



CLEAN ENERGY
MINISTERIAL

Accelerating the Transition to Clean Energy Technologies

ACCELERATING THE GLOBAL ADOPTION OF CLEAN VEHICLES

Pre-Read for Public-Private Roundtable

Clean Energy Ministerial

14:15 – 15:45

17 April 2013

Taj Palace

New Delhi, India

OUTLINE

- 1 Objective
- 2 Current Landscape
- 3 Barriers and Potential Solutions
 - A. PEVs
 - B. NGVs
- 4 Existing Efforts
 - A. PEVs
 - B. NGVs
- 5 Opportunities for Progress

OBJECTIVE

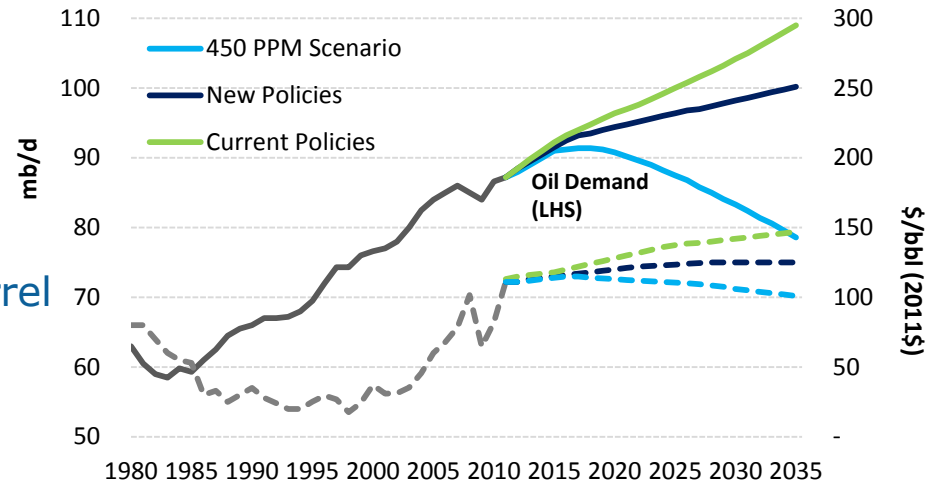
- This roundtable will examine the potential of plug-in electric vehicles (PEVs) and natural gas vehicles (NGVs) for reducing or eliminating GHG emissions and oil-dependency in automotive transportation. The scope will include light, medium, and heavy duty vehicles.
- The technology, policy, and economic opportunities, as well as obstacles, of these two technologies will be considered. Relevant issues include harmonization of standards, interoperability, public vs. private investment, and grid/pipeline integration.
- The roundtable will also focus on creating sustainable and successful business models for infrastructure build-out and operation, and government's role in market transformation.
- The roundtable will consider specific action items and notional goals for PEV and NGV deployment.

Current Landscape

THE CHALLENGE

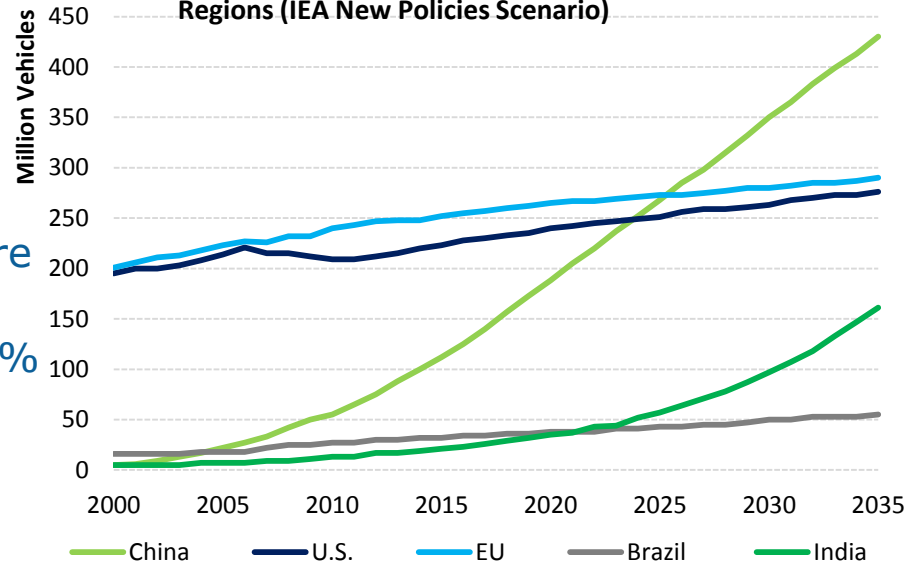
- World oil consumption:
 - 89 million b/d today
 - 110 million b/d by 2035 at \$150/barrel under current policies
- World CO2 emissions today:
 - 31 gigatons/year
 - Automotive ~5.7 gigatons (14.6%)
- World auto park
 - ~1 billion vehicles in 2011
 - ~1.7 billion by 2035
 - China alone is projected to have more vehicles than the EU or US by 2025
 - Fuel demand is expected to grow 40% by 2035.

World Oil Demand and Oil Price by Scenario



Source: IEA, World Energy Outlook 2012

Passenger Light Duty Vehicle (PLDV) Fleet in Selected Regions (IEA New Policies Scenario)

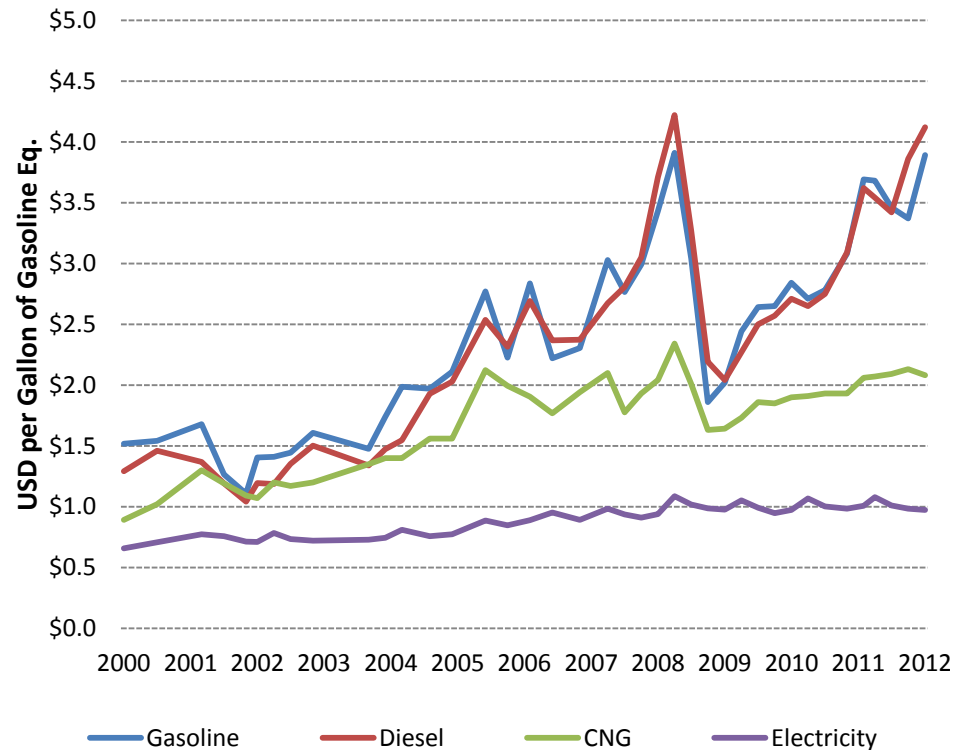


Source: IEA, World Energy Outlook 2012

THE OPPORTUNITY

- Price spikes in the global oil market create uncertainty and economic costs for consumers and businesses, whereas electricity prices are relatively stable and thus mitigate risks from oil price volatility.
- Natural gas prices are low in the U.S. and may fall in other countries as the scale of LNG and shale gas production grows.
- Shifting from oil to electricity and natural gas provides increased flexibility for an oil-dependent transportation system.
- PEVs and NGVs can significantly reduce GHG emissions in the transportation sector.

U.S. Average Retail Alternative Fuel Prices



Source: Clean Cities, DOE

PEVs AND NGVs

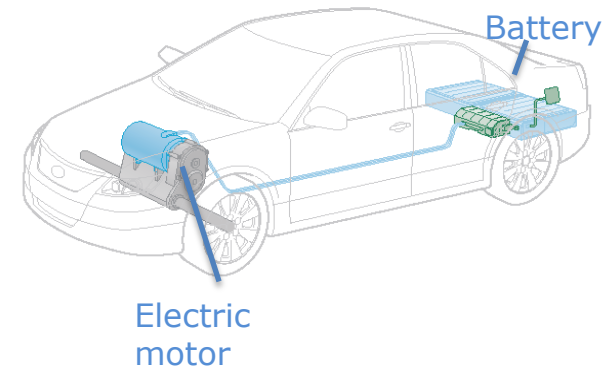
Plug-in electric vehicles (PEV) run on electricity from an external source stored in on-board batteries.

- Battery Electric Vehicles (BEV) generally consist of a lithium-ion battery and electric motor and have a range of 60-300 miles (110-480 km).
- Plug-in Hybrid Electric Vehicles (PHEV) consist of a battery, motor and internal combustion engine to extend the vehicle range.

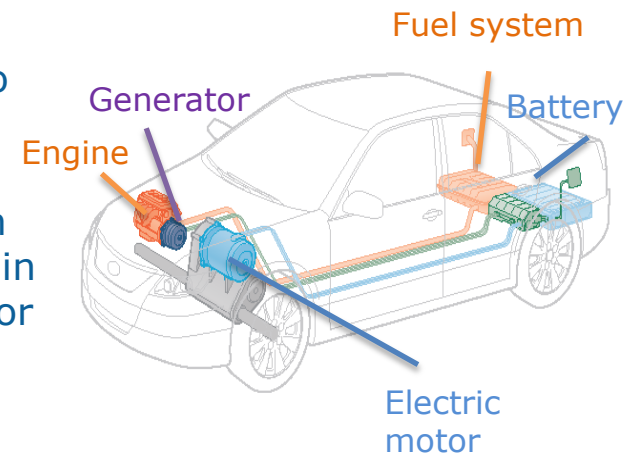
Natural gas vehicles (NGV) are traditional internal combustion engine (ICE) vehicles configured to run on natural gas that has been liquefied or compressed.

- Liquefied natural gas (LNG) is natural gas that has been cooled to -260 degrees and compressed at 70-150 psi to form a liquid.
- Compressed natural gas (CNG) is natural gas that has been compressed and stored at 3000-3600 psi. CNG can be stored at lower pressure (500 psi, the pressure used in natural gas pipelines) in materials like activated carbon or metal-organic frameworks.

BEV



PHEV



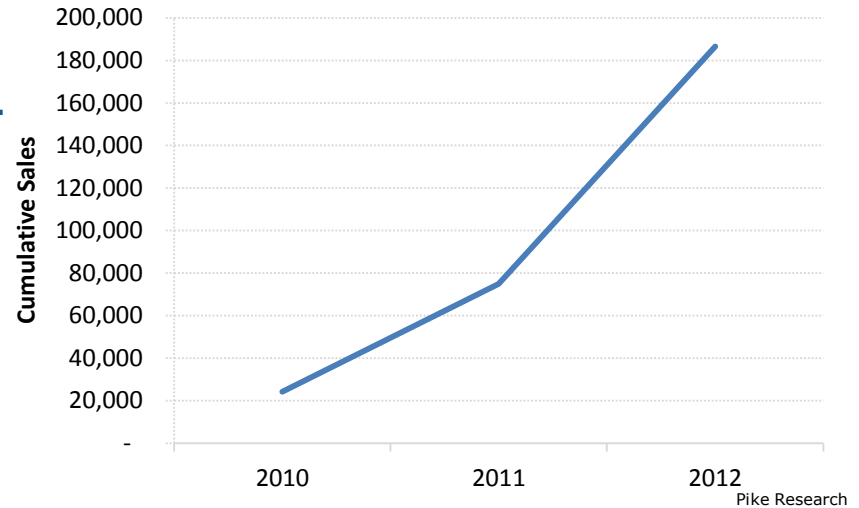
ENVIRONMENTAL CONSIDERATIONS FOR PEVs AND NGVs

- PEVs
 - PEVs can reduce vehicle smog-producing pollutants by 100% and eliminate emissions of particulate matter (PM), NOx, non-methane hydrocarbons, and evaporative products (hydrocarbons).
 - However, GHG emissions reductions depend on the source of electricity (e.g. coal, natural gas, renewables, nuclear, etc.).
- NGVs
 - Natural gas light-duty vehicles (LDVs) can reduce smog-producing pollutants by 60-90%.
 - Medium- and heavy-duty natural gas vehicles (MDVs and HDVs) have lower emissions of PM, NOx, non-methane hydrocarbons, and evaporative products (hydrocarbons).
 - There is considerable debate as to whether switching to natural gas from traditional liquid fuels reduces GHG emissions. A major concern is fugitive methane emissions during natural gas production.
 - One estimate is that for light-duty natural gas vehicles to improve GHG emissions, methane leakage would have to be below 1.6%. By some estimates fugitive methane emissions are below this, but others put fugitive methane emissions above 10%.

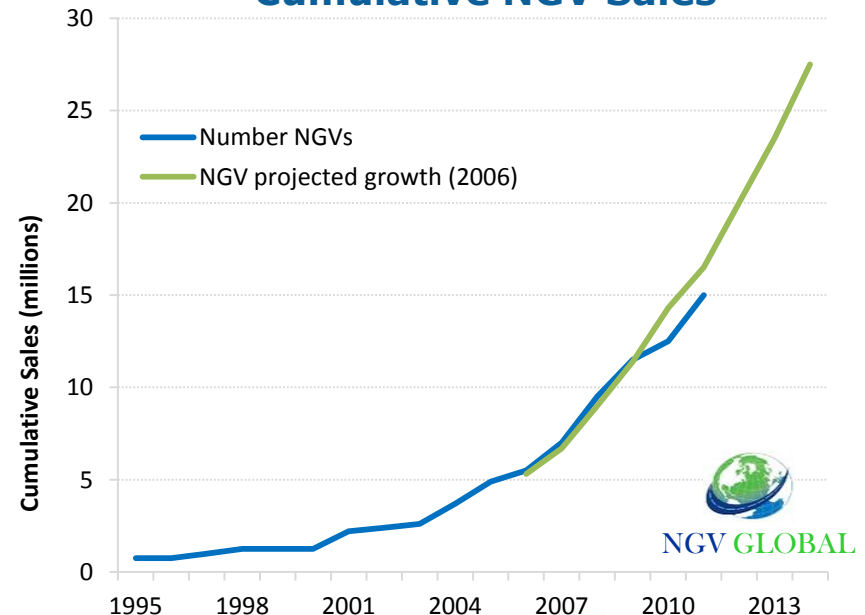
PEV AND NGV AVAILABILITY

- PEVs
 - Global PEV sales surpassed 100,000 in 2012.
 - ~45 EV models slated for global market in 2014.
 - Global sales of electric motorcycles and scooters were ~13 million in 2012 and projected to grow to 18.6 m in 2018.
 - China accounts for 81% global market.
 - India projected to be second largest e-scooter market in 2018.
- NGVs
 - ~15 million natural gas vehicles on the road and ~18,000 refueling stations.
 - 6 countries have over 1 million NGVs on the road. For example, Iran and Pakistan have saturation rates of 64% and 19%.
 - Annual growth rate for NGVs since 2001 is 22.9% with the steepest growth in the Asia-Pacific region, followed by Latin America, and Europe.
 - Refueling stations have generally tracked a similar growth and geographic trajectory as vehicle sales.

Cumulative PEV Sales (LDV)



Cumulative NGV Sales



Barriers and Potential Solutions

OVERVIEW: BARRIERS TO DEPLOYMENT

- **Technology barriers**

Energy storage limitations represent a primary obstacle for both PEVs and NGVs.

- **Cost barriers**

PEVs and NGVs both have higher capital costs than traditional petrol-powered vehicles. However, cheaper fuels (~\$1 per gallon equivalent for electricity and ~\$2.10 per gallon equivalent for natural gas in the U.S.) mean that total cost of ownership (TCO) is potentially lower.

- **Infrastructure barriers**

Both technologies require new refueling infrastructure and there are currently inadequate public recharging and refueling locations.

- **Consumer acceptance barriers**

Consumers' lack of knowledge regarding PEV technology and environmental concerns regarding NGVs are slowing rates of adoption.

BARRIERS & SOLUTIONS: PEV TECHNOLOGY

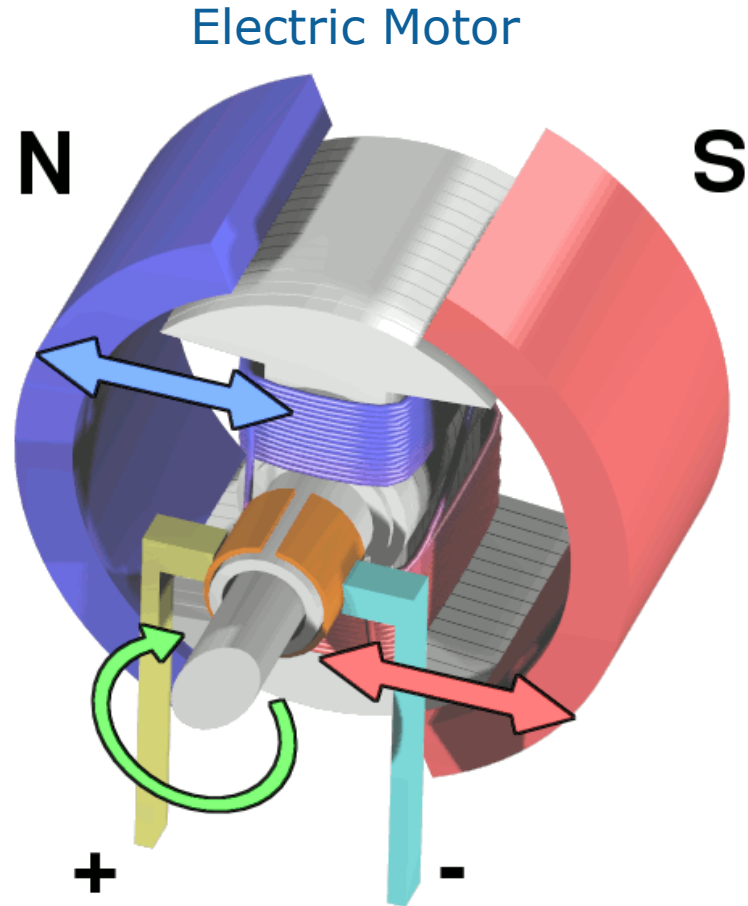
Battery Performance:

- Energy density - Increased energy density will reduce weight and size, increase vehicle range, and potentially lower costs (current density ~150 Wh/kg).
 - Next generation lithium-ion chemistries up to ~400 Wh/kg (higher energy density ~lower price)
 - Lithium/sulfur/air batteries may achieve energy density up to ~3000 Wh/kg
- Durability → increase cycle life for batteries.
- All-weather performance
 - Address through superior HVAC to improve battery thermal management and extend battery cycle life and vehicle range.
- Charge speed
 - New fast-charge technologies can reduce the time penalty associated with public charging for EVs.

BARRIERS & SOLUTIONS: PEV TECHNOLOGY

The balance of system

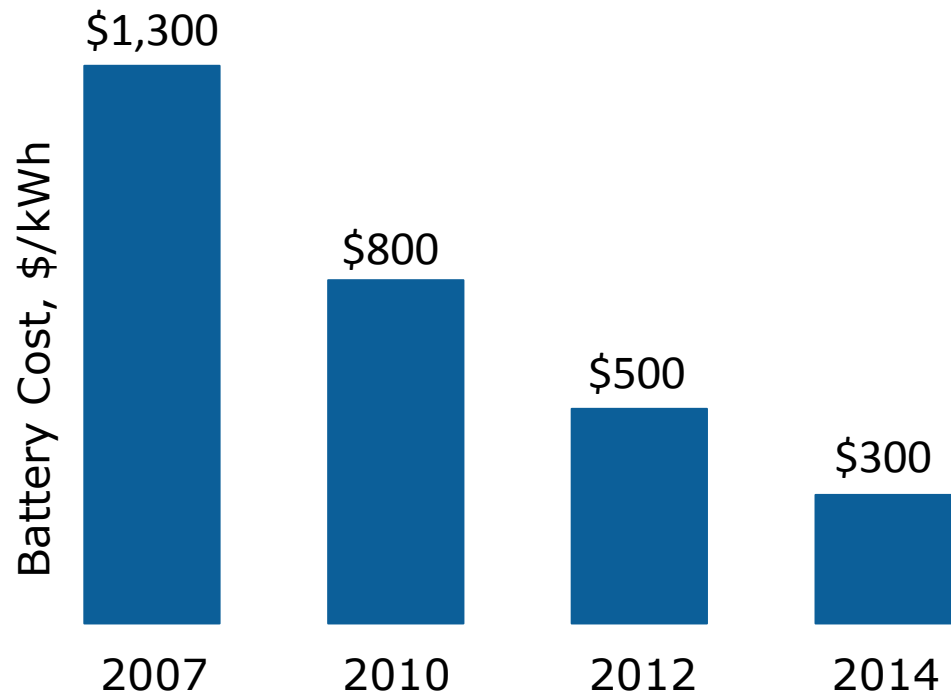
- Many electric motors and some batteries rely on materials that may have limited availability in the future:
 - Eliminate the need for rare earths
 - Recycle
 - Promote development of geographically diverse critical materials sector



BARRIERS & SOLUTIONS: PEV BATTERY COST

Batteries are primarily responsible for the incremental cost of PEVs.

→ Through targeted research, manufacturing efficiencies, and scale production, lithium ion battery costs may reach \$300/kWh by 2014



Source: U.S. Department of Energy

BARRIERS & SOLUTIONS: PEV INFRASTRUCTURE

Infrastructure: speed, regulation and economics of build-out are unclear

- Some government support of infrastructure will likely be necessary.
- Install charging infrastructure in high traffic areas and parking lots with long dwell times to help overcome range anxiety without having unused, orphan equipment.
- Streamline regulations so that approval for residential charging station is easy and can be secured in less than 24 hours.
- Devise schemes to sub-meter multi-unit dwellings and consider zoning some residential parking for charging spots.
- Amend building codes and laws to mandate charging capability (such as EV-ready wiring and conduit) in all new construction.
- Incentivize utilities to take a proactive approach to preparing for PEVs (e.g. adopting discounted time-of-use rates).
- Countries and companies should develop common standards across borders.
- Until common standards are developed, infrastructure should support multiple standards (e.g. SAE and CHAdeMO DC fast chargers).

BARRIERS & SOLUTIONS: PEV CONSUMER ACCEPTANCE

Cost: Direct incentives for vehicle purchase and lease, tax exemptions, reduced registration fees, and education can help speed deployment.

- Direct incentives for EV purchase can improve the economics of EV purchases for consumers.
- Government and corporate fleet purchasers can form purchase consortia to obtain vehicles at a lower price.
- Non-financial incentives, such as access to high occupancy vehicle (HOV) lanes and using bus lanes in congested areas.
- Policy makers should incentivize secondary battery market.
- Focus consumers on Total Cost of Ownership (TCO).
- Educate consumers about the reduced fuel and maintenance costs of PEVs and give them ways to compare the TCO of conventional vehicles and PEVs, such as through easy-to-understand labeling on vehicles to inform consumers of the fuel savings and TCO benefits of electric drive models on the market.
- Fleet operators tend to use TCO for purchases, so fleets are an important sector for driving PEV adoption and therefore driving down vehicle cost. PEV adoption should be encouraged in government, corporate, and university fleets.

BARRIERS & SOLUTIONS: PEV CONSUMER ACCEPTANCE

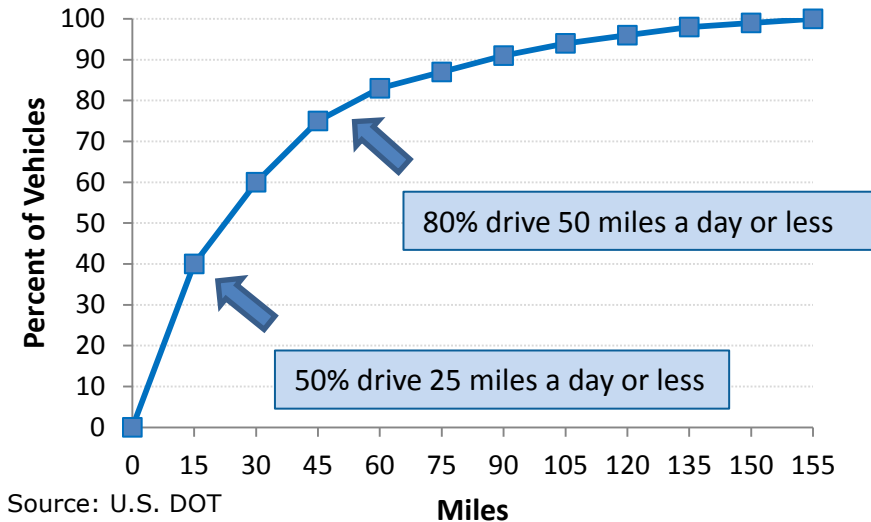
Consumers frequently purchase vehicles for what they *may* do with them, not their average daily drive.

- Support deployment communities that bring together infrastructure deployment, vehicles, and education to show that PEVs can work when the complete ecosystem is created.
- Create opportunities to drive or rent a PEV outside of a dealership. "Ride and Drive" events can be sponsored by local governments, OEMs, NGOs, or charging station providers. Car rental and car share companies can incorporate PEVs into their fleets.
- Provide PEV users another option for instances when PEV range may not suffice.

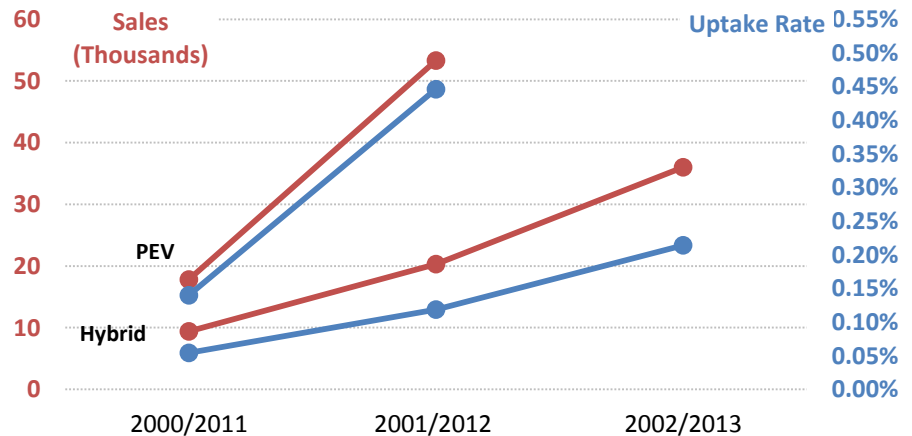
Market development is making progress

- PEV sales have been far higher than hybrid vehicle sales were in their first 3 years on the market.

Average Daily Driving (U.S.)



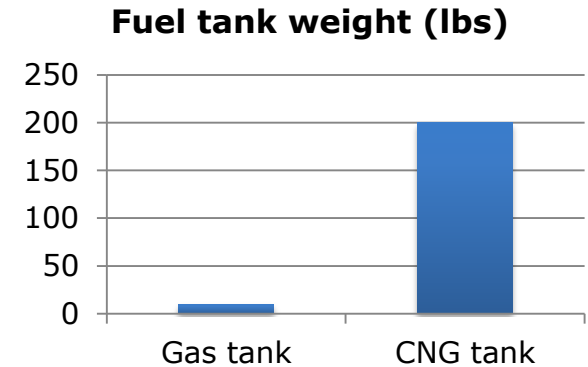
PEV and Hybrid Sales from Year of Introduction (U.S.)



BARRIERS & SOLUTIONS: NGV TECHNOLOGY

Fuel storage

- NGVs are a relatively mature technology. Major challenge comes from fuel storage.
 - Compared to gasoline and diesel tanks, NGVs tanks are heavy and costly.
 - CNG tanks also require up to six times more space, reducing passenger and/or cargo space.
 - CNG vehicle takes about twice as long to fill up as a gasoline-powered passenger vehicle.
 - Limited fuel storage reduces range and exacerbates concerns about adequate refueling infrastructure.
- Launch R&D programs to develop innovative fuel storage technology.



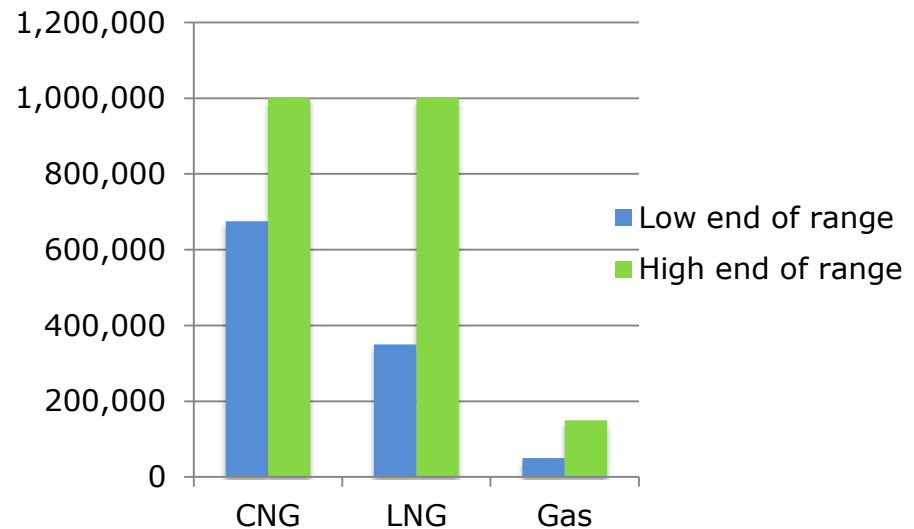
BARRIERS & SOLUTIONS: NGV INFRASTRUCTURE

Refueling Infrastructure is sparse

- There are currently fewer than 20,000 natural gas refueling stations globally.
- For example, in the United States there are only 594 retail natural gas stations (1,166 retail and private) compared to almost 160,000 retail gasoline stations.
- Building a CNG refueling station costs between \$200,000 and \$500,000, depending on the country and the size of the station.

- Identify strategic travel arteries along which to make the fuel more widely available. Launch initiatives with specific plans for infrastructure deployment, especially for LNG refilling stations.
- Incentivize investment in refueling stations by allowing businesses and individuals to reduce their tax liability by an amount specified by the credit.
- Encourage public-private partnerships to incentivize private fleet owners to allow public refueling at their central CNG refueling stations.

Ranges of installation cost in the US (US\$)



BARRIERS & SOLUTIONS: NGV COST & CONSUMER ACCEPTANCE

NGVs are seen as expensive, but total cost of ownership (TCO) is comparable: \$37,398 for CNG compacts and \$35,588 for gasoline compacts (2012).

→ Provide other benefits such as income tax credits for vehicle purchases, excise tax credits for fuel, reduced registration and parking fees and access to HOV lanes.

Many consumers do not understand the potential benefits of NGVs

→ Governments can promote NGV uptake by offering incentives and preferential benefits; educating consumers; and leading by example by converting their fleets.

In many places, environmentally conscious consumers have concerns regarding natural gas extraction

→ 1) Develop standards for extraction, production, and transport for the sake of public and environmental safety, and 2) promote gas as a “bridge fuel” to carbon-free energy.

Safety of NGVs remains a concern for consumers in some countries

→ NGVs can be as safe as conventionally fueled vehicles, but strong national regulations and oversight are needed to ensure this.

There is limited availability of NGVs in some markets

→ New NGVs are being released in 2013 and beyond, and as governments convert their fleets, the increased demand will drive product availability. It is also possible to convert traditional gasoline-powered vehicles.

Existing Efforts

EXISTING EFFORTS: PEV DEPLOYMENT

Giving consumers an opportunity to try PEVs

- Some communities are implementing concerted programs aimed at familiarizing residents and visitors with PEVs
 - Nagasaki, Japan and Orlando, USA have both instituted PEV rental programs.
 - Certain car sharing services (Zipcar, Autolib, etc.) are adding PEVs to their fleets.
 - In Normal, USA a resident can check a car out from Town Hall for a day or two.
 - Shanghai has created a test drive and ride center for citizens.
 - North East England has an extensive vehicle trial program.
- Drive Electric Northern Colorado is working to create a model ecosystem for PEV deployment by building appropriate infrastructure, providing public education and marketing, building public-private partnerships between local businesses and the cities, and generally working to make owning and operating a PEV a smooth experience.

EXISTING EFFORTS

PEV adoption

- Norway has the highest adoption rate of PEVs in the world (5.2% of new vehicle sales in 2012). By eliminating the import tax, Norway made PEVs the same price or cheaper than most conventional vehicles. Norway also eliminated the purchase tax and the annual road tax.
- Many city, state, and federal governments have started to put PEVs in their fleets. Private companies are also embracing this technology. For example, FedEx has over 125 PEVs in their fleet globally. Delivery drivers embrace EVs because they are quiet and lack diesel fumes.

EXISTING EFFORTS: NGV CASE STUDIES

Programs to address technology barriers:

- The U.S. Department of Energy's ARPA-E "Methane Opportunities for Vehicular Energy (MOVE)" program funded 13 projects in 2012 (~USD 30 million). The projects aim to reduce the costs and streamline the designs of **fuel storage tanks** and **home refueling appliances** for NGVs. Grant recipients include GE Global Research, Eaton Corp., and Ford Motor Co. Through this program, Ford is developing an on-board fuel system designed to increase the energy density of CNG at low pressures, which would expand the driving range of CNG vehicles.
- The Polish government's National Centre for Research and Development has funded a project at the Technical University of Lublin for 3 million zloty (~USD 0.9 million) to develop a diesel/CNG **dual-fuel engine** that will have reduced fuel consumption and emissions (2012).
- The U.S. Department of Energy's Clean Cities program holds a regular **Natural Gas Vehicle Technology Forum** to share information on research and development of heavy and light duty NGVs.

EXISTING EFFORTS: NGV CASE STUDIES

Programs to address cost barriers

- Beginning in March 2013, purchasers of alternative-fuel vehicles such as NGVs in Italy will receive price reductions that vary with CO2 emissions level. The maximum reduction is currently 5,000 EUR.
- In the United States, the Congestion Mitigation and Air Quality Improvement Program (CMAQ) provides \$3.3 billion funding for state and local transportation projects including diesel retrofit projects.
- The Netherlands is subsidizing buses and trucks with emissions meeting the Euro VI standard up to EUR 4500 per vehicle.
- The United States has an alternative fuel excise tax credit of \$.50 per gallon of CNG or LNG. State and local governments with NGV fleets and on-site fueling stations are eligible for this incentive.

EXISTING EFFORTS: NGV CASE STUDIES

Programs to address consumer acceptance barriers

- **Initiatives and partnerships for knowledge transmission**

- The EU's Clean Fleets Project (2012-2015) aims to improve the transfer of knowledge by means of training programs, information exchange on its Clean Vehicles portal, and circulation of best practices.
- The Clean Cities Coalition in the United States is a partnership of fleets, government agencies, community groups, and businesses that share information and collaborate on initiatives aimed at curbing petroleum.

- **Overcoming apprehension through mandates, benefits and example**

- The Supreme Court of India, in an effort to improve air quality, required that Delhi's public bus system be converted to CNG (1998).
- The South Coast Air Quality Management District (SCAQMD) in the United States requires that some public transportation fleets switch to alternative fuel vehicles during procurement.
- In the Philippines, new building permits are issued for businesses that include parking spaces only if free spaces are provided to alternative fuel vehicles (2011).
- Beijing Public Transportation Group plans to purchase over 3000 LNG buses in 2013. In 2011, the Dominican Republic began converting its 20,000 public transportation vehicles to CNG.

Opportunities for Progress

OPPORTUNITIES FOR PROGRESS: PEVs & NGVs

Policymakers

- Can offer incentives for:
- Vehicle purchase while PEVs and NGVs are still emerging technologies
 - Infrastructure development for both PEVs and NGVs
 - R&D to improve the technologies

Governments & Private Industry

Can adopt PEVs and NGVs into their fleets to help drive economies of scale. They can also work to educate consumers.

Academia & OEMs

- Can participate in research to:
- Develop new battery chemistries and electric motors that do not use critical materials (for PEVs)
 - Improve fuel storage, increase driving range and reduce overall costs (for NGVs)

Governments

- Should continue to work together to overcome common obstacles through:
- The CEM's Electric Vehicles Initiative (EVI) for PEVs
 - Technology sharing forums