HYBRID SYNERGY DRIVE
INFORMATION TERMINAL

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Benefits

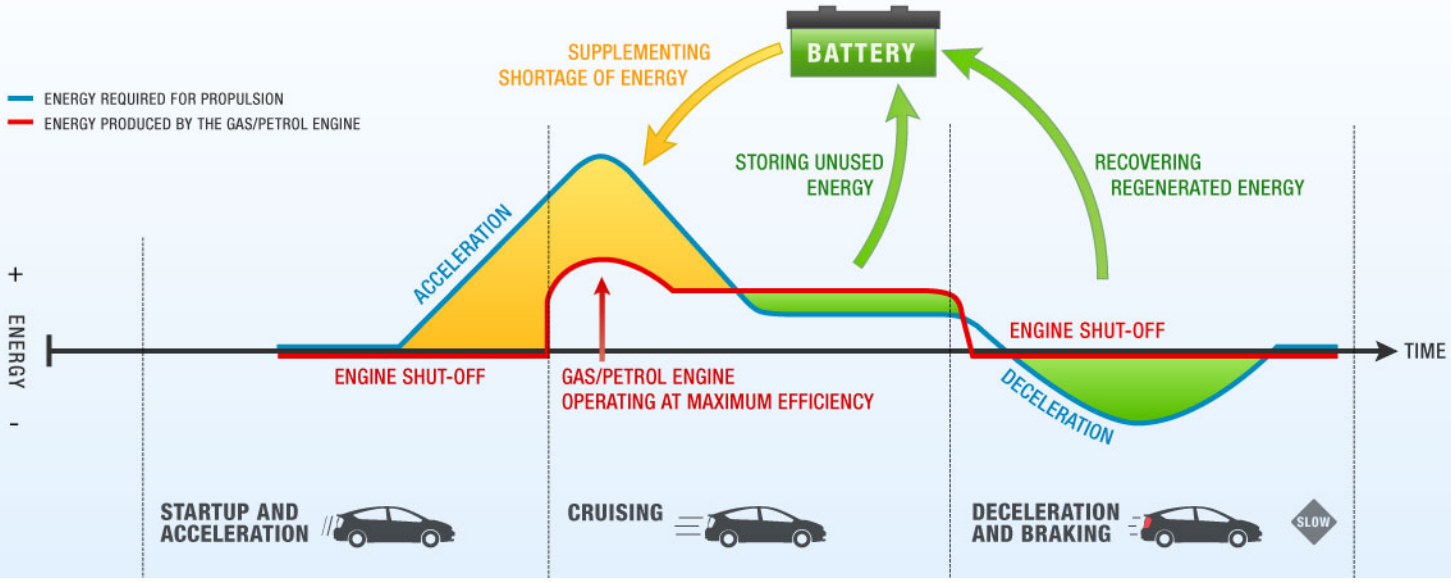
Powertrain delivering outstanding fuel efficiency, acceleration, quietness and low emissions

Toyota's HYBRID SYNERGY DRIVE is the new type of powertrain that combines the strong attributes of two kinds of power sources: the electric motors and the gas/petrol engine. HYBRID SYNERGY DRIVE delivers world class performances in terms of the fuel efficiency, low emissions, driveability and quietness desired of cars today.

Fuel Efficiency

World's top level fuel efficiency

HYBRID SYNERGY DRIVE makes intelligent selective use of its electric motors and gas/petrol engine to deliver fuel efficiency comparable to cars of one class smaller in engine displacement/body size, and at the same time the power comparable to cars one class larger.
HYBRID SYNERGY DRIVE delivers the highest level of fuel efficiency for cars of the same-size engine displacement.



Fuel Efficiency: How it Works

Selective use of the electric motors and gas/petrol engine to take advantage of their key attributes.

HYBRID SYNERGY DRIVE makes intelligent use of its electric motors and gas/petrol engine to take advantage of the key attributes of the two power sources to ensure that the car operats at optimum fuel efficiency.

1. At start-off/low-speeds, HYBRID SYNERGY DRIVE runs the car on the electric motors only, since the gas/petrol engine does not perform efficiently.

2. However, the gas/petrol engine is quite energy efficient for cruising. Power produced by the gas/petrol engine is used to drive the wheels and also the generator to provide power to the electric motors or to charge the battery.

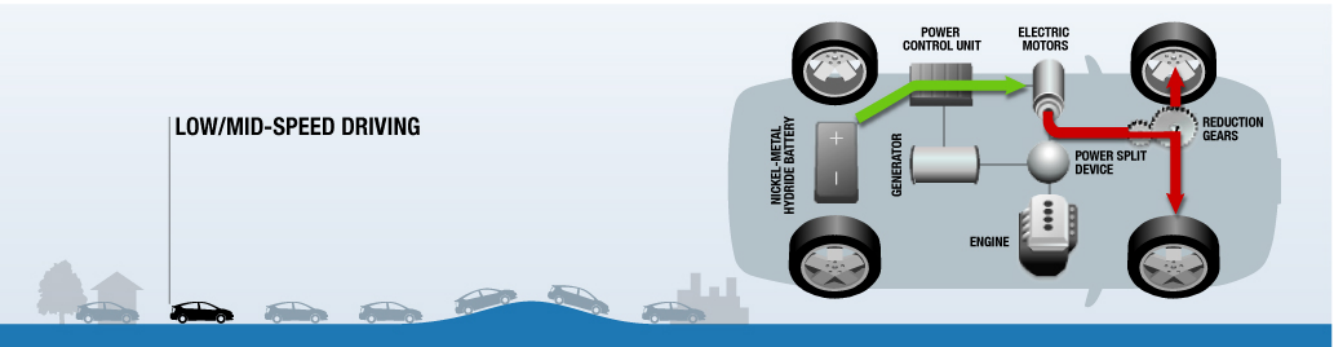
3. Under deceleration or braking, HYBRID SYNERGY DRIVE uses the car's kinetic energy to let the wheels turn the electric motors and recover regenerative energy to recharge the battery.

Starting Off

Taking advantage of the electric motors' low-speed torque at start-off

When the car starts off, HYBRID SYNERGY DRIVE uses only the electric motors, powered by the battery, while the gas/petrol engine remains shut off. A gas/petrol engine cannot produce high torque in the low r.p.m. range, whereas electric motors can - delivering a very responsive and smooth start.

*When the ignition is initially turned on, the gas/petrol engine is turned on and kept running until it is warmed up.



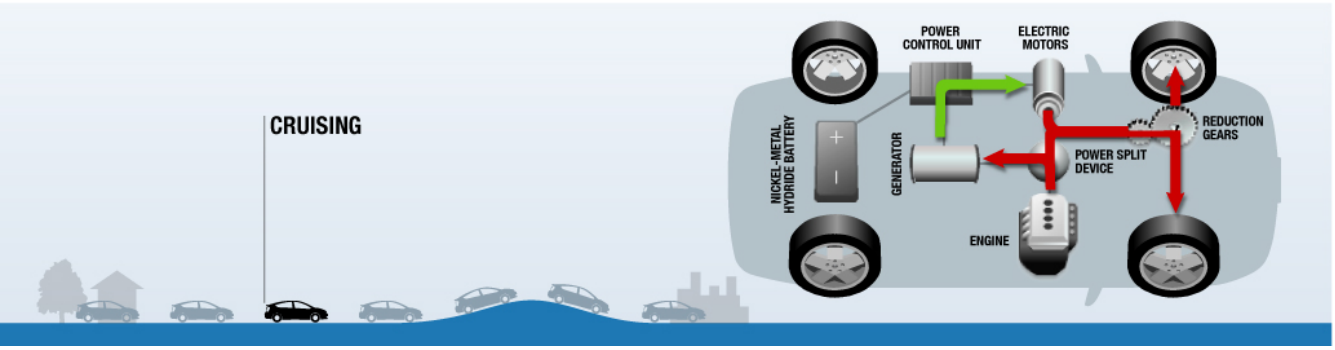
Low/Mid-Speed Driving

Energy-efficient motor-driven running

A gas/petrol engine is not energy efficient in running a car in the low/mid speed range. On the other hand, an electric motors are energy efficient in running a car in the low/mid-speed range.

Therefore, HYBRID SYNERGY DRIVE uses the electric energy stored in its battery to run the car on the electric motors in the low/mid speed range.

*If the battery charge level is low, the gas/petrol engine is used to turn the generator to supply power to the electric motor.

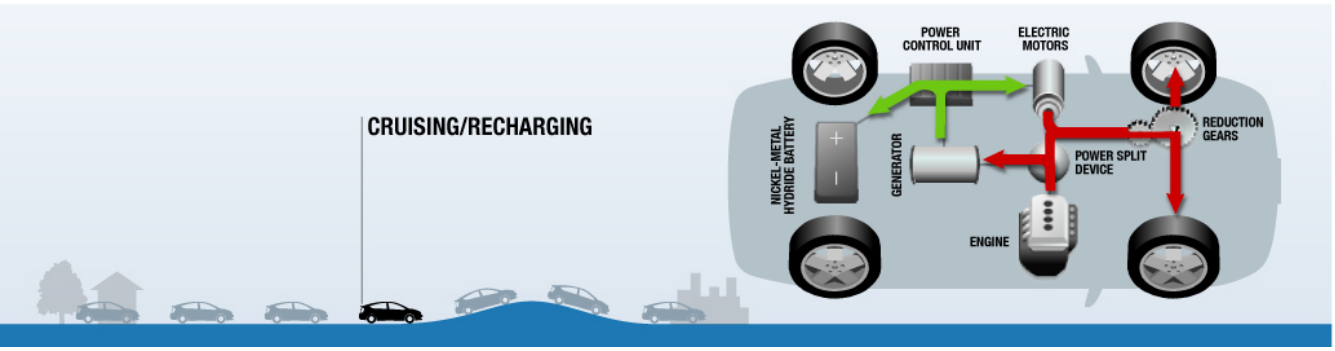


Cruising

Energy-efficient driving, using the gas/petrol engine as the main power source

HYBRID SYNERGY DRIVE uses the gas/petrol engine in the speed range in which it operates with good energy efficiency.
The power produced by the gas/petrol engine is used to drive the wheels directly, and depending on the driving conditions, part of the power is distributed to the generator. Power produced by the generator is used to feed the electric motors, to supplement the gas/petrol engine.
By making use of the engine/motor dual powertrain, the energy produced by the gas/petrol engine is transferred to the road surface with minimal loss.

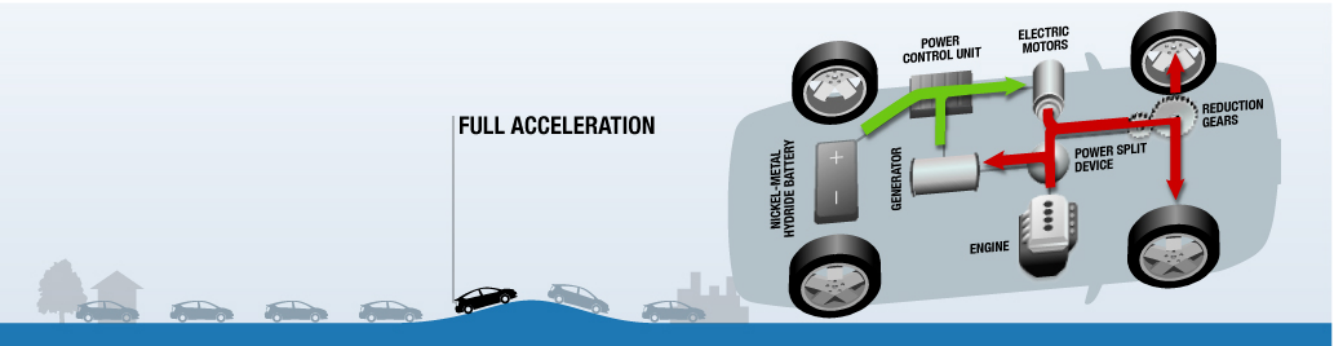
*If the battery charge level is low, the power output from the gas/petrol engine is increased to increase the amount of electricity generated to recharge the battery.



Cruising/Recharging

Recharging the battery with surplus energy

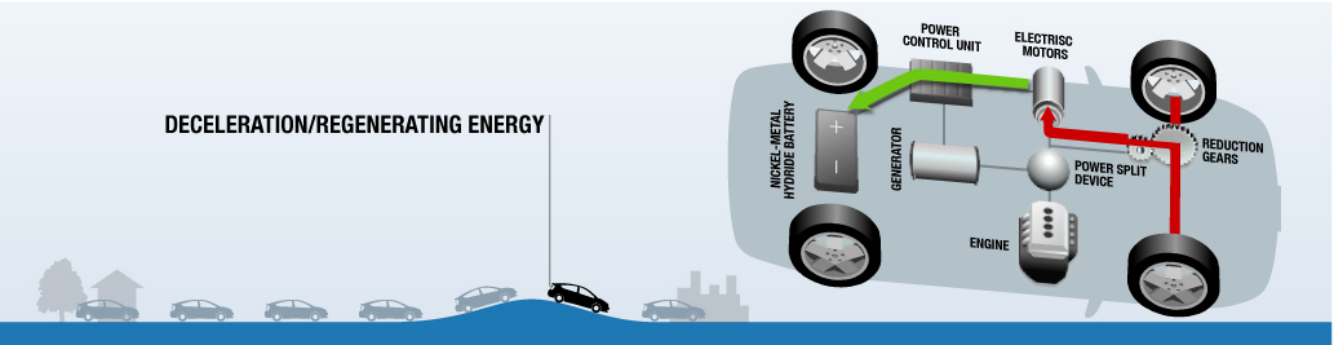
Since HYBRID SYNERGY DRIVE operates the gas/petrol engine in its high efficiency range, the gas/petrol engine may produce more power than is necessary to drive the car. In this case, the surplus power is converted to electric energy by the generator to be stored in the battery.



Full Acceleration

Dual power for acceleration one class higher

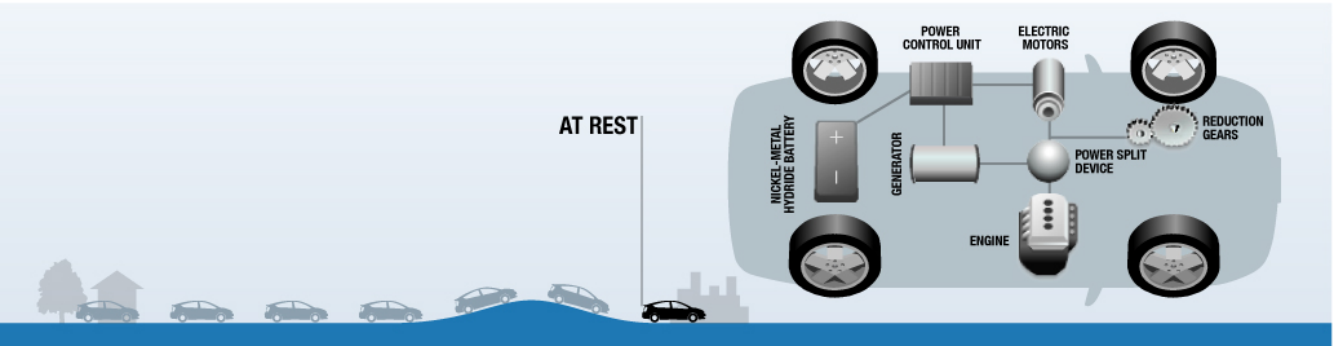
When strong acceleration is called for (e.g, for climbing a steep slope or overtaking) the power from the battery is supplied to the electric motors to supplement driving power. By combining the power from the gas/petrol engine and the electric motors, HYBRID SYNERGY DRIVE delivers power comparable to cars having one class larger engine displacement.



Deceleration/Regenerating Energy

Storing regenerated energy under deceleration in the battery

Under braking or when the accelerator is lifted, HYBRID SYNERGY DRIVE uses the kinetic energy of the car to let the wheels turn the electric motors, which function as regenerators. Energy that is normally lost as friction heat under deceleration is converted into electrical energy, which is recovered in the battery to be reused later.



At Rest

Shutting down entire powertrain when the car is at rest

The gas/petrol engine, the electric motors and the generator are automatically shut down when the car comes to rest. No energy is wasted by idling.

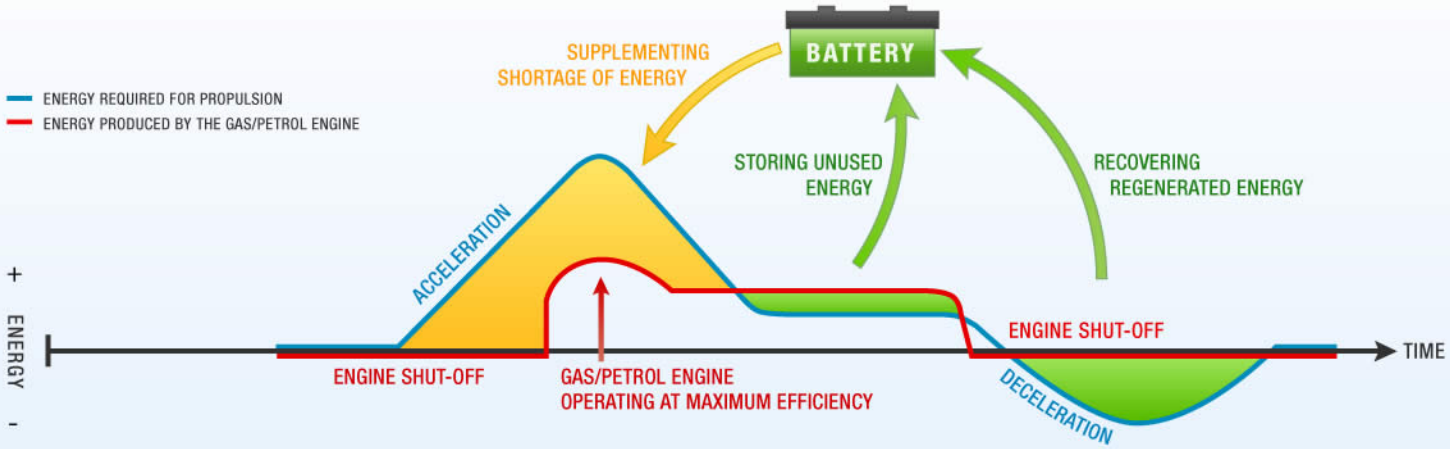
*If the battery charge level is low, the gas/petrol engine is kept running to recharge it. In some cases, the gas/petrol engine may be turned on in conjunction with the air-conditioner switch operation.

Low Emissions

Clearing the world's most stringent emissions regulations

HYBRID SYNERGY DRIVE pursued outstanding fuel efficiency with the goal to reduce CO2 emissions, and also realized a significant reduction in emissions of other substances in its exhaust gas.
For example, Prius sold in the US complies with the world's most stringent regulation, "AT-PZEV (Advanced Technology Partial Zero Emissions Vehicle) Regulation" of the State of California of the USA, while Prius for the EU market complies with "EURO-IV" regulation implemented in EU from 2005.*Highlander Hybrid has also been certified "SULEV" compatible, meeting the most stringent of California's automobile exhaust emissions regulations "LEV II".
All the models equipped with HYBRID SYNERGY DRIVE, including the two models mentioned above, have cleared the stringent exhaust gas regulations enforced in various countries of the world.

* Based on calculations derived from in-house measurements.



Low Emissions: How it Works

Reducing Fuel Consumption and Restricting Emissions

CO2 (carbon dioxide) is always produced when gasoline/petrol is burnt. CO (carbon monoxide), NOx (oxides of nitrogen), HC (hydrocarbons) and other substances are also emitted.*

HYBRID SYNERGY DRIVE addresses this issue in three ways: with outstanding fuel efficiency, to use less fuel and reduce exhaust emissions; with highly efficient combustion, which reduces output of other substances; and by employing various devices to clean the exhaust gases. HYBRID SYNERGY DRIVE thus realizes one of the world's cleanest exhaust emissions.

* CO2 is recognized worldwide as a factor in global warming.
* CO/NOx can be harmful to health if inhaled.
* NOx/HC are factors in the production of photochemical smog.
* NOx is one of the substances in acid rain.

Acceleration

The Joy of Driving - a completely new experience

Although HYBRID SYNERGY DRIVE delivers outstanding fuel efficiency, it also offers driving performance, the original appeal of cars. In particular, "the seamless acceleration", "powerful take off and overtaking acceleration" and "undiminishing G(gravity) force" are new driving sensations which can only be experienced with a hybrid car.

Acceleration: How it works

Intelligent engine/motor management

HYBRID SYNERGY DRIVE does not just combine electric motors and a gas/petrol engine. It makes intelligent use of their respective strengths and applies advanced control systems to realize superb acceleration and driving stability.
HYBRID SYNERGY DRIVE reacts responsively to the driver's intent by providing the appropriate driving power.
It also monitors and analyzes the driving conditions at all times, so as to provide the optimum driving power for a safe and comfortable driving experience.

Driver Assistance Mechanisms

Sensors monitoring operations for optimum powertrain management

The HYBRID SYNERGY DRIVE system's responsive electric motors are equipped with sensitive rotation sensors, by means of which it constantly monitors the driving conditions and ensures that the required amount of power is instantly produced, on demand, to maintain a steady drive. The HYBRID SYNERGY DRIVE motors can independently produce sufficient power to start off and/or accelerate, thus providing precise assistance to meet any driver need.

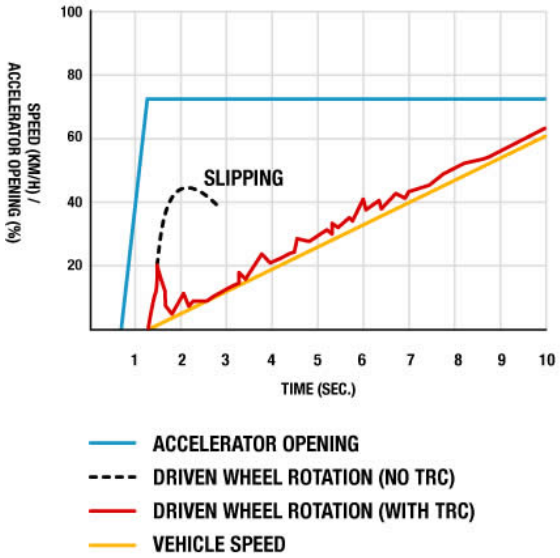
Motor TRC

Controlling tyre slip with drive from the motors

Motor TRC is a system that uses the power produced by the electric motors to prevent tyres from slipping.*
It helps lessen the load on the driver when driving on a snow covered road or a wet/unpaved road surface. If the rotation sensors detect a condition where a wheel is about to slip or is slipping, the electric motors are instantaneously called to feed power to the driving axle so as to recover the grip on that driving axle. TRC in a normal gas/petrol engine car uses the engine and brakes to prevent slipping, but with HYBRID SYNERGY DRIVE, the power from the electric motors are used to perform this function.

*Motor TRaction Control also functions to protect HYBRID SYNERGY DRIVE from being damaged by any sudden surge/drop in voltage supplied to the electrical systems, or by over-revving the planetary gear of the power split device.

EFFECTIVENESS OF MOTOR TRC CONTROL
Difference wheel rotational speed:
starting off acceleration on snow covered road



Uphill Power Assistance

Power from the electric motors to assist accelerator operation when going uphill

The uphill power assist control calls upon the electric motors to supplement drive power when driving uphill, to assist the driver in accelerator operations.

The driver need not make abrupt accelerator operations when coming up against a hill or change in slope while climbing. Very sensitive rotation sensors are used to monitor slope angle, total vehicle weight and other information, and to modify power output to suit the driving conditions.

Hill Start Control

Effortless, smooth hill start with help from the motors

Hill Start Control uses drive power from the electric motors for stopping and starting on a slope to prevent the car from rolling back.

The car will not roll back even if the driver takes the foot off the brake pedal, making hill starts smoother and easier.

The sensitive rotation sensors can detect even the smallest forward/backward wheel rotations, and the system draws precisely the amount of power from the electric motors that is sufficient for the slope angle and accelerator opening angle.

Powerful Acceleration Mechanism

Ideal powertrain control

Electric motors can produce high torque from low r.p.m., whereas a gas/petrol engine operates most effectively in the high revving range. HYBRID SYNERGY DRIVE delivers responsive, smooth and seamless acceleration from the low-speed range to high-speed range with optimum control of the dual power sources.
In addition, the increased power output of the electric motors and gas/petrol engine used in HYBRID SYNERGY DRIVE deliver start-off/overtaking acceleration comparable to cars one class higher (e.g. 1800 cc Prius delivers 2400 cc class performance).

Torque on Demand Control

Seamless acceleration/deceleration with continuous variable transmission

"Torque on Demand Control" is the name we gave to the technology for providing continuous variable transmission without loss of energy. Distribution of the r.p.m. and the torque output of the electric motors and gas/petrol engine are electronically and steplessly controlled by the HYBRID SYNERGY DRIVE transmission.*
This system makes it possible to transfer the required amount of drive power to the road efficiently, in accordance with the road conditions and the driver's intent.The system delivers responsive and smooth acceleration/deceleration from low speeds to high speeds seamlessly.

* Only the r.p.m. of the electric motors is controlled in proportion to the vehicle speed.

Outstanding Quietness

Drive silently through a residential area late at night without hesitation

Quiet running is one of the benefits of electric motors powered HYBRID SYNERGY DRIVE — for instance, early in the morning or late at night through a residential area. You can even move quietly in and out of a parking garage, where sound is often amplified.

Quietness: How it Works

Drive only on the electric motors in the low to mid-speed range

HYBRID SYNERGY DRIVE allows the driver to select to drive using only the electric motors in the low to mid-speed range. The electric motors, drawing power from the battery, is a very quiet power source, so driving this way is remarkably quiet compared to a gas/petrol engine.

EV Drive Mode

Drive with the gas/petrol engine off

In the low/mid-speed range, gas/petrol engine do not use fuel efficiently, so HYBRID SYNERGY DRIVE runs the car using only the power produced by its electric motors.
Some HYBRID SYNERGY DRIVE models are equipped with the "EV Drive Mode" to let the driver select driving on the electric motors only — in other words, driving with the gas/petrol engine off.*1
(Under 55 km/h; range: a few hundreds of meters)*2

*1 EV drive mode is automatically cancelled if any one of the following conditions occurs:
- Battery charge drops below specified level
- Vehicle traveling speed exceeds 55 km/h
- Accelerator pedal opening angle exceeds pre-defined angle

*2 The figure indicated is for Prius. The range of travel will depend on the condition of the battery powering the electric motors. This option is not available on some of the hybrid systems.

Technology

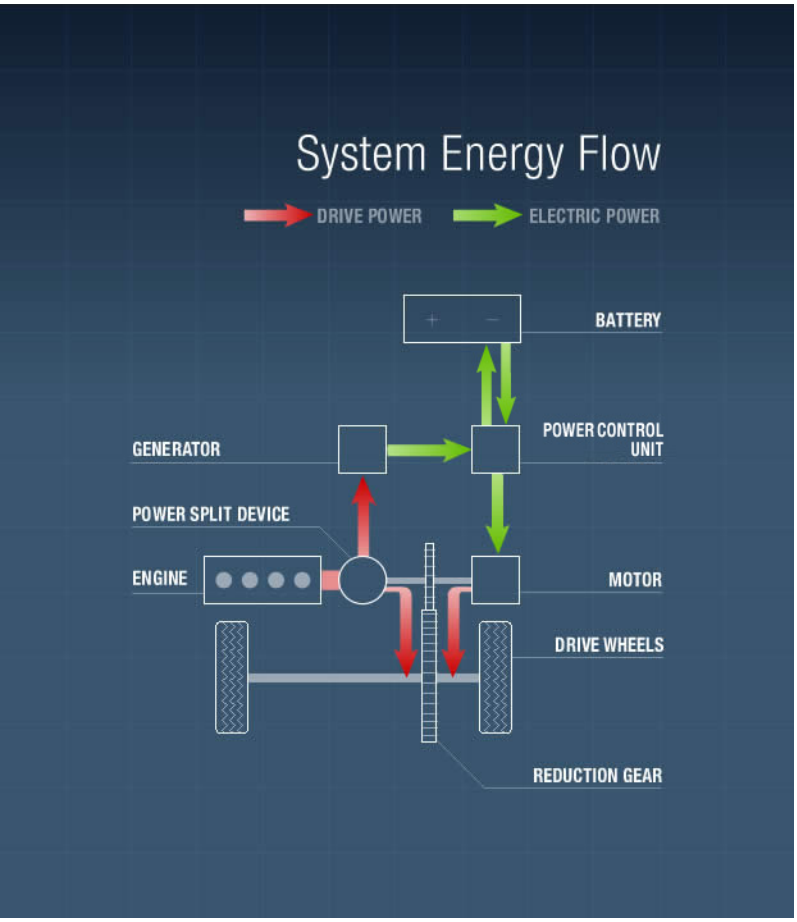
The most advanced hybrid powertrain

The HYBRID SYNERGY DRIVE power unit integrates the advantages of an electric motor and a gas/petrol engine.
It is not merely a package that has an electric motor and a gas/petrol engine on board.
Toyota applied cutting edge technologies based on latest research to integrate dual power sources in the most ideal way.

Technology: Overview

The best elements of previous hybrid systems

There are several ways in which electric motors and a gas/petrol engine can be combined. HYBRID SYNERGY DRIVE uses what is called a "Series Parallel Hybrid System".
This is an ideal combination of the "Series Hybrid System" that Toyota has been developing and the "Parallel Hybrid System", which has a different approach. HYBRID SYNERGY DRIVE takes the best of what each system has to offer and integrated them into a single system, the best of both.
By adopting the "Series Parallel Hybrid System" and incorporating cutting edge technologies, Toyota has improved and developed the powertrain, electricity generation and control systems. As a result, we are offering many benefits never before possible with a conventional powertrain.



Series Parallel Hybrid System

Driving the wheels with the electric motors and the gas/petrol engine, yielding electricity via the generator to self-charge the battery

With the Series Parallel Hybrid System, it is possible to drive the wheels using the dual sources of power (electric motors and/or gas/petrol engine), as well as to generate electricity while running on the electric motors.
The system runs the car on power from the electric motors only, or by using both the gas/petrol engine and the electric motors together, depending on the driving conditions. Since the generator is integrated into the system, the battery can be charged while the car is running.

The basic components of the system are the electric motors, the gas/petrol engine, the generator, the power split device and the power control unit (inverter/converter). The power split device transfers part of the power produced by the gas/petrol engine to drive the wheels, and the rest to the generator to either provide electric power for the electric motors or to recharge the battery.

This system takes advantage of the energy-efficient electric motors when the car runs in the low speed range, and calls on the gas/petrol engine when the car runs in the higher speed range. In other words, the system can control the dual sources of power for optimum energy-efficient operation under any driving conditions.

Toyota has incorporated other cutting edge technologies to improve and develop the powertrain, the generating and control systems. As a result, we are offering many benefits never before possible with a conventional powertrain.

Nickel Metal Hydride Battery

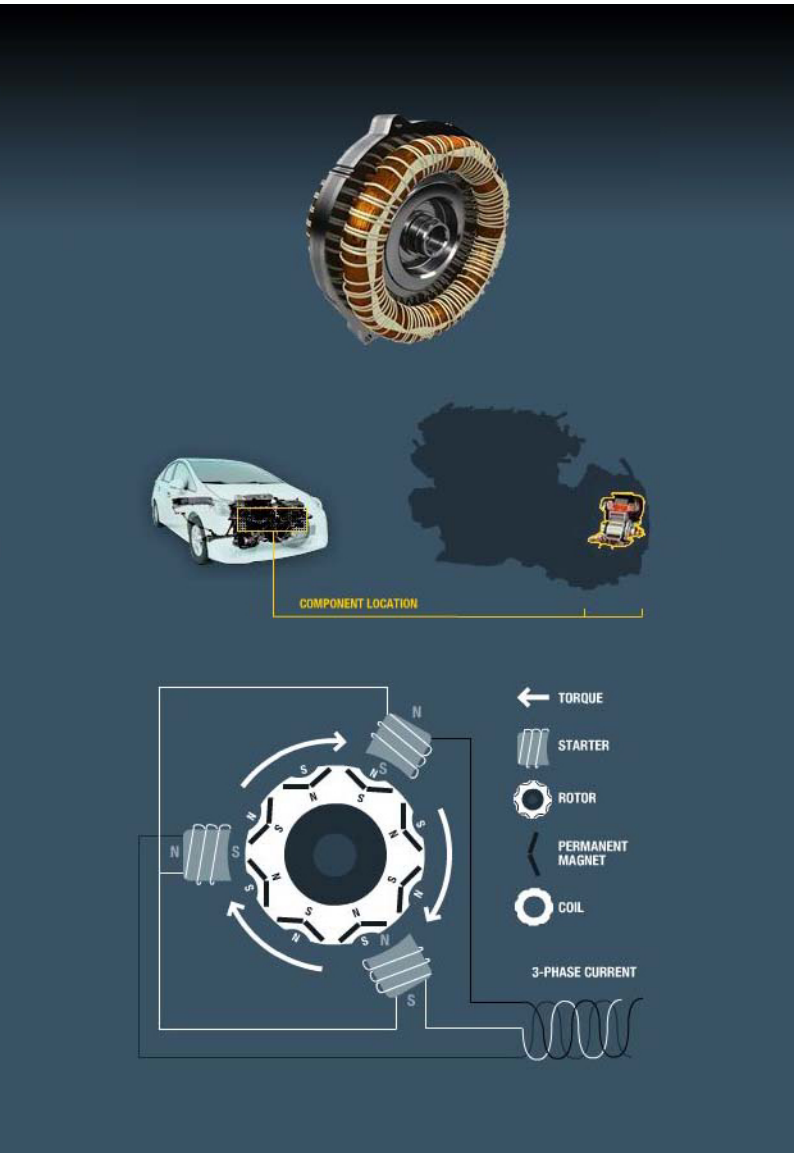
World's top level input/output to weight ratio - light weight

In addition to being light-weight, the high power output nickel metal hydride (Ni-MH) battery used in the HYBRID SYNERGY DRIVE system provides a high input/output to weight ratio. (power output in relation to weight)

The battery pack and its components have been redesigned for the new Prius. The cooling system for the battery cells including the cooling duct is optimized, while components such as the system main relay are designed for reduction in size and weight.

Furthermore, the system maintains the battery charge at a constant level at all times by monitoring and computing the cumulative amount of discharge under acceleration, and recharging by regenerative braking or with surplus power under normal running conditions.

The hybrid battery (traction battery) has a limited service life. The lifespan of the hybrid battery (traction battery) can change in accordance with driving style and driving conditions.



High Output Electric Motor

Employing synchronous A/C motor for compact packaging, light weight and high efficiency

HYBRID SYNERGY DRIVE uses synchronous A/C motors, which can efficiently produce strong torque up into the high revolution ranges and provide freedom to control motor revolutions and torque.
Toyota has also succeeded in making electric motors more compact, light-weight and efficient, for smoother starts/acceleration.
- 3-phase A/C
- Optimum control of the angle between rotating magnetic field and rotor magnets
- Permanent rotor magnets positioned in the ideal V-figure configuration

Moreover, the reduction gear adopted by the new Prius enables weight reduction and higher output.

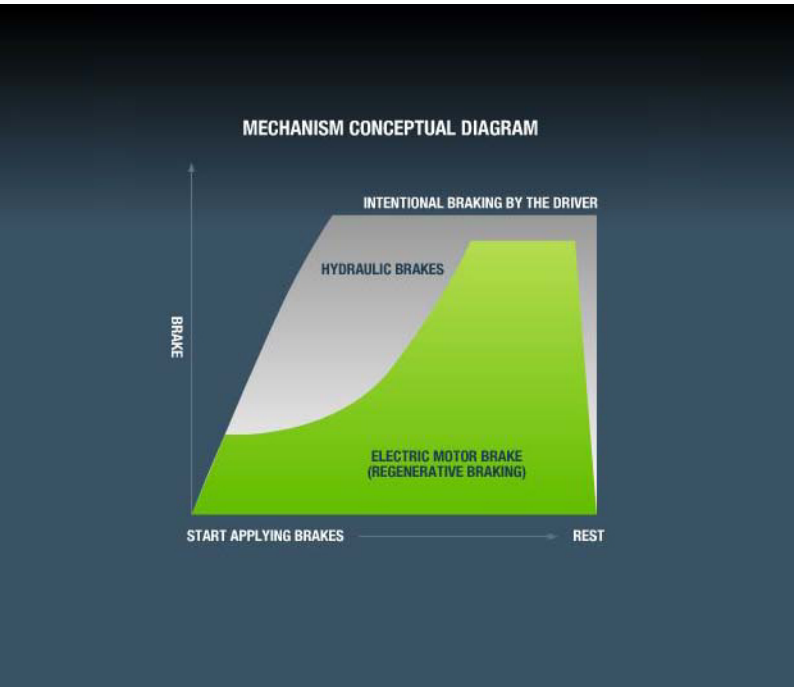
Specification

Maximum voltage:650V

Maximum output:60kW

Maximum torque:207Nm

* The figures are for Prius manufactured to Japanese market specification.



Regenerative Braking

Reuse of kinetic energy by using the electric motors to regenerate electricity

HYBRID SYNERGY DRIVE can reuse kinetic energy by using its electric motors to regenerate electricity in what is called "regenerative braking".
Normally, electric motors are turned by passing an electric current through it. However, if some outside force is used to turn the electric motors, it functions as a generator and produces electricity. This makes it possible to employ the rotational force of the driving axle to turn the electric motors, thus regenerating electric energy for storage in the battery and simultaneously slowing the car with the regenerative resistance of the electric motors.

The system coordinates regenerative braking and the braking operation of the conventional hydraulic brakes so that kinetic energy, which is normally discarded as friction heat when braking, can be collected for later reuse in normal driving mode.
Typically, driving in city traffic entails a cycle of acceleration followed by deceleration. The energy recovery ratio under these driving conditions can therefore be quite high.
To take advantage of this situation, the system proactively uses regenerative braking when running the car in the low speed range. Taking Prius as an example, the system can save the energy equivalent of 1ℓ of gas/petrol while running in city traffic for 100 km.

Power Control Unit

Power Control Unit with DC/AC inverter and Voltage-Boosting Converter

HYBRID SYNERGY DRIVE is equipped with a Power Control Unit that consists of an inverter, a Voltage-Boosting Converter and an AC/DC converter to run the car on electric motors.

Inverter

The inverter converts DC supplied by the battery to AC to turn the electric motors and to use in the generator. Conversely, it converts AC generated by the electric motors and the generator into DC to recharge the battery.
Direct cooling of switching device is featured in the new Prius, improving cooling efficiency and enabling inverter downsizing and weight reduction.

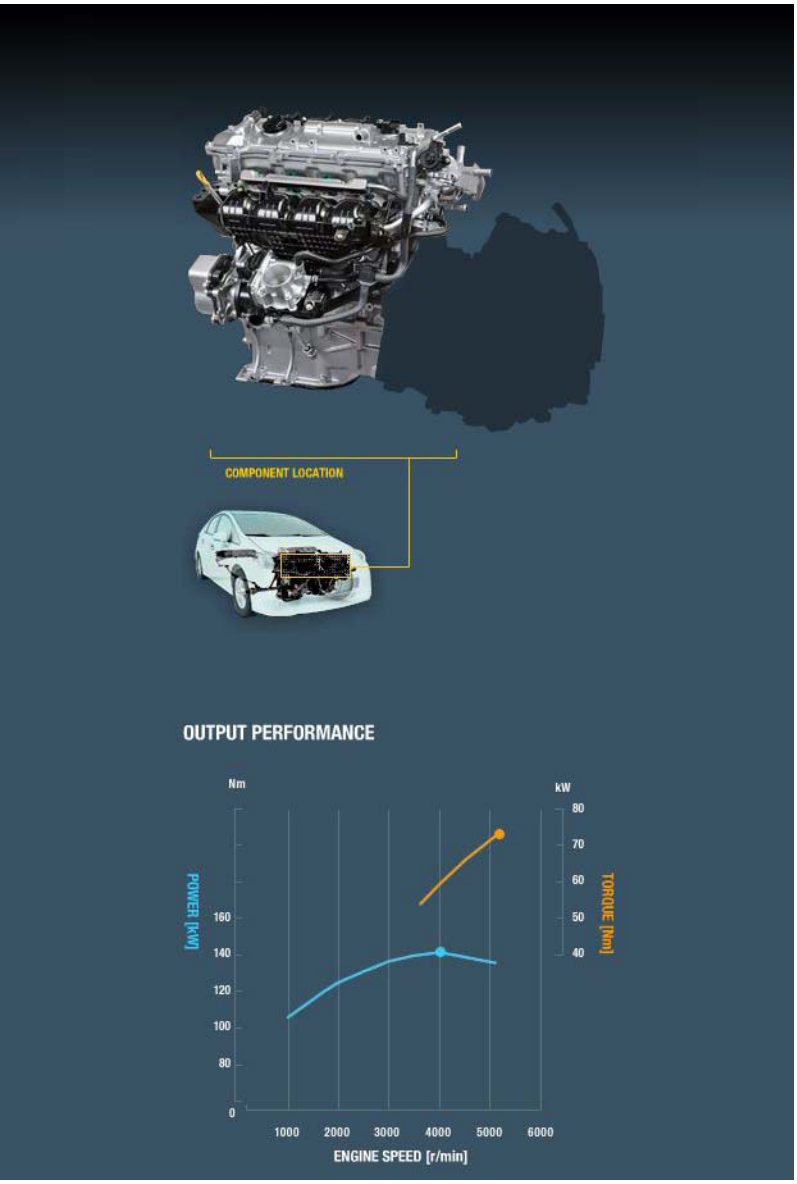
Voltage-Boosting Converter

The Voltage-Boosting Converter steplessly increases the normal 201.6 V DC supply voltage to a maximum of 650 V(*1) to feed the electric motors and the generator as required. This means more power can be generated from a small current to bring out high performance from the high output motors, enhancing overall system efficiency. It also means that the inverter could be made smaller and lighter.

DC/DC Converter

The DC/DC converter steps down the 201.6 V supply voltage from the battery to 12 V, to be used by ancillary systems and electronic devices like the ECU.

*1 for Highlander Hybrid.



Highly Efficient Gas/Petrol Engine

Energy-efficient, high-output gas/petrol engine

The gas/petrol engine used in HYBRID SYNERGY DRIVE is more energy-efficient, producing higher output than conventional gas/petrol engines.

The new Prius' 1.8L 2ZR-FXE high-expansion-ratio Atkinson cycle engine replaces the former 1.5L 1NZ-FXE. The wealth of torque created by an increased displacement decreases the engine r.p.m. during high-speed cruising. Further improvements in fuel efficiency have been achieved through the following new mechanisms.

Electric water pump

The water pump is now driven by electricity from the battery. Elimination of the drive belt decreases mechanical loss, and the flow of the coolant can be controlled even more precisely according to the vehicle's conditions.

Exhaust heat recirculation system

This system utilizes exhaust heat – what used to go wasted – for the heater and to warm up the engine, allowing quicker heater and engine warmups.

Cool-EGR system

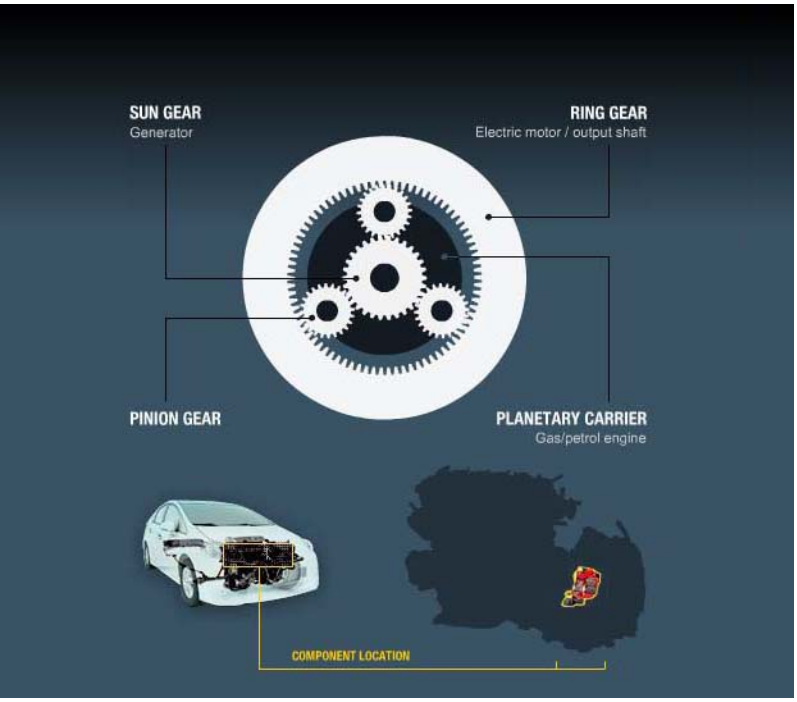
Flow volume of the exhaust gas is controlled carefully by the electric EGR valve and is channeled into the intake manifold, alleviating negative pressure in the manifold and decreasing pumping loss in the engine. Cooling the exhaust gas with the EGR cooler actualizes large volume EGR.

Roller rocker arm

The valve train system features roller rocker arms, decreasing friction loss in valve movements.

Specification

Maximum power output: 73kW(99PS)/5,200 r.p.m.
Maximum torque: 142Nm(14.5kgfm)/4,000 r.p.m.

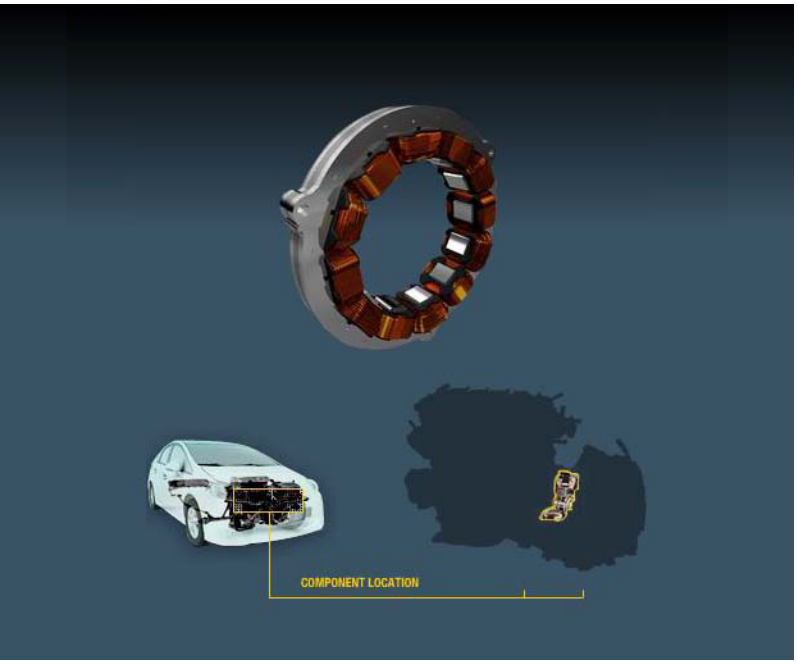


Power Split Device

Splitting power produced by the gas/petrol engine between the drive train and the generator

The HYBRID SYNERGY DRIVE power splitting device distributes the power produced by the gas/petrol engine to the drive train and to the generator. To divide the power efficiently, it uses a planetary gear consisting of a ring gear, pinion gears, a sun gear and a planetary carrier.

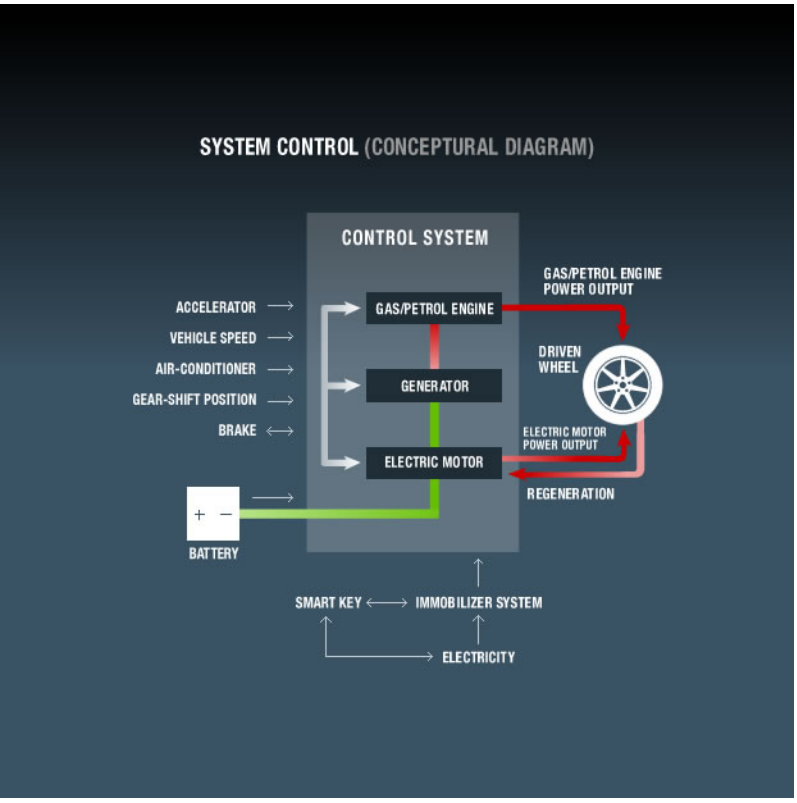
1. The rotating axle of the planetary carrier is directly connected to the gas/petrol engine and rotates the perimeter ring gear and the sun gear inside via the pinion gears.
2. The rotating axle of the ring gear is directly connected to the electric motors, and thus transfers the driving power to the wheels. The axle of the sun gear is directly connected to the generator and converts the power produced by the gas/petrol engine into electric energy.



Generator

High speed rotation for higher maximum power output

As with electric motors, HYBRID SYNERGY DRIVE uses a synchronous AC generator capable of high speed axial rotation, realizing substantial electrical power while the car is running in the mid-speed range. Toyota has put together the ideal generator, high output electric motor and gas/petrol engine combination to enhance low to mid-speed range acceleration.
The new Prius has a more compact, light-weight design realized through centralized winding of the coils.



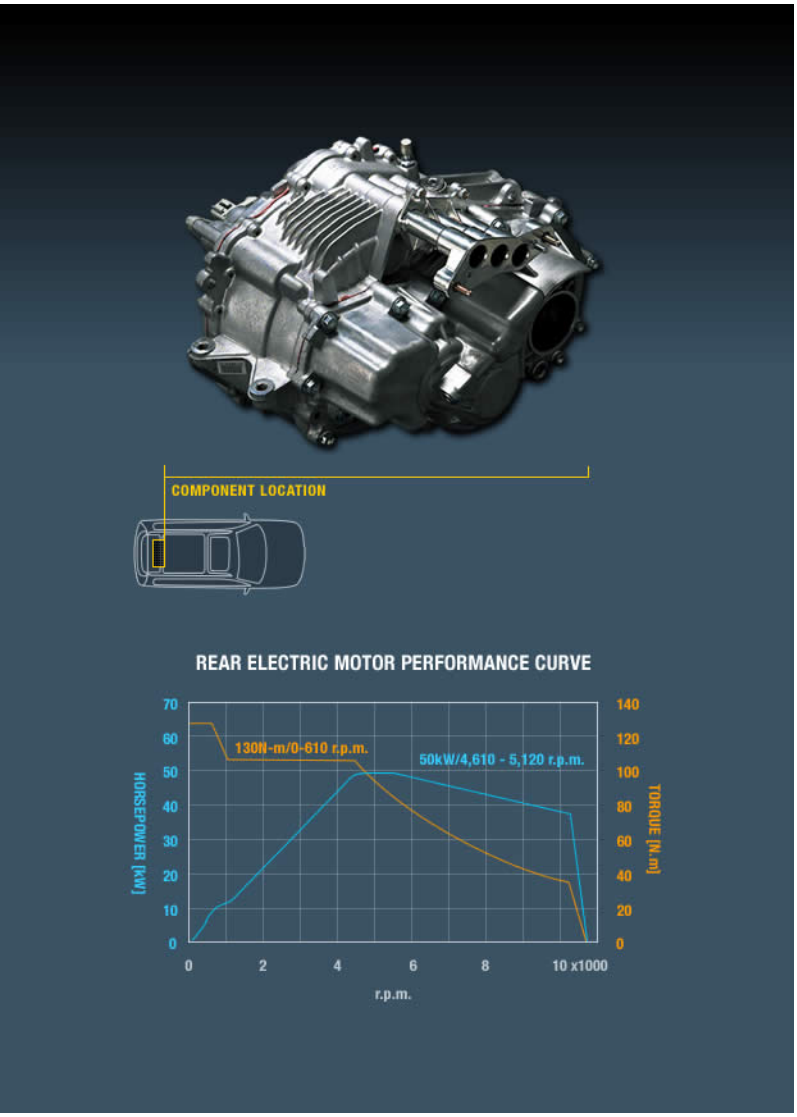
ECU

The Brain: Running the car safely, comfortably and at maximum efficiency

The various devices of the car are centrally controlled by the ECU*, which could be said to be the car's "brain". HYBRID SYNERGY DRIVE uses the ECU to constantly monitor the operational status of these devices, and of energy consumption, on a real-time basis. This enables it to execute quick, precise and comprehensive management to run the car safely, comfortably and with maximum efficiency.

- Monitors operational status of each hybrid component (gas/petrol engine, generator, electric motors, battery)
- Monitors braking data received via car's control network
- Monitors instructions (accelerator pedal opening angle, gear shift position) from the driver
- Monitors energy consumption of driver assisting -operated systems (e.g. air-conditioning, headlamps, navigation system etc.)
- Controls each device electronically, based on information derived from monitoring activities listed above, to ensure safe, comfortable and efficient operation of the car.

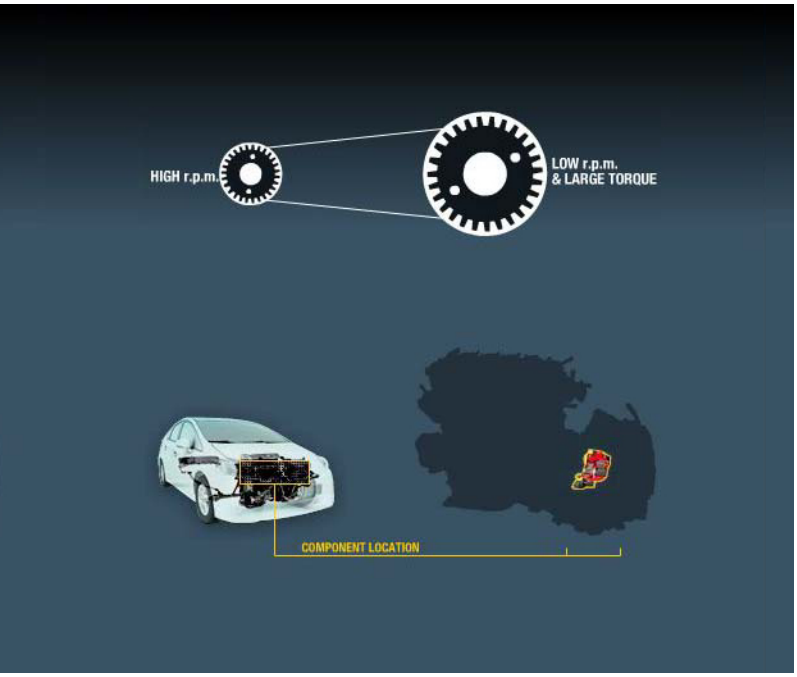
* ECU: Electric Control Unit



Highlander Hybrid Rear Electric Motor

High output rear motor for electric 4WD and high regeneration ratio

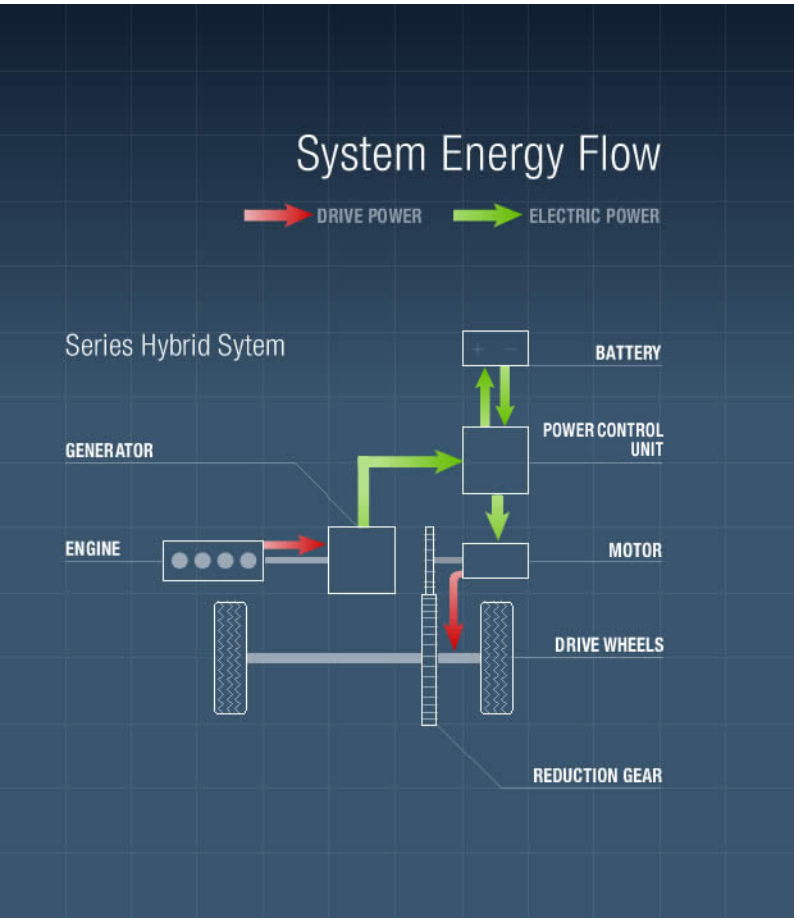
In addition to the front electric motors, Highlander Hybrid is equipped with a permanent magnet synchronous A/C high output rear electric motor. By raising the operating voltage to 650V, it can produce up to 50 kW (68 PS).
Adding the rear electric motor also made it possible to implement an electric 4WD system. The rear electric motor is instantaneously engaged under full acceleration or on a snow-covered road or other slippery road surface, shifting the vehicle into 4WD mode.
The rear electric motor also functions as a regenerator under braking. Together with the front electric motors, it thus contributes to the high regeneration ratio.



Reduction Gear

Reduction gear amplifies torque from the electric motors

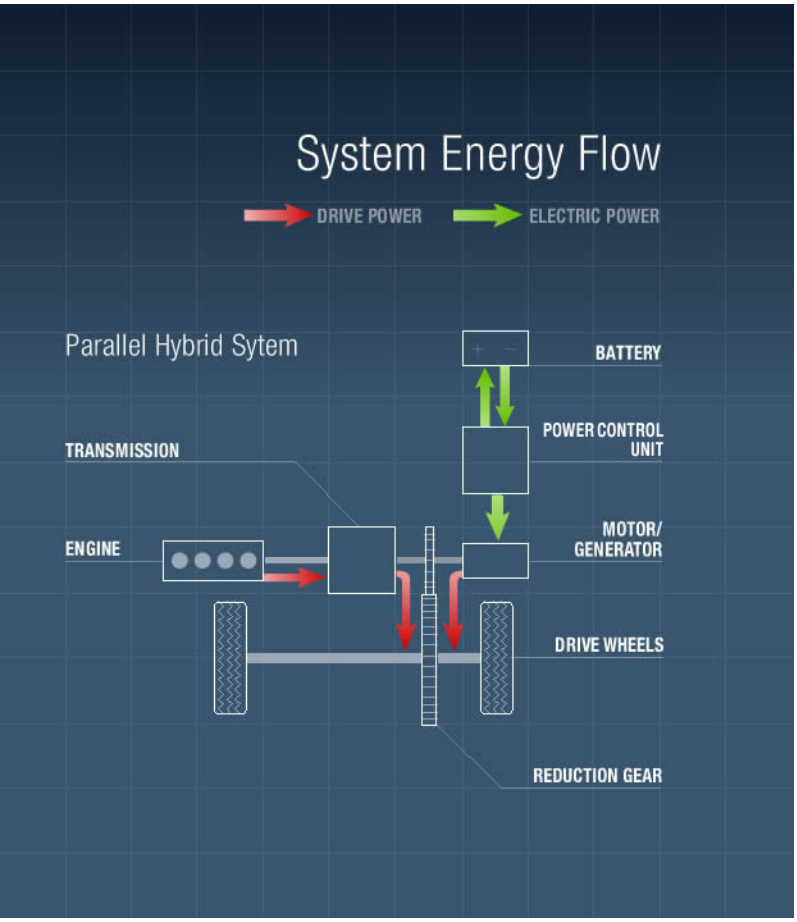
HYBRID SYNERGY DRIVE incorporates the newly developed reduction gear. The reduction gear is designed to reduce the high r.p.m. of the front electric motors so that the power produced can be transferred to the wheels, with the added benefit of torque amplification, i.e. with greater power.This torque amplification effect, coupled with higher revving capability of the front electric motors, combine to provide seamless acceleration at will.



Series Hybrid System

Driving the wheels with electric motors, using electric power generated by an internal combustion engine

A series hybrid system uses an internal combustion engine to turn a generator, which produces electric power to drive the wheels.
Its basic components are electric motors, an internal combustion engine, a generator, a battery and an inverter.
A small displacement internal combustion engine is turned on to intermittently turn the generator to supply electric power directly to the motor or to recharge the battery as the car runs. The name "Series Hybrid" is derived from the fact that the power produced by the internal combustion engine is connected in series to the electric motors.



Parallel Hybrid System

Driving the wheels with an electric motor and an internal combustion engine, using the electric motor to recharge the battery

A parallel hybrid system uses both an electric motor and an internal combustion engine to drive the wheels. Its basic components are an electric motor, an internal combustion engine, a battery, a power control unit and a transmission. With the parallel hybrid system, the motor is powered by the battery to drive the wheels, and is also used as a generator to recharge the battery. Consequently, the motor cannot be used to generate electricity while the car is running. Because the flow of power is in parellel, this system is called a "Parallel Hybrid System".

Countries/Regions Where Hybrid Vehicles are Available

Distributing to various countries/regions around the world

AMERICAS
Canada
Costa Rica
Ecuador
Guatemala
Hawaii
Peru
Puerto Rico
United States of America

AFRICA
Mauritius
South Africa

ASIA&OCEANIA
Australia
China
Guam
Hong Kong
Indonesia
Israel
Japan
Jordan
Lebanon
New Zealand
Philippines
Saipan
Singapore
Syria
Taiwan
Thailand

EUROPE
Austria
Belgium
Bulgaria
Canary Islands
Cyprus
Czech Republic
Denmark
Finland
France
Germany
Gibraltar
Great Britain
Greece
Hungary
Iceland
Italy
Ireland
Malta
Netherlands
Norway
Poland
Portugal
Reunion
Romania
Slovenia
Spain
Sweden
Switzerland