Just the Basics

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Combustion

What Is Combustion?

Combustion (or burning) is a basic chemical process that releases energy from a fuel and air mixture. As examples, a campfire is combustion in a simple and familiar form; rocket engines also rely on combustion using much more complex fuels. Yet both are fundamentally the same—releasing the chemical energy inside the fuel through combustion. In all cases, the process of combustion is exothermic (that is, it gives off heat.) Because of this, we have come to depend on combustion for many vital things in our lives—hot water, space heating, electricity, and transportation, to name a few.

Whether it relies on conventional gasoline or diesel fuel, transportation-based combustion accounts for the majority of our fossil fuel use in the United States, which has led the U.S. to demand a lot of imported oil. Besides forcing us to import this foreign oil, transportation-related combustion also produces polluting emissions.

How Does Combustion Work?

The spark ignition internal combustion engine that most passenger cars still rely on today was developed in the 1800s. It relies on fuel (usually gasoline), air, spark plugs, and compression to facilitate the release of the gasoline's chemical energy in a useful form. The engine's piston motion draws air into its cylinders,

Combustion and Efficiency-Improving Technologies Being Researched with Funding Support from the U.S. Department of Energy

Category	Explanation
Emission Control Subsystems	Sensor-based electronic controls to modify engine load and speed operating characteristics according to evolving efficiency and emissions boundaries
NO_x (oxides of nitrogen) Catalysts and Sensors	Improved catalysts to adsorb or transform NO_x, and sensor technologies to detect and respond to changing NO_x levels, while maintaining or improving efficiency Consideration of "regeneration" for such catalysts using available fuel(s) or carried-chemicals in conjunction with normal vehicle duty cycles
Particulate Control	Strategies and devices to capture and "neutralize" particulates before they are released from the vehicle, while maintaining or improving efficiency
Exhaust Gas Recirculation (EGR)	Exhaust gas recirculation systems that reduce NO_x emissions without sacrificing efficiency
Model Development	Computer-based tools to simulate the effects of design changes before large-scale investments are made in building and testing prototypes to validate research
Combustion Regimes	Identifying appropriate operating characteristics for emerging concepts like low temperature combustion and homogeneous charge, compression-ignition (HCCI) engines in heavy-duty vehicles
Fuels and Lubricants	Advanced petroleum and non-petroleum-based fuels such as low-sulfur diesel and fuels with oxygenating additives; alternative fuels such as, ethanol (and other and alcohols/blends), natural gas (methane), propane, biomass-derived diesel substitutes; and new lubricant formulations (low sulfur) that can reduce friction as well as fugitive emissions
Vehicle Systems	Improved vehicle designs that offer enhanced aerodynamics, and cut power losses caused by tire rolling resistance and braking; provide better thermal management within the engine and aftertreatment devices; and explore new alternative fuels, engines and hybrid engine combinations
Diesel Engines	Clean diesel technologies that can meet emissions standards without sacrificing performance
Materials	Lightweight, high-strength materials to reduce fuel consumption tied to vehicle weight, also high temperature-tolerant, friction-reducing materials for use in the internal combustion propulsion components
Environment and Health	Improved approaches and tools to measure, test, and better analyze environmental hazards to ensure no adverse effects from efficiency improvements

which it then compresses. Fuel can be introduced and mixed with the incoming air by different methods (e.g. carburetors or injectors). When the piston reaches its optimal "compressed" position, the spark plug ignites the fuel-air mix. The ensuing explosion and expansion of hot combustion gas forces the pistons down, finishing when the exhaust valve opens and the products of combustion exit out through the exhaust system, allowing the cycle to start anew. The reciprocating motion of the pistons is transferred to the crankshaft, which causes the vehicle's wheels to turn. Though this process has been enhanced over the decades, today's car engine isn't really all that different in operating principle from the engine found in Henry Ford's Model T back in the early 1900s.

Diesel engines are different in that they don't utilize a spark plug to initiate combustion. Instead, a diesel engine relies on the internal heating resulting from higher compression of the air-fuel mixture to produce an explosion. To achieve that result without a spark, diesel engines depend on a fuel that can easily auto-ignite. Diesels are inherently more efficient (produce more torque for same fuel energy input) than gasoline engines for several reasons, including their lack of a throttle (found in spark ignition engines), their operation at higher pressures, and their ability to sustain internal combustion at very low loads (e.g. idle) using a smaller amount of fuel compared to the air charge.

Unfortunately, as anyone who has spent time behind an older diesel truck or bus will tell you, diesel fuel typically burns "dirtier" (in terms of visible smoke or soot from the tailpipe) than gasoline, unless a considerable amount of excess air is supplied for combustion. Modern exhaust aftertreatment technologies have greatly reduced the levels of these pollutants from today's diesels—but usually with some penalty to efficiency.

Nevertheless, what you can't see can sometimes hurt you, and that's certainly the case with diesel (as well as spark ignition) exhaust emissions. Although the American public has traditionally shunned diesel vehicles because they perceive them to be dirtier than gasoline vehicles, the invisible chemical compounds emitted by cars (semivolatile organic compounds, nitrogen oxide, carbon monoxide, sulfur dioxide, and nanoparticulate matter) are potentially just as bad for human health and the environment.

What's the Solution?

There are several ways to approach the problem of making combustion cleaner and more efficient:

- *Engineer improvements into internal combustion engines so they burn less fuel and do so with fewer by-products;*
- *Capture combustion by-products before they are released to the environment;*
- *Alter the composition of fuel so that it contains fewer harmful substances and/or add substances that can help fuel burn more cleanly; and*
- *Develop alternative fuels that can be used in today's engines with little or no alteration.*

The U.S. Department of Energy (DOE) is funding research into solutions such as these for both gasoline and diesel engines. Private industry, academia, and national laboratories are working together to identify, test, and build promising technologies.

This low-cost permeable membrane developed at Argonne National Laboratory separates ambient air into oxygen- and nitrogen-rich air before it enters a diesel engine to reduce harmful exhaust emissions.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy

Energy Efficiency and Renewable Energy

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