Hybrid, Electric and Advanced Vehicle Technologies for GHG and Fuel Efficiency

Advanced Transportation Technologies and Solutions

Richard Parish
Senior Program Manager - HTUF

Government Fleet Expo and Conference
Denver, Colorado
June 18, 2012

Agenda

- Brief Background: CALSTART
- We Live in Rapidly Changing Times
  - Many Drivers Pushing Advanced Tech
- What Technologies are Available?
- How Drive Cycle Affects Cost Effectiveness
- Summary

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CALSTART

CALSTART is a unique national, non-profit, advanced transportation technologies organization.

Founded in 1992 as a public-private partnership to launch and grow a clean transportation industry.

Mission: via programs and services support and expand the growth of a clean transportation technologies industry that will:

- **Create high-quality jobs;**
- **Clean the air;**
- **Reduce dependence on foreign oil; and**
- **Reduce global warming emissions**

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CALSTART: Catalyst for the Advanced Transportation Industry

2012

150+ Worldwide Member Network

3 Offices in US

Four focus areas:

- ***Tech Commercialization***
- ***Fleet, Port Consulting***
- ***Industry Services***
- ***Policy Development***

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CALSTART Unique Position: Supports All Clean Fuels/Tech (partial member list)

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Commercial Vehicle Activities

CALSTART operates across all vehicles sizes, from bikes to cars to trucks and buses. However, we have a strong practice area in commercial vehicles and their users.

HTUF
Hybrid, Electric & Advanced Truck Users Forum

HVIP
HYBRID TRUCK AND BUS VOUCHER INCENTIVE PROJECT

CalHEAT
TRUCK RESEARCH CENTER

National Fuel Cell Bus Program

GREEN TRUCK SUMMIT
The Future of Clean Commercial Vehicles

US-CHINA CLEAN TRUCK & BUS FORUM

Fleet Action for Clean Transportation (FACT)

HTAG Hybrid, Electric & Advanced Truck **Action Group**

- National program and conf to speed hybrid and advanced truck commercialization funded by and in partnership with US Army
- $43M incentive program – purchase vouchers – for hybrid and electric trucks funded by CARB, CEC
- Hybrid, Efficient and Advanced Truck Center to focus and drive effective R&D funded by California Energy Commission
- National program to validate, speed fuel cell & low carbon bus technology with DOT/FTA
- National conference on clean fuels and tech for trucks, partnership with NTEA
- Program to build export and business opportunities for US M/HD tech companies in China
- Fleet action group to speed clean vehicle deployments
- HTAG- Industry-fleet policy advocacy group for hybrid, electric and advanced trucks

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Trends & Drivers of Change

- **ENERGY SECURITY: FUEL SUPPLY AND COSTS** – Traditional fuel supplies more expensive
  - The need for alt and biofuels is increasing but so are questions about their impacts/benefits
  - Huge glut of low cost natural gas in North America from new production process (hydrofracturing)
  - Regional fuel variation and choice becoming more prevalent

- **GLOBAL WARMING** – Push to reduce GHGs intensifying and pushing **fuel economy** –
  - *CAFE revised to match CA CO2 rules: rules for med & heavy trucks heads to phase 2*
  - Climate non-starter in Congress – but higher fuel economy moves same direction
  - Energy efficiency reduces GHG impact; Fuel switching and blending reduces GHG impact; Modal split (transit and rail) has long term role

- **EMISSIONS REDUCTIONS** – World population increasingly urban and world emission standards increasingly move to EPA/CA/Euro standards
  - Fine particulates (nano particles) will be of increasing concern from combustion
  - Diesel fuel still challenged in dirtiest regions (ports, Southern California)

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New LD Fuel Economy Goals Clear

- Steadily increasing FE requirements through 2025 for cars and light trucks – to near 56 mpg
- Will require increasing use of advanced technologies
- Light weight materials, advanced combustion and powertrain, electrification

	2016 base	2017	2018	2019	2020	2021	2022	2023	2024	2025
Passenger Cars	37.8	40.0	41.4	43.0	44.7	46.6	48.8	51.0	53.5	56.0
Light Trucks	28.8	29.4	30.0	30.6	31.2	33.3	34.9	36.6	38.5	40.3
Combined Cars & Trucks	34.1	35.3	36.4	37.5	38.8	40.9	42.9	45.0	47.3	49.6

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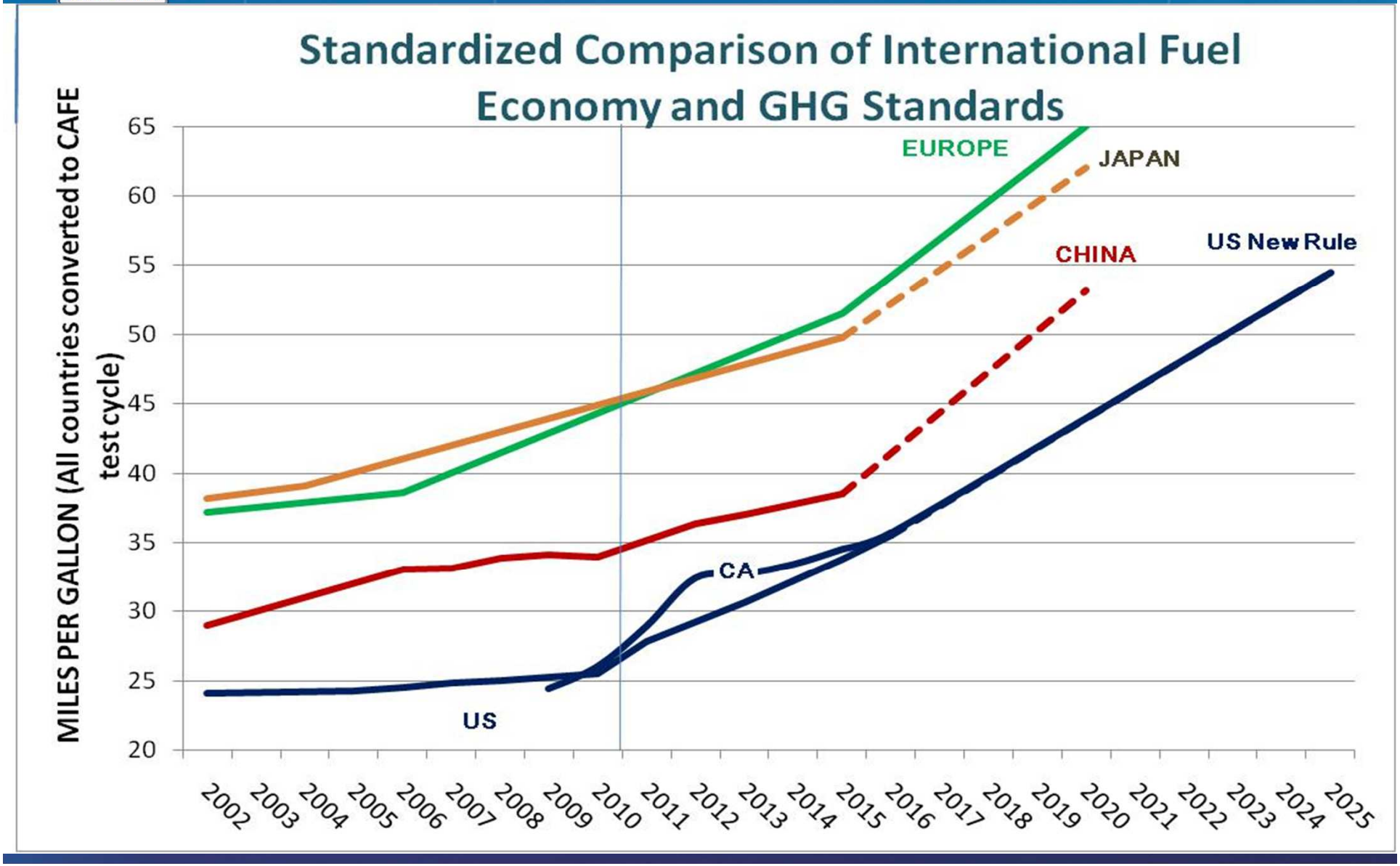
Comparison of World-wide Fuel Economy Standards



HDV FE Directions Clear: But Design Has Outcomes

- First phase aimed – rightly – at tractors as highest fuel users, best first target
- But slow ramp up structure left a lot of achievable reductions off the table, especially in vocational trucks
- Can have unintended outcome of possibly slowing deployment of more advanced technology
- Second phase of rule will be aimed at vocational vehicles

Final 2017 Standards (% reductions)

	Day Cab		Sleeper Cab
	Class 7	Class 8	Class 8
Low Roof	(10%)	(10%)	(17%)
Mid Roof	(10%)	(10%)	(17%)
High Roof	(13%)	(13%)	(23%)

Final Rule
Tractors: 10-23%
Vocational Vehicles: 6-9%
Pickup Trucks & Vans: 12-17%

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Rule Flexibility Helps – But May Not be Needed by OEMs

- Rule so far being easily met, many OEs pre-certifying vehicles
- May not need credits until perhaps 2017

Incentivizing Technology

- Advanced Technology Credits
  - Final rule will provide 1.5x multiplier for credits generated on vehicles or engines using advanced technologies such as hybrids, plug-in hybrids, EVs, and Rankine waste heat recovery
- Certifying Innovative Technologies
  - Like the light-duty GHG rule, this rule will provide a compliance mechanism to certify innovative technologies that are not fully accounted for by the test procedures.
- Alternative Fuel Vehicles - Natural Gas & EVs
  - GHG and fuel consumption compliance are calculated based on a vehicle's CO_2 emissions.
  - Low carbon fuels like natural gas will perform 20-30% better than comparable gasoline or diesel engines under this approach.

NHTSA

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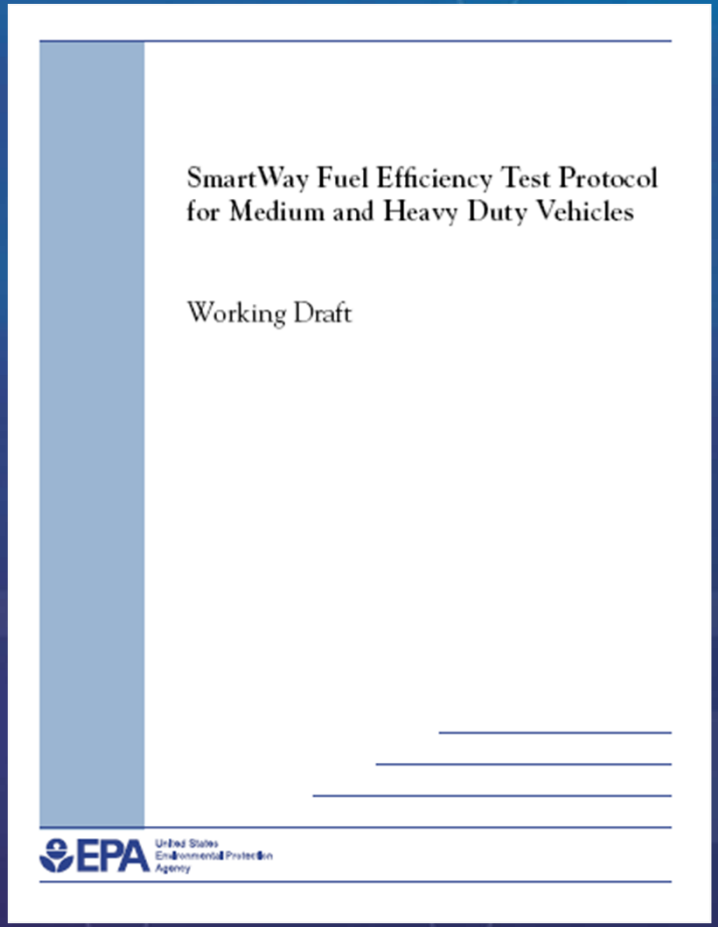
For Phase 1 and 2 of Rule Duty Cycles are Increasingly Critical

- Needed for hybrid and advanced tech testing in Phase 1
- Likely be the basis of full-vehicle certification in Phase 2
- Baseline duty cycles from HTUF already part of EPA fuel economy testing protocol



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What Technologies are Available?

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Advanced Tech and Fuel Roller Coaster

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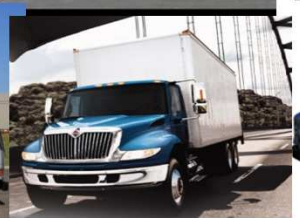
Hybrid electric, hybrid hydraulic, plug-in, all-electric and advanced systems – 75% of these trucks are in production!

http://www.calstart.org/htuf-vehicle-directory.aspx



HTUF – A Decade of Success

HTUF
Hybrid, Electric & Advanced Truck Users Forum

- **User-driven process** to commercialize med- and heavy-duty hybrid, electric & advanced vehicles
- Co-founded by **CALSTART-U.S. Army** (TARDEC-NAC); operated by CALSTART
- **TARDEC PM – Brad McNett**
- **Process speeds advanced dual-use truck commercialization**
  - By creating common fleet requirements, volume purchase commitments, targeted development, leveraging DOE/DOD/DOT investments
  - Working Groups formed around high-promise candidate commercial truck applications in weight/function benefitting military needs

All Major Truck Makers and System Suppliers involved
(partial list)

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Key HTUF Outcomes to Date

HTUF
Hybrid, Electric & Advanced Truck Users Forum

- HTUF process has taken 1-2 years off the development cycle of med and heavy-duty hybrids
- HTUF has integrated military requirements into commercial system design
  - Power generation/export capability
  - Silent watch capability

- HTUF directly helped launch first hybrid truck production; sped capability for electrics
  - International first production of medium duty hybrids Fall 2007; Peterbilt/Kenworth started production of medium duty hybrids in 2008; Freightliner entered volume production late 2008

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HTUF Success & Leverage

- Via HTUF and outcomes to date, more than 4,600 production medium and heavy-duty hybrid trucks now on road in North America
- More than 1000 of those supported directly by incentive programs HTUF helped create
- HTUF has driven a >16:1 impact of activity to investment
  - Incentive funds, vehicle match, conference support; does not count industry internal technology investments

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Current HTUF Program Activities

- Widening the scope of activity to include electric and other advanced truck technologies
- Planning 2012 HTUF National Conference (12th Annual Meeting)
  - Sept. 18 – 20, 2012; Charlotte Convention Center
- Operating 8 HTUF Vehicle Working Groups and 2 Task Forces
- E-truck best uses, challenges, and business case analysis
- Hybrid and E-Truck market demand study

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HTUF Working Groups

- ***8 Working Groups:***
  - Class 8 Regional – *Hybrid Class 8b Regional Delivery; KPPs set*
  - Commercial Construction Equipment – *demos of more efficient loaders, excavators, bulldozers, etc.*
  - Military Installations – *production hybrid trucks being deployed on military installations*
  - Telecommunication trucks –*Class 3/4 work trucks (predominantly self-supported group); KPPs and specs completed; RFP near issue*
  - Utility trucks – *Hybrid Electric Class 7/8 International/Eaton Bucket Trucks (completed); Class 4/5 Bucket Trucks; KPPs and specs completed; RFP near issue*
  - Parcel Delivery trucks – *Hydraulic Hybrid Class 6 Package Delivery; vehicles scheduled for delivery to fleets in April*
  - Refuse Truck – *Hydraulic and Electric Hybrid Class 8 Crane Carrier Rear Loader Refuse Trucks (deployed in NYC Dept. of Sanitation); gathering data on existing hybrids in other fleets*
  - Small Bus – *Hybrid buses on truck chassis deployed with multiple fleets*
- ***2 Special Activities:***
  - E-Truck Task Force – *understanding barriers and challenges to greater incorporation of electric trucks into commercial operations*
  - Fleet Action for Clean Transportation (FACT) – *identifying and addressing on-going maintenance, performance issues; expanding fleet participation*

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First HTUF Success: Utility Bucket Truck

- Deployed and completed field evaluation of 24 International/Eaton Class 6/7 bucket trucks
- Fuel economy improvements: 10% – 55% reduction in fuel use depending upon duty cycle
- Got the hybrid commercial truck market “off the ground”
- Led to offerings of similar hybrid trucks from Freightliner, Peterbilt, Kenworth, and variants from Dueco/Odyne
- Hybrid trucks now available in a wide variety of configurations including flatbeds, stake beds, package delivery, tree service, food delivery, regional tractors, etc.

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Upgraded Eaton Hybrid

- Announced week of June 4, 2012
  - New high-capacity battery
  - Single-phase 5 kW 115-volt AC Aux Power Gen (APG)
  - Higher capacity clutch (up to 860 ft-lb/300 hp)
  - Remanufactured battery for aftermarket purchase
- Should result in:
  - 5 to 10% increase in fuel savings
  - Improved vehicle performance
  - Double the engine-off capability for jobsite operations
- Available 3rd quarter of 2012

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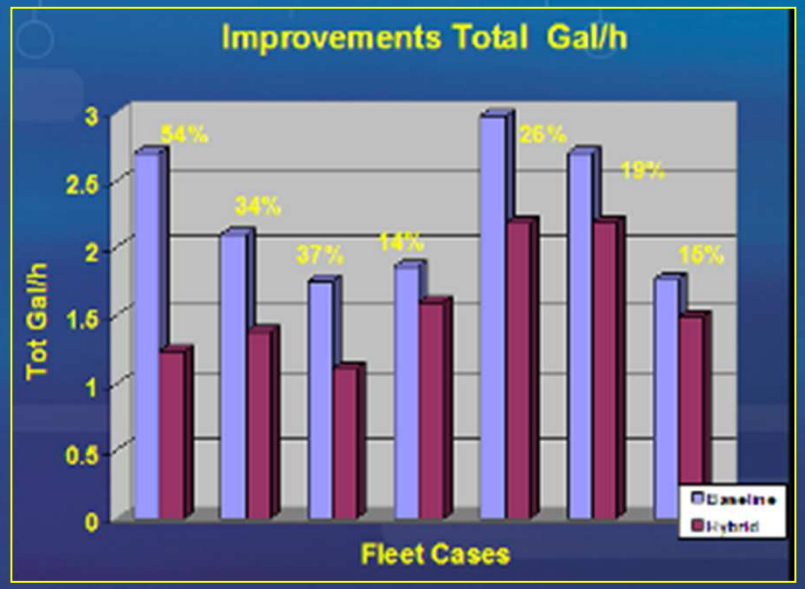
Benefits of Hybrid Truck Technology to U.S. and Canada

- **Hybridization provides significant immediate benefits**
  - **ENERGY SECURITY: Reduced fuel consumption (30-50%)**
  - **EMISSIONS/CLIMATE: Reduced criteria (NOx) and GHG emissions (10-60%)**
    - **One of few strategies to improve on 2010 emissions reductions**
  - **ECONOMY: North American leadership in technology, manufacturing**



Fuel consumption reduction from HTUF field testing data

Emissions/fuel reduction from HTUF dyno testing data performed at SwRI

TABLE 10 AND FIGURE 9. PERCENT DECREASE IN RATE OF EMISSIONS (g/hr) AND PERCENT INCREASE IN FUEL ECONOMY (mpg) OBTAINED BY USING THE HEV TRUCK COMPARED TO THE BASELINE USING FOUR EATON-SPECIFIED MISSION CYCLES

Mission Cycle ID (given in Table 8)	HC (g/mi) %	CO (g/mi) %	NOx (g/mi) %	PM (g/mi) %	Fuel (mpg) % (increase)	Miles Driven	Hours of Operation (hydraulic + electric)
A	58	50	34	25	68	70	1.5
B	73	94	34	34	80	70	4.5
C	78	73	61	37	139	48	3
D	80	74	58	32	150	38	3

Reductions come just from hybrid system, no additional after-treatment

CO2 reductions closely tracked fuel reduction percentages

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Utility Working Group

- Group looking at next phase work truck
  - Class 4/5 boom truck
  - Large numbers and a duty-cycle receptive to drivetrain hybridization
  - Will include plug-in hybrid option
- Key performance parameters and a RFI were released for comment
- RFP should go out this summer

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Telecom Working Group

- Predominantly self-supported group looking at Class 3 hybrid truck
  - AT&T and Verizon are principal players
  - Seeking light-aerial configuration w/driveline hybrid & work-site capabilities
  - Will include plug-in hybrid option
- RFP should be released soon

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Class 8 Regional Delivery

- Class 8b – up to 88K lbs. GVWR
  - 4x2 daycab configuration
- Preliminary interest expressed by FedEx Ground, UPS, Purolator, Penske, Ports of LA and Long Beach
- Cooperating with EPA SmartWay Program
- Have established the initial set of chassis and key performance requirements
- Accomplishing data acquisition and evaluation for drive cycle definition
- RFI to be released in summer timeframe

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Hybrid Prototype: DTNA

- Prototype Class 8 hybrid developed for testing with WalMart
- Conventional drive for one axle, electric drive for second axle
- Could provide high efficiency in road driving, assist truck in urban and slow speed driving

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Clean Construction Equipment Projects

- Hydraulic System Efficiency Improvement
  - Goal 25% fuel savings
  - Project Partners: Eaton, U.S. Army/TARDEC, U.S. Navy
- Hybrid Wheel Loader Demonstration
  - Goals 30% fuel savings, 40% GHG 30% NOx & 40% PM reductions
  - Partners: Terex, U.S. Hybrid, SJVAPCD, Maddox Dairy
- Hybrid-Electric Bulldozer – Data Collection, Evaluation and Verification
  - Goals: verify expected 25% fuel savings, 10% increase in productivity
  - Partners: U.S. Army, U.S. Navy, Caterpillar

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Military Installations Working Group

- Military utilizes many of the same trucks that are now commercially available in hybrid form
- Aim is to increase deployment of currently available commercial hybrids throughout the services
- Main obstacle is overcoming high incremental costs, purchase process
- **HTUF DEPLOYING 4 TRUCKS THIS YEAR (and data collection)**

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Parcel Delivery Working Group

- Working group has selected Freightliner Custom Chassis with Parker-Hannifin hydraulic hybrid system and Morgan Olson body
  - Activity predominantly funded by DOE
- Vehicles are being deployed April/May 2012
  - One demo vehicle each for FedEx Ground, Purolator, and UPS
  - Projected 40 – 70% FE improvement
- Data acquisition will begin upon acceptance of vehicles this summer

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Refuse Working Group

- Working Group selected Crane Carrier to provide
  - Electric hybrid (HEV) in collaboration with ISE
  - Hydraulic hybrid vehicle (HHV) teaming with Bosch Rexroth

- 2 fleets participated in purchase
  - Dept. of Sanitation, NYC (3 HEVs, 2 HHV)
  - City of Chicago (1 HHV)

- As a result of testing, NYC has contracted with Mack to provide 10 HHVs with Bosch-Rexroth systems with an option for many more
- CALSTART now acquiring data from fleets across U.S. using hybrid refuse trucks

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New Hybrid Offering: Autocar-Parker Hannifin

- E3 Hydraulic hybrid refuse truck uses Parker “Runwise” system
- Claims 30-50% reduction in fuel use
- Moving into production after pre-production validation in Florida

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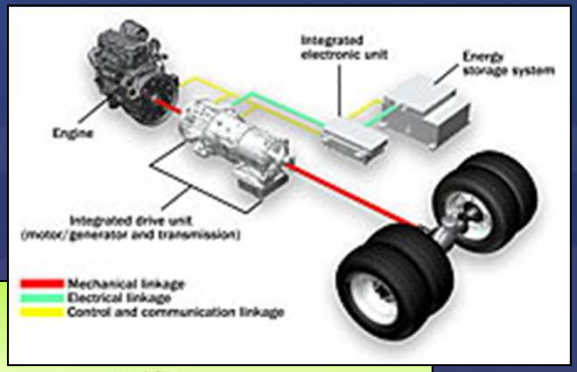
New Hybrid Offering: BAE

- Focus on heavy-duty vocational truck (Class 6-8) segment
- Adapts their system to parallel design with Caterpillar transmission
- Long experience in transit market (over 3,000 systems) with series design
- In field demonstration
- In production Q1 2013



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Newest Hybrid Offering: Hino

- Class 4 and 5 cab-over design – perfect for urban delivery
- Aisen transmission, parallel hybrid driveline
- Long experience in hybrid tech in Japan market
- Promises extremely price competitive system
- Should be available mid to late 2012

From: Gizmag

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Electric Technology

- Emergence of Electric Vehicles!
- Medium-duty all-electric trucks available in North America from Smith Trucks, Navistar, EVI – FCCC coming soon, some others entering space for light/medium duty trucks
- Improving battery technology partly thanks to hybrids (lithium ion)
- Still expensive, range limited but energy storage costs dropping steadily
- Increased petroleum prices makes an improving business case in right applications
- Criteria and GHG emissions very low; varies depending on fuel source of power plants, each region different
- However: powerplant emissions improving over time everywhere

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Multiple Manufacturers Bring Electric Trucks

Navistar E-Star

Smith

Capacity

Freightliner Custom Chassis

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E-Trucks

EVI

Boulder EV

US Hybrid

Zero Truck

Balqon

Vision Industries

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E-Truck White Paper

- Major Areas Assessed:
  - Perception
  - Performance/Operation
  - Business Case
  - Manufacturing Issues
  - Infrastructure
  - Data needs
  - Overall Barriers
  - Incentives

www.calstart.org/Projects/E-Truck-Project/E-Truck-Task-Force-White-Paper.aspx

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E-Truck Task Force Key Findings

- ✓ Vehicle Cost/Price are Top Issues/Barriers
  - Production/battery costs; need for incentives
  - 50% (or greater) funding of incremental cost needed
  - Costs do show decline over time
- ✓ Vehicle Quality/Support Needs to Improve
- ✓ Validation of Performance and Business Case are Key Gaps
- ✓ Infrastructure is a Surprise to Fleets and Important Next Tier Issue
- ✓ Better Guidance on Vehicle Placement, Use Needed

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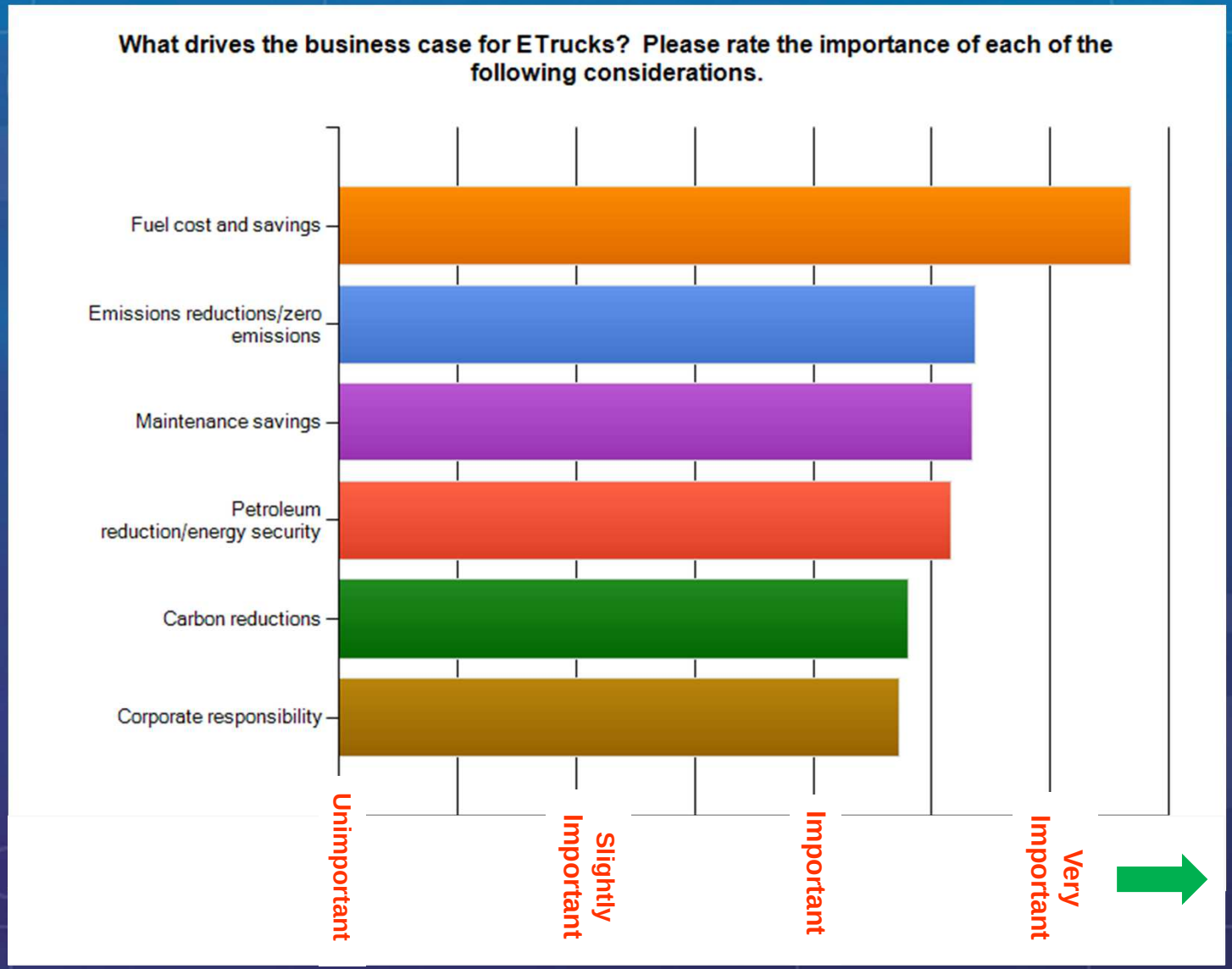
What Drives the Business Case?



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Best General Use/ Duty Cycles

1. Fixed route applications - **70%**
   - Stop and go
   - Localized, dedicated routes
   - Short haul
   - Limited range
   - ‘Spoke and hub’
   - Urban Delivery, Refuse, Mail trucks, Transit Buses

2. Facility vehicles – **19%**
   - Airports, seaports, railyards, military bases, parks, resorts
   - Warehouse support and maintenance
   - Cargo handling

3. High idle, work site applications – **11%**
   - Aerial devices
   - PTO
   - Utility vehicles

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Best Use to Achieve Business Case

To get sufficient payback, need to drive maximum miles possible (or maximum use of energy)

- Dedicated, return-to-base routes with known daily mileage highly valuable

High Utilization/Daily miles (5-7 days a week) seems important

70-100 miles/day seems like an initial “sweet spot” for fuel savings payback (sufficient miles to generate fuel savings needed)

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Vehicle to Grid (V2G) – Could Support EV Business Case

- MIT, DOD and CALSTART studies show V2G could support, underwrite business case for purchasing and using electric trucks
- DOD starting tests in Hawaii, California
- Smart grid, V2G test by Mitsubishi
- V2H demos by Nissan and Toyota

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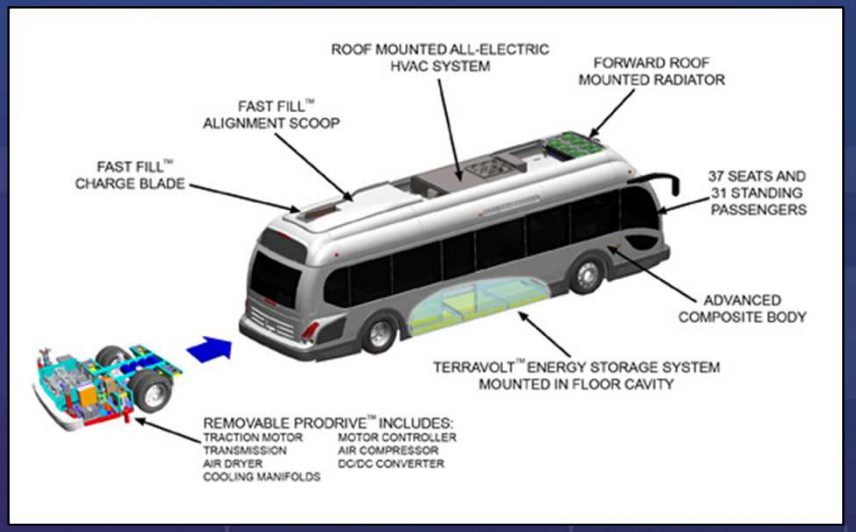
Full Battery Electric

- Balqon drayage trucks in demonstration at port
- Proterra all-electric bus operating with Foothill transit
- Reduced battery pack size augmented with fast charge



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Road-Connected Power

- Well known in transit industry (electric trolley-bus)
- Used widely in mining with extremely heavy equipment
- Now beginning testing in Europe (Siemens) for heavy-haul trucks
- Other tests looking at in-road power alternative

Siemens eHighways Concept (from 2/17/11 CalHEAT Forum briefing)

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Plug-in Hybrid Electric Vehicles

- Lots of attention and interest in PHEVs among policy makers, environmentalists
- Until recently most PHEVs were conversions from small firms – very few on road
- OEM production coming – still demo vehicles
- Benefits: increased fuel economy, GHG reductions, possible zero emission driving
- Cost and life cycle of energy storage (batteries) are prime limiter, along with infrastructure network (can plug at home)
- Most focus is on passenger cars – however while trucks offer additional challenges, there may be possible business case benefits before cars

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Chrysler Ram PHEV

- DOE program to demonstrate capability
- Will not go to market – at least not on this platform
- Demonstrating minivans too

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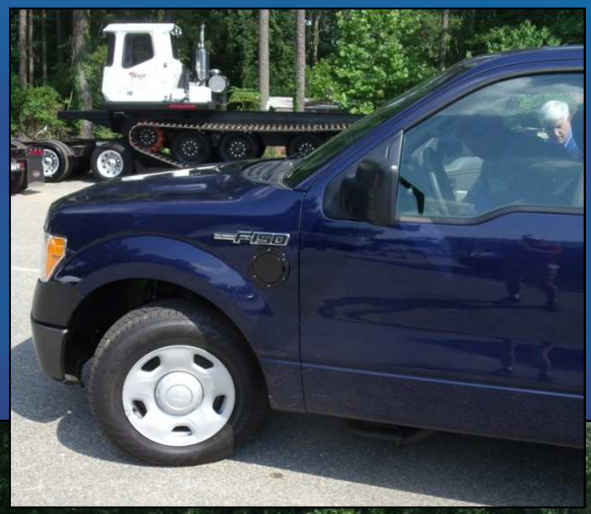
Plug-in Light Commercial Vehicle

- Quantum refining a Ford F-150 plug-in conversion – high fleet interest
- Possible 35 miles all-electric range
- Combined driving 475 miles (gas and electric)
- Top speed 95 mph
- 22 kwh lithium-ion battery (Dow Kokam)
- Recharge 110 or 220 V
- Working on Escape version as well



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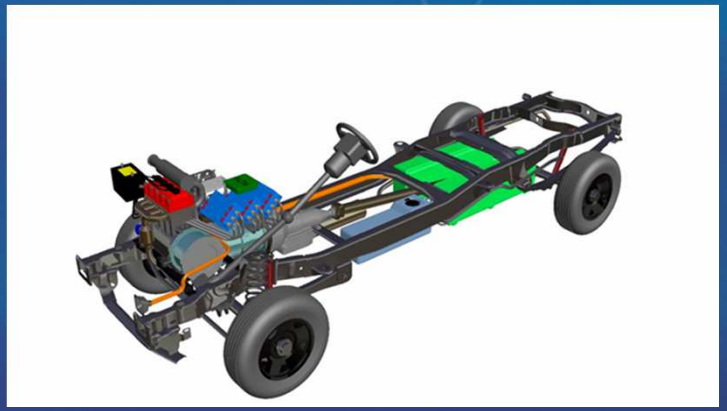
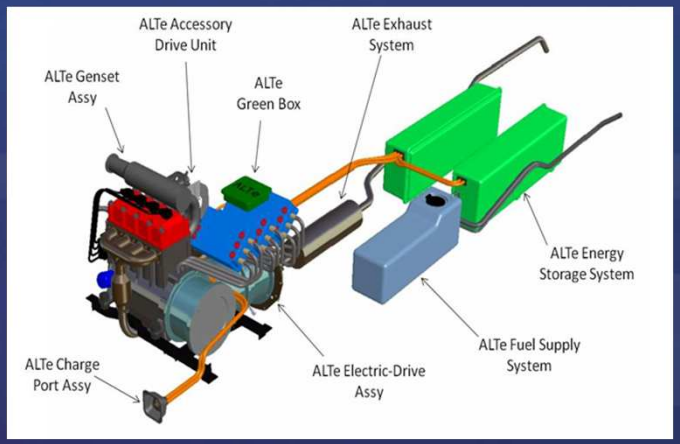
Light Extended Range E-Trucks

- ALT-e REEP; VIA; Quantum
- F-150 Class (4 cylinder 2 liter engine 25 kwh pack; 52 mile EV range; 32 mpg possible FE
- Many fleets interested in this capability but OEMs not yet responding





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Plug in Hybrid Trucks Emerge: Several Utility Industry Variants

Dueco-Odyne plug-in "material handler" (above), "digger-derrick" (middle), compressor truck (bottom).

Eaton PHEV utility trucks

Plug-in port

- Commercial work trucks show potential for PHEV functionality *before cars*
- Extra energy storage boosts idle reduction/work site engine-off ops
- Diesel fuel costs cause rapid review of potential business case
  - Energy Storage costs still high
- Dueco-Odyne first into market
  - Plug-in hybrid utility bucket trucks
  - PHEV "digger-derrick" version 6/08, a higher power-demand work truck
  - Trucks carry 35 kwh of energy storage (lead-acid, 3000 pounds) for long work site ops
  - PHEV underground compressor truck
- Eaton has two prototypes
  - Class 6/7 variant based on production truck, system
  - Class 5 "Superduty" prototype with EPRI

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Plug-in Energy Storage Bodies

- Growing interest from fleets if fuel saving not needed from driving cycle
- Altec, Terex, Time, Azure and others with systems
- Stored energy to operate lift, tools at work site
- Separate from and does not change conventional driveline
- Fuel savings and idle reduction benefits

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Series Electric/Hybrid – Range Extender

- Artisan – Parker prototype electric drive system with turbine extender (multi-fuel turbine)
- Much development in turbines, focus on NG
- Vision Industries prototype series electric with fuel cell range extender

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Top 5 E-Truck Action Recommendations

1. Seek **purchase vouchers** equal to ½ of incremental cost.
2. Establish and agree to **common use profiles** industry-wide.
3. Reduce system design and manufacturing costs via **increased R&D and demonstration**.
4. Create a **commercial EV charging rate**.
5. Eliminate or **reduce demand charge** for commercial EV charging.

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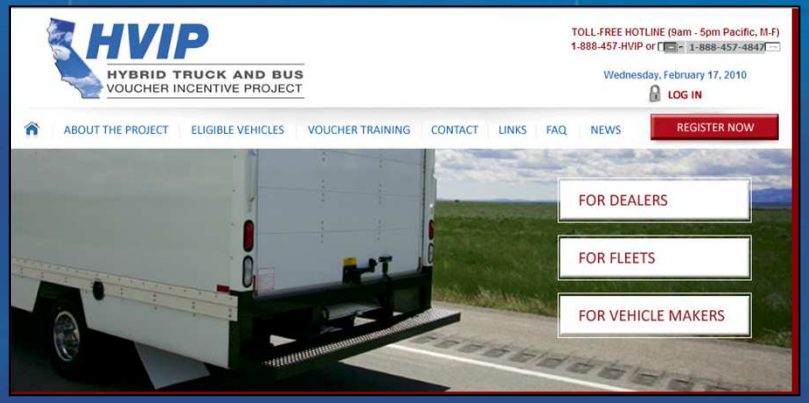
Smart Incentives to Move the Market: States Leading

- Tax credits at federal level have expired
- BUT: California has invested in a voucher program for hybrid and electric trucks a parallel program for NGVs
- New York launching $19M voucher program in June for hybrid, electric and NG trucks



www.californiahvip.org

New York State

nyserda

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GSA Vehicle Availability

GSA Truck Categories with Hybrid-Electric Drivetrain Option – source: GSA Autochoice website

- School and adult work buses – various lengths
- Light-duty shuttle buses – various lengths
- Medium-duty shuttle buses – various lengths
- Medium and heavy-duty 4x2 cab chassis – 21K, 25.5K, 33K, 35K lbs.
- 4x2 dump trucks – 21K, 25.5K, 33K lbs
- 4x2 refrigerated vans – 14 ft (21K), 16 ft (25.5K), 20 ft (33K)
- 4x2 stake trucks – 16 ft (21K), 18 ft (25.5K), 22 ft (33K)
- 4x2 vans - 18 ft (21K), 20 ft (25.5K), 22 ft (33K)

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GSA Vehicle Availability

GSA Truck Categories with Electric Drivetrain Option

- 4x2 utility-service truck (10,001 to 19,500 GVWR depending on options) – EVI and Zerotruck
- 4x2 stakebed truck (10,001 to 19,500 GVWR depending on options) – EVI and Zerotruck
- 4x2 van – 20 ft (21,000 to 28,000 GVWR depending on options) - Newton

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How Drive Cycle Affects Hybrid Fuel Economy and Vehicle Cost Effectiveness

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CALSTART Data Collection

- CALSTART collected data from Class 8 hybrid beverage delivery trucks
  - Over 420 HVIP orders have been in this Class vehicle
  - CEC sponsored CalHEAT program
  - Vehicles operated in Los Angeles from Santa Monica, CA and Downtown LA
- Four vehicles for long term performance evaluation:
  - Conventional Freightliner
  - Eaton Hybrid Freightliner (280 hp)
  - Eaton Hybrid Freightliner (325 hp)
  - Eaton Hybrid Kenworth (325 hp)

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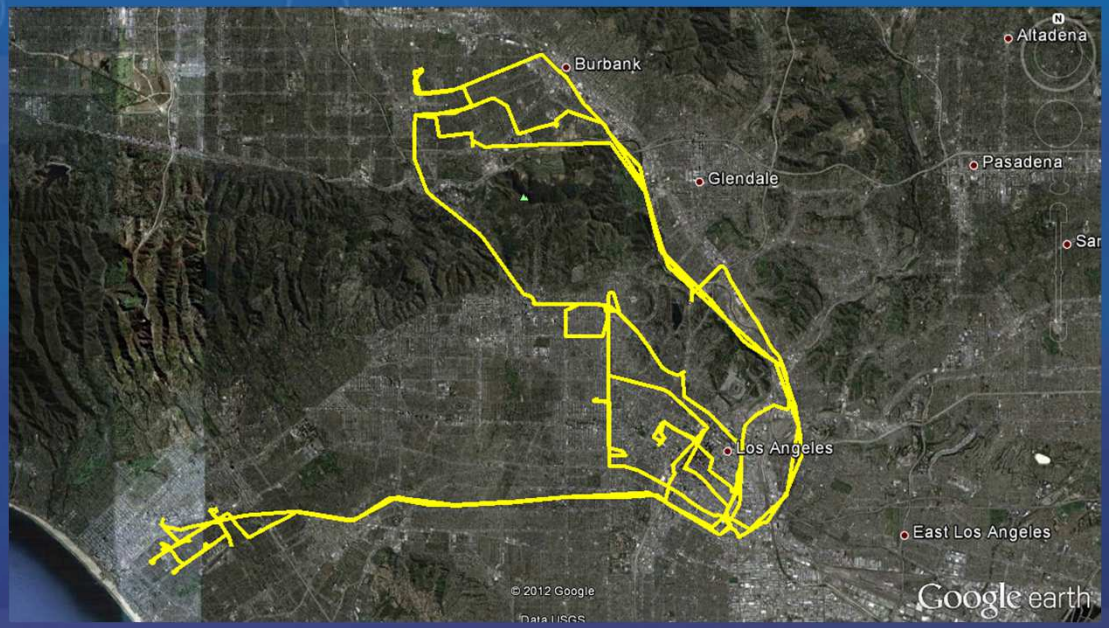
Typical Beverage Vehicle Route



- Average of the 4 Vehicles
  - 650 miles traveled per Month
  - 60 hours of operation per month
  - 115 gallons of fuel used per month

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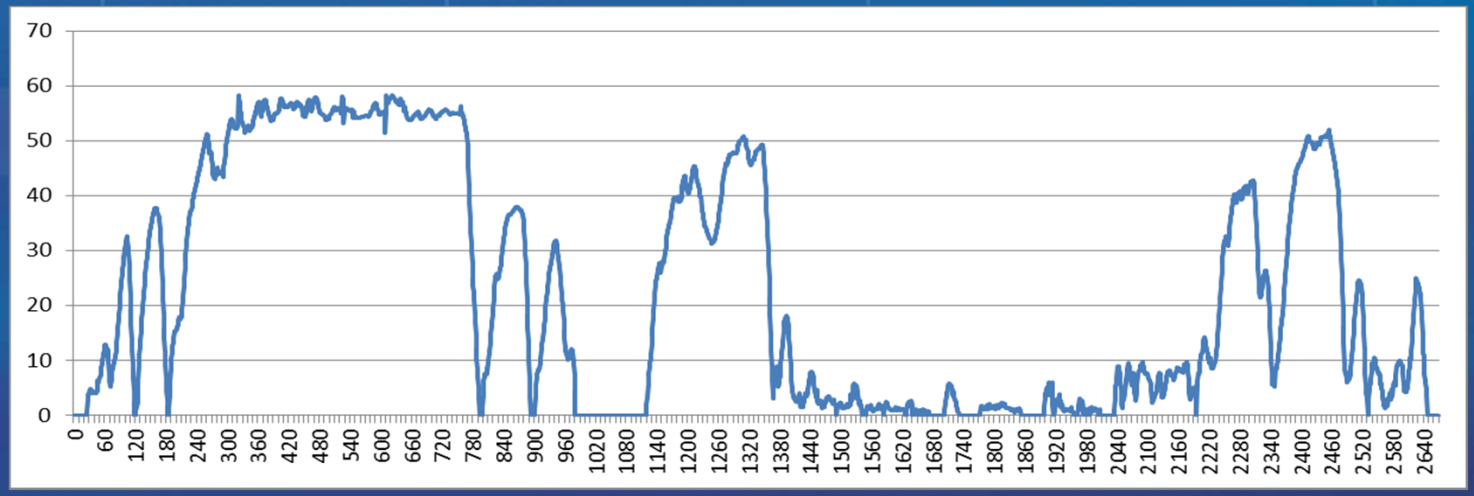
Vehicle Operation Profile/Duty Cycle



- Average fuel economy improvement with hybrids ~ 18%
- Vehicles demonstrated stop and go driving to highway driving; a variety of operational profiles
- Vehicle “microtrips” were developed based on parameters specific to the observed vehicle profile
  - Microtrips - trips made between vehicle stops

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Data Analysis and Operation Modes

- Microtrips were isolated to define vehicle operation modes
- Parameters used to characterize microtrips
  - % Idling
  - % Creep (speed < 10mph)
  - Average Speed
  - Other parameters such as load, altitude, engine speed, throttle position are also considered but not stressed here
- The microtrip data collected on the vehicles were separated into 3 operation modes based on speed, creep, and idling percentages.
  1. Local/Urban Delivery - Low speeds with high idling %
  2. Regional Delivery – Medium average speeds with mixed idling %
  3. Over the Road Delivery - High speed with low idling %

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CalHEAT Truck Categories and their Duty Cycles

Class 7/8 Tractors

Over the Road

- Younger Trucks; High Annual VMT
- Mostly higher average speed, highway driving

Short Haul/ Regional

- Between cities; Drayage; Day Cabs
- Average VMT, Medium Average speeds

Class 3-8 Vocational Work Trucks

Urban

- Cargo, freight, delivery collection
- Lower VMT; Lower Average speed; Lots of stop start

Rural/ Intracity

- Cargo, freight, delivery collection
- Higher VMT; Higher Avg speed; Combined urban/ highway

Work site support

- Utility trucks, construction, etc.
- Lots of idle time; Lots of PTO use

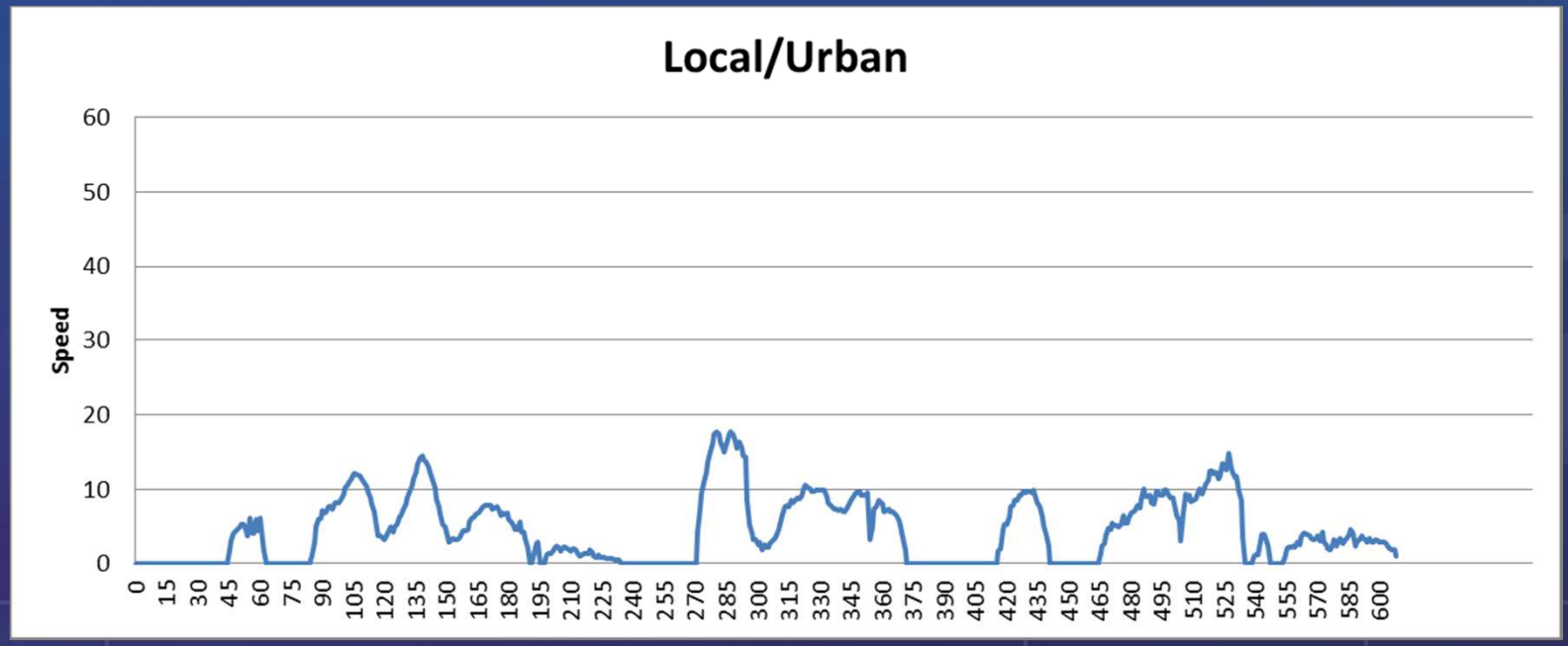
Class 2B/3

Pickups/ Vans

- Commercial use; Automotive OEMs & volumes

1. Local/Urban

- Operational Mode Characteristics
  - Low Average Speed: ~ 8 MPH (including stops)
  - Vehicles idles 48% of the time
  - Vehicle travels in creep mode (<5MPH) 25% of the time
- Observed Hybrid Fuel Economy Benefit: ~40%



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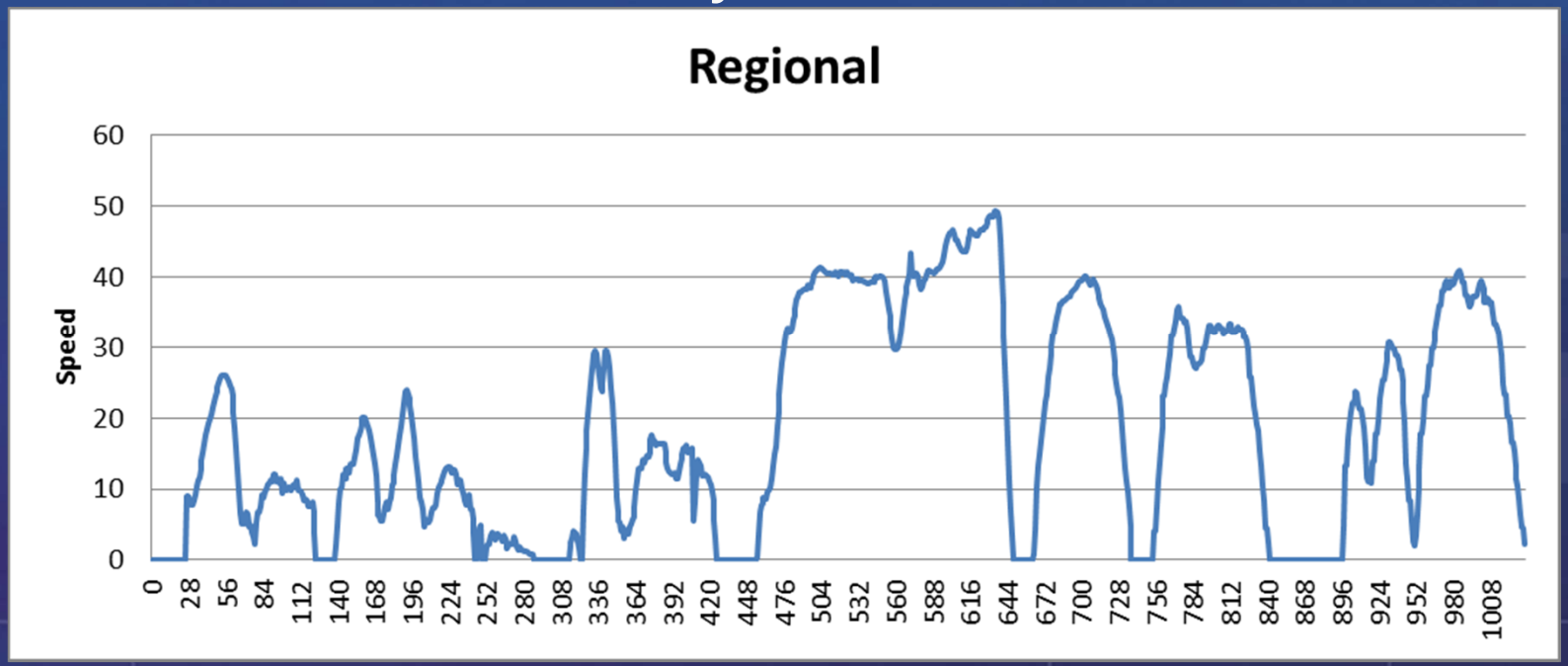
2. Regional

- Operational Mode Characteristics
  - Medium Average Speed: ~ 23 MPH (including stops)
  - Vehicles idles 15% of the time
  - Vehicle travels in creep mode (<5MPH) 14% of the time
- Observed Fuel Economy Benefit: ~20%



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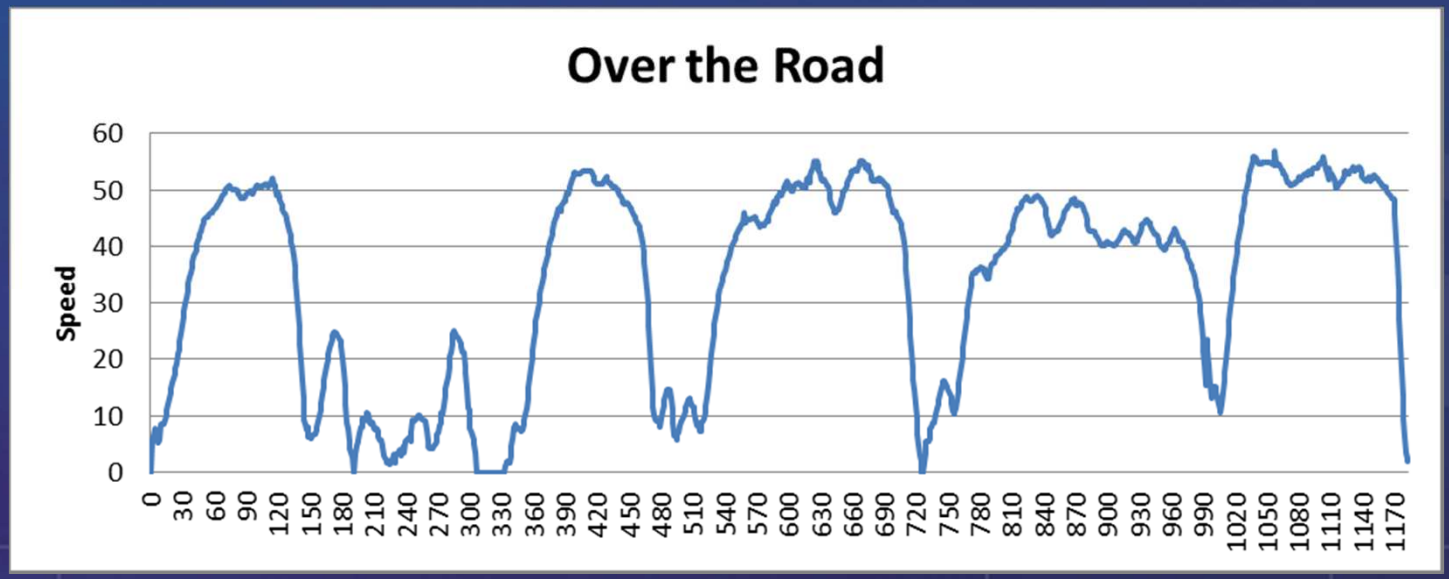
3. Over the Road

- Operational Mode Characteristics
  - Higher Average Speed: ~ 38 MPH (including stops)
  - Vehicles idles 5% of the time
  - Vehicle travels in creep mode (<5MPH) 3% of the time
- Observed Fuel Economy Benefit: ~13%



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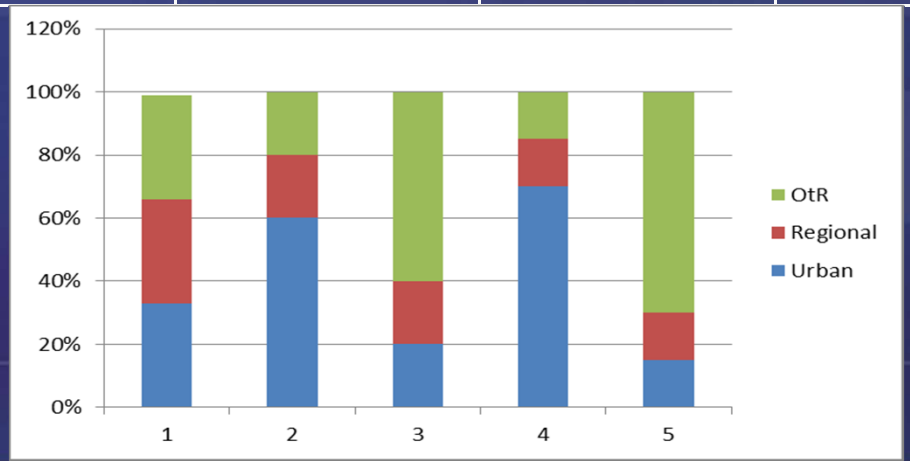
Sample Duty Cycles

- Fuel Consumption is dependent on Duty Cycle
- Overall Vehicle Duty Cycle will be a mixture of the 3 operational categories

	Urban	Regional	OTR	% Benefit
1	33%	33%	33%	24%
2	60%	20%	20%	31%
3	20%	20%	60%	20%
4	70%	15%	15%	33%
5	15%	15%	70%	18%



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Business Case Assumptions

- Class 8 Hybrid Electric Tractor
  - Hybrid system incremental cost: **$45,000**
  - Maintenance costs decreased by **10%**
  - **10-year lifetime** – 5 days/week – 50 weeks/year
- California Diesel Prices as of 02/27/2012
  - **$4.410** per gallon
  - Fuel Escalation Rate at **3% per year**
- HVIP Incentive at **$25,000**
- Discount Rate for Net Present Value (NPV) at **7%**

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Hybrid System Benefits

- Local / Urban Delivery: 50 miles/day – 6 MPG
  - Hybrid system fuel economy improvement **~40%**
- Regional Delivery: 150 miles/day – 7 MPG
  - Hybrid system fuel economy improvement **~20%**
- Over-the-road: 350 miles/day – 7 MPG
  - Hybrid system fuel economy improvement **~13%**

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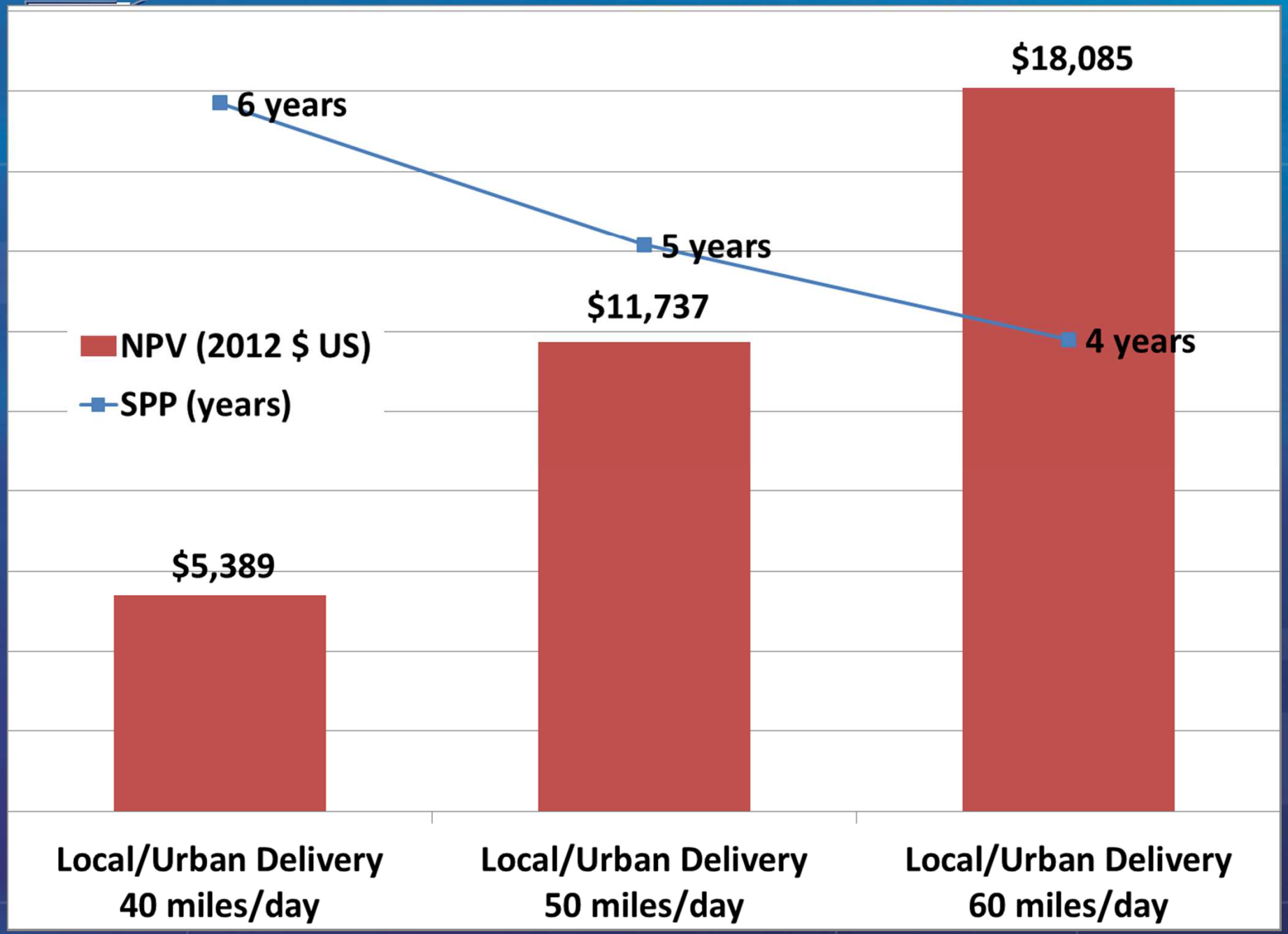

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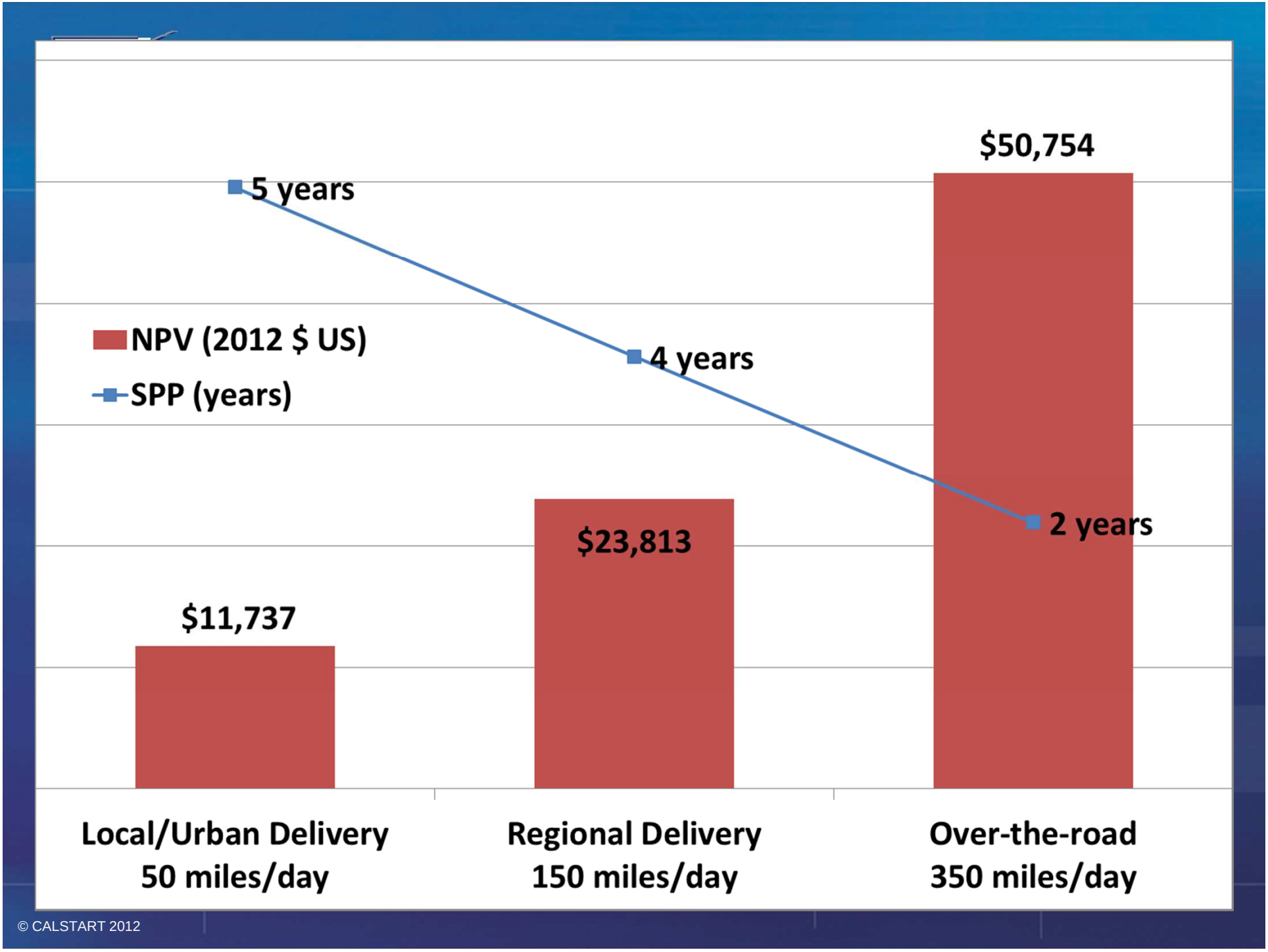

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Cost Effectiveness Conclusions

- Drive cycle heavily affects hybrid fuel economy
  - Know your drive cycle; take some data
  - Make sure your drive cycle will result in adequate savings
  - Consult with truck manufacturers/hybrid system suppliers
- Consider the savings over the life of the vehicle, not just simple payback
- Take advantage of regional, state, and federal incentives to help reduce first cost

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Summary

- A wide variety of hybrid and electric medium and heavy-duty solutions exist
- Early adopter fleets help initiate the market, but the second tier of fleets is needed to sustain and drive the market
- Next generation hybrids are emerging with improved performance and fuel efficiency
- Evaluate your needs and determine if advanced tech can help

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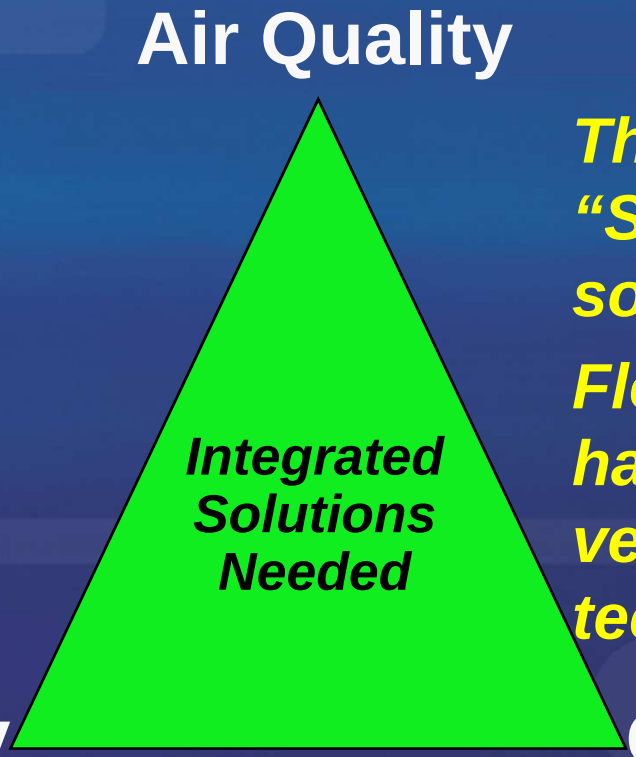
Find Combination Strategies

We must find solutions that address all three competing needs



There is no one "Silver Bullet" solution

Fleets will likely have a portfolio of vehicle technologies

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www.calstart.org

For info contact:

Richard Parish
rparish@calstart.org

www.htuf.org

Backup Slides

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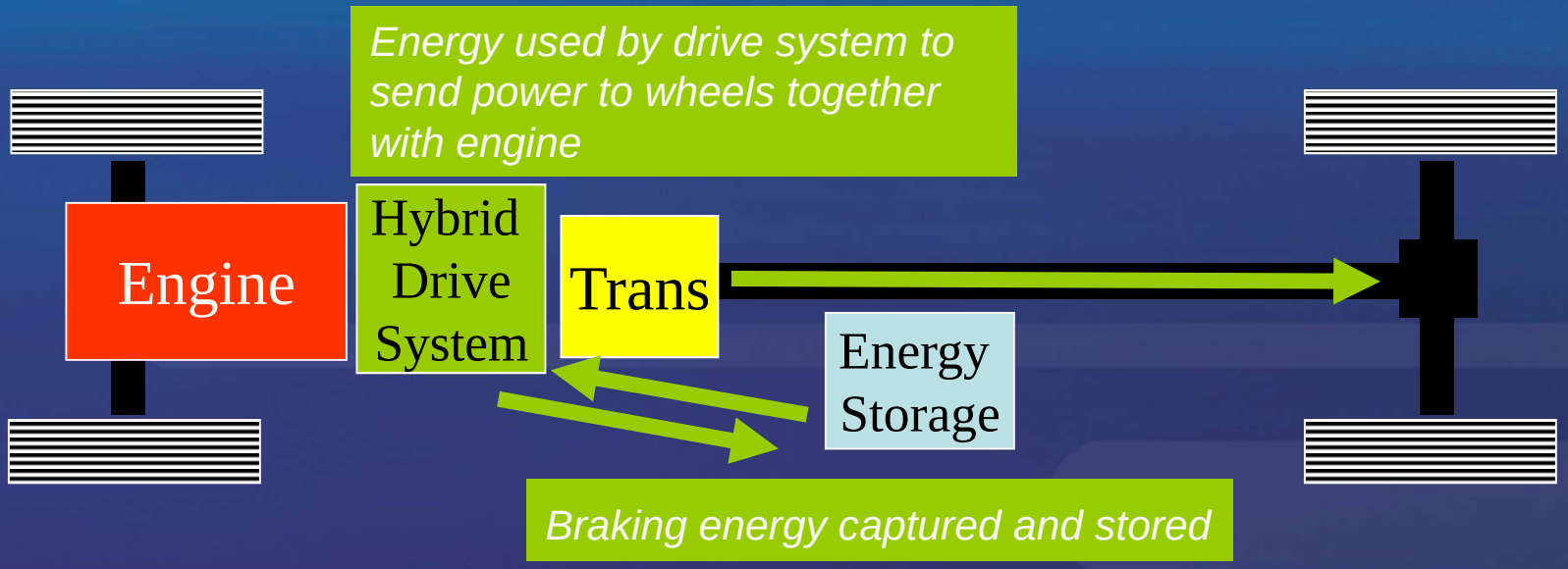
Electric Hybrids

- Parallel Design: engine and hybrid system both direct power to wheels



Benefits: Can be integrated into existing drivelines; generally uses smaller energy storage

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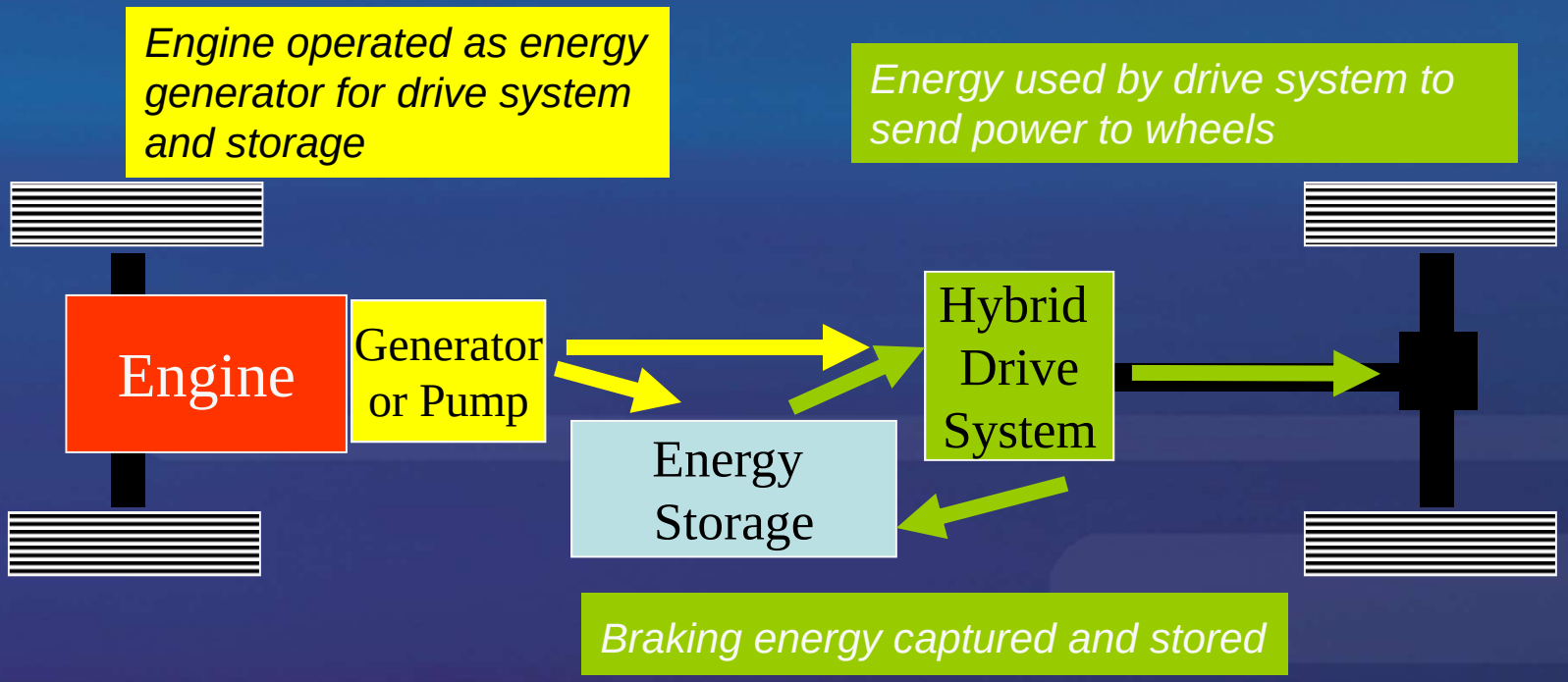
Electric Hybrids

- Series Design: engine generates energy for hybrid system, which then powers wheels



Benefits: Can be more energy efficient in some duty cycles; generally higher cost due to increased energy storage

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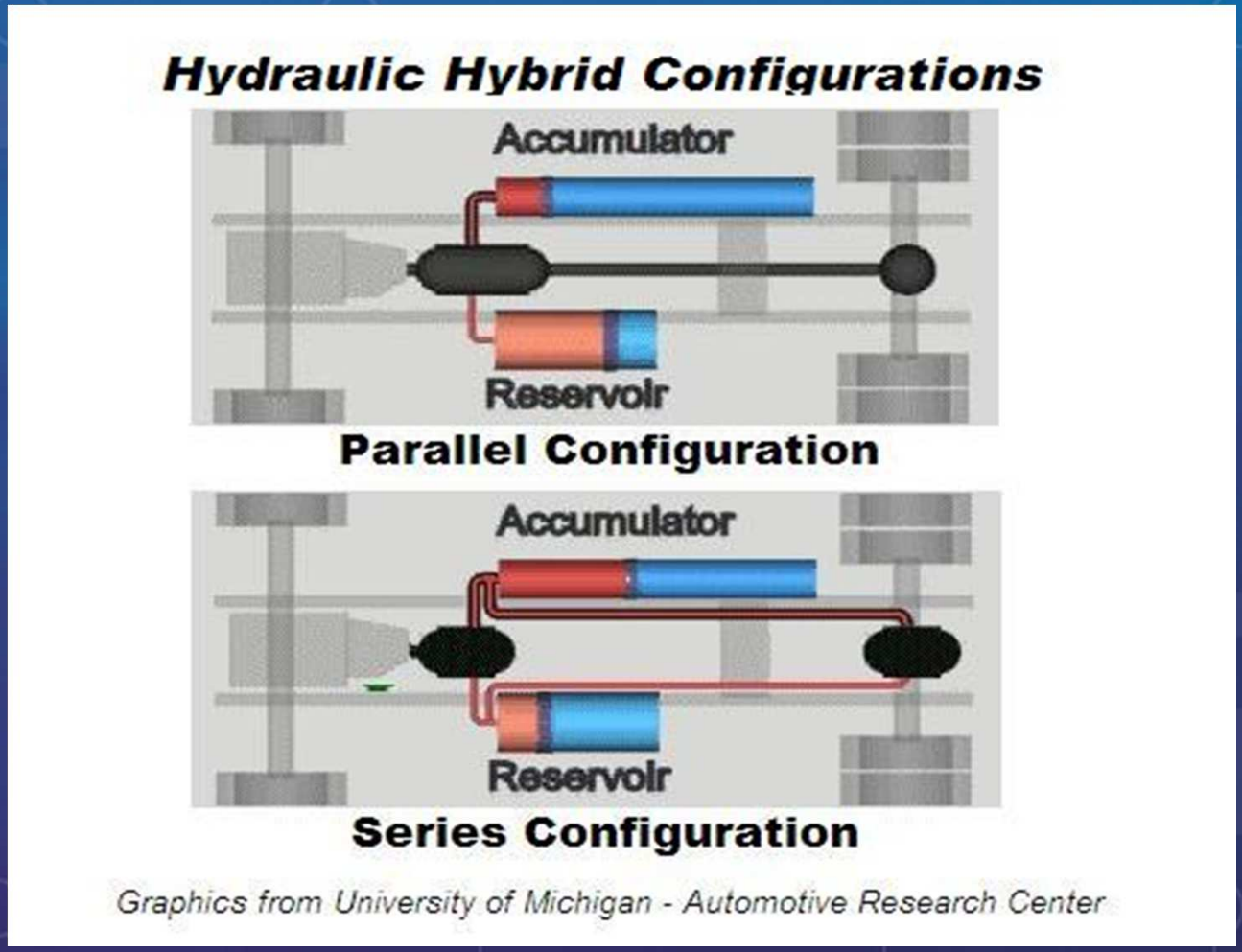
Hydraulic Hybrids



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