1. ALTERNATIVE POWER SOURCES

Fuel Cell Hybrid Vehicle (FCHV)

Fuel cells are based on the chemical process of reverse electrolysis. The variety that are being developed as possible automobile power sources convert hydrogen and oxygen into water, producing an electric current as they do so. Direct and highly efficient, these fuel cells produce pure water vapor as their only by-product. Even if another fuel such as methanol or natural gas is reformed to create hydrogen, such systems are still tremendously energy-efficient and release significantly less carbon dioxide than internal combustion engines do.

Fuel cell-powered vehicles can be characterized as a type of electric vehicle—one that carries around its own electric power source, producing electricity on-board to power an electric motor. They can also be considered an advanced hybrid vehicle in which two power sources—the fuel cell and the batteries—supply energy to the motor to drive the vehicle. Toyota's Fuel Cell Hybrid Vehicle seeks to run the entire vehicle at its most efficient, utilizing both fuel cells and the batteries as sources of power.

Through its development work on the Prius and other hybrid vehicles, Toyota has developed considerable expertise in electronically controlled powertrains that operate with high voltages and large amounts of electric current. This has been accompanied by large strides in the control of the charging/discharging of batteries. The Toyota Hybrid System is highly adept at charging the batteries with energy derived from the efficient running of the engine. This helps give the Prius its incredible fuel efficiency.

Toyota is now working to incorporate many of the advances it has made in hybrid powertrain electronics with the Prius into its Fuel Cell Hybrid Vehicle. Toyota is striving to achieve continuous, precise control of the power generation process, and to match the Prius' efficiency in storing in the batteries unused energy created during this process. Toyota has already devised ways of harnessing and storing large amounts of energy when decelerating via a regenerative braking system. This harnessed energy provides rapid, stable bursts of large amounts of power to the FCHV when starting off, accelerating or going uphill. Regenerating energy and using that energy as a power source uniquely positions Toyota's Fuel Cell Hybrid Vehicle.

Another crucial part of this ongoing program is the development of smaller, lighter yet more efficient FCHV components, notably fuel cell stacks, reformers, air compressors, and hydrogen-absorbing alloy tanks. To aid commercialization of the FCHV, Toyota aims to shrink each of these parts and reduce their weight, while boosting their performance.

Toyota first displayed a fuel cell hybrid vehicle incorporating hydrogen-absorbing alloy tanks back in October 1996. A year later came a similar vehicle powered by a fuel cell and methanol reformer, the first such vehicle in the world. As Toyota moves from the research phase to the product development phase, steady progress is being made in the development of both the main system components (the "hardware") and the electronic control systems for the vehicle's electrics (the "software").

The choice of fuel for the FCHV remains an important issue. Toyota is working on a variety of different hydrogen sources for a fuel cell, from pure hydrogen itself to a range of fuels that could be reformed to produce it. These include methanol, natural gas, gasoline and other potential fuels. Toyota is investigating the practicality and feasibility of each of these options, particularly with regard to future infrastructure implications.

CNG vehicles

Toyota has developed a vehicle with a modified gasoline engine designed to run on compressed natural gas (CNG), of which methane is the principal component. Since reserves of natural gas are plentiful and fairly evenly distributed around the world, CNG has the potential to be a practical fuel alternative to gasoline. CNG has a high octane rating, which means it allows higher compression ratios and improves thermal efficiency while reducing carbon dioxide emissions.

CNG's principal drawback is that, since it is a gas at room temperature, it is difficult to store in sufficient quantities to power a vehicle for a long time. The cruising range of CNG-powered vehicles has thus tended to be low. To get around the problem, Toyota has developed a special 135-liter CNG fuel tank that can withstand 250 atmospheres of pressure. Situated in front of the luggage space, this tank can store enough CNG to give the vehicle a cruising range of 350 km on a single charge. The tank is made out of an aluminum-carbon fiber composite to reduce mass: it weighs just 65 kg.

2. POWERTRAINS

Toyota has developed a range of gasoline engines that feature continuously variable valve timing. Called BEAMS (Breakthrough Engine with Advanced Mechanism System), these engines' VVT-i (Variable Valve Timing–intelligent) valve trains increase output and boost fuel efficiency while reducing carbon dioxide emissions.

Toyota has also made advances in diesel engine technology with the development of several small engines featuring common rail fuel-injection systems. By using high-pressure injection at low engine speeds, fuel efficiency can be improved and black smoke emissions can be reduced.

In addition, the environmental benefits derived from both these types of engines are enhanced when combined with Toyota's next-generation lightweight "Super ECT" electronically controlled automatic transmission.

2-1. GASOLINE ENGINES

BEAMS D-4 VVT-i engine

The D-4 3.0-liter engine, which is fitted in the new Crown model in Japan, is an in-line 6-cylinder, 4-valve-per-cylinder gasoline engine. Stable combustion of ultra-lean air-fuel mixtures is made possible by injecting fuel directly into the cylinders at high pressure. This benefit is enhanced by high dispersion of the injected spray through an improved nozzle design, together with refinements to the piston heads. As a result, this engine produces a fuel efficiency that is top in its class, of 11.4 km/l in Japan's 10-15 mode test (which simulates mainly city driving). The superior torque and excellent response are boosted by the use of straight low-resistance intake ports in combination with the VVT-i valve system and an electronically controlled throttle.

Displacement:	2,997 cc
Type:	In-line 6-cylinder (direct-injection)
Max. output:	220 PS/5,600 rpm
Max. torque:	30.0 kg-m/3,600 rpm

BEAMS 1NZ-FE VVT-i engine

Available on Toyota's newest compact Japanese models such as the Platz (U.S. name: Echo) and the Fun Cargo (European name: Yaris Verso), this is a newly developed 1.5-liter in-line 4-cylinder gasoline engine. VVT-i and the use of slanted squish-type combustion chambers improve fuel efficiency, while intake efficiency is boosted by the use of a long port plastic intake manifold combined with a long branched exhaust manifold made of stainless steel. This helps to improve acceleration at low and medium engine speeds. The use of an aluminum die-casting cylinder block and a plastic intake manifold reduces the engine's mass, making it one of the lightest in its class. In addition, when combined with the specially designed small, lightweight 4-speed automatic Super ECT transmission, it produces top-of-class fuel efficiency. VVT-i, an improved atomization fuel injector, and a rearward exhaust layout that accelerates the warming of the catalytic converter to its optimal operating temperature, all combine to make the engine's emissions much cleaner.

Displacement:	1,496 cc
Type:	In-line 4-cylinder
Max. output:	110 PS/6,000 rpm
Max. torque:	14.6 kg-m/4,200 rpm

BEAMS 1SZ-FE VVT-i engine

Fitted to Toyota's newest compact Japanese models such as the Vitz (European name: Yaris) and the Platz (U.S. name: Echo), this is a newly developed, small, compact 1.0-liter in-line 4-cylinder gasoline engine. VVT-i and the use of smaller combustion chambers improve fuel efficiency; intake efficiency is boosted by the use of a plastic intake manifold with branches of equal length, combined with a long, branched exhaust manifold made of stainless steel. An offset crankshaft is one of several ways in which component friction losses have been reduced, producing an engine that combines ample torque at low and medium engine speeds with high fuel efficiency. In conjunction with the newly designed, small, lightweight 4-speed automatic Super ECT transmission, this puts its fuel efficiency at the top of the 1.0-liter engine class. VVT-i, an improved atomization fuel injector, and a forward exhaust layout that accelerates the warming of the catalytic converter to its optimal operating temperature, all combine to produce extremely clean engine emissions.

Displacement: 997 cc
Type: In-line 4-cylinder
Max. output: 70 PS/6,000 rpm
Max. torque: 9.7 kg-m/4,000 rpm

2-2. DIESEL ENGINES

Compact 3.0-liter direct-injection turbocharged diesel engine

Developed for sports-utility vehicles, this 3.0-liter turbocharged diesel engine exemplifies the combination of powerful response, superior fuel efficiency and reduced engine noise that direct injection makes possible. It incorporates 4-valve double overhead cams (DOHC), a common rail fuel injection system and a variable-nozzle turbocharger to produce high output with a torquey response at low engine speeds—just what you need in an SUV. At the same time, the superior fuel efficiency and cleaner emissions make it an environment-friendly choice. Moreover, the engine delivers significant reductions in engine noise through pilot injection (the injection of a small quantity of fuel into the cylinder prior to the main injection) and precise electronic control over injection provided by the common rail system.

Displacement: 2,982 cc
Type: In-line 4-cylinder

Compared with conventional 3.0-liter swirl chamber diesel engines: about 20% more output; about 20% greater fuel efficiency (Japanese 10-15 mode, internal Toyota data)

Compact 2.0-liter direct-injection turbocharged diesel engine

This is the first Toyota 2.0-liter direct-injection diesel engine designed for passenger cars, and it was introduced to European markets this September in the Avensis model. It features a newly developed common rail direct-injection system, along with a 4-valve double overhead cam (DOHC) design that places the fuel injector in a central, upright position. Together, these features help the engine to produce high output with superior fuel efficiency. Improved combustion and high-precision exhaust gas recirculation (EGR) control ensure cleaner emissions. Also, the engine has been made impressively quiet through the use of pilot injection, combined with an aluminum oil pan and a specially designed engine cover.

Displacement:	1,995 cc
Type:	In-line 4-cylinder
Max. output:	110 PS/4,000 rpm
Max. torque:	25.5 kg-m/2,000 rpm

Compact 1.4-liter lightweight direct-injection turbocharged diesel engine

Designed for passenger cars, this engine's direct-injection system produces a winning combination of higher output with better fuel efficiency compared with conventional swirl chamber diesel engines of comparable size. Featuring a newly designed aluminum die-casting cylinder block, it is one of the lightest engines in its class. The use of a roller locker arm reduces friction losses, while the common rail fuel-injection system helps reduce carbon dioxide output, and also cuts the emission of other exhaust gases.

Displacement:	1,364 cc
Type:	In-line 4-cylinder

Compared with conventional 1.5-liter swirl chamber diesel engines: About 10% more output

TSOP (Toyota Super Olefin Polymer)

Automotive plastics need to be especially rigid and resistant to impact, yet flexible. In addition, environmental concerns dictate that they should be easy to recycle. Since finding materials that meet all these requirements is difficult, Toyota often develops ones of its own. TSOP is a good case in point. The result of the application of advanced molecular design and crystallization technologies, this thermoplastic is much more resistant to impact than conventional polypropylene, and is much easier to recycle. Toyota has used it to make a variety of parts both inside and outside the vehicle, such as bumpers, instrument panels, and interior trim.

Recently, Toyota has developed a new version of TSOP that is more rigid yet retains good impact resistance. As such, it is ideally suited as a material for bumpers. Compared with its predecessor, new TSOP has 70% higher rigidity (as measured by its bending elasticity) and 17% less bulk, which results in a weight reduction of about 10%. In addition, as well as having more than twice the flowability, it has a much smoother surface, which results in a much more high-quality external appearance. Bumpers made out of the new TSOP are being incorporated into the new Crown Royal series and Crown Majesta models in Japan.

Like their predecessors, these new-TSOP bumpers are easy to recycle. Toyota can recycle every TSOP bumper—whether made out of the new or old material—that is replaced by dealers or service outlets into brand new bumpers. Across the whole of Japan, Toyota collected approximately 380,000 bumpers in 1998.

Recycling Technology for End-of-Life Vehicles (ELV)

At the scrapping process, End-of-Life Vehicles (ELV) first have their engines and other readily reusable parts removed. They are then shredded, and the ferrous and non-ferrous metals are extracted and collected. What remains—a mixture of plastic, fibers, glass and other materials—is called Automobile Shredder Residue (ASR).

In the past, there was just one destination for ASR—the landfill. To raise vehicle recovery rates, Toyota decided to work on creating methods to extract and sort reclaimable materials from ASR. Toyota engineers developed novel dry sorting methods based on physical processes and various reclaiming technologies.

Following two and a half years of pilot-plant testing of the procedures, in August 1998 Toyota commenced operation of the world's first ASR recycling plant at Toyota Metal Co., Ltd. Every month the plant processes about 2,000 tons of ASR, the equivalent of around 15,000 vehicles. This ingenious plant manages to recover and produce several useful materials from ASR, including polyurethane foam, fiber, copper, glass particles and resin. Those ASR components that cannot be recycled are fused into pellets in what is called "melt-bricking." Melt-bricked materials are much easier to transport, dump and store in landfill sites.

The recycled materials produced have a variety of uses. Polyurethane foam and fiber extracted from ASR are used to make sound-proofing materials for cars. The copper extracted from the wiring harnesses is added to aluminum castings to increase their strength. The glass is pulverized, then used to reinforce construction tiles. And, because of their high calorific values, resin and rubber components that are separated can be used as a fuel alternative to coal and oil.

Through these programs, Toyota has already achieved two environmental goals mandated by the Japanese government: 85% vehicle recovery rate by weight (a goal for 2002; Toyota's current rate is 87%), and an 80% reduction in the volume of ASR sent to landfill sites (by 2015).