What's the Deal with Hybrid and Electric Cars?

Day 2: An in-depth look at Electric Powertrains

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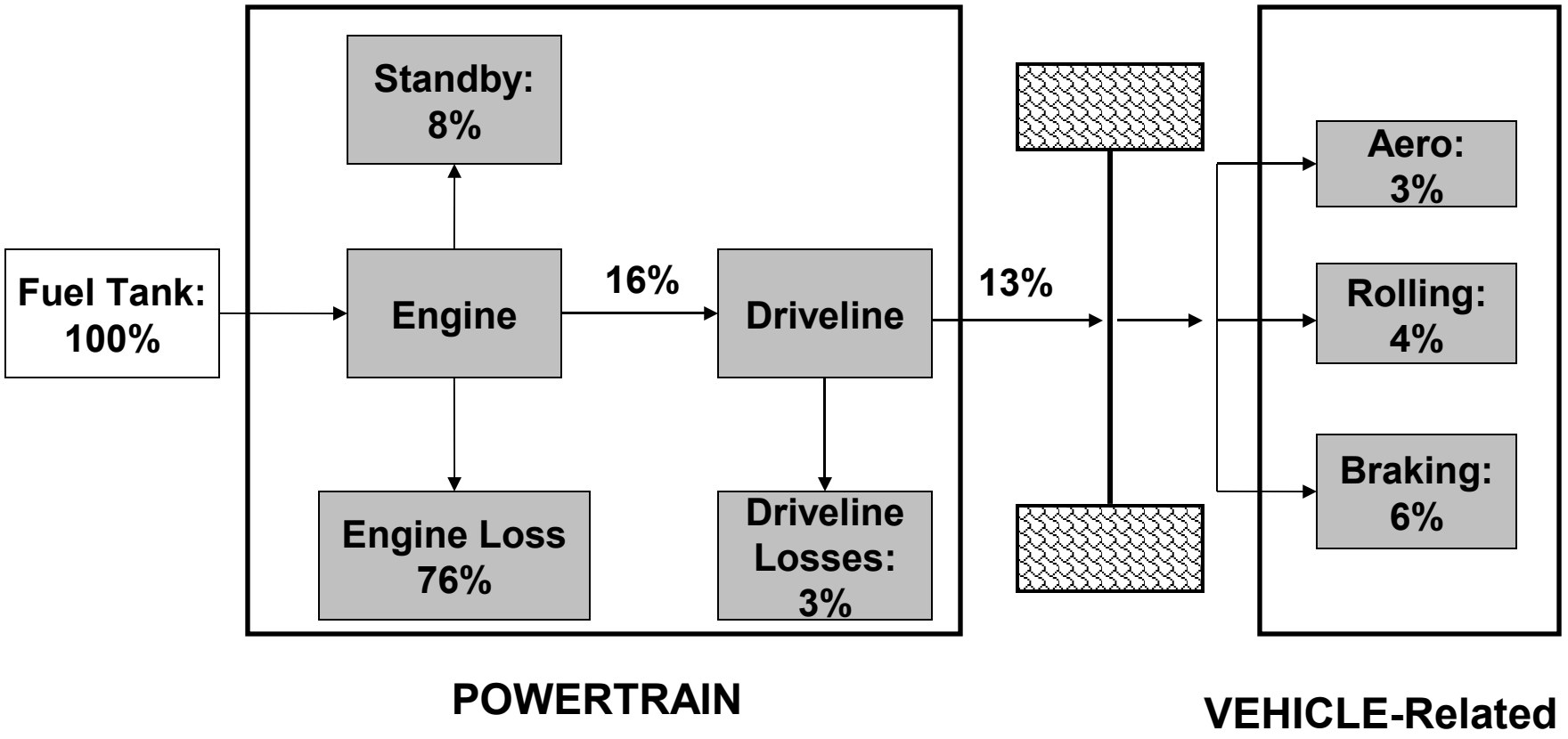
web.mit.edu/evt/iap2009

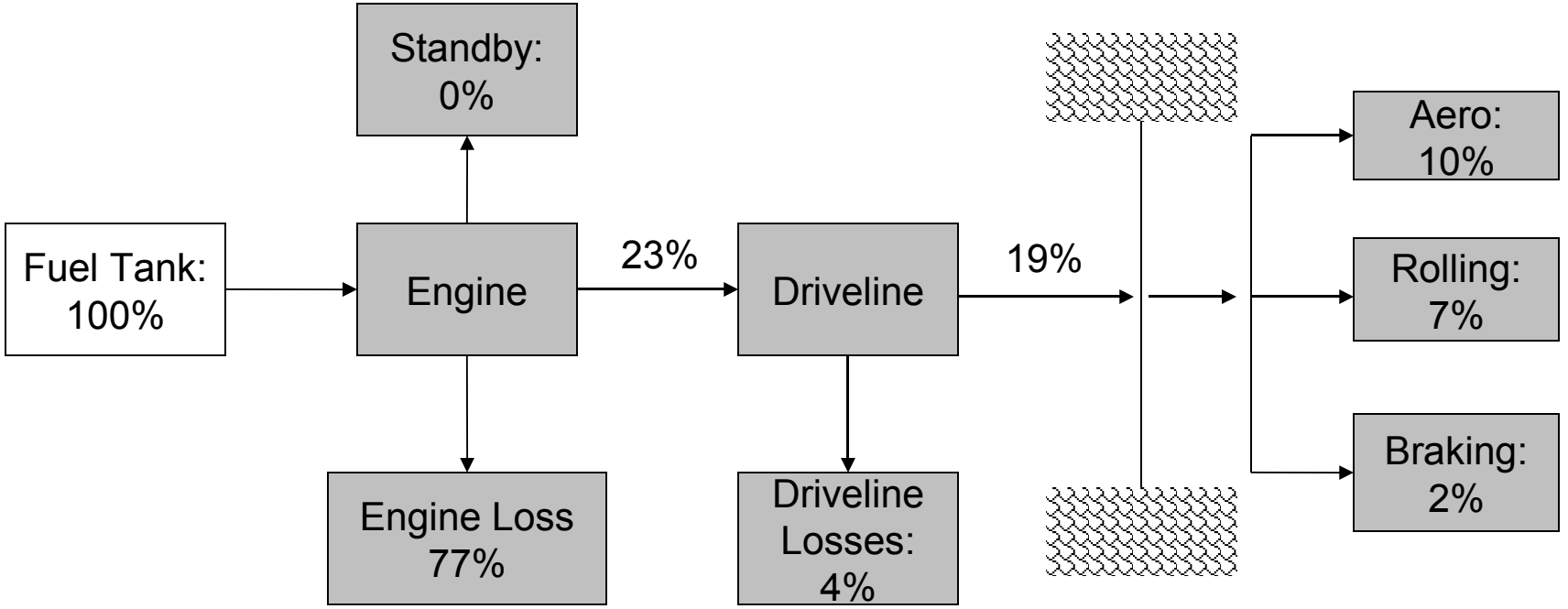
Outline

1. Ways in which hybridization improves efficiency.
2. Hybrid Architectures-Overview.
3. Hybrid Powertrain Case Studies
4. An Outlook at the Future
5. Plug-in hybrids

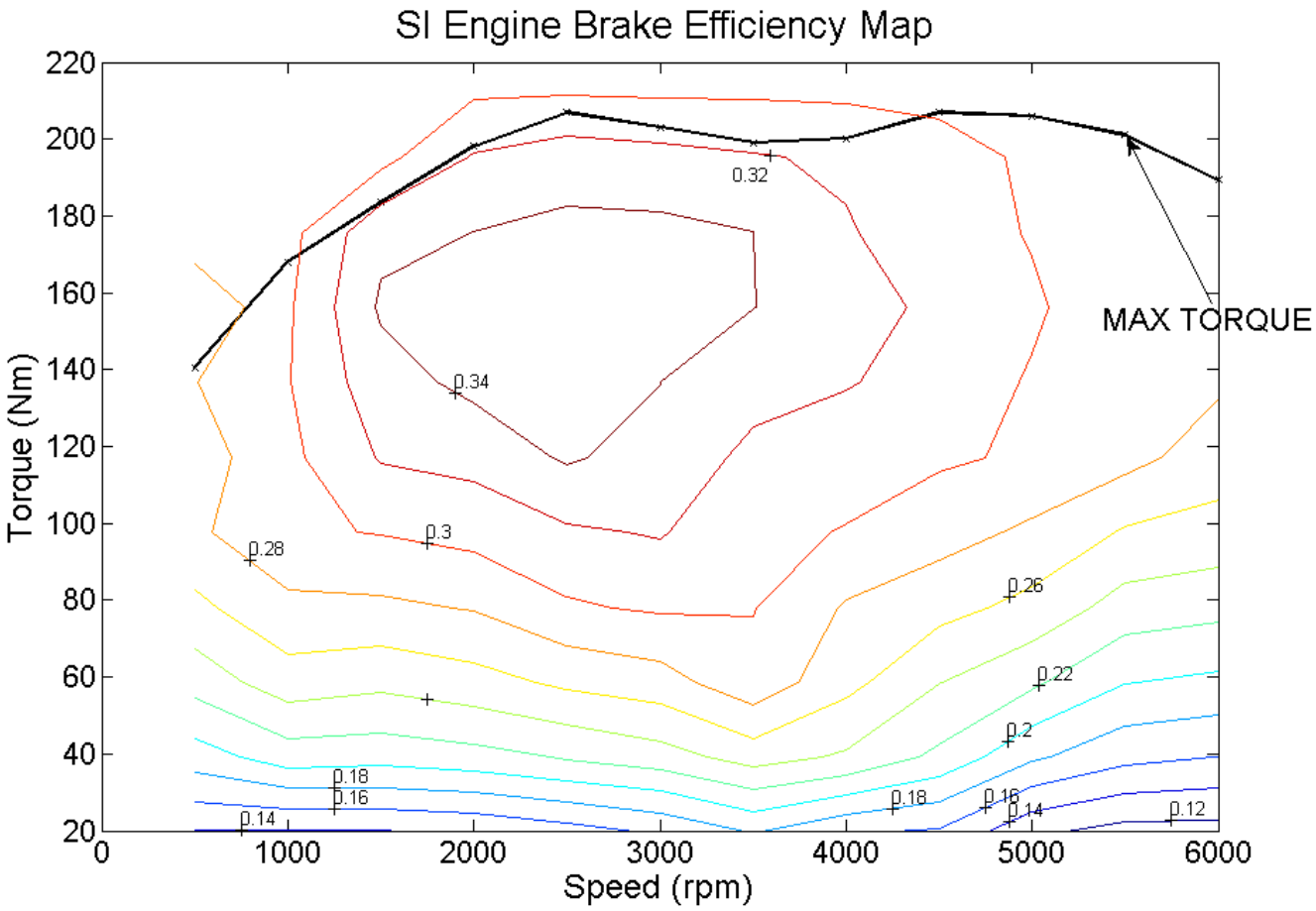
Urban Drive Cycle Energy Balance
2005 3 L Toyota Camry



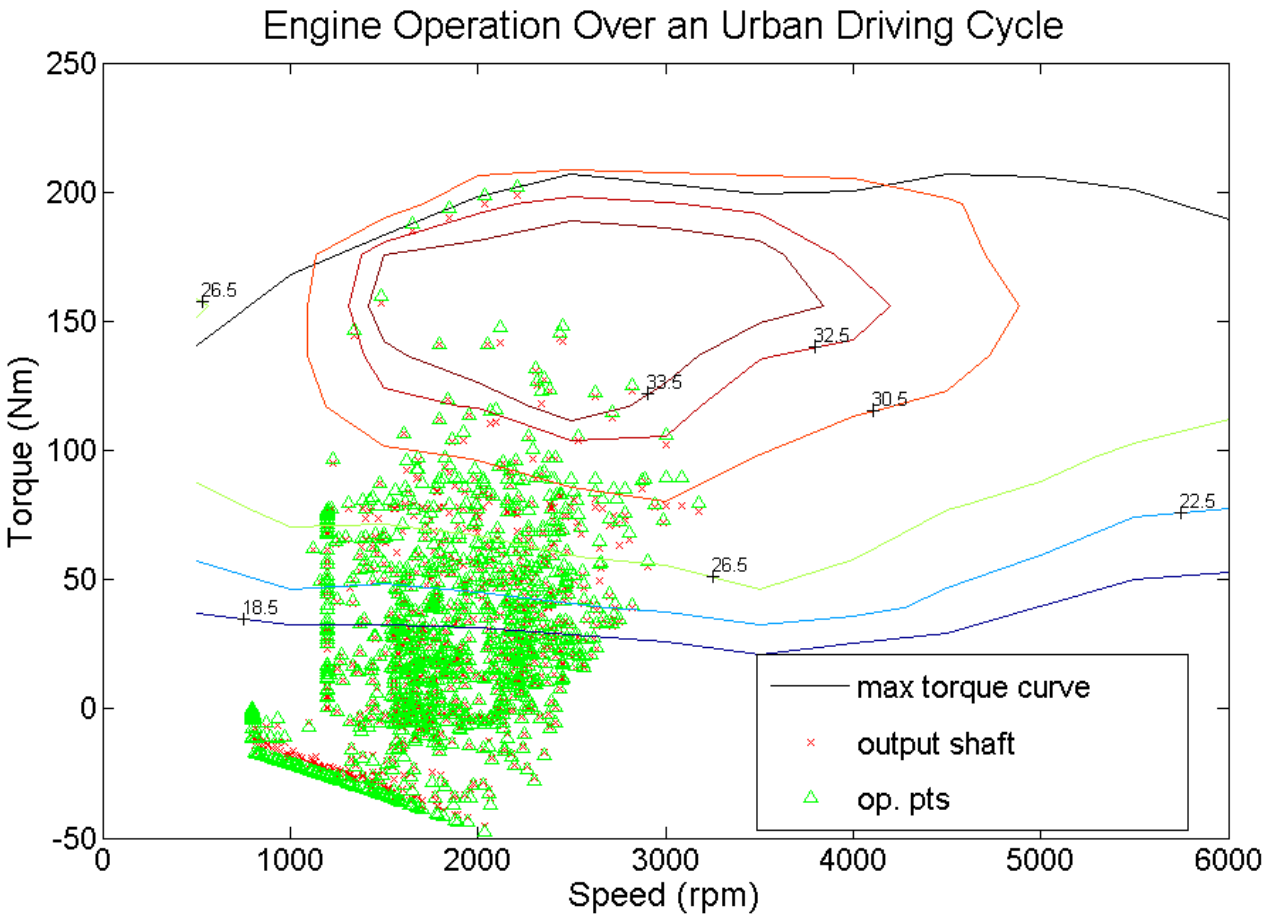
Highway Drive Cycle Energy Balance
2005 3 L Toyota Camry



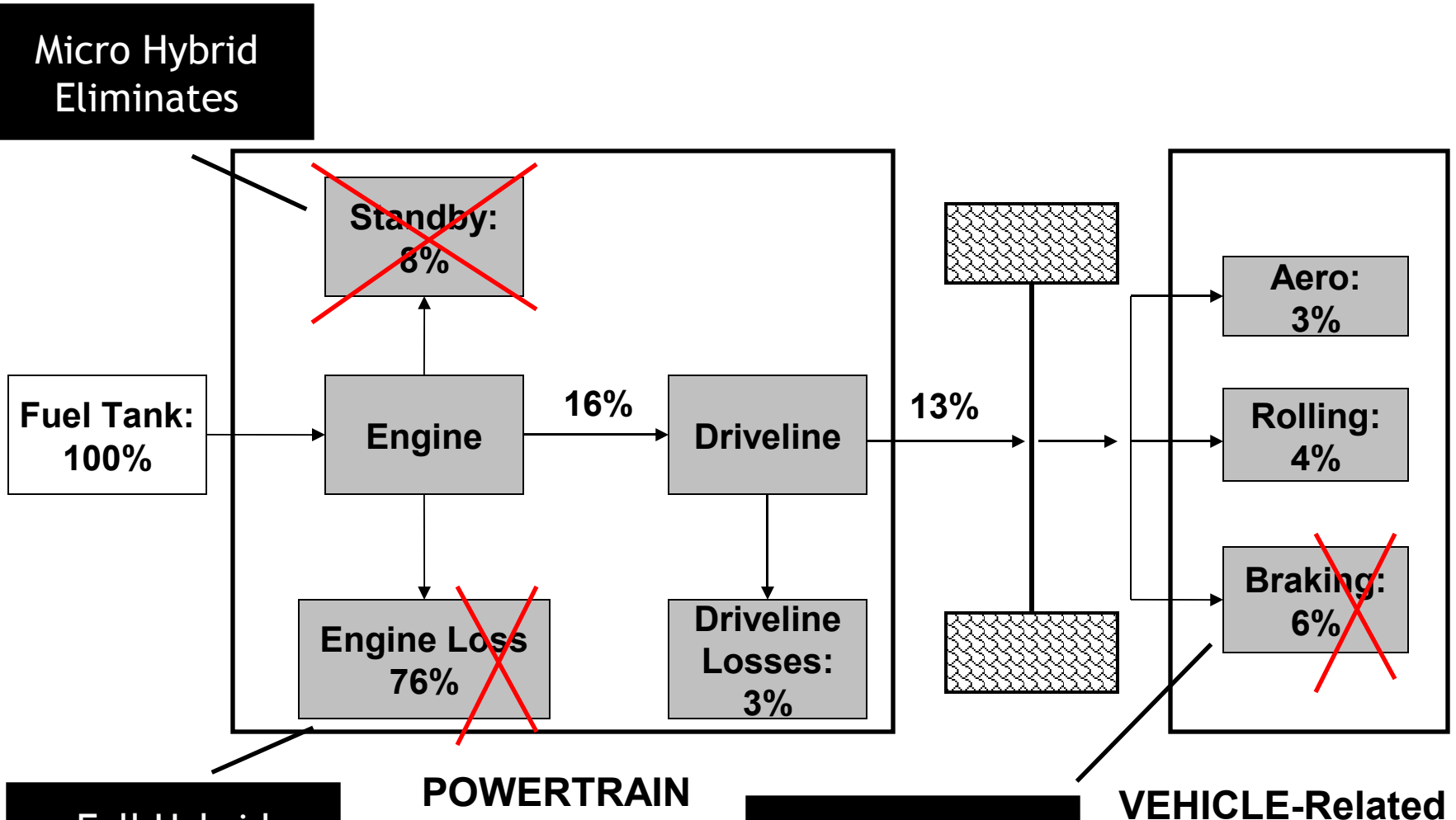
Introduction to Engine Map



Engine Operating Points vs. Efficiency



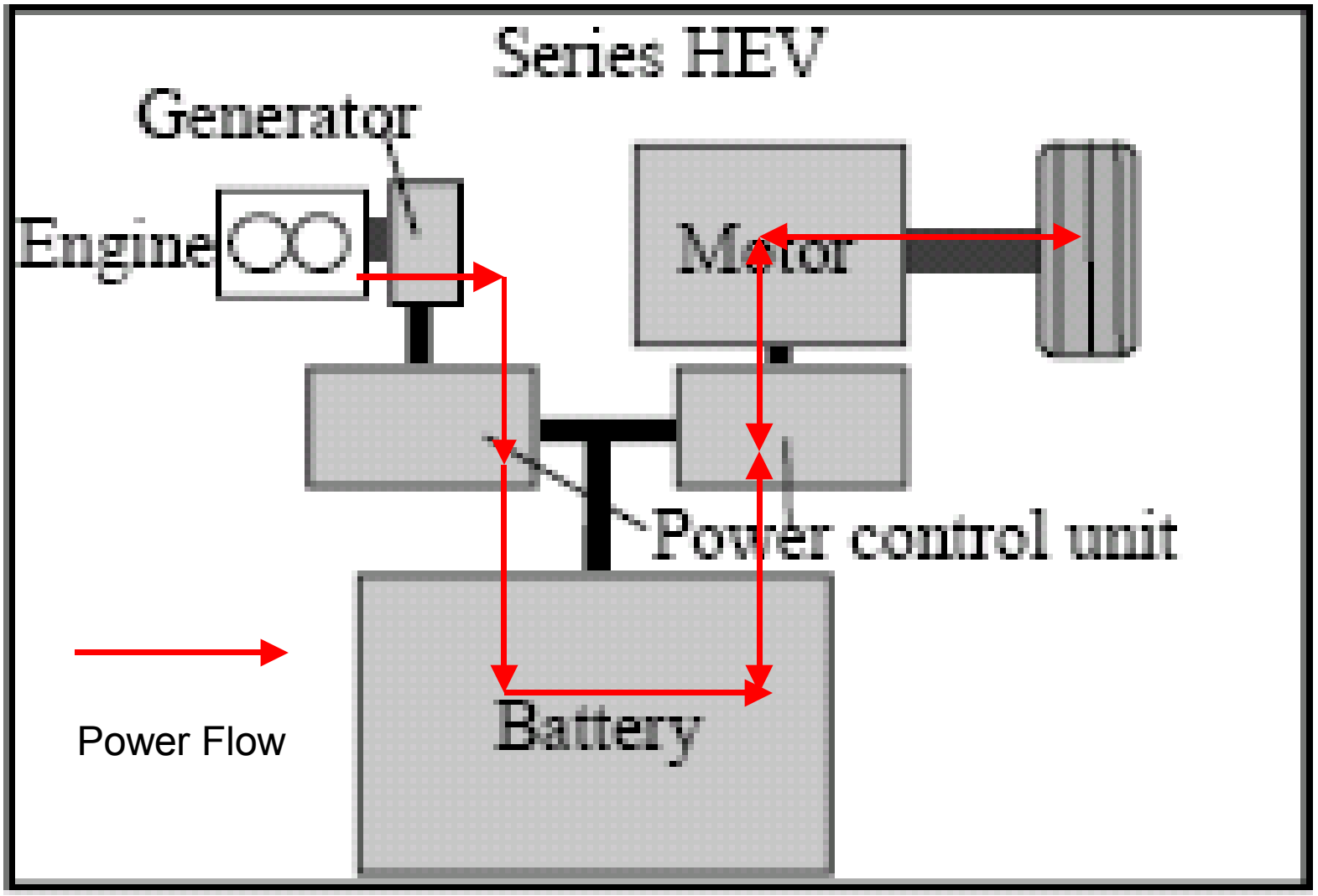
Opportunities for Energy Savings



Classification of Hybrids

1. By Architecture:
   a. Series
   b. Parallel
   c. Series/parallel
2. By Relative Size of Electric Part
   a. Start/Stop- Micro Hybrid
   b. Mild Hybrids
   c. Full Hybrids
3. By Connection Topology (next slide)

Series Hybrid

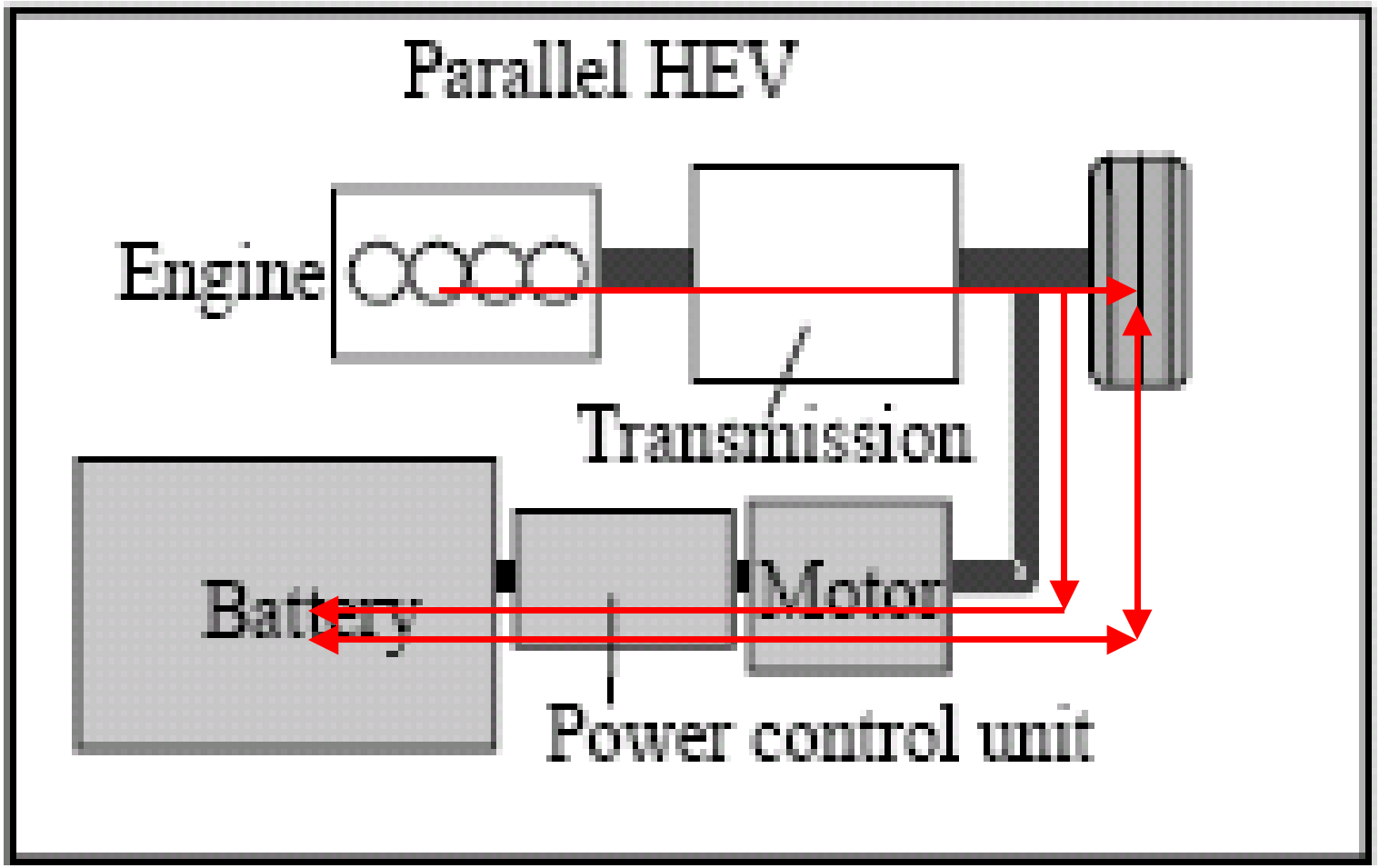


Source: SAE 2003-01-0083

Pros: Engine Optimization

Cons: Unnecessary Electric Losses,Battery Size

Parallel Hybrid Architecture



Pros: Most Efficient P source directly to wheels

Cons: Tough Engine Optimization

Source: SAE 2003-01-0083

Parallel/Series Architecture

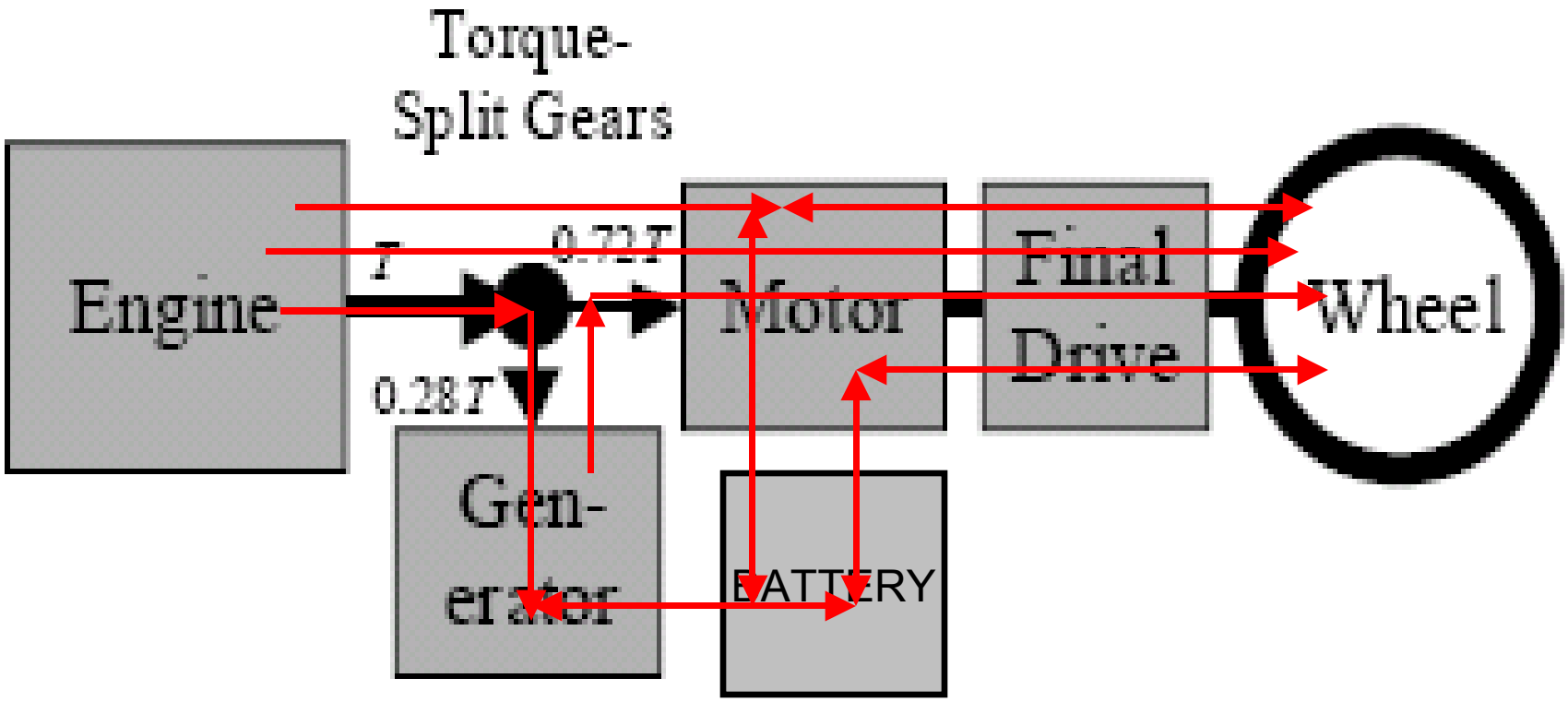
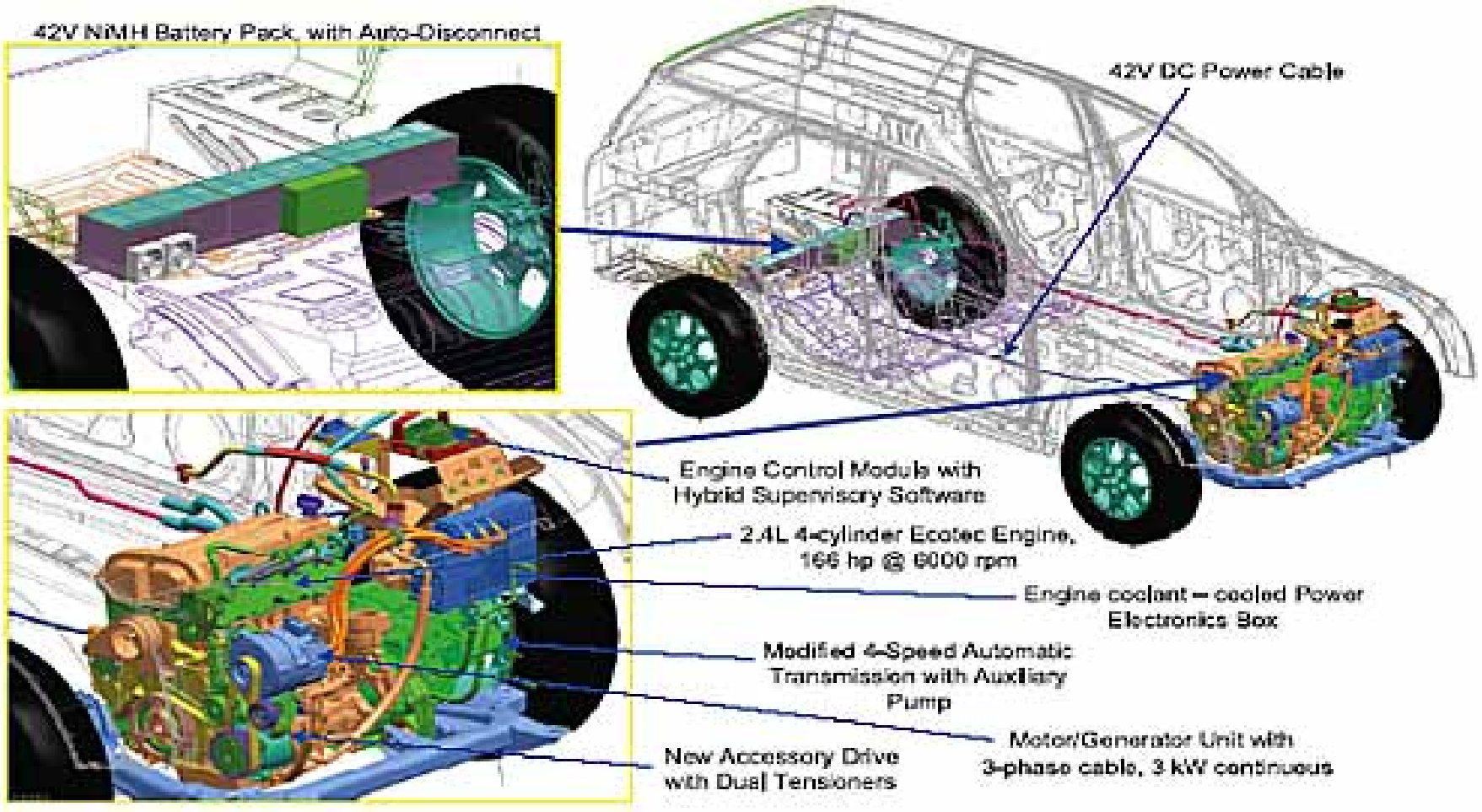
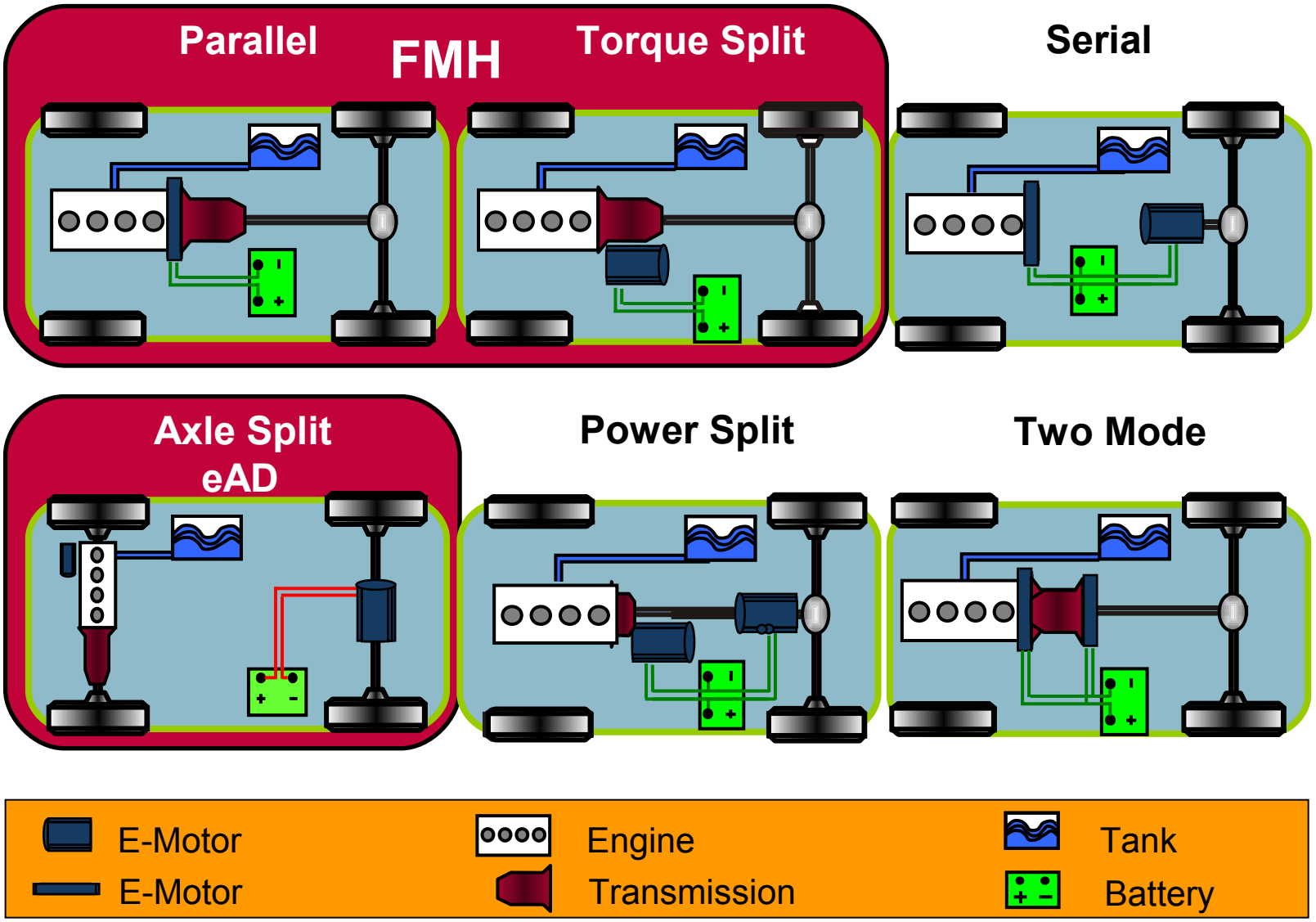


Figure 2: Toyota Hybrid System (THS) Layout

- SAE 2001-01-1335

Micro Hybrids-The Saturn VUE





Courtesy: Dr. Keim, LEES MIT, Dr. Rinderknecht, Getrag

One Parallel Implementation-Honda IMA

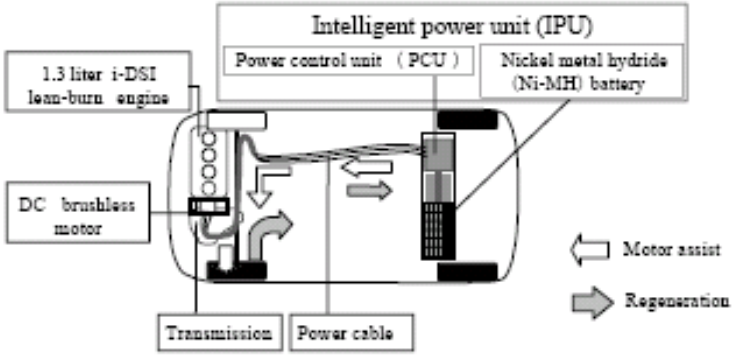
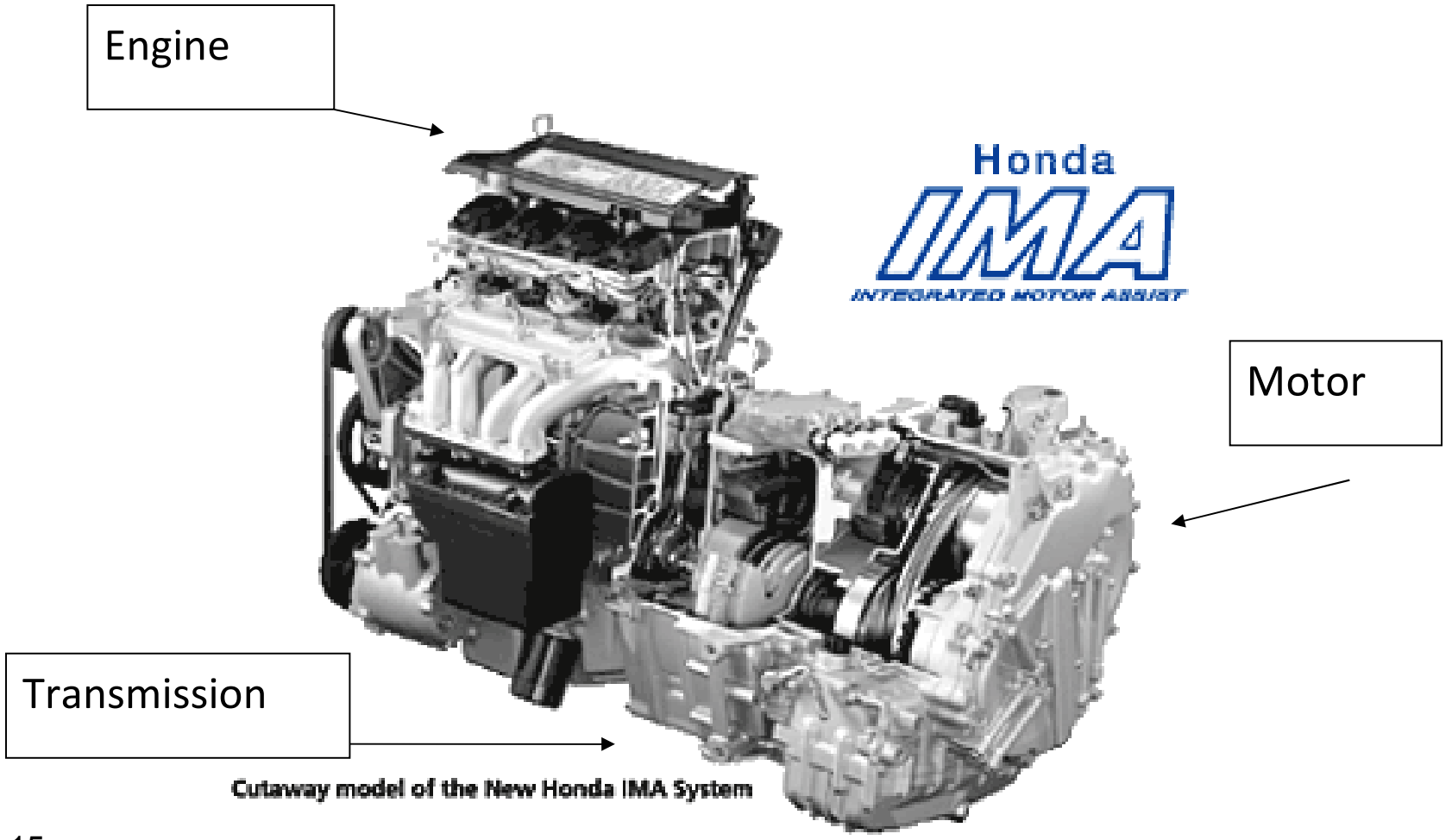


Fig.4 IMA system construction

2010 Honda Insight Hybrid with Integrated Motor Assist (IMA)

Source: http://blog.webridestv.com/2008/09/06/2010-honda-insight/

Parallel Only Implementation-Honda IMA



Parallel Only Implementation-Honda IMA

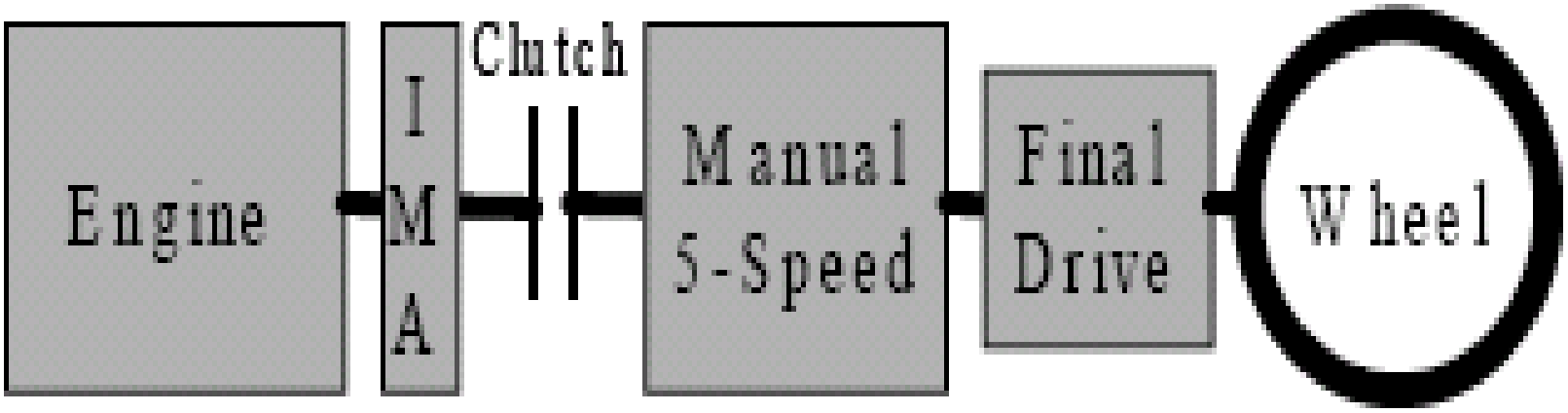
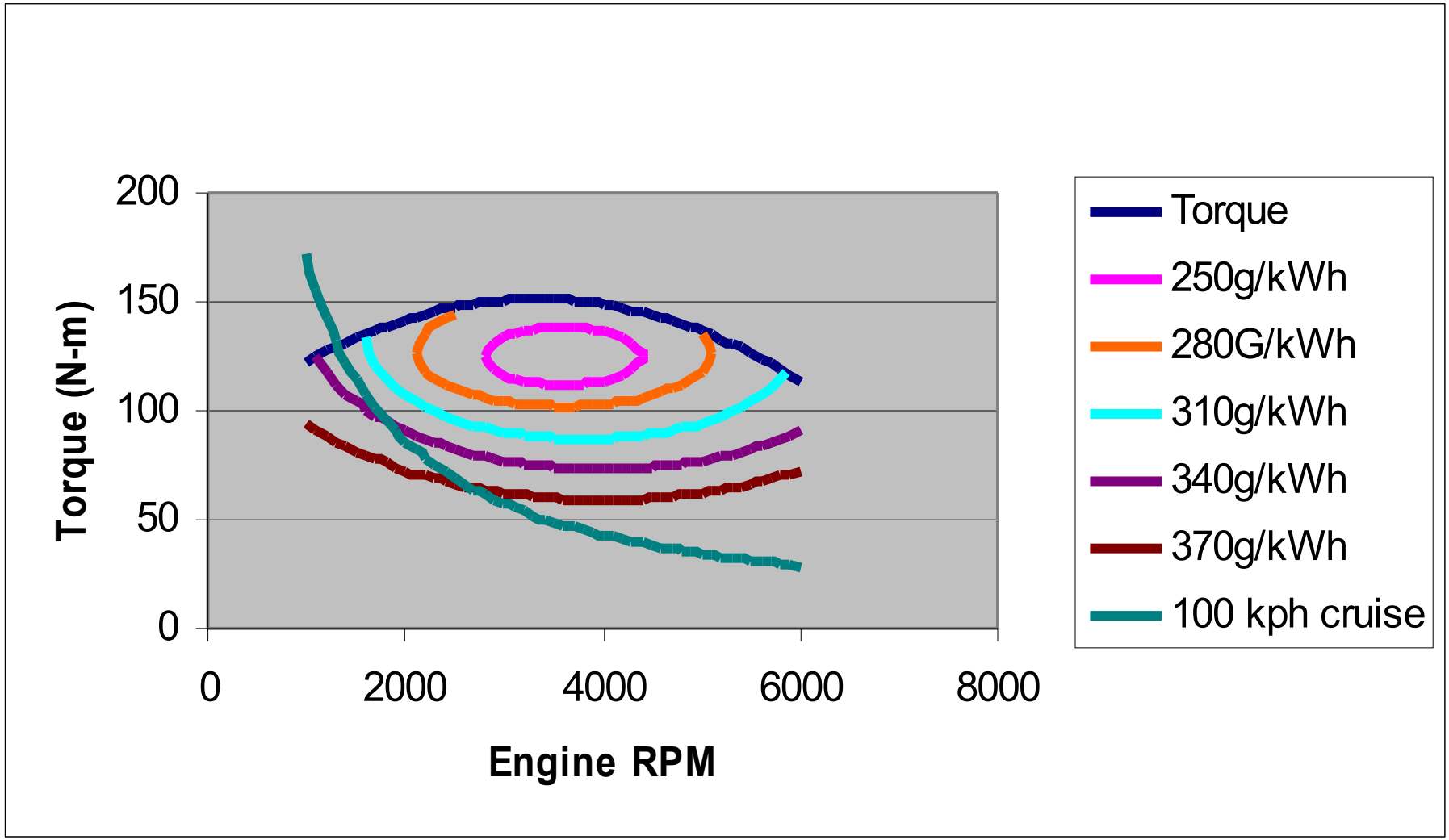


Figure 1: Honda Insight Powertrain Layout

Pros: Simple, cheap, easy packaging, most of the fuel savings.

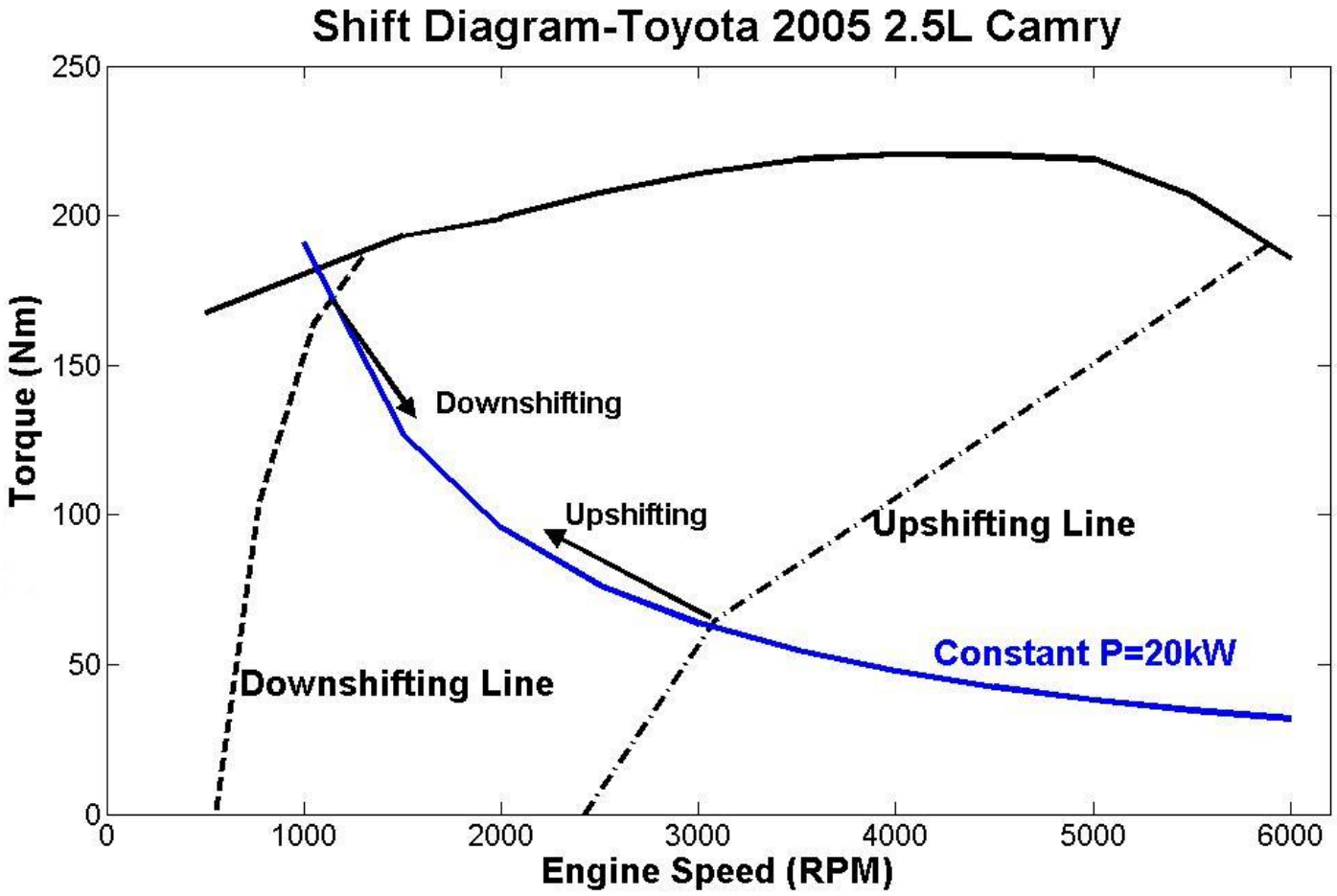
Cons: Engine Optimization, Regen. Braking

Engine Fuel Consumption Map



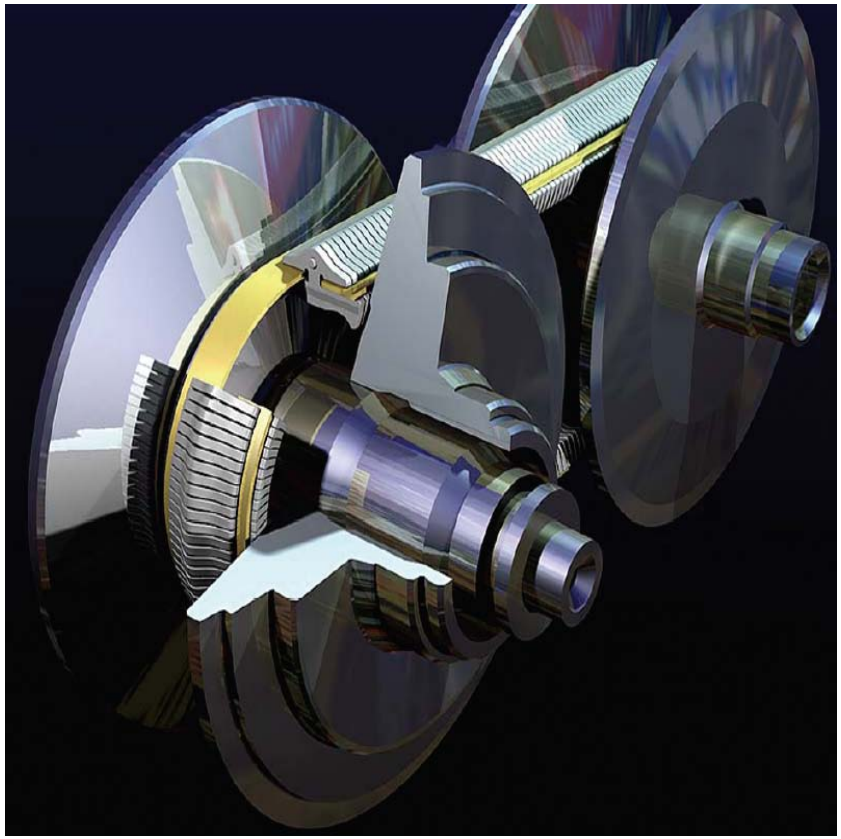
Courtesy:Dr Keim ,LEES MIT

Transmission Effects

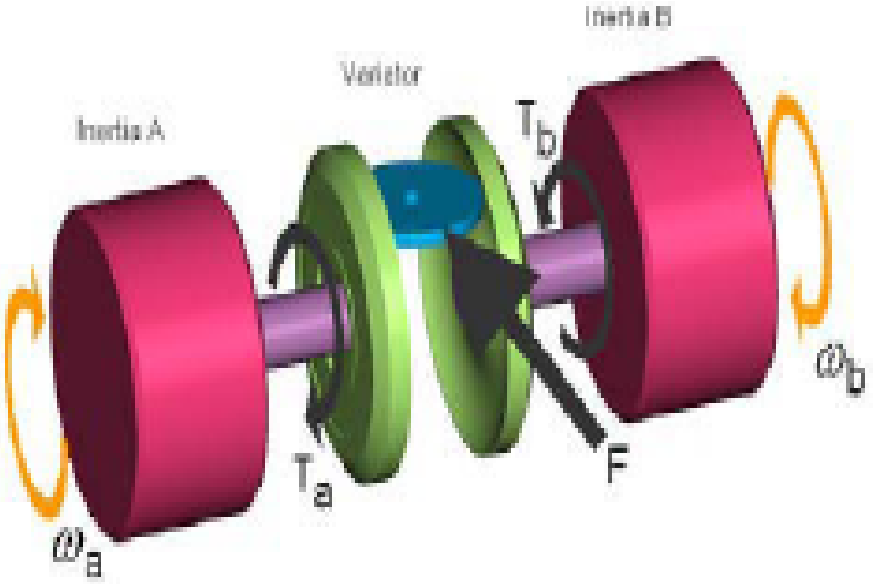


Efficient Continuously Variable Transmission in the Horizon?

Conventional CVT



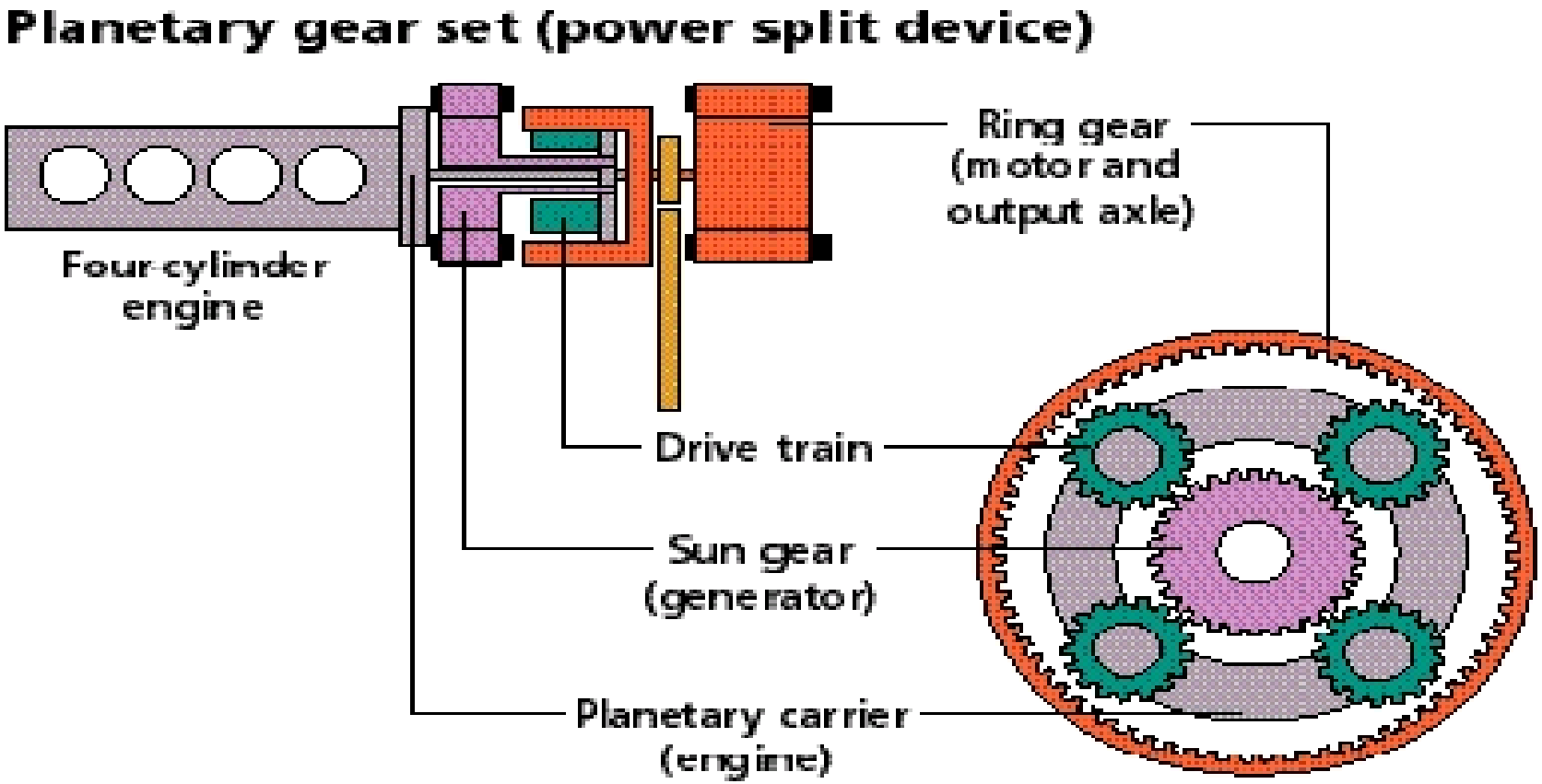
New (Toroidal) CVT



Toyota Prius 2010

Source: http://www.autobloggreen.com/photos/possible-leakage-2010-toyota-prius/1100518/

Toyota Parallel/Series Architecture



 Source: ADVISOR documentation

Prius

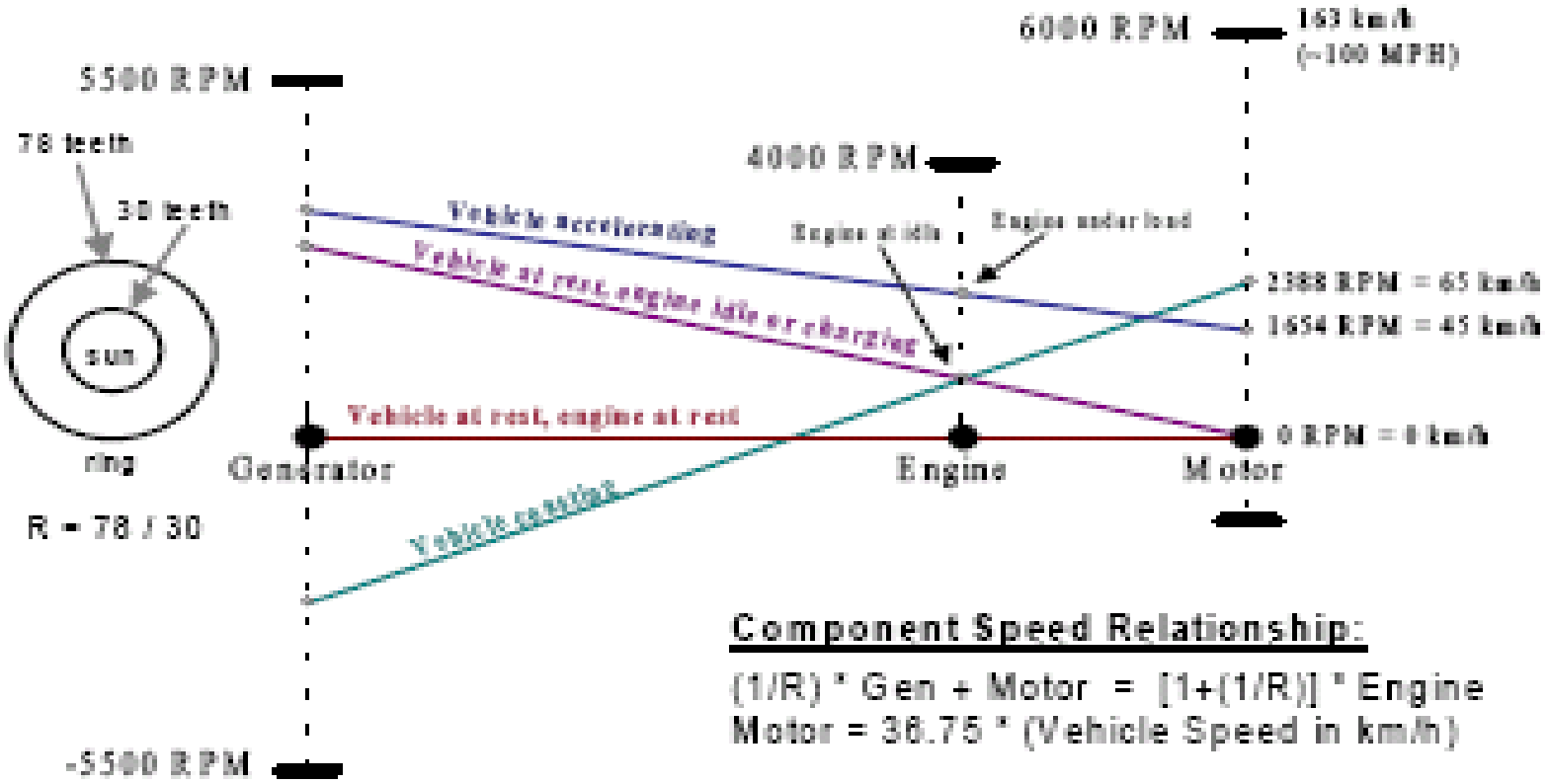


Figure 3: Relationship of Component Speeds of Japanese Prius

SAE 2004-01-0064

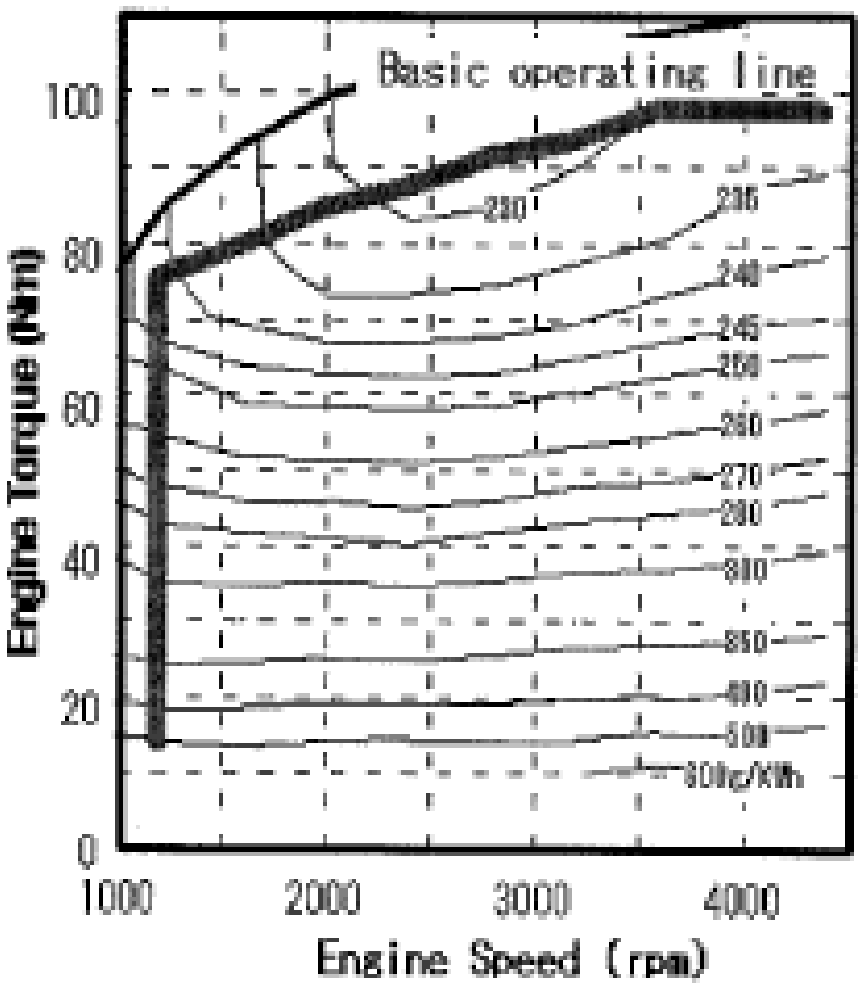


Fig.16 Basic Engine Operating Line

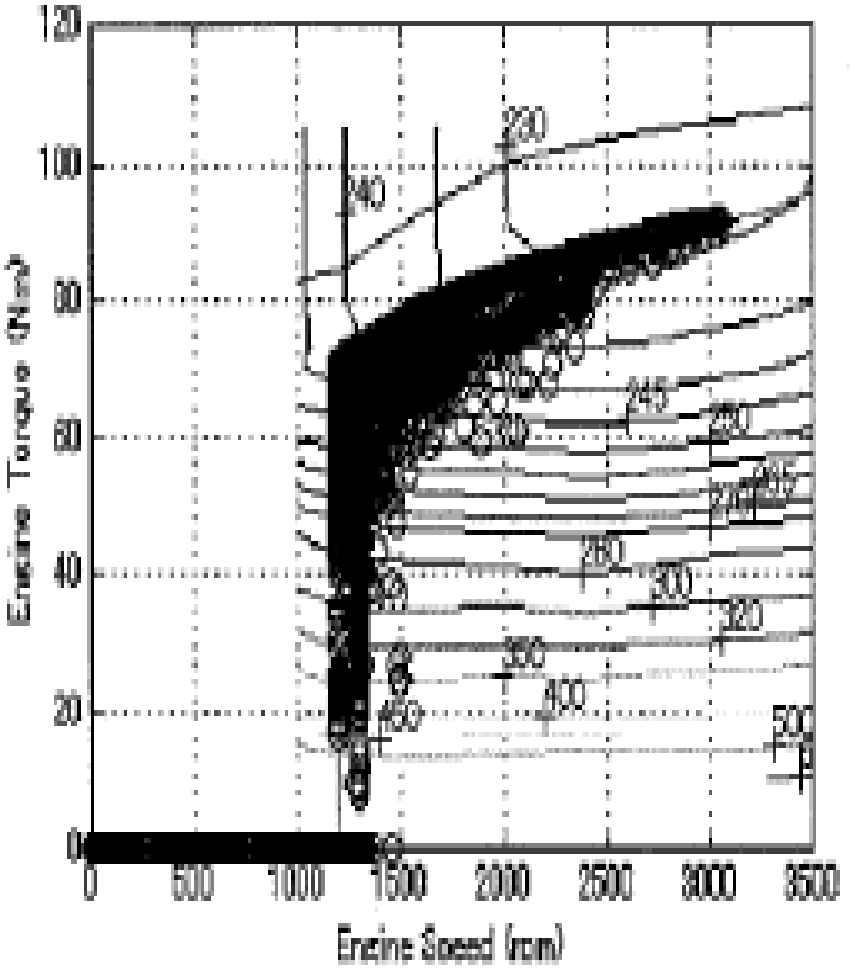
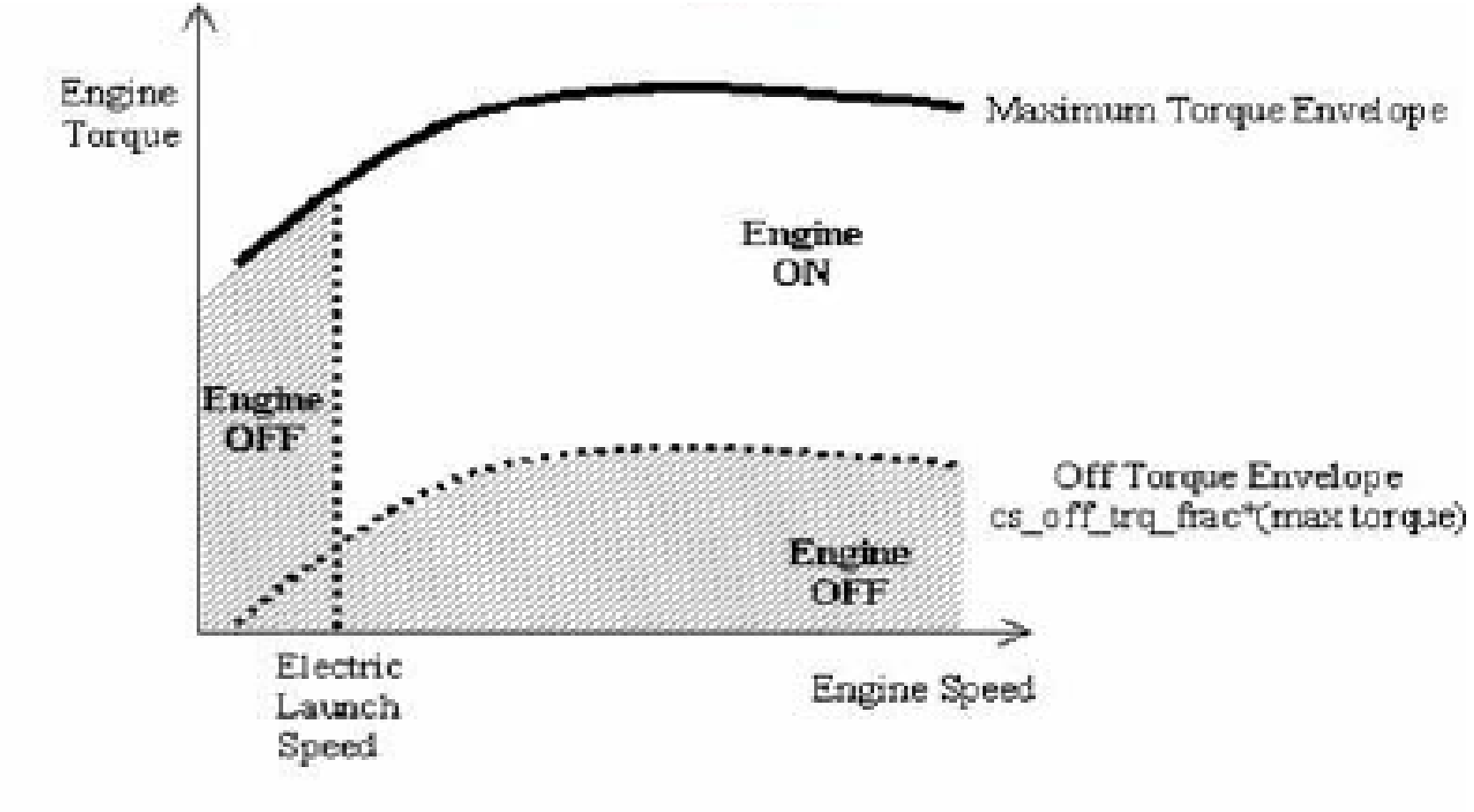


Fig.22 Engine Operating Area (LA4 cold start)

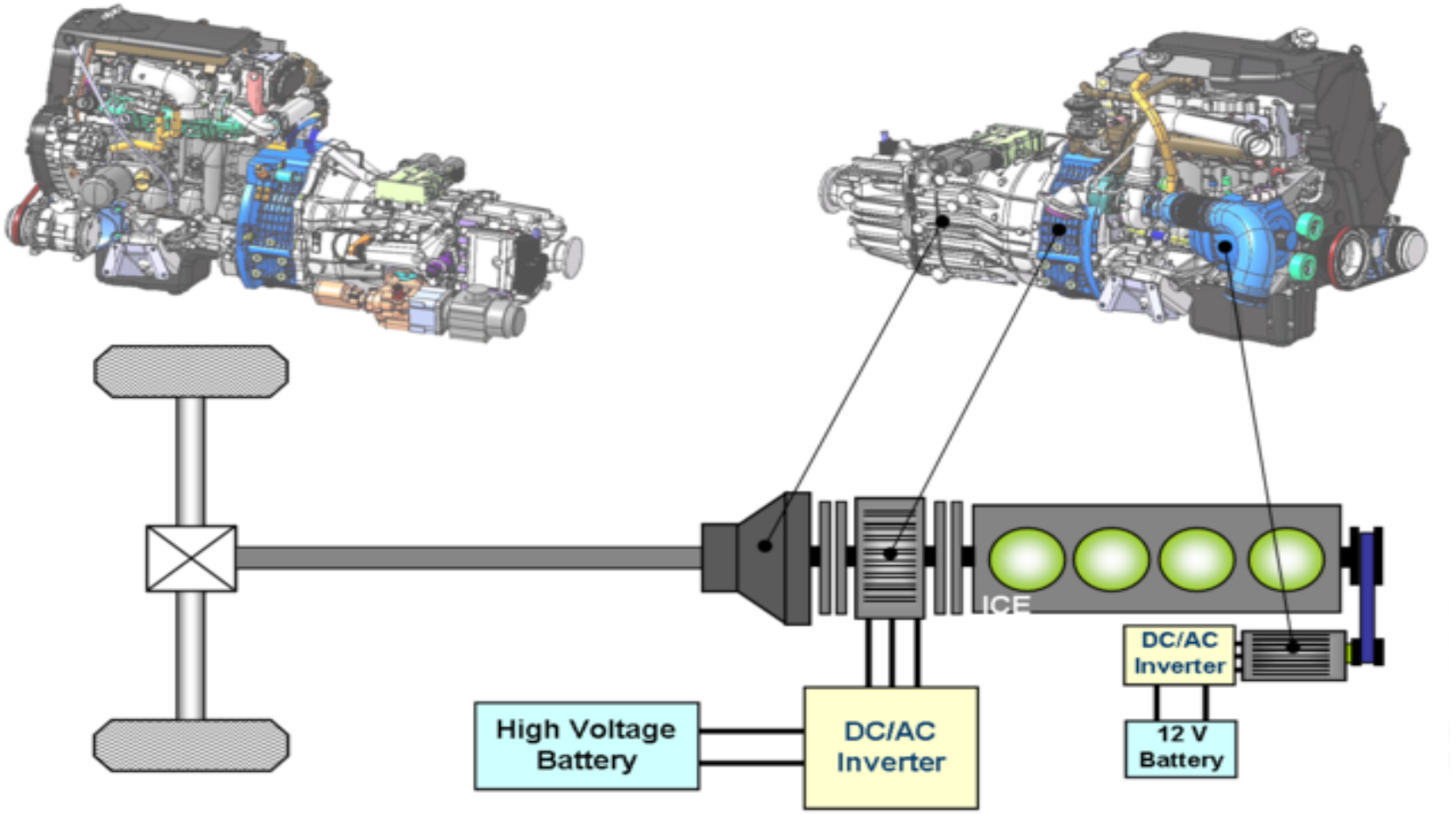
Hybrid Architecture/Control Strategy



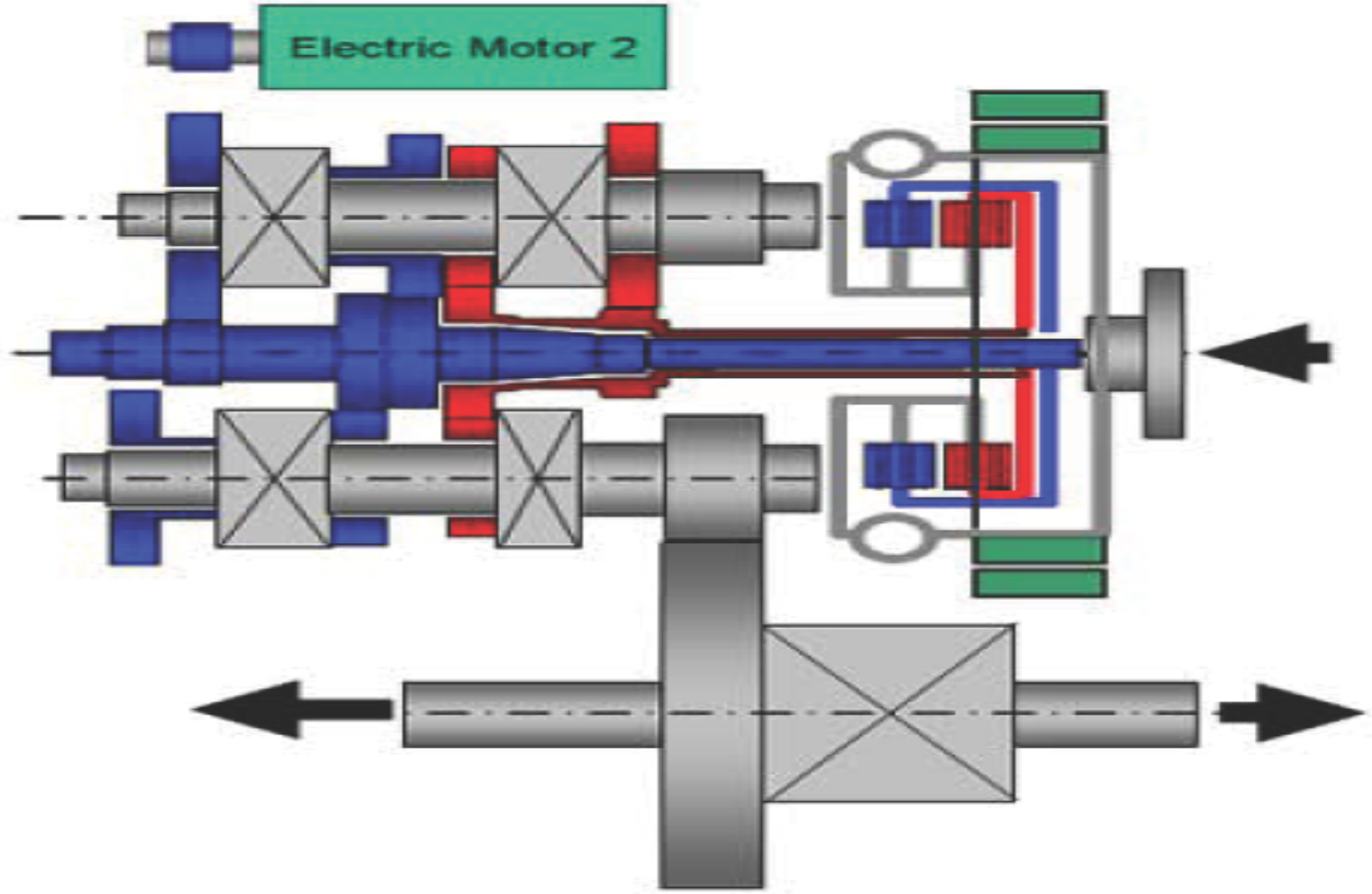
Fiat Hybrid

Source: http://www.autobloggreen.com/2008/04/14/fiat-going-hybrid-with-home-grown-system-within-the-next-3-years/

IVECO Hybrid System



Bosch-Getrag Hybrid System

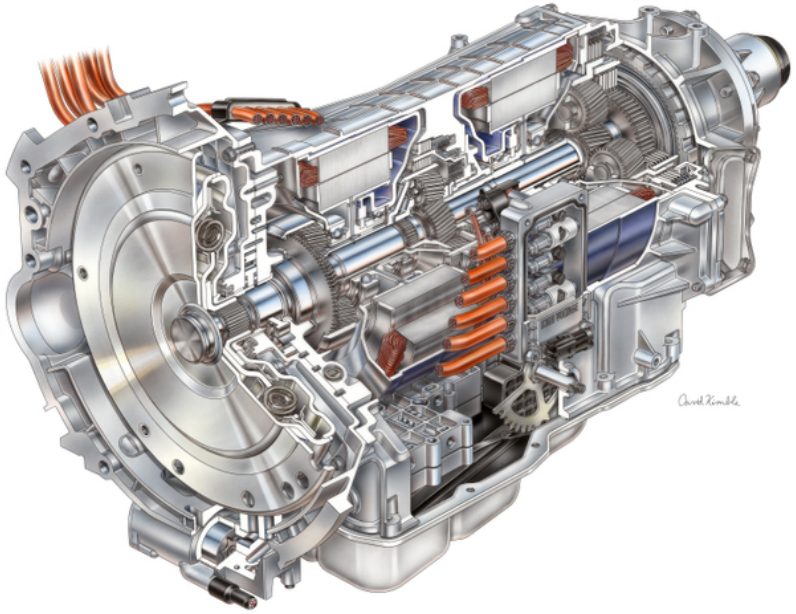


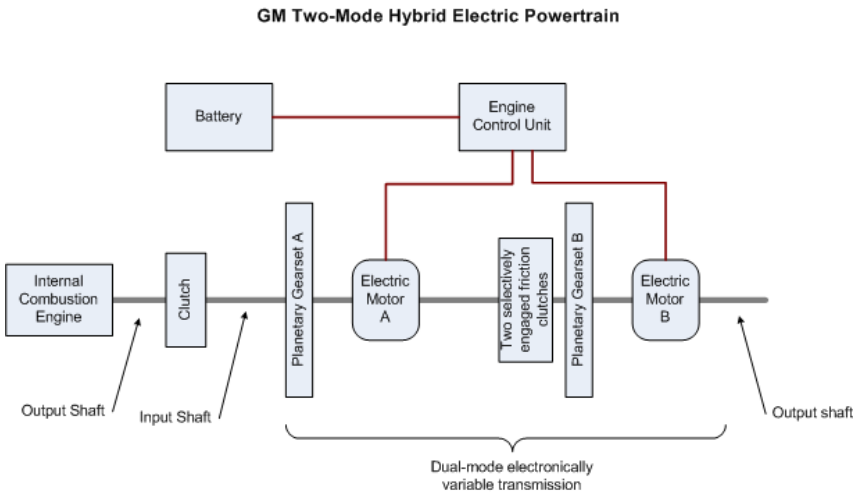
GM/Daimler/BMW Hybrid System

2009 GMC Yukon 2 Mode Hybrid

Source: http://www.motortrend.com/roadtests/suvs/112_0803_2009_gmc_yukon_2_mode_hybrid_first_test/index.html

GM/Daimler/BMW Hybrid System





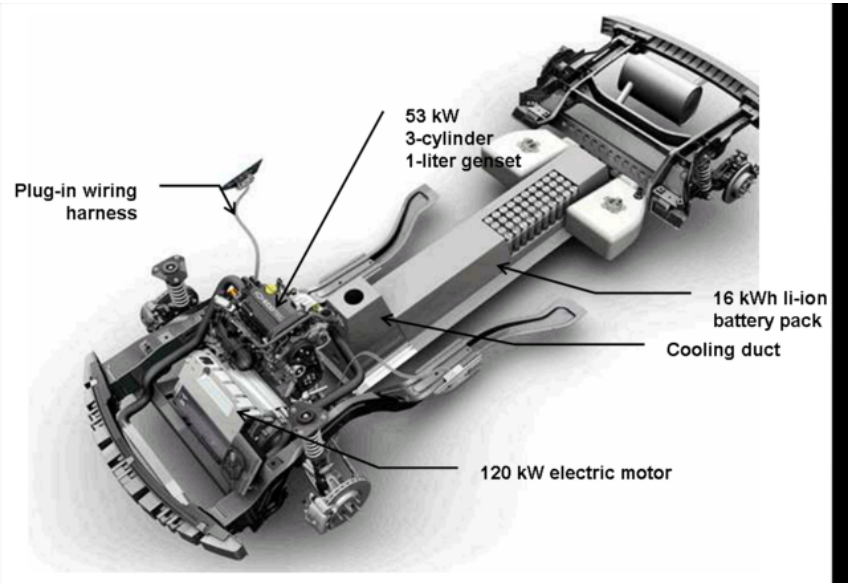
Possible Future Hybrid Architecture Pathways

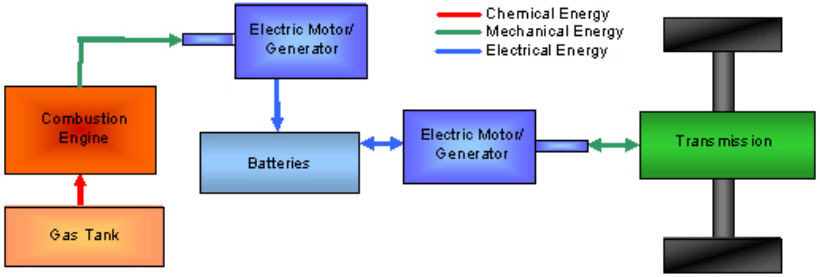
- "Actively" Optimizing
  - Power-Split Architecture (parallel/series)-Electric CVT
  - Parallel Architecture-Mechanical CVT. Gearbox Efficiency critical.
  - Parallel Architecture- "Special Manual/Automatic Transmission"
- Non "Actively" Optimizing
  - Parallel Architecture with Manual/Automatic transmissions (Honda)
  - Start/Stop (Micro Hybrids) with Boosted Efficient Engines
- The issue of relative electric system-What is Optimum?.

Chevrolet Volt

Source: http://www.nytimes.com/2008/09/14/automobiles/14AUTO.html?_r=1&oref=slogin

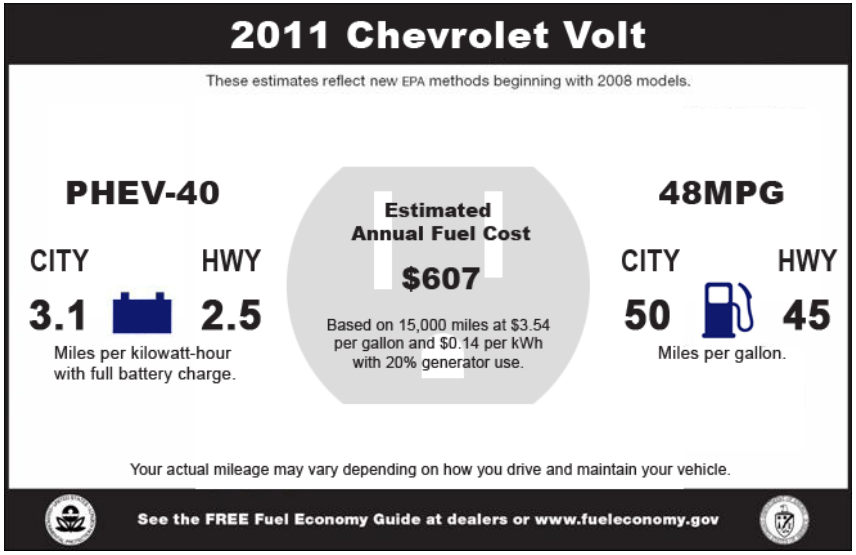
Series Hybrid





Source: http://www.advancedenergy.org/corporate/initiatives/heb/hybrid_tech.php

Can it get over 100 mpg?



Source: http://www.carbodydesign.com/archive/2007/01/10-chevrolet-volt-concept/
http://gm-volt.com/2008/10/13/epa-closer-to-giving-the-chevy-volt-at-least-a-100-mpg-rating/

Tesla Roadster

Tesla Roadster

1 BATTERY PACK
THE POWER SUPPLY IS SPLIT INTO 11 SECTORS OF 621 LITHIUM-ION CELLS. EACH SECTOR IS CONTROLLED BY ITS OWN PROCESSOR, WHICH MONITORS THE CHARGE AND DISCHARGE RATE OF EVERY CELL.

2 SAFETY MONITORS
AN ACCELEROMETER, SMOKE DETECTOR, VOLTAGE METER, TEMPERATURE GAUGE, AND WATER SENSOR CAN DETECT A CRASH OR OTHER FAILURES AND SHUT THE BATTERIES DOWN TO PREVENT FIRE OR EXPLOSION.

3 INVERTER
THE INVERTER USES 72 INSULATED TRANSISTORS TO TRANSFORM THE BATTERY'S DC ENERGY INTO AC POWER. IT DELIVERS ALMOST 80 PERCENT MORE POWER THAN GM'S NOW-DISCONTINUED EV1.

ELECTRIC RIDE

THE TESLA ROADSTER PUTS THE CHARGE BACK INTO SUPERCHARGED, THE ALL-ELECTRIC, HIGH-PERFORMANCE SPORTS CAR IS POWERED BY THE SAME BATTERIES THAT RUN YOUR LAPTOP. WIRED GOT THE FIRST GUIDED TOUR. – J.D.

4 MOTOR
AT THE HEART OF THE AC ELECTRIC MOTOR IS A HIGH-EFFICIENCY ROTOR. THE BREAKTHROUGH: IT'S MADE OF BRAZED COPPER, WHICH IS MORE CONDUCTIVE THAN CONVENTIONAL ALUMINUM ROTORS.

5 COOLING
THE INVERTER'S TRANSISTORS PRODUCE VERY LITTLE HEAT, ALLOWING THE CAR TO USE LIGHTWEIGHT, ENERGY-EFFICIENT AIR COOLING, WHICH VENTS THROUGH A TAILPIPE.

6 HEATING
SINCE THERE IS NO CONVENTIONAL ENGINE TO PROVIDE CABIN HEATING, THE ROADSTER HAS AN ELECTRIC HEATER. ONE BONUS: IT DELIVERS HEAT IMMEDIATELY – NO WAITING FOR AN ENGINE TO WARM UP.

7 PARTS
TESLA HAS DEALS WITH VARIOUS MANUFACTURERS TO SUPPLY THE WINDSHIELD WIPERS, BRAKES, SUSPENSION, AND OTHER COMPONENTS – THERE'S NO NEED TO REINVENT THE HIGH-PERFORMANCE WINDSHIELD WIPER.

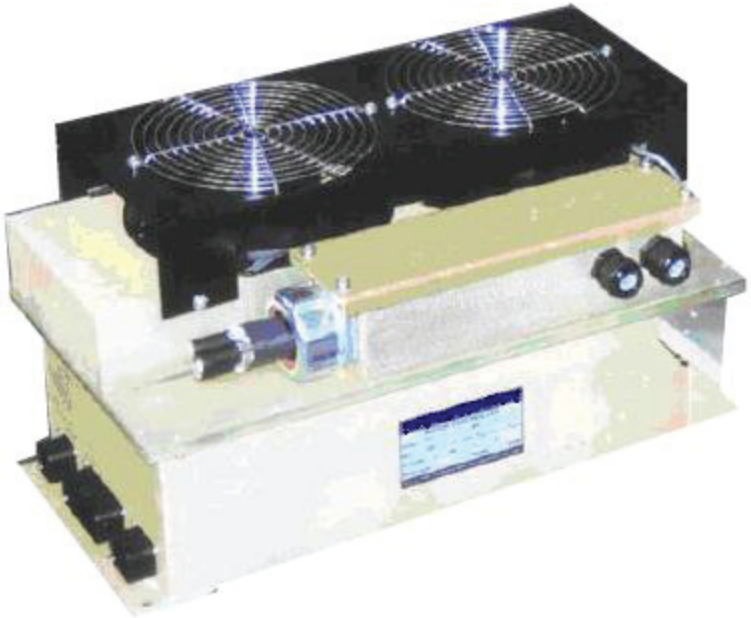
Source: www.treehugger.com

DIY Conversions

Motor

Fixed gear transmission

DMOC (Digital Motor Controller)



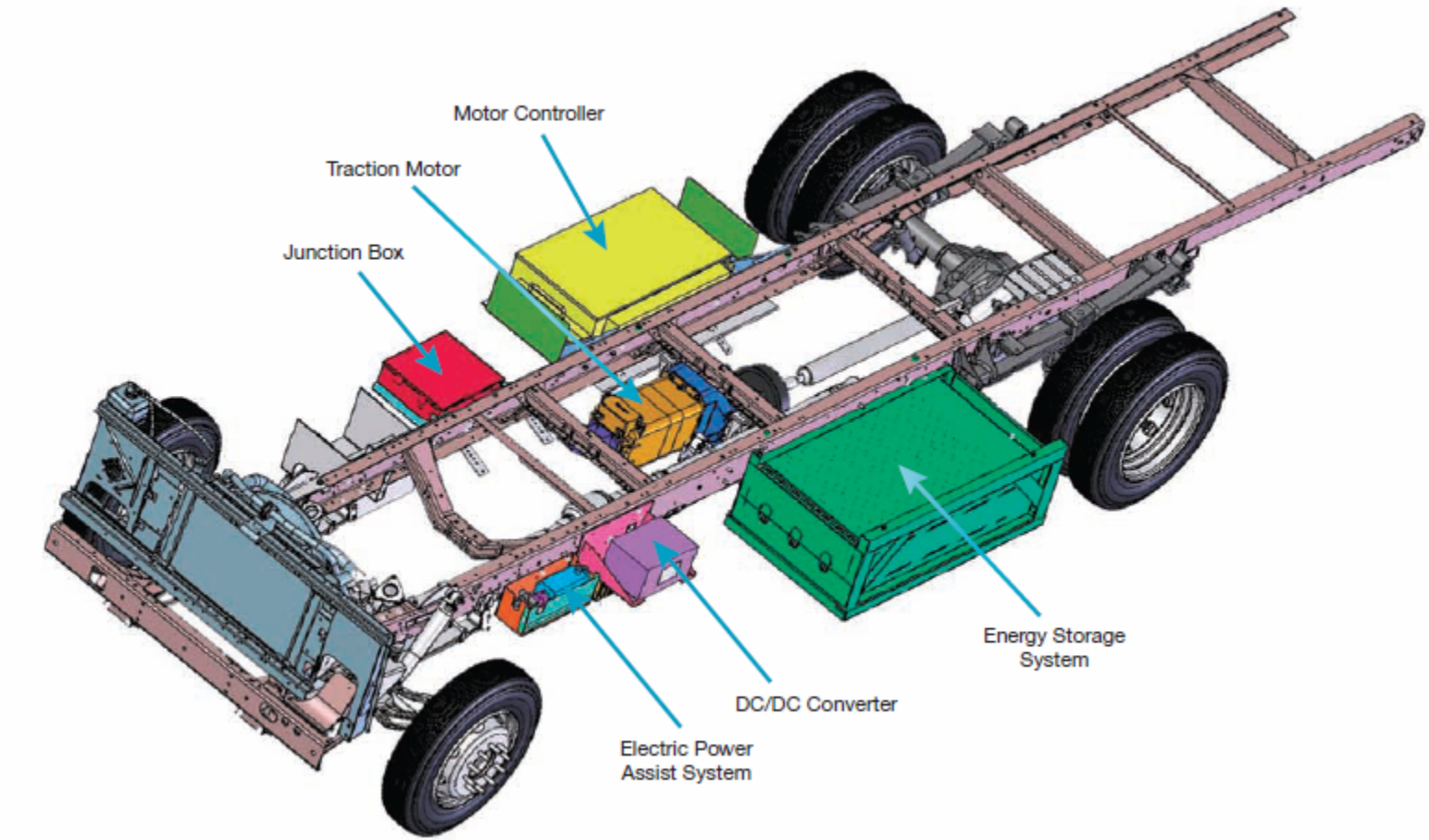
Azure Dynamics (former Solectria) AC24LS kit

All-Electric conversion

1995 Chevrolet S-10
~$12,000 not including labor

Source: http://www.cnn.com/2008/TECH/ptech/08/14/electric.cars/index.html

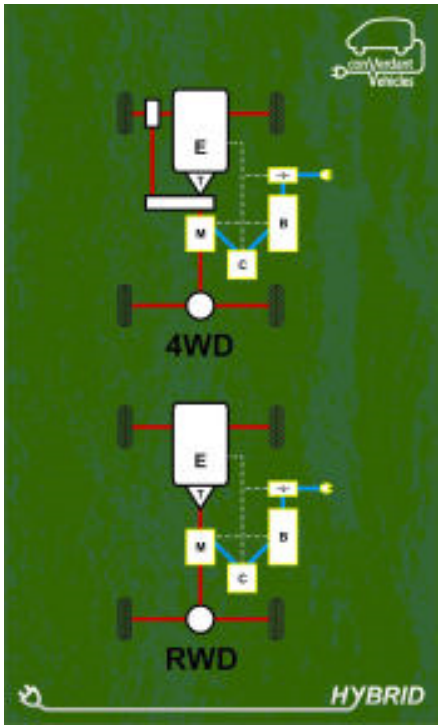
All-Electric Truck Conversion



Source: Azure Dynamics

Plug-in Hybrid Truck Conversion

Post-transmission motor mounted on transaxle



Source:http://www.converdantvehicles.com

Hybrid to Plug-in Hybrid Conversion

Hymotion/A123 L5 Li-Ion plug-in hybrid conversion kit

Purchase price is $9995 (plus a $400 “destination fee”) for a 5 KWh pack with a 4.5 hour charge time, 30-40 PHEV miles, and adding 180 pounds.

Source: cnet.com, http://www.eaa-phev.org/wiki/Hymotion

Final Topic: Policies for EVs

- Economics of EVs and HEVs
- Options for Promoting EVs
  - Market Incentives
  - State and Local Incentives
- Obama and EVs
- Project Better Place

http://www.evworld.com

http://www3.allaroundphilly.com

http://graphics8.nytimes.com

Cost of Driving: EV vs. Conventional

Battery Electric Vehicle

On-board energy consumption	300 Wh/mile
Charging Efficiency	90%
Electricity consumption	333 Wh/mile
Electricity Cost	10 cents/mile
Driving Cost (electricity only)	**3.3 cents/mile**

Conventional Gasoline Vehicle

Fuel economy	25 MPG
Fuel Cost	$2.00/gallon
Driving Cost (fuel only)	**8.0 cents/mile**

At 15,000 miles/year, you would save $700/year on fuel

The estimated price range for advanced batteries is $500 - $1,000 per kWh

~ buying 1 kWh of battery energy (~3 miles of electric range) each year

Economics of Hybrids Available Today

Vehicle	Hybrid Premium	Payback time (years)
Toyota Prius	$2,303	4.2
Chevrolet Malibu Hybrid	$535	4.6
Toyota Camry Hybrid	$1,381	4.8
Ford Escape Hybrid	$2,310	5.0
Saturn Vue Green Line	$1,774	5.8
Honda Civic Hybrid	$2,734	7.4
Nissan Altima Hybrid	$2,221	8.4
Saturn Aura Green Line	$1,095	9.4
Lexus GS450h	$2,280	10.8
Lexus RX400h	$4,767	11.7
Toyota Highlander Hybrid	$6,986	22.8

http://money.cnn.com/galleries/2007/autos/0711/gallery.hybrids_that_pay/2.html

Primary Options to Advance EVs

1. Market incentives
   - Federal tax credit for energy efficient vehicles of the Energy Policy Act of 2005
   - Plug-in Electric Drive Vehicle Credit of the Emergency Economic Stabilization Act of 2008
   - State tax credits
   - Regional and local incentives

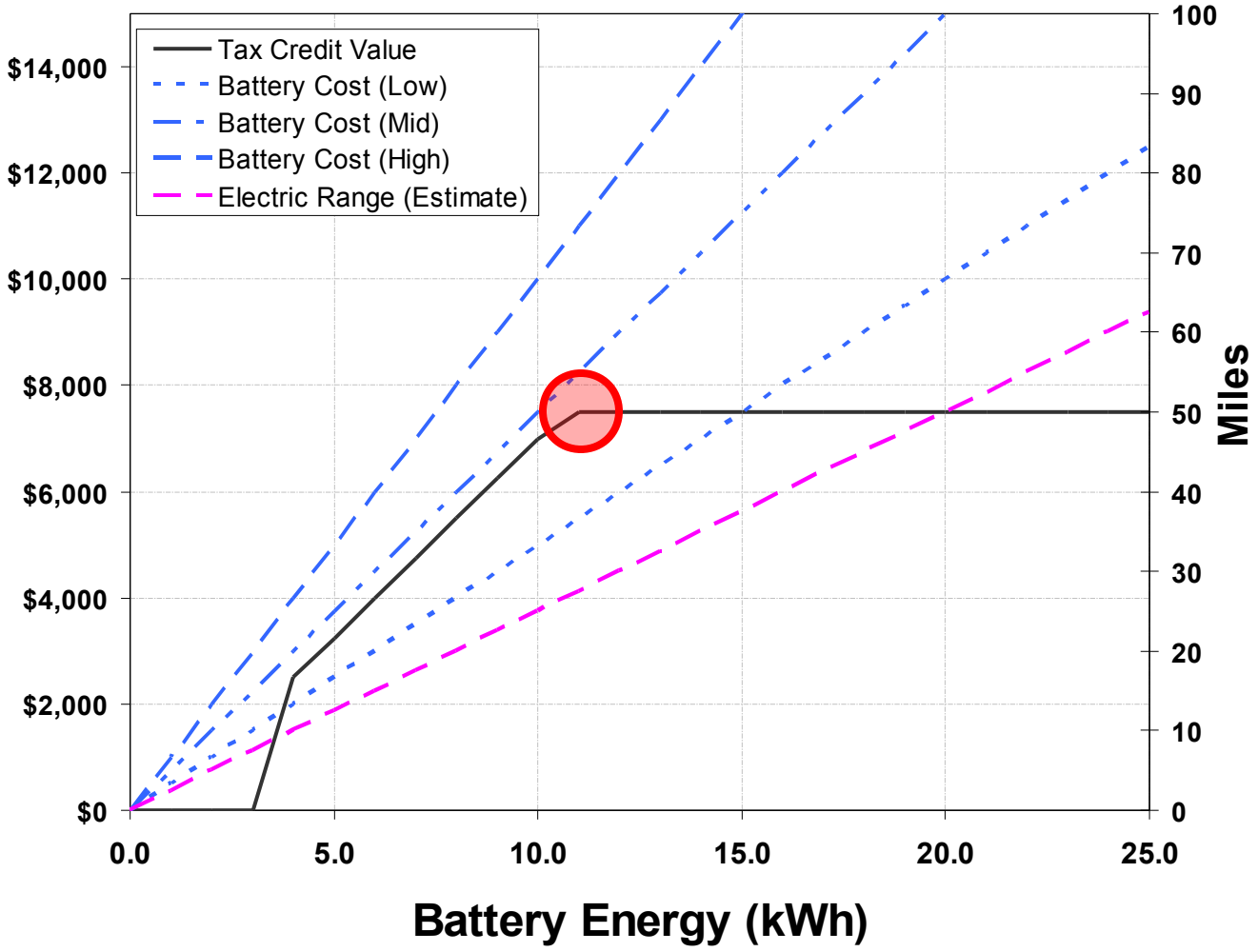
1. R&D

1. Demonstration and deployment

http://www.transportation.anl.gov

http://www.energy.gov

Federal Plug-in Electric Drive Vehicle Tax Credit of 2008



Regional Incentives

Use of HOV lanes

AZ, CA, FL, GA, NJ, NY, UT, VA

Free parking

Select cities in CA, MI, MD, TX

State Tax Credit or Rebate

CO, IL, OR, PA, SC, WV

Partial Sales Tax Exemption

CT, ME, NM, TN, WA

Battery Manufacturing Incentives

MI

http://www.toyota.com

http://www.treehugger.com

Better Place plans to bring an entire EV infrastructure

http://www.wired.com

Business plan like that of mobile phone

Better Place owns the batteries, the consumer pays for energy (miles)

Plan includes charging stations and battery swapping

So far: *Israel, Denmark Australia, California, Hawaii, and Canada*

Obama and EVs: promises and decisions

Promises

- Put 1 million Plug-In Hybrid cars on the road by 2015

Decisions

- Attach strings to automaker bailouts?
- Allow states to establish GHG limits?
- Establish new CAFE standards?

http://graphics8.nytimes.com

In conclusion; you now know more than most about EVs, PHEVs, and HEVs

- Introduction to EVs
- EV Issues and Terminology
- Batteries for EVs
- Electric Motors for EVs
- EV and HEV Powertrains
- EV and PHEV Conversions
- Policies and Initiatives for EVs

For more information:

web.mit.edu/evt/iap2009

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Questions?