy Analysis

TECHNICAL ACCOMPLISHMENTS – Platooning National Impact

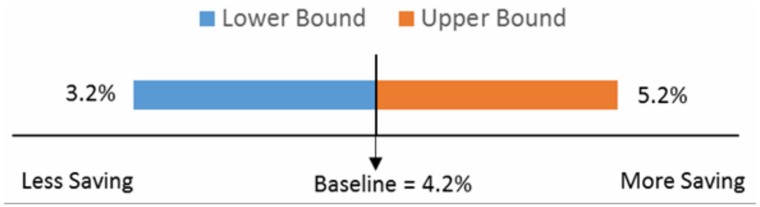
Quantified freight sector total energy reduction due to platooning and mode shift



(evaluation and graphics provided by ANL)

TECHNICAL ACCOMPLISHMENTS – Platooning National Impact

Sensitivity analysis for energy saving due to platooning at 2040

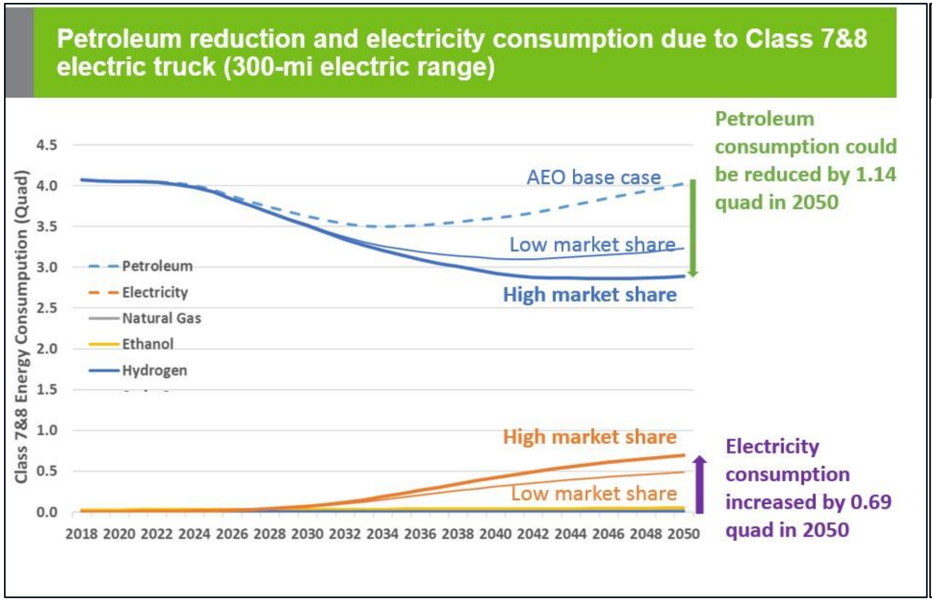


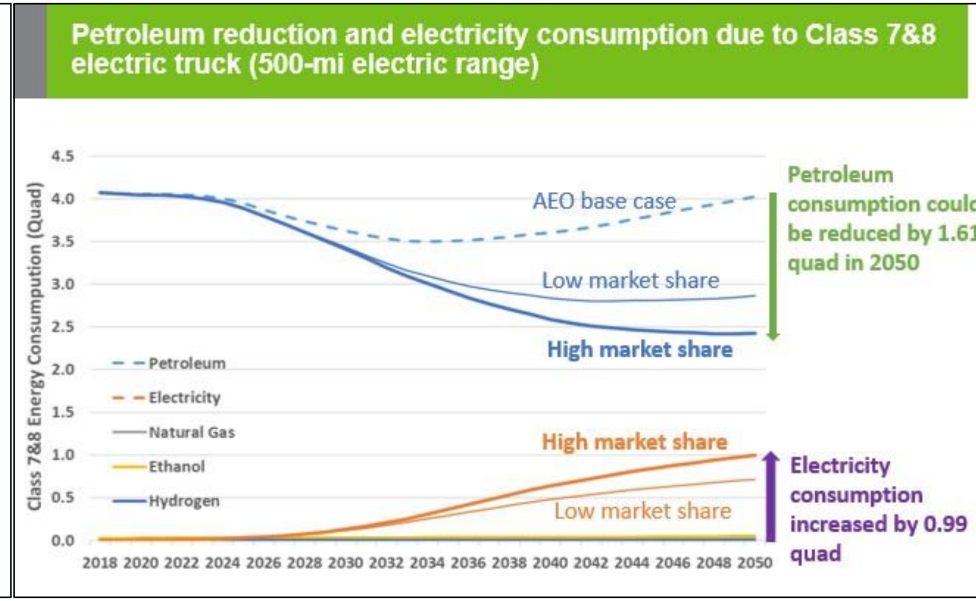
Cumulative Energy Saving and Greenhouse Gas (GHG) Emissions Reduction via Platooning Technology Adoption

		Low	Medium	High
Total Energy Use (Trillion Btu)	Value	3331.1	3816.8	5329.8
	%	1.5%	1.7%	2.3%
GHG Emissions (Million MT CO_2 Eqv)	Value	284.9	326.3	455.8
	%	1.4%	1.6%	2.3%
Upstream Energy Use (Trillion Btu)	Value	765.9	877.2	1225.4
	%	1.5%	1.8%	2.5%

(evaluation and graphics provided by ANL)

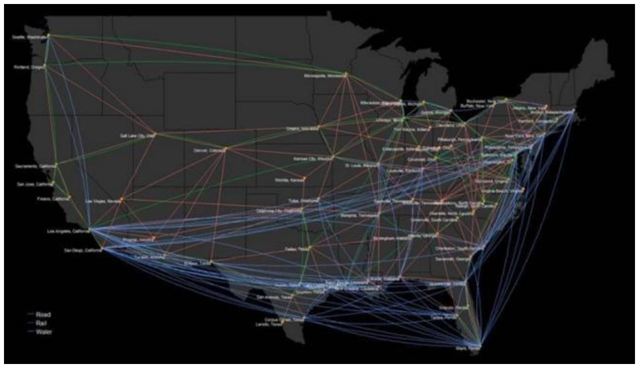
TECHNICAL ACCOMPLISHMENTS – Class 8 Inter-City Electrification Impacts





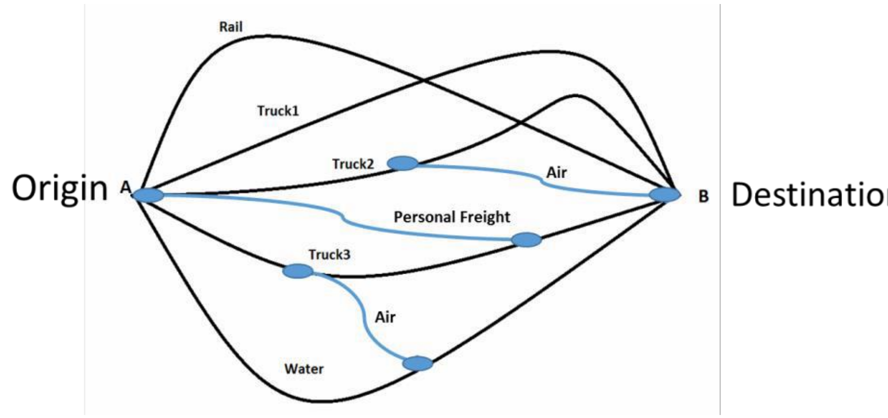
Opportunities for class 8 electric truck with 300 mile and 500 mile range evaluated (evaluation and graphics provided by ANL)

TECHNICAL ACCOMPLISHMENTS – Created Origin-Destination Model to Assess Technology and Mode Shift



Baseline Catalog and Characterization of O-D for National Freight Movement

Combined with an Understanding of National Freight Movement and Volume



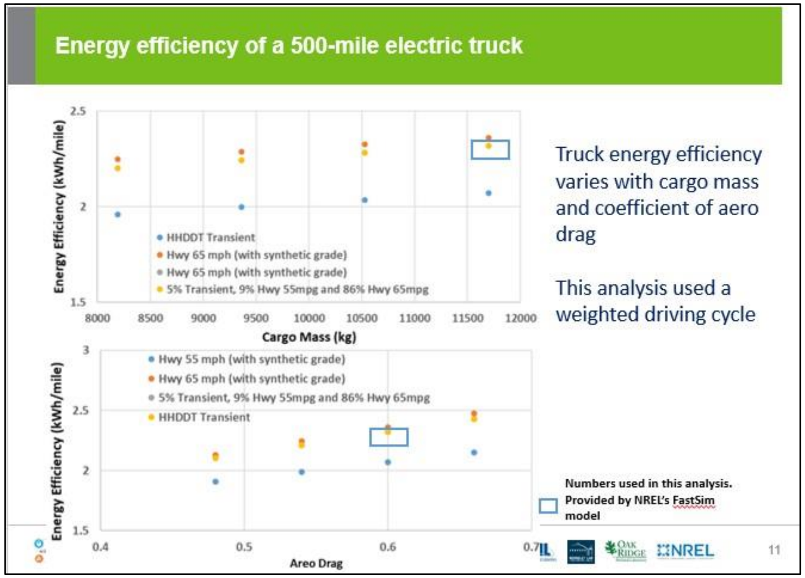
- Baseline
  - Current practice of inter-city freight movement

- Multi-modal
  - Combination of rail, freeway, waterway, and air
  - Shortest path algorithm to find the combination of different modes with minimum energy consumption

TECHNICAL ACCOMPLISHMENTS – Scenarios Identified

- Current Freight volumes and mode optimized for greatest energy efficiency with pathways to evaluate
- Current Freight volumes mode optimized for speed
- Mixed optimization function using current freight volumes
- Future Freight scenarios using - FAF/BTS Volumes for 2045
- Enhanced trucking technology to include:
  - Supertruck II technology
  - Conventional w/triple trailers
  - Supertruck w/triple trailers
  - Trailer load /capacity optimization
  - Full EV truck (300 mile and 500 mile range)
  - Full EV truck w/electric roadway and/or fast charge batteries
  - Full EV truck w/triple trailers
  - Hydrogen long range
  - Hydrogen w/triple trailers
  - Autonomous Operation (conventional, STII, EV variations, H2) – assumes lower speeds, constant operation
  - Platooning

TECHNICAL ACCOMPLISHMENTS – Technology Energy Analysis



- Efficiencies of 300 mile and 500 mile truck were calculated
- Real World Drive Cycles including grade, mass and aerodynamic drag assumptions were included
- Additional Vocations, Trucks and Technologies are being analyzed for energy efficiency

Drive Cycle	Aero Drag C_d	Real World		Standard			Weighted
		Grove City	Sanger	HHDDT Transient	Hwy 55 mph (with synthetic grade)	Hwy 65 mph (with synthetic grade)	5% Transient, 9% Hwy 55mpg and 86% Hwy 65mpg
Energy Efficiency (kWh/mile)	0.66	2.417	2.579	2.087	2.150	2.475	2.427
	0.60(Baseline)	2.307	2.477	2.060	2.068	2.361	2.320
	0.54	2.196	2.374	2.038	1.988	2.246	2.212
	0.48	2.086	2.272	2.016	1.909	2.128	2.103
Total Energy (kWh)	0.66	166.527	161.807	5.944	64.746	76.002	70.997
	0.60(Baseline)	158.927	155.486	5.867	62.299	72.534	67.903
	0.54	151.309	149.102	5.805	59.912	69.009	64.775
	0.48	143.738	142.777	5.744	57.543	65.404	61.583

Drive Cycle	Aero Drag C_d	Real World		Standard			Weighted
		Grove City	Sanger	HHDDT Transient	Hwy 55 mph (with synthetic grade)	Hwy 65 mph (with synthetic grade)	5% Transient, 9% Hwy 55mpg and 86% Hwy 65mpg
Energy Efficiency (kWh/mile)	0.66	2.416	2.578	2.070	2.156	2.475	2.426
	0.60(Baseline)	2.304	2.475	2.050	2.072	2.360	2.319
	0.54	2.193	2.372	2.024	1.994	2.246	2.212
	0.48	2.083	2.269	1.996	1.912	2.131	2.104
Total Energy (kWh)	0.66	166.439	161.954	5.897	64.976	76.044	71.030
	0.60(Baseline)	158.760	155.539	5.842	62.478	72.543	67.914
	0.54	151.138	149.099	5.768	60.124	69.042	64.803
	0.48	143.564	142.668	5.687	57.666	65.536	61.674

Estimated energy consumption for 300 and 500 mile range vehicles (kWh/mile)

RESPONSE TO PREVIOUS YEAR REVIEWERS' COMMENTS

- **"The reviewer found no mention of the dependencies between potential efficiency benefits and route selection (e.g., there will not be much benefit from platooning or reducing aerodynamic drag if a slow-speed, residential route is selected). Similarly, the reviewer commented, fuel savings from idling reduction is not likely to have much impact if the route selected is mostly on uncongested freeways."**
  - To address the concerns voiced by the previous reviewer, the team has chosen to incorporate modal/technology selection characteristics into the national freight network model.
- **"The reviewer indicated that a key aspect of the stated approach is to optimize for energy within cost and time constraints. However, the reviewer noted, it is not clear if the team has fully explored the various relationships between cost and time."**
  - To address the concerns voiced by the previous reviewer, the team has reached out to industry partners to gather additional insight into the relationship between cost and time as a means of incorporating these features into the national freight model. Depending on commodity and mode choice, there will be a non-trivial number of factors to consider when optimizing mode choice, especially when forecasting freight movement into the future.

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- DOE National Laboratories:
  - INL
  - ANL
  - ORNL
- Industry Partners:
  - UPS
- Other Institutions:
  - Mid-Ohio Regional Planning Commission (MORPC)
- Indirect Data Providers:
  - U.S. DOT
  - FHWA
  - DOHS
  - INRIX
  - RL Polk
  - Others

DATA

- Need improved model data for evaluating energy benefits from modal shifts
- Need to further identify and characterize new modes of future goods delivery
- Need to work with freight shipping companies to understand technology adoption rates and impacts
- Need more information on the energy profiles for new vehicle options such as drones
- Need to further enhance tour-based models to identify finer detail on energy impacts and how to represent shifts in modes.

PROPOSED FUTURE RESEARCH*

1. Develop Freight Mobility Metric
2. Identify mode shift and efficiency improvement scenarios due to automation (all levels), connectivity and advanced vehicle technologies
3. Work with industry partners and research institutions to qualify scenario assumptions and technologies
4. Quantify advanced technology efficiencies (in BTU/ton-mile)
5. Quantify / estimate penetration rates of advanced technologies and define impacts on modal share shift
6. Refine route + mode optimization algorithms developed for MM task 3.1 and develop inter-city freight optimization capability in TransCad
7. Using #6 Framework/Capability: Estimate & optimize potential time and energy impacts of new technologies and mode shifts using O-D routing & technology scenarios

*Any proposed future work is subject to change based on funding levels.

Summary

This task will quantify impacts of inter-city freight movement due to modal shifts combined with advanced technology improvements expected by 2040 and compare to current scenarios through tour-based modeling approaches. To date, this task has:

- Quantified advanced technology efficiencies for a variety of trucks (in BTU/ton-mile)
- Identified key scenarios to evaluate and began analyzing platooning and class 8 electric truck opportunities
- Assessed current baseline efficiencies
- Created models/algorithms to analyze impacts of technology and scenarios in multiple cities / regions
- Developing a Freight Mobility Energy Productivity Metric to understand where freight mobility improvements is needed. Technology efficiencies, modes and scenarios developed and analyzed within this task will enable this approach.