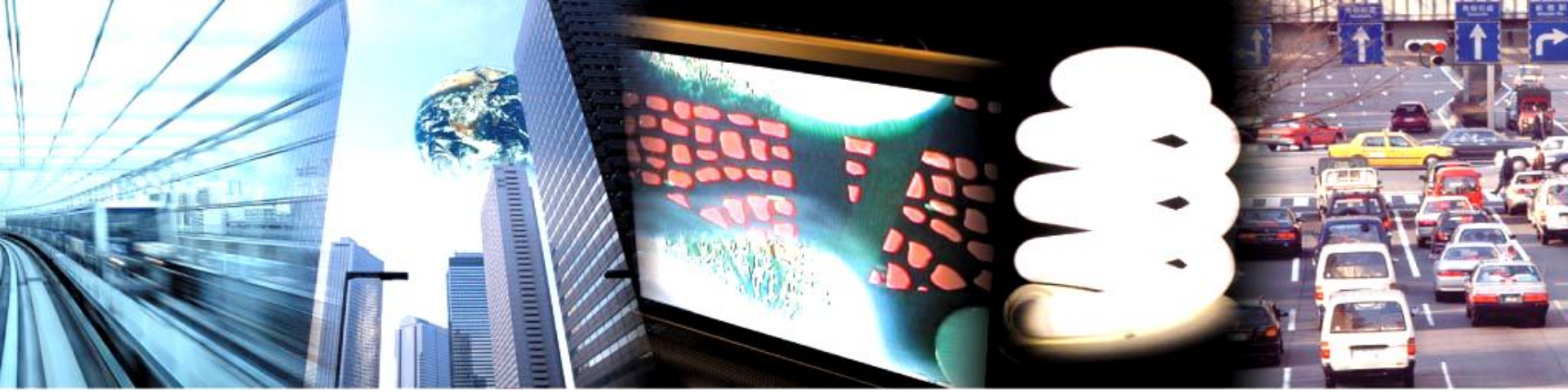


APERC Annual Conference

26 February 2013

APEC Virtual Clean Car Alternative Case

"Economic, oil security and carbon pathways"

Luke Leaver

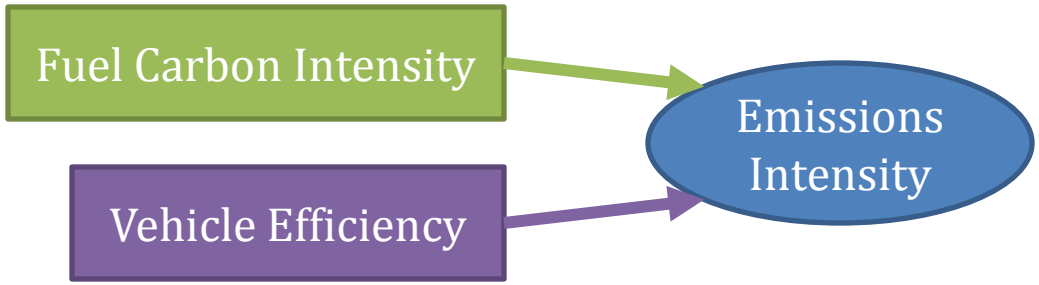
Asia Pacific Energy Research Centre (APERC)

Asia-Pacific Economic Cooperation

Virtual Clean Car Race - Model

Key Assumption

1. Accelerated adoption of light vehicle alternative technologies
2. Sales of alternative vehicles in increase from the same as BAU in 2013 to 50% higher than BAU by 2020 and thereafter



Four alternative vehicle scenarios are studied

1. Hyper Cars - An ultra-efficient conventional vehicle, achieved using ultra light composite materials, advanced power trains and state of the art aerodynamic design
2. Electric Vehicles - Uses electricity as its only energy source
3. Hydrogen Fuel Cell Vehicle - Uses hydrogen fuel cells in combination with electric power train as its energy source
4. Natural Gas Vehicle Transition - Natural gas instead of oil as its energy source

Hyper Car Specifics

Hyper (passenger) Car – Super Efficient but uncompromised performance

- Light weight carbon composites substitute, *where possible,* for traditional steel – resulting in a car which is **50% lighter** (reduction of ~500-600 kg)
- An efficiency of **38 km per liter** (90 miles per gallon) or double that of new conventional non-hybrid gasoline vehicles (no assumed change in performance)
- 2/3 of efficiency gains are from weight reduction, 1/6 from hybridization and 1/6 from reduced drag, rolling resistance and accessory loads
- Safety maintained with the strength and energy absorption of carbon composites being higher than steel or aluminum

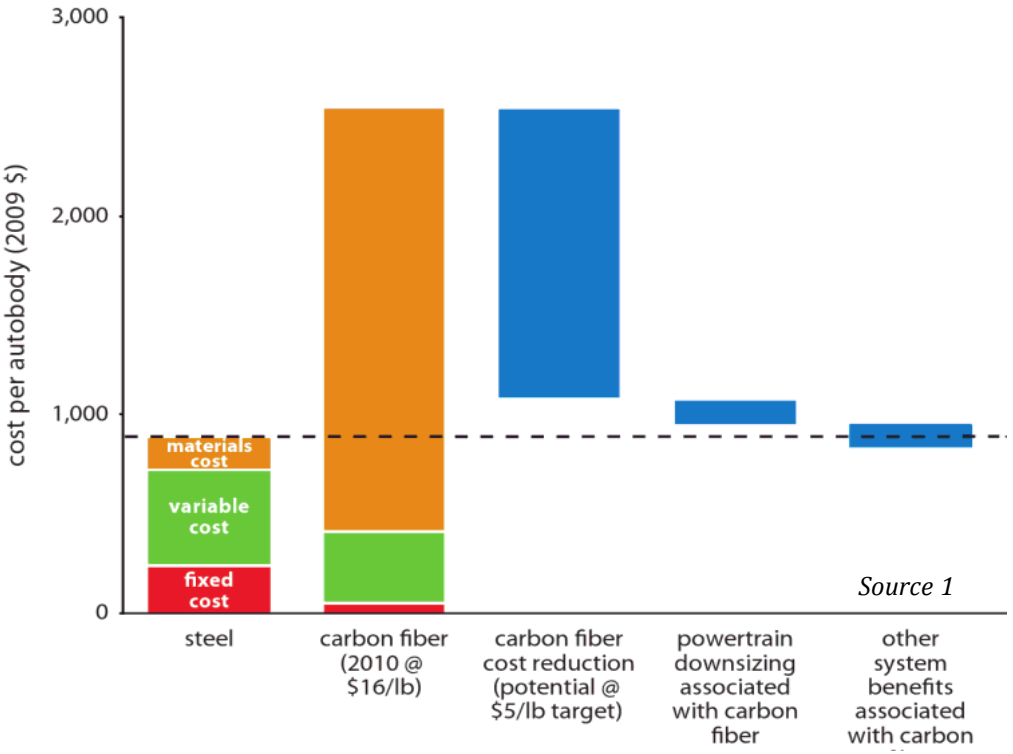
2035 Increase in Retail Price from Standard vehicle

Estimates range from about USD 4,000-6,000 in today's dollars

Lovins et al (2005) *Winning the Oil Endgame: Innovation for Profits, Jobs and Security* . Rocky Mountain Institute, USA.
Cheah and Heywood (2011) *Meeting U.S. passenger vehicle fuel economy standards in 2016 and beyond*. Energy Policy, 39(1), pp. 454-466.

Hyper Car Cost Insights

- An unfinished Carbon Fiber auto body has *higher material* costs (+ USD **2-3k**)
- Fixed costs could reduce by **80%** and variable costs by up to **25%**
- Reducing the cost of Carbon Fiber to <US$7/lb gives a comparable price to steel car



[1] Lovins et al (2010) *Reinventing Fire: Bold Business Solutions for the New Energy Era.* Rocky Mountain Institute, USA.

Technical Challenges Remain but Automotive Industry is Shifting

Challenges

- High Material Cost
- Long Production Cycles
- Investment Barriers

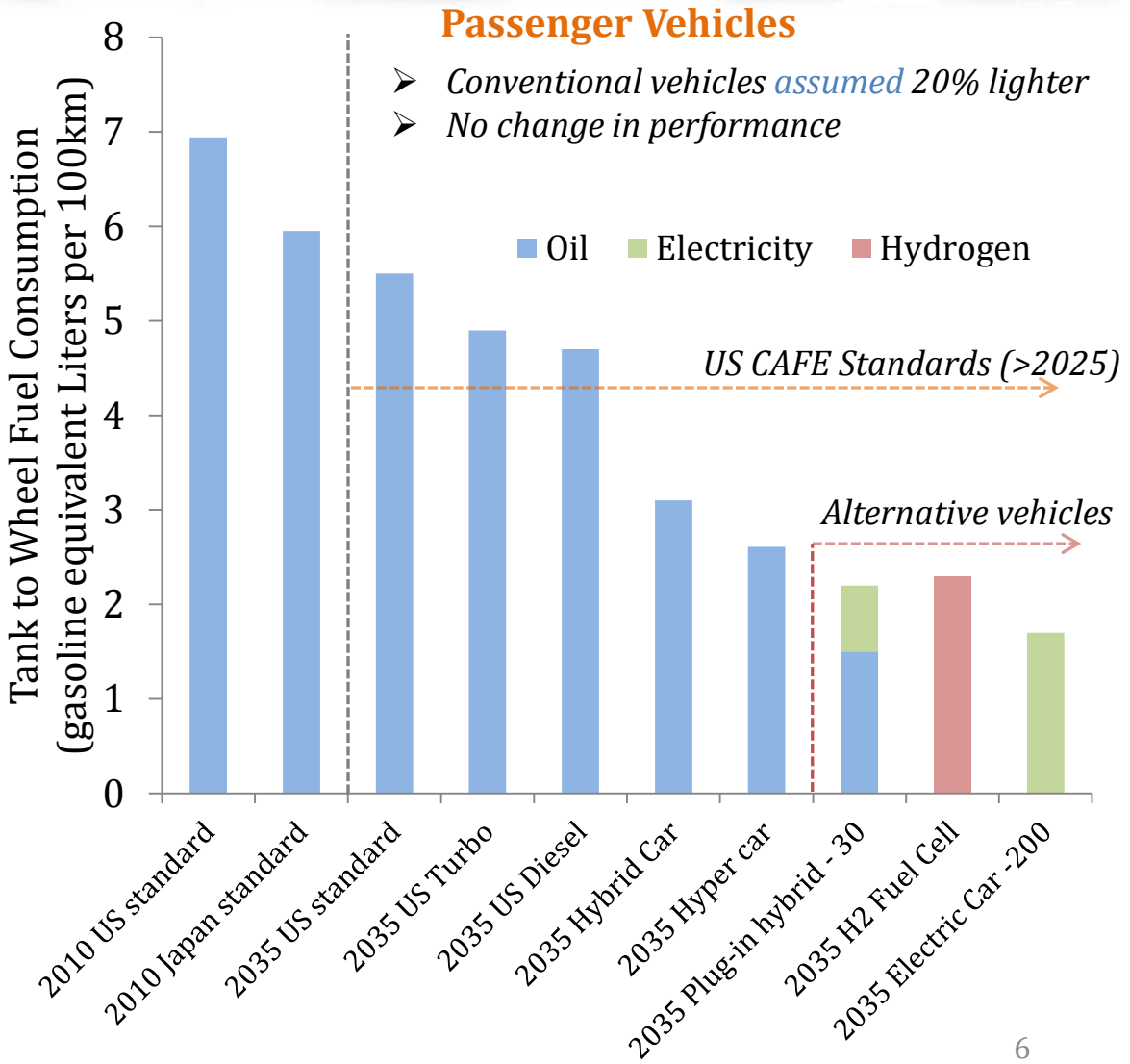
Industry News

- ***Ford Motors*** - Demonstrated a prototype carbon fiber composite bonnet for the Ford Focus which weighs more than 50% less than a standard steel version
- ***BMW*** – Established production facility in place for the i3 (battery electric) and i8 (hybrid) carbon fiber vehicles
- **Toyota** – Carbon Fiber 2007 1 X Plug-in hybrid concept car
  - 1/3 the weight of the Prius (or about 420 kg) + >100 MGP

Relative Efficiency of Vehicles

Transition of an Industry

- Weight reduction is *essential* for US to achieve future CAFE targets
- Hyper-Car is a lighter version of the 2035 HEV
- Not all fuels created equal
  - Oil is a primary energy
  - Electricity & Hydrogen are energy carriers *(with an efficiency cost)*



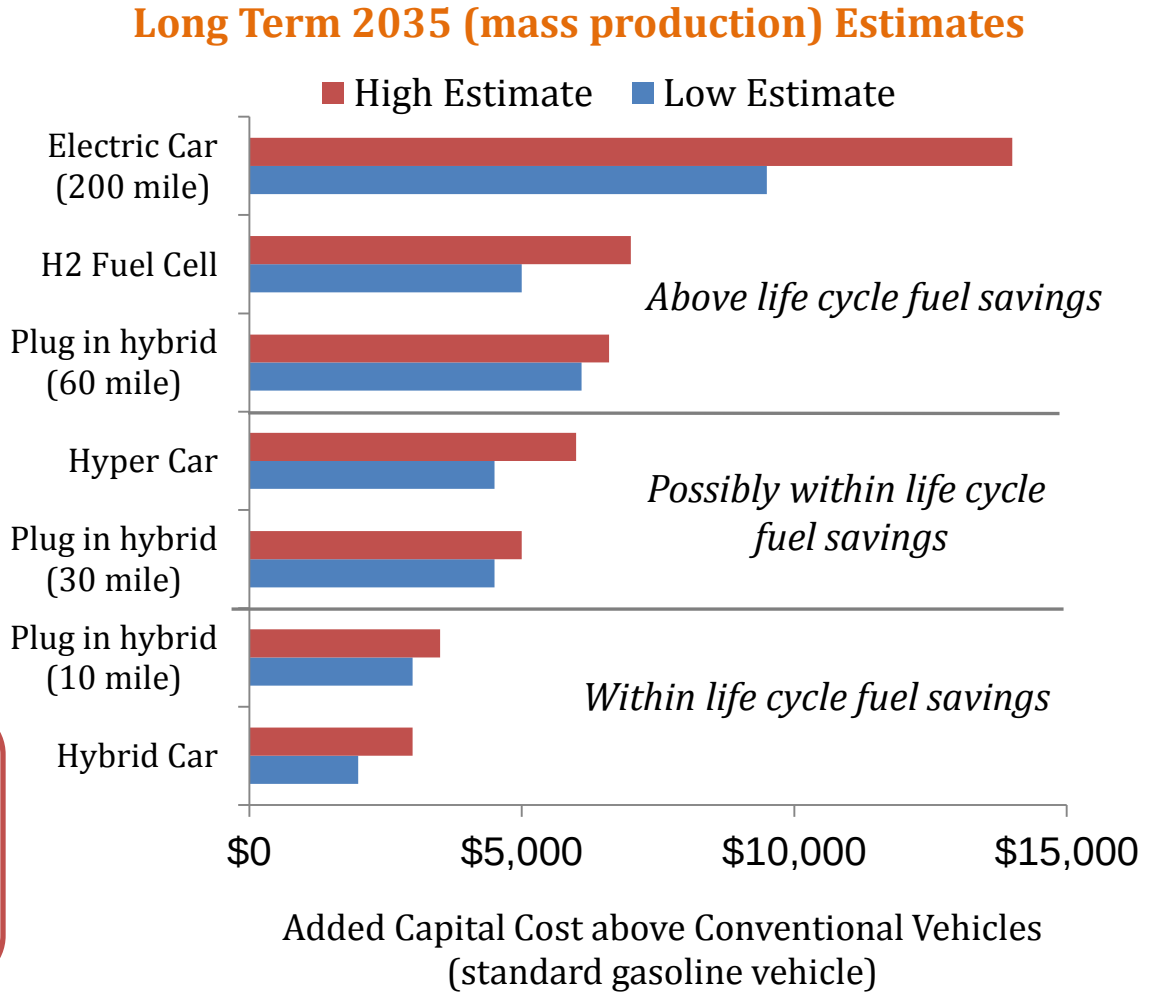
Bandivadekar et al (2008) *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG emissions.* Laboratory for Energy and the Environment, MIT, USA

Source: APERC Analysis & Bandivadekar et al

Capital Costs Considerations

- Hydrogen Fuel Cell and Electric Vehicles are *expensive*
- The Hyper Car is similar in cost to a low range plug-in hybrid
- The Hyper Car is a feasible alternative for the rational consumer

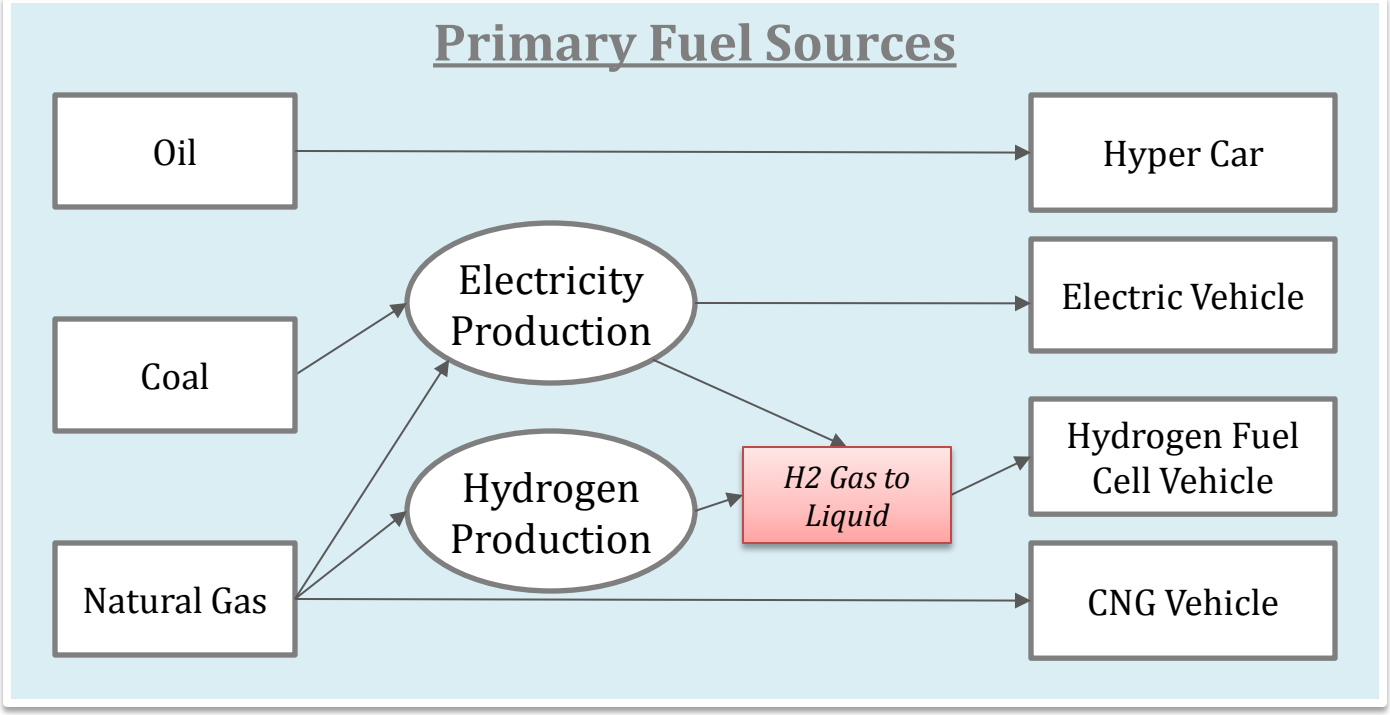
- *Price is important* – An electric vehicle charged on renewable energy could have zero emissions but will the consumer buy?



Source: APERC Analysis & Kromer and Heywood

Kromer, M and Heywood, J (2007) *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet*. MIT Laboratory for Energy and the Environment, Cambridge, Massachusetts. Publication No. LFEE 2007-03 RP.

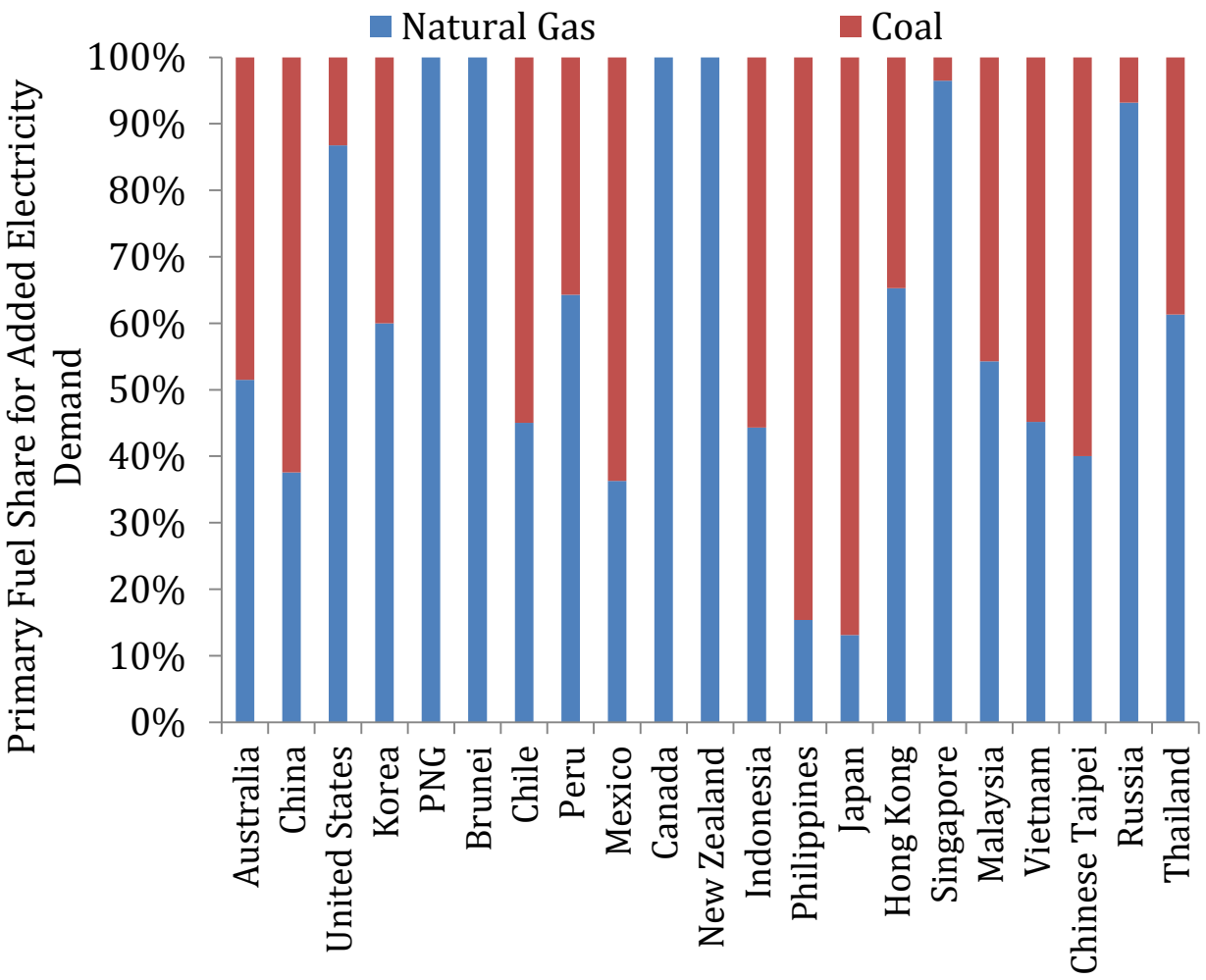
Primary Fuel Sources



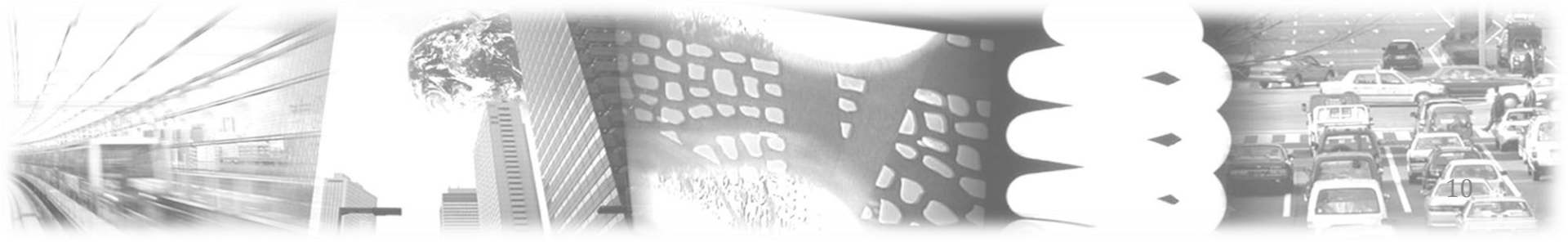
- The *Hyper Car* and *Natural Gas Transitions* use a primary energy source directly
- The *Hydrogen Fuel Cell* and *Electric Vehicle Transitions* use an energy carrier as a fuel which must be produced from a primary energy source, at an efficiency cost
- Hydrogen production requires energy to liquefy and transport to local refueling stations

Added Electricity Production

- Case by Case assessments of each APEC economy as to the availability of coal or gas to meet added electricity demand
- Fossil fuels considered to ensure no double counting of renewable energy benefits



Key Findings

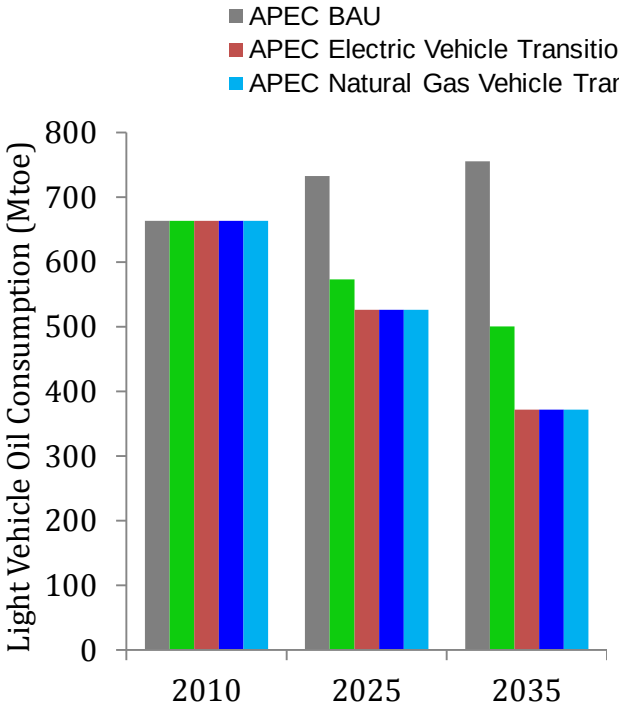


Virtual Clean Car–
Overall Results for Oil Demand and CO_2 Emissions

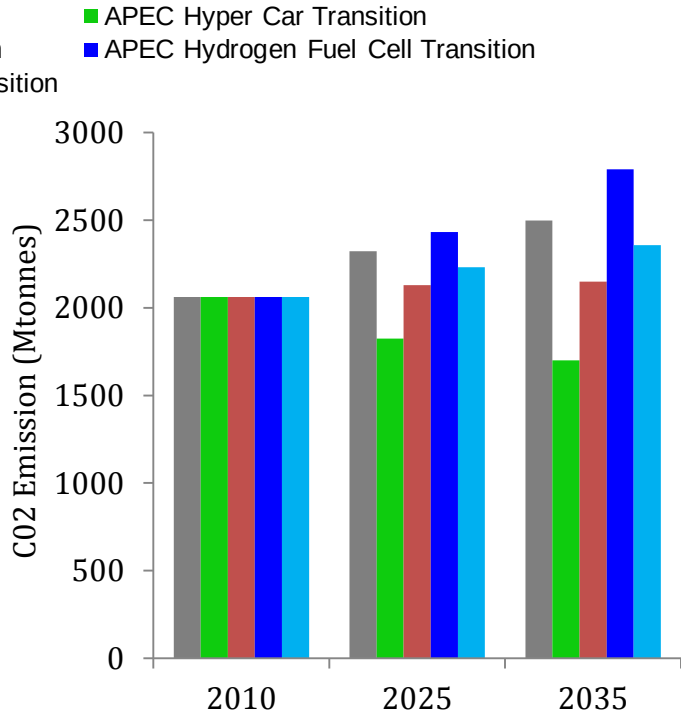
Introduction

- How will the adoption of light vehicle alternative technologies impact the energy sector if we take into account fuel production?

Light Vehicle Oil Consumption



Light Vehicle CO_2 Emissions

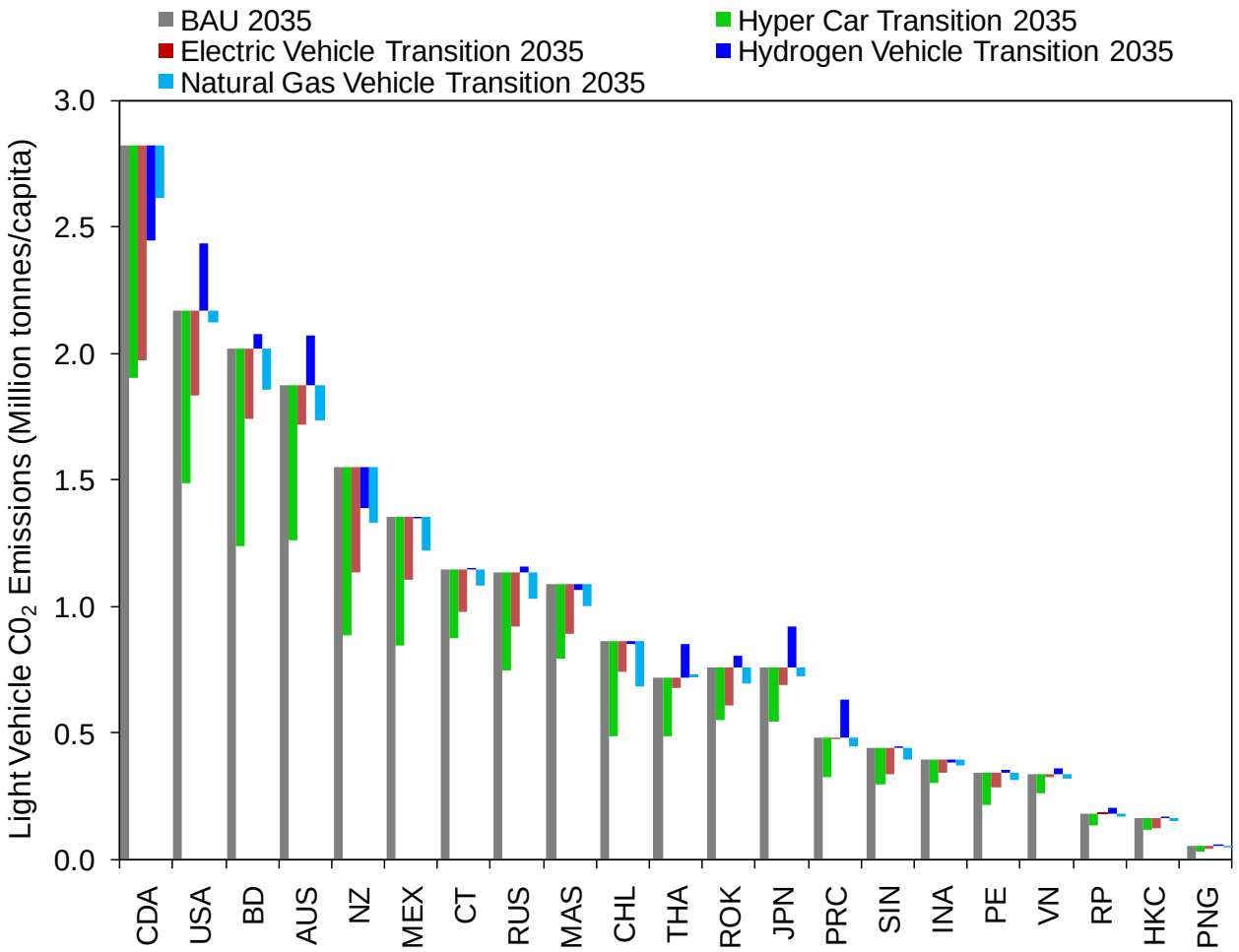


- The results can vary dramatically by economy depending on the marginal source for electricity generation
- APEC-wide, hyper-cars has the best emissions reduction benefits.

Source: APERC Analysis

Virtual Clean Car–
Results by Economy for CO_2 Emissions

Light Vehicle CO_2 Emissions



- Emission vary from differences in carbon intensity of electricity production
- Each economy has varying fuel efficiency assumptions under BAU

Source: APERC Analysis

Virtual Clean Car–
Points to Ponder

- Pathways to low carbon transportation are more *complicated* than promoting alternative fuels and will require multiple solutions
- R&D has focused on battery and fuel cell technology but perhaps *light weight composites* should be given greater priority
- The Hyper Car could be *combined* with alternative fuel vehicles with net benefits to sustainability and oil security
- A major benefit of electric and hydrogen vehicles is that they could provide a *pathway to non-fossil* transportation

Source: APERC Analysis

Thank you for your attention

http://www.ieej.or.jp/aperc