Electric Vehicles & Energy Security

Paul N. Leiby*

Michael Shelby**

Ed Coe**

***ORNL**
****U.S. EPA**

January 15th, 2014

Presented at 93rd Annual Meeting of the Transportation Research Board Washington, D.C.

Overview

- Background
- Previous Literature
- How do we define energy security?
- Assumptions/Inputs
- Results
- Conclusions

Do Electric Vehicles Enhance Energy Security?

- As Grove notes (2008), the physical characteristics of oil and electricity can have very different consequences for energy security
- Oil is a fungible commodity that "flows though fleets of tankers across oceans" as a globally traded commodity
- Electricity use in vehicles (EVs), on the other hand, "can only be transported over land, so it stays on the continent that it is produced"
  - He coins the term "sticky" to describe this characteristic of electricity

Why Electric Vehicles Enhance Energy Security?

- Since electricity is produced domestically, the wider use of electricity in vehicles reduces oil import costs, exposure to oil disruptions
- In addition, future electricity supply is not anticipated to have:
  - significant disruption possibilities as oil does, and
  - electricity supply disruptions, when they occur, are not likely to be correlated with oil price disruptions
    - U.S. total electricity generation share from petroleum is currently ~0.3%; projected to be 0.2% petroleum by 2025, 0.1% by 2040 (AEO 2013)
  - As a result, the cost of electricity production generally does not co-vary with oil prices

Why Electric Vehicles Enhance Energy Security

- Finally, electricity provides both short and long-run substitution opportunities
  - "Flexibility": drivers can shift to electricity, which increases the elasticity of demand for oil
  - These benefits occur because there is more substitutability in end-use fuel use

Previous Literature

- Strong claims have been made about the energy security benefits of EVs (Grove 2008, Grove and Burgelman 2008)
  - These papers make the case that the economic, diplomatic/geopolitical and military costs of oil use are high and argue that major shifts to electric vehicles are necessary to break cycle of dependence on petroleum
- Other studies have focused on the option value of fuel-flexibility of PHEVs (Lemoine, 2010, Mackenzie 2007)
  - Option value is the ability to use the cheapest fuel-gasoline or electricity; both find the option value modest from the perspective of the consumer
  - Do not address societal or energy-security value of the fuel-flexibility option

Previous Literature

- **Still other studies have focused upon the energy security benefits if EVs provide electric grid-stabilization**
  - **either through use of used vehicle batteries or operational EVs (Vehicle-to-Grid (V2G)) (Williams and Lipman 2011, Greenberger 2011)**
- **One recent paper provides a direct estimate of the energy security benefits of EVs (Michalek et al. 2011)**
  - **based on quantity of oil displaced, applying a combination of premium component estimates from Brown and Huntington, Leiby, and Delucchi (for military)**

How Do We Define U.S. Energy Security?

- **Energy security is defined as protecting the U.S. economy against risk of significant short-term and long-term increases in energy costs**
- **Concerns are a result of:**
  - **Sustained high oil import costs**
    - **Non-competitive oil supply**
  - **Vulnerability to episodic shocks**
    - **Importance of oil to the economy**
- **We define "energy security costs" (or "dependence costs") in a *measurable* way, and include:**
  - **the long-run economic costs to the U.S. from the sustained exercise of supplier market power;**
  - **plus the short-run costs of oil shocks measured as:**
    - **added import costs during shocks**
    - **dislocation losses in GDP**

What is the Oil Security Premium?

- **Premium =**

  ***marginal* economic costs associated with security and market power that are *not* accounted by private agents in the U.S.**

- **Two major components to oil security premium:**
  - **Monopsony (Demand) Effect**
    - **(recoverable) cartel rents**
  - **Macroeconomic Disruption/Adjustment Costs**

- **Determine *marginal* variation in these components with U.S. oil import level**

- **Generally excluded: U.S. military costs, diplomatic/geopolitical costs**

Monopsony (Demand) Component in the Oil Market

- **Like a monopolist (sole supplier), a monopsonist (sole or large demander), can have an effect on price of a product**
  - **U.S. is large demander of oil**
    - **If U.S. reduces imports, then demand for oil and price for oil per barrel worldwide would likely drop**
    - ***The quantity of oil imported times the drop in price is the monopsony effect***
    - **This represents a economic benefit to the U.S. since fewer barrels are imported and all imported barrels of oil still purchased are bought at a lower price**
- **Range of estimates is typically wide because of possibility of strategic behavior**
    - **OPEC options, e.g. can reduce exports in response to demand decrease, keeping price per barrel high**
    - **Or they can defend market share, and let price decline**

Macroeconomic Disruption/Adjustment Costs

- In order to estimate the macroeconomic disruption/adjustment costs to the U.S. economy, several steps must be taken
  - First, estimate the likelihood of oil supply disruptions in the future
  - Second, assess the likely impacts of a potential oil supply disruption on the U.S. economy
  - Third, determine how these costs change with changed U.S. consumption or imports levels
  - The value of avoided price-spike cost from reduced oil consumption/imports becomes the value of this portion of the oil security premium

Key Issues and Driving Factors for Cost Estimation

- Supplier behavior (non-competitive and competitive) and response to change in oil use
- Likelihood of oil shocks
- Economic costs of oil shocks (GDP sensitivity)
- Role and effect of existing policies (e.g., Strategic Petroleum Reserve (SPR))
- For substitute fuel (like electricity)
  - Risks of disruptions to electricity supply
  - Effect of EVs on short and long run demand flexibility

Electricity In Vehicles

- For this analysis, we consider two separate types of electric vehicles
  - Plug-in Hybrid Vehicles (PHEVs)
  - Battery Electric Vehicles (BEVs)
- A small but growing literature seeks to understand recharging behavior for BEV and PHEV owners, and estimate the fraction of vehicle use that is fueled by electricity rather than gasoline (Davies 2013, Zoepf et al 2013)

Electricity in Vehicles

- This fraction, or "electrical utilization rate", will depend on:
  - vehicle type (electric range)
  - individual daily driving patterns
  - recharging infrastructure availability, and other factors influencing cost and convenience including relative electricity and gasoline prices
- "Utility Factors" attempt to estimate the amount of driving per day by EVs on electricity
  - The method used here is based upon the SAE standard developed in "Utility Factor Definitions for Plug-in Electric Vehicle Using Travel Survey Data", SAE J2841, 2010

Electricity in Vehicles

- For this analysis, we assume that PHEVs/BEVs have the following characteristics:
  - PHEVs:
    - PHEV20: 20 mile All Electric Range (AER) uses electricity for 40% of total distance;
    - PHEV40: 40 mile AER uses electricity for 63% of total distance
  - BEVs: AER of 100 miles
    - replaces conventional gasoline vehicle fuel one-for-one
  - Baseline charging assumption: 1 charge per day
  - Reference vehicle in 2025: mid-size, gasoline powered, 40 on road mpg*, has a lifetime VMT of ~207k miles

* 40 mpg real world is equivalent to about 50 mpg CAFE and about 54.5 mpg including A/C refrigerant credits

Major Inputs/Assumptions

- **Reference (undisrupted) market projections (EIA Annual Energy Outlook 2013)**
  - **U.S. oil import levels and world oil price ($117 rising to $155)**
- **Supply response: OPEC and non-OPEC, short-run and longer-run (1.7 average long run for OPEC)**
- **Elasticity of Non-U.S. net import demand (-1.05 long run)**
- **Short Run demand/supply elasticities (15% of long run)**
- **Disruption frequency and size (for all fuels)**
  - **Share of disruption price anticipated (mean 38%)**
  - **GDP sensitivity to disruption price (mean GDP elasticity -0.032)**

Initial Results

Energy Security Benefits in 2025 (2013$)
(Undiscounted lifetime fuel savings)

Vehicle Type	Monopsony ($/vehicle)	Macroeconomic Disruption ($/vehicle)	Total ($/vehicle)
PHEV20	$523	$482	$1,006
	($178 - $1004)	($239 - $769)	($579 - $1497)
PHEV40	$729	$672	$1,402
	($248 - $1400)	($334 - $1072)	($807 - $2087)
EV100	$1,060	$978	$2,040
	($361 - $2037)	($486 - $1560)	($1174 - $3036)

These benefits include average economic benefits for assumed vehicle use pattern and exclude benefits of greater short run flexibility, or military/foreign policy benefits, any effects on grid reliability, and costs to EV owners of electricity disruptions. (Ranges are 5% - 95%)

Omitted Factors in Energy Security Estimate

- Military/foreign policy security costs
- *Catastrophic scenarios* where global oil trade breaks down (global war?)
- Electricity supply disruption possibilities
- Omits possible long-run benefits of early EV penetration
  - may offer by easing rapid major transition to electric drive vehicle, if necessary in future
- Full analysis of PHEV contributions to demand/supply flexibility
  - These *could* strongly enhance security effectively through increased market diversifications and flexibility (not fully captured)
  - Household flexibility to alter vehicle use

Strategic materials security issues (rare earths, other)

Conclusions

- EVs can help improve the energy security position of the U.S.
- EVs can enhance energy security by:

  (1) lowering world oil prices for all oil the U.S. consumes, and

  (2) lowering the impacts of potential future oil disruptions on the U.S. economy
- In this analysis, BEVs have higher energy security benefits than PHEVs due to the "oil displacement effect", but we have not completely analyzed all factors affecting energy security (i.e., "flexibility" benefits of PHEVs)

For more information:

LeibyPN@ornl.gov
Shelby.Michael@epa.gov
Coe.Edmund@epa.gov