MAXIMIZING BENEFITS FROM CURRENT TECHNOLOGY

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PASSENGER VEHICLE GHG SYMPOSIUM
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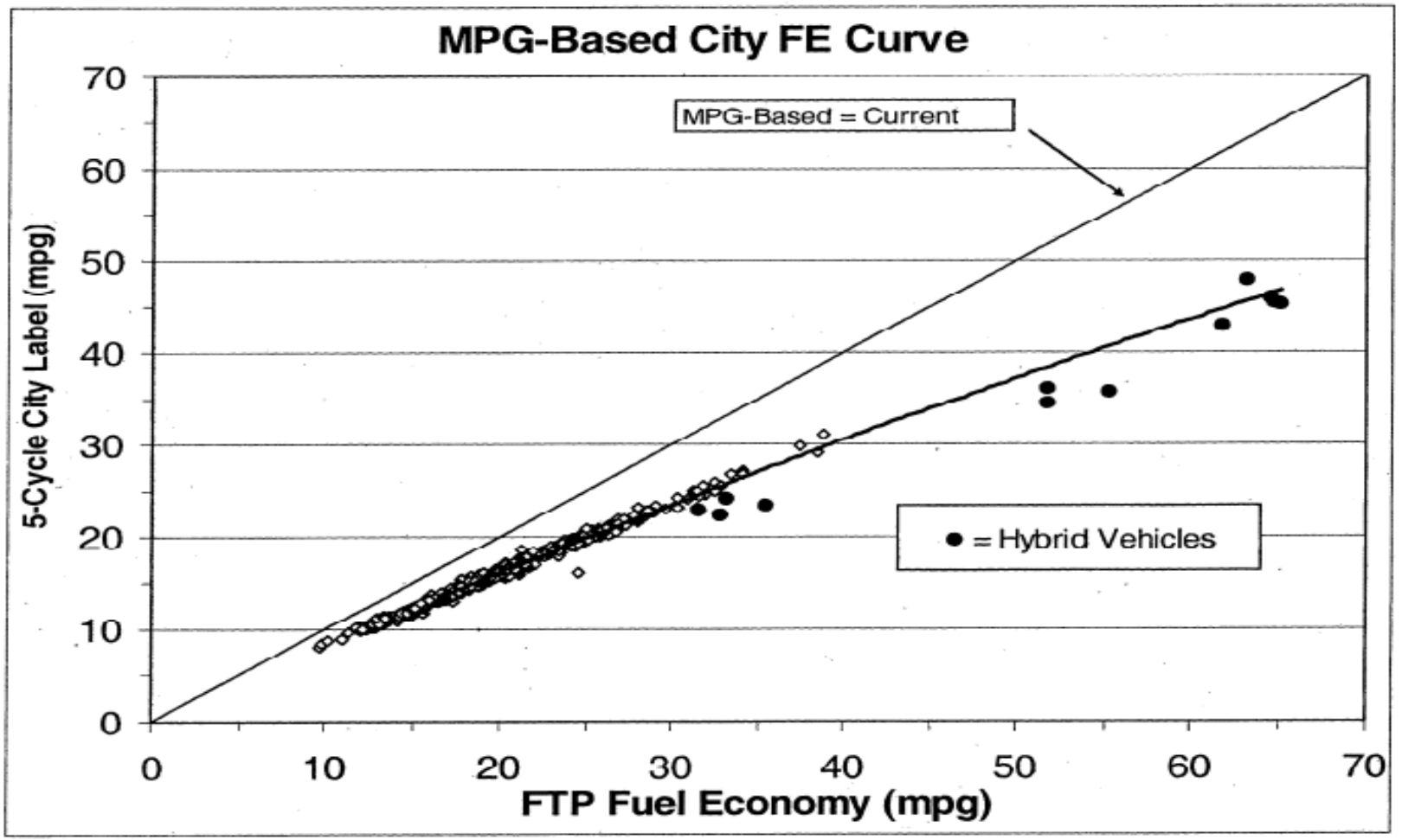
Challenges for California

- GHG targets for 2020 for passenger vehicles are aggressive; accounting shows another 10 to 15% reduction is needed even with Pavley 2 and LCF standards.
- Moving beyond proposed Pavley targets for 2016 is tough; 2020 proposed targets may be at limit for new cars and light trucks.
- Answer to challenge lies in the fact that on-road FE is much lower than FTP FE :
- MEET PAVLEY TARGET SHORTFALL BY REDUCING ON-ROAD SHORTFALL !

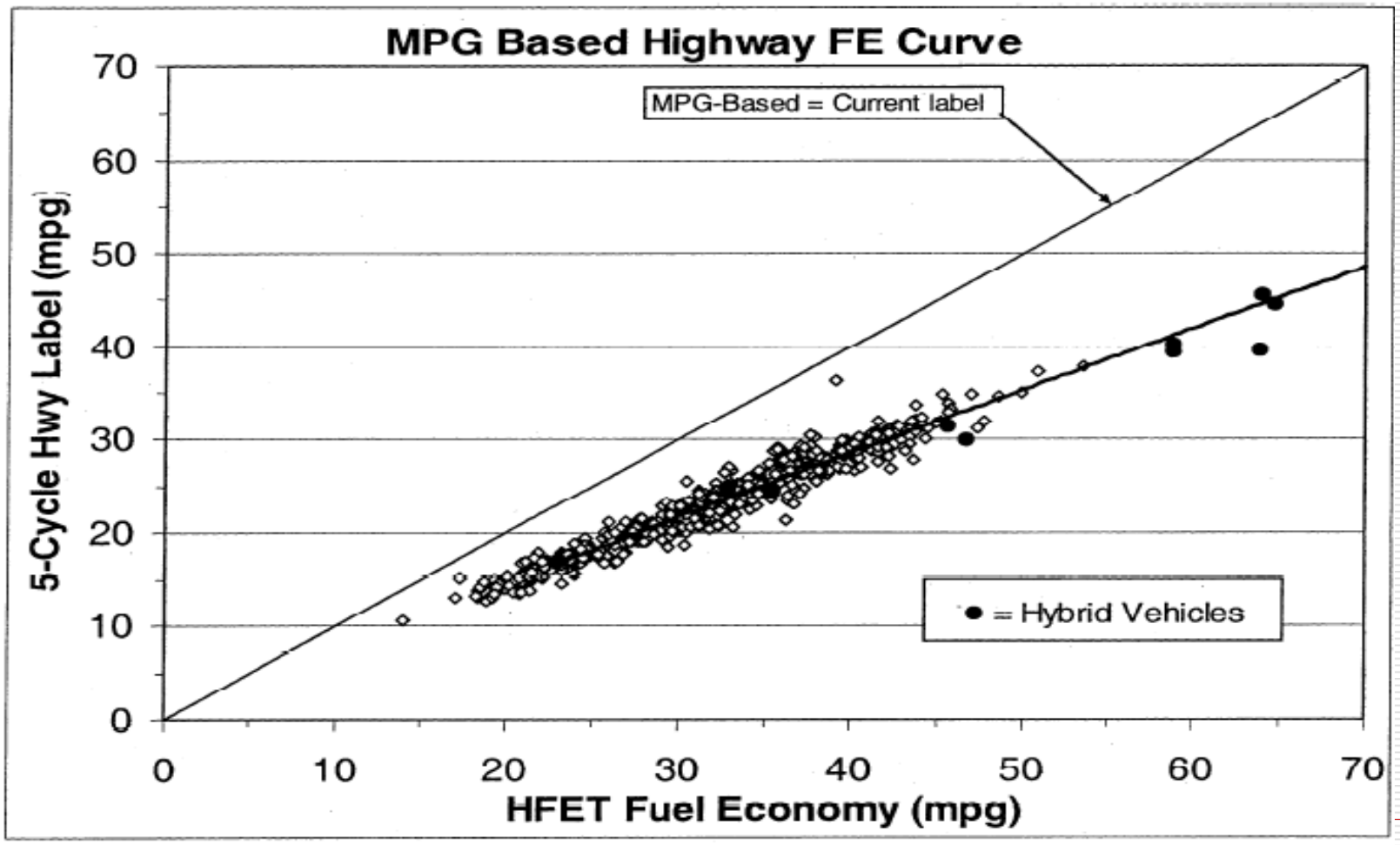
ON ROAD SHORTFALL

- Although there is little hard data, limited evidence suggests that the difference between FTP FE and on-road FE is growing.
- EPA's analysis for new vehicle FE labels shows that %shortfall increases as absolute FE increases.
- Size of the shortfall is in the range of 20 to 25%, i.e. fuel consumption and GHG emissions are 16 to 20% higher on-road relative to CAFÉ or GHG target on FTP.

EPA FINDINGS: CITY SHORTFALL



EPA FINDINGS: HIGHWAY SHORTFALL



Causes of On-Road Shortfall

- While there are many reasons why vehicles have lower FE on-road, four of the major causes are
  - Air conditioner use during warm weather
  - Excessive idling and very low speed operation in congested driving conditions
  - Cold start related loss from engine warm-up, especially on short trips and at low ambient temperatures
  - Aggressive driving, city and highway

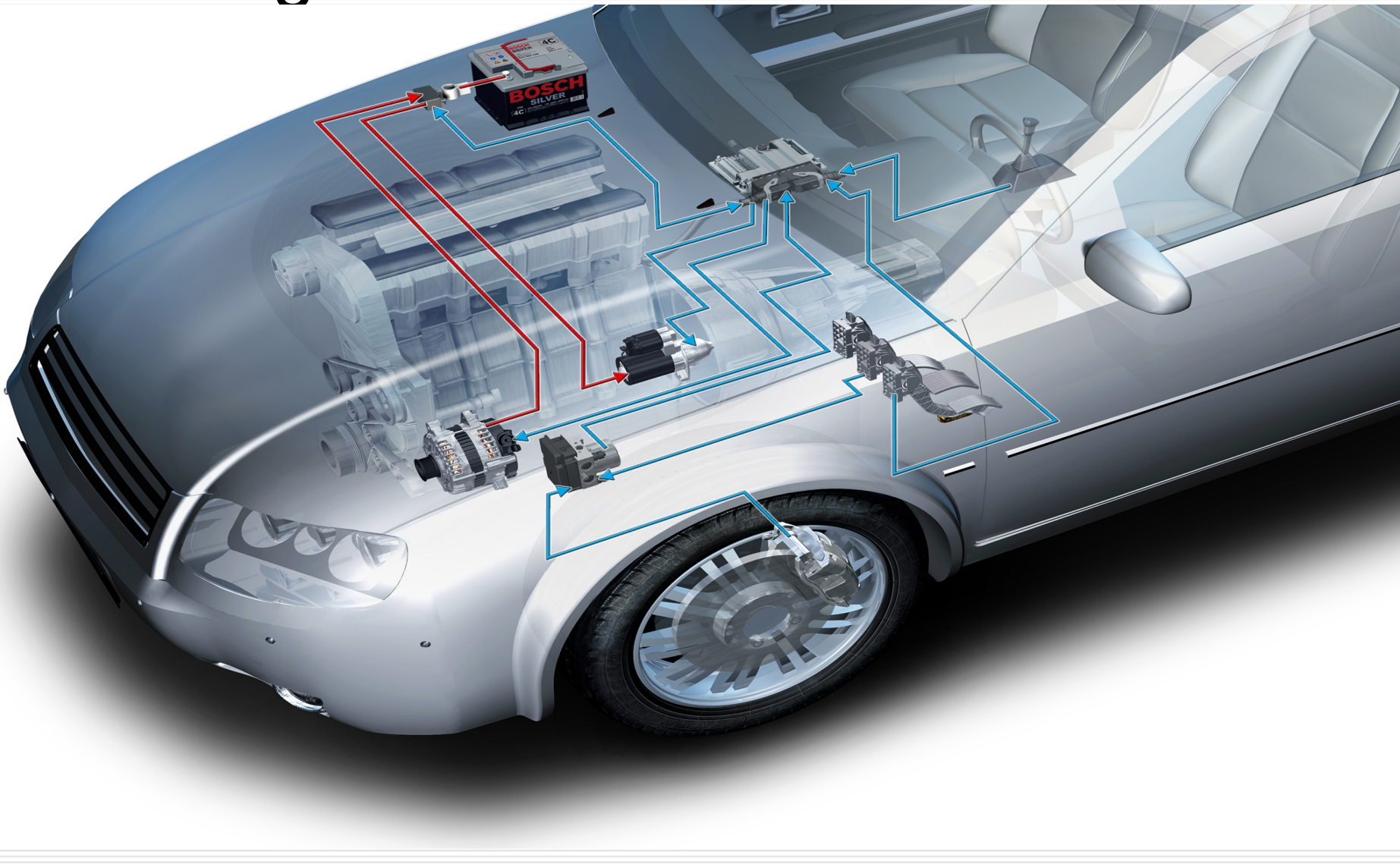
Attention to On-road FE

- ARB and others like IEA have focused on several elements of shortfall, e.g., after market tires, Fuel efficient lubricants, AC efficiency credits, etc.
- EEA analysis suggests that a suite of technologies provides more benefit on-road than on the FTP, to reverse shortfall trends.
- Importantly, the technologies have very favorable synergies with each other and very favorable effects on actual emissions

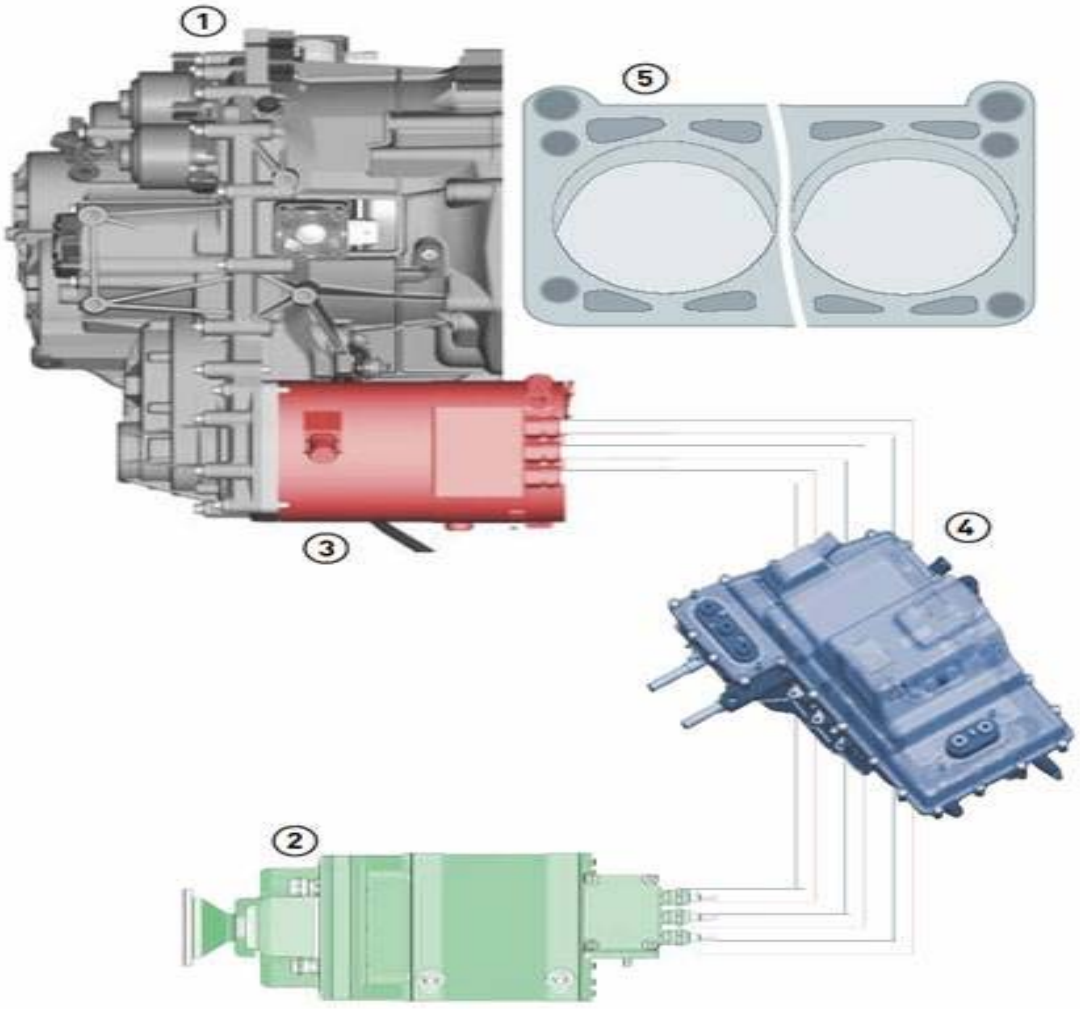
KEY TECHNOLOGY

- EEA-ICF analysis shows engine shut-off at idle to be a key ‘enabling’ technology that has many benefits.
- ARB analysis for Pavley and ZEV mandate focuses on Prius type hybrid but options include
  - Enhanced starter which is lowest cost approach
  - Belt starter-alternator, 14V or 42V
  - Crankshaft mounted one-motor hybrid (IMA)
  - Double clutch AMT with electric motor(s)

Intelligent Starter



Double Clutch AMT - Hybrid

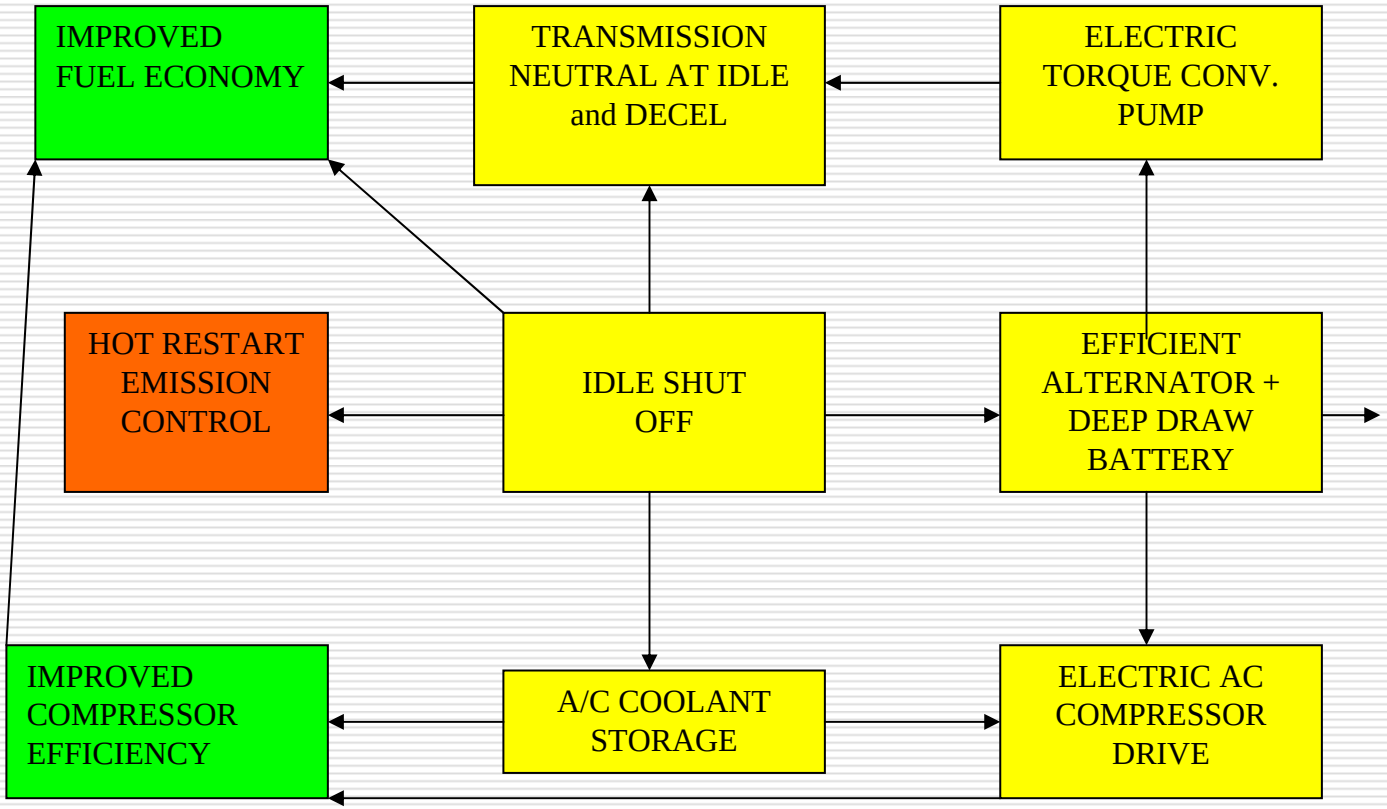


1. **GETRAG PowerShift® Doppelkupplungsgetriebe**
   GETRAG PowerShift Dual-Clutch Transmission
2. **Elektrisch betriebener Hinterachsantrieb**
   Electrical rear Axle Drive
3. **E-Maschine**
   E-machine
4. **Leistungselektronik**
   Power Electronics
5. **Motor**
   Engine

Basic Technology Suite

- While idle-stop can be implemented cheaply even with enhanced starter, it forces
  - Transmission shifting to neutral at idle and deceleration
  - an electric pump for the torque converter.
  - Significant upgrade of battery and electrical system even for 14V systems
  - AC coolant storage strategy, with possible electrical drive of AC compressor
  - Possible very low speed electric drive with BAS and more expensive concepts
  - AMT based mild hybrid concepts can eliminate torque converter with reduction in converter loss.

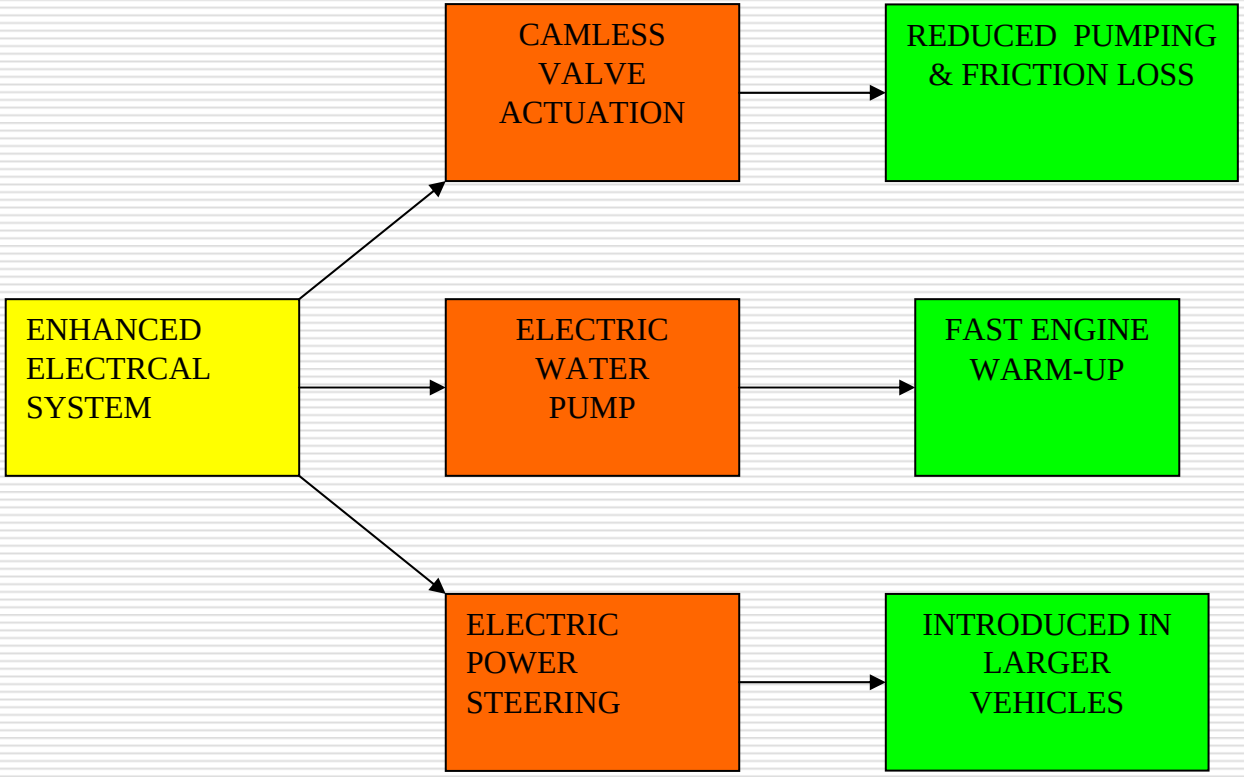
Idle Stop Requirements



Further Favorable Synergy

- The idle-stop system requires a upgraded electrical system in vehicles which make a range of additional improvements possible and very cost-effective:
  - Electric water pumps that can promote fast warm-up of the engine
  - Electric power steering which requires high power in larger vehicles
  - Camless valve actuation that is more efficient in conjunction with an efficient alternator and an electric system that supports additional power demand.

Secondary Synergies



Impact on Shortfall Causes

- Idle stop will have very significant benefit in congested driving, especially if electrical system can provide “creep”, possible with BAS and higher concepts.
- Electric water pump can reduce warm-up time by ~50% at cold ambient
- Electric AC drive with coolant storage and other vehicle improvements (paints, glass) can reduce AC drive energy by an additional 30 to 40% over contemplated system improvement.
- Indirect effect on making EPS and Camless valves more cost effective will help advance technology to meet Pavley goals.

Potential Policy Needs

- While ARB and CEC have been paying attention to several specific technologies, there can be an integrated policy thrust to combine technology that reduces shortfall.
- Many of these technologies could be provided “extra-credits” if FTP FE benefit is small relative to on-road benefit.
- Preliminary assessment suggests very good cost to on-road benefit ratio.
- Detailed assessment of integrated cost benefit of favorable technology synergy on FE on the FTP and on-road is necessary.

Aggressive Driving

- Only major cause of shortfall not addressed by technology is aggressive driving.
- As gasoline prices move up to $4, consumer may be receptive to driver training and lower HP vehicles.
- European driver training programs have claimed large and persistent benefits of 6 to 10% improvement in FE, although this may be due to early shifting of manual transmissions.
- Visual feedback of MPG (as in hybrid models) may have some effect on driving habits at high gasoline prices, although this is difficult to predict.
- Indirect effect of vehicle HP on driver aggressiveness may also be impacted by HP or engine size based tax.

Conclusions

- The size of the on-road to FTP shortfall in FE is a great opportunity to meet the 10+% shortfall in meeting 2020 GHG reduction targets.
- A suite of low cost technologies with favorable synergies show potential to significantly reduce on-road FE shortfall but may have smaller benefits in FTP testing.
- Policies to promote on-road shortfall reducing technology can be used as an adjunct to Pavley
- An integrated rather than technology specific approach by ARB to reduce shortfall may yield the desired reduction and also be very cost-effective.