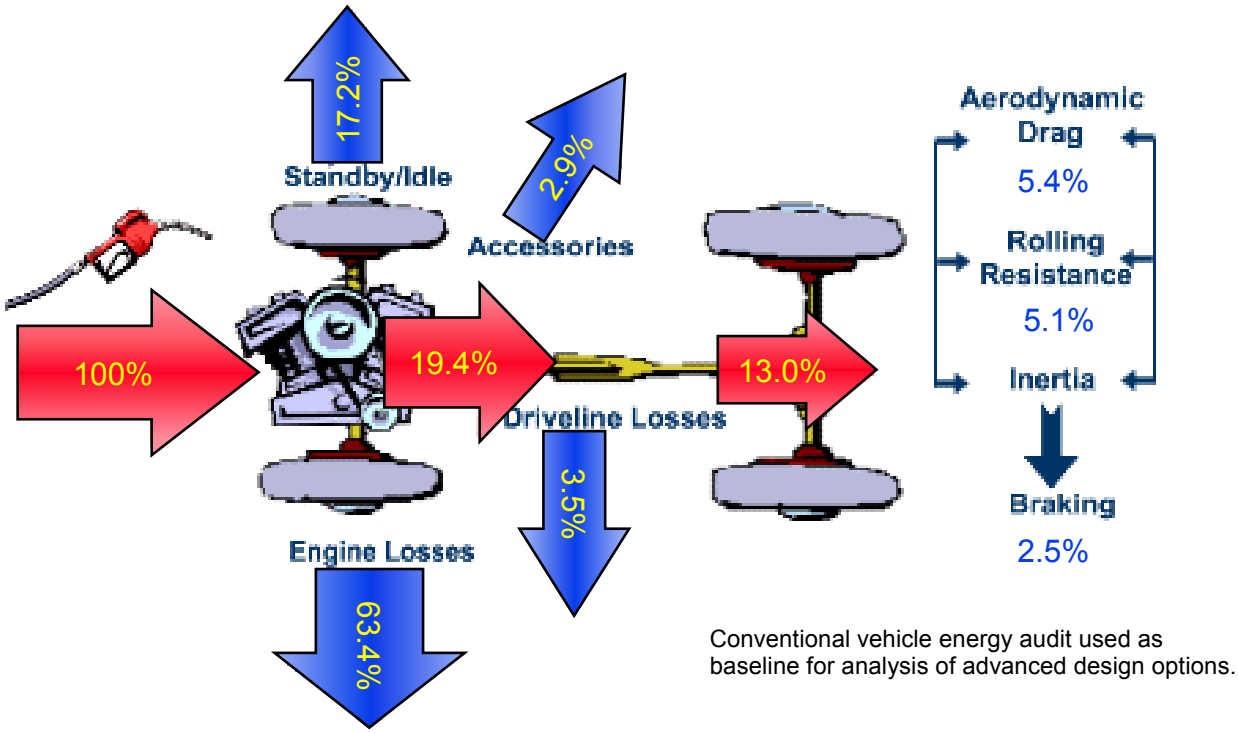
1.0 REDUCING EMISSIONS FROM ENERGY END USE AND INFRASTRUCTURE
1.1 TRANSPORTATION
1.1.1 LIGHT VEHICLES – HYBRIDS, ELECTRIC, AND FUEL CELL VEHICLES

Technology Description



Conventional vehicle energy audit used as baseline for analysis of advanced design options.

Hybrid electric vehicles (HEVs) use a combination of electric and mechanical power. An HEV with a compression ignition, direct-injection (CIDI) engine could offer low carbon emissions and peak energy efficiency more than 70% greater than available from present-day gasoline engines. Advanced combustion engines could reduce fuel consumption by 50%. Fuel cell vehicles (FCVs) directly convert fuels to electricity. Although FCVs may initially run on gasoline or other fuels reformed to produce hydrogen, in the long term they will be powered by hydrogen stored onboard. FCVs using onboard hydrogen produce only water as a tailpipe emission. The fuels used and how they are produced will determine the degree of carbon-emissions reduction compared to conventional vehicles.

System Concepts

- HEVs that provide limited power-assist during acceleration can dramatically reduce peak engine size, resulting in substantial fuel economy benefits.
- HEVs have led to the introduction of "idle-off" strategies using a combined alternator/starter. The engine automatically turns off when the engine is idling or under low-load – such as decelerating or coasting. In such cases, stored energy is required to operate the ancillary loads, such as cabin climate control.
- FCVs can either store a liquid fuel onboard that uses a reformer or other chemical reaction to produce hydrogen, or it can directly store hydrogen in gaseous or liquefied (cryogenic) form.

Representative Technologies

- HEVs and FCVs will require energy storage systems, including some high-power storage that may include electrochemical batteries, ultracapacitors, or other forms of energy storage.
- HEVs also use an internal combustion engine such as CIDI, gasoline direct-injection, as well as efficient electric motors.

Technology Status/Applications

- GM, Ford, and DaimlerChrysler are developing HEVs. Toyota and Honda have sold more than 140,000

HEVs in Japan and the United States since 1997. Some automakers have announced target sales of HEVs of 500,000 in less than 10 years.

- Although several versions of EVs were available, the cost of manufacturer support coupled with limited demand and high battery pack cost has nearly eliminated EVs as an option for consumers.
- Polymer electrolyte membrane fuel cells are being demonstrated on developmental vehicles and buses.
- Sales of vehicles with CIDI engines have exceeded 35% of the new light-duty vehicle sales in Europe and sales are more than 50% in some countries. U.S. sales may be limited due to impending Tier 2 emissions regulations. J.D. Power believes that diesel sales could be 12% of the U.S. market by 2010.

Current Research, Development, and Demonstration

RD&D Goals (by 2010)

- To ensure reliable systems for future fuel cell powertrains, with costs comparable with conventional internal-combustion engine/automatic transmission systems, the goals are:
  - Electric-propulsion system with a 15-year life capable of delivering at least 55 kW for 18 seconds and 30 kW continuous at a system cost of $12/kW peak.
  - 60% peak energy-efficient, durable fuel cell power system (including hydrogen storage) that achieves a 325 W/kg power density and 220 W/L operating on hydrogen. Cost targets are $45/kW by 2010, $30/kW by 2015.
- To enable clean, energy-efficient vehicles operating on clean, hydrocarbon-based fuels – powered by either internal combustion powertrains or fuel cells – the goals are:
  - Internal combustion systems that cost $30/kW, have a peak brake engine efficiency of 45%, and meet or exceed emissions standards.
  - Fuel cell systems, including a fuel reformer, that have a peak brake engine efficiency of 45% and meet or exceed emissions standards with a cost target of $45/kW by 2010 and $30/kW in 2015.[2] [3]
- To enable reliable HEVs that are durable and affordable, the goal is:
  - Electric drivetrain energy storage with 15-year life at 300 Wh with discharge power of 25 kW for 18 seconds at a cost of $20/kW.
- To enable the transition to a hydrogen economy, ensure widespread availability of hydrogen fuels, and retain the functional characteristics of current vehicles, the goals are:
  - Demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources. Targets: 70% energy efficiency well-to-pump; cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $1.50 per gallon (2001 dollars).[4]
  - Hydrogen storage systems demonstrating an available capacity of 6 wt% hydrogen, specific energy of 2000 Wh/kg, and energy density of 1100 Wh/L at a cost of $5/kWh.[5]
- Internal combustion systems operating on hydrogen that meet cost targets of $45/kW by 2010 and $30/kW in 2015, have a peak brake engine efficiency of 45%, and meet or exceed emissions standards.
- To improve the manufacturing base, the goal is:
  - Material and manufacturing technologies for high-volume production vehicles that enable and support the simultaneous attainment of:
    - 50% reduction in the weight of vehicle structure and subsystems,
    - affordability, and
    - increased use of recyclable/renewable materials.

Notes:

1. Cost references are based on CY 2001 dollar values. Where power (kW) targets are specified, those targets are to ensure that technology challenges that would occur in a range of light-duty vehicle types would have to be addressed.
2. Does not include vehicle traction electronics.
3. Includes fuel cell stack subsystem, fuel-processor subsystem, and auxiliaries; does not include fuel tank.
4. Targets are for hydrogen dispensed to a vehicle assuming a reforming, compressing, and dispensing system capable of dispensing 150 kg/day (assuming 60,000 SCF/day of natural gas is fed for reforming at the retail dispensing station) and servicing a fleet of 300 vehicles per day (assuming 0.5 kg used in each vehicle per day). Targets also are based on several thousand stations, and possibly demonstrated on several hundred stations. Technologies may also include chemical hydrides such as sodium borohydride.
5. Based on lower heating value of hydrogen; allows over a 300-mile range.

RD&D Challenges

- All advanced vehicles face the challenge of achieving competitive cost, reliability, and consumer acceptance.
- HEVs and FCVs need affordable, durable, lighter, and more compact energy storage.
- Power electronics, required by all high-voltage systems, are expensive, need active cooling, and require significant space.
- All energy-efficient vehicles face a severe fuel economy penalty when ancillary loads are applied. Nonpropulsion related loads must be reduced.
- FCVs have no existing infrastructure for refueling or repair.
- Onboard storage of hydrogen in quantities sufficient to meet range requirements is a challenge.
- Significant reductions in catalyst materials or inexpensive substitutes are needed for fuel cells.

RD&D Activities

- DOE, through the FreedomCAR Partnership, is working with industry and other local, state, and Federal government agencies on vehicle-systems analysis, combustion technologies, materials R&D, fuels R&D, and technology introduction through fleet testing and evaluation.
- DOE is working on light vehicles through FreedomCAR that includes component and vehicle simulation, ancillary load reduction, component testing, energy storage, advanced engines, and lightweight materials.

Recent Progress

- GM, Ford, and DaimlerChrysler have developed a variety of hybrid-electric vehicles. The technical feasibility of these concepts has matured, although cost remains an issue.
- Advances in energy storage systems – including hybrid storage consisting of batteries and ultracapacitors – show promise.
- Prototype FCVs are being tested.

Commercialization and Deployment Activities

- HEVs: The biggest competition for gasoline HEVs are advanced combustion conventional vehicles. In Europe, high-efficiency diesel vehicles have demonstrated fuel economies similar to that of gasoline HEVs. Consumer acceptance and willingness to pay a little more for a more fuel-efficient, high-technology vehicle is key. HEVs use conventional fuels, with no refueling infrastructure challenges. Some HEVs have long ranges, appealing to consumers who dislike frequent refueling stops.
- FCVs: FCVs have the zero emissions of an EV but not yet the range of conventional vehicles. Fuel cell vehicles have the potential to require less maintenance due to fewer moving parts and lower operating temperatures. However, cost, hydrogen storage, and infrastructure requirements are substantial barriers.

Market Context

- The market for these technologies is all light vehicles (cars and light trucks). To be successful in the marketplace, these technologies need to be made less expensive and more attractive to new vehicle buyers.