Toyota's New, More Efficient Engines

April 10, 2014

Toyota Motor Corporation

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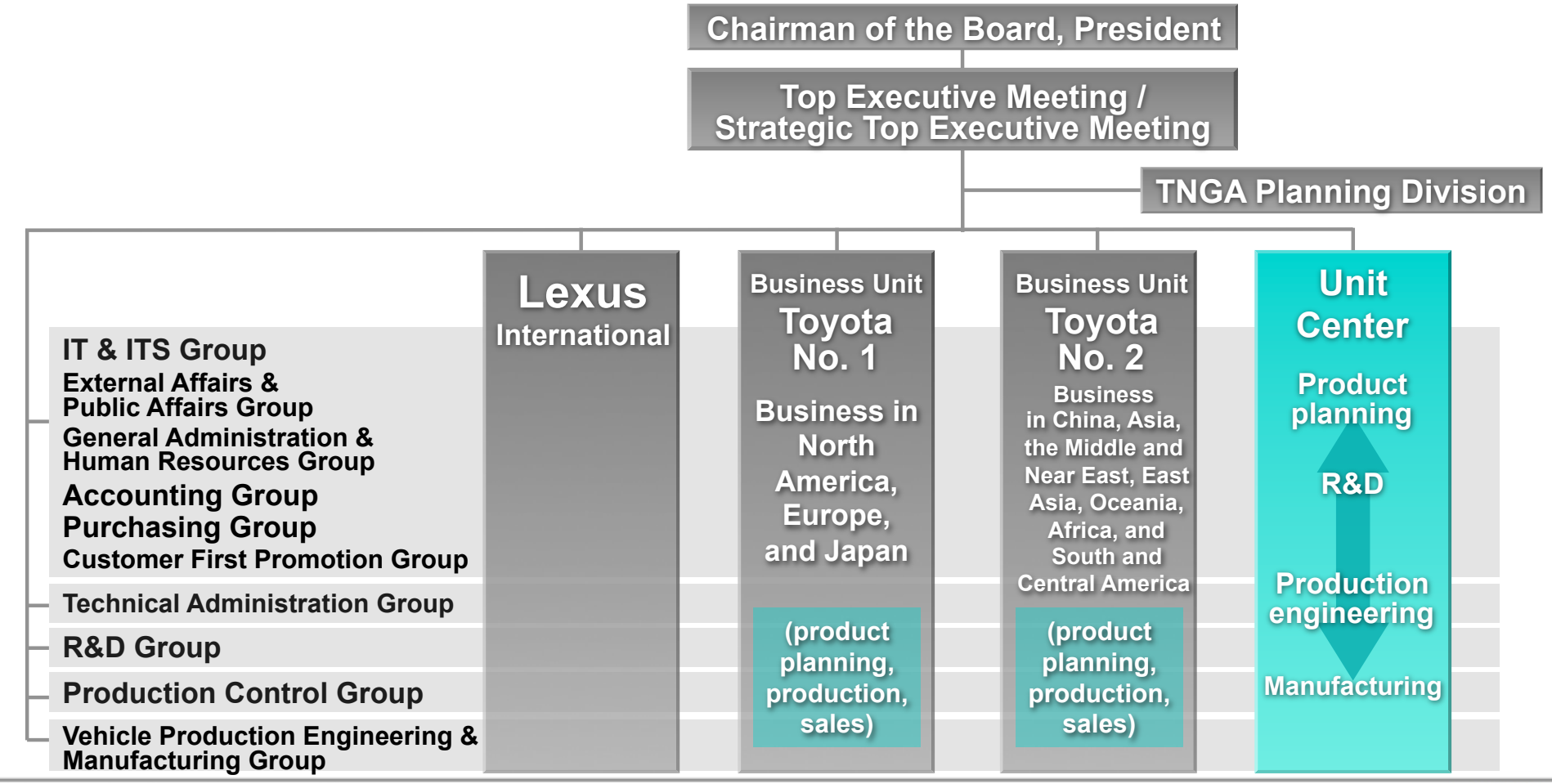
1 The Unit Center



1 The Unit Center

Unit Center

- Unit Management Division
- Engine Engineering Field
- Drivetrain Engineering Field
- Hybrid Vehicle Engineering Field
- Unit Production Engineering Field
- **Plants** (Honsha, Motomachi, Kamigo, Miyoshi, Tsutsumi, Myochi, Shimoyama, Kinuura, Tahara)

Our mission is to develop the most competitive units in the world and to put them swiftly into production.

1 The Unit Center

Powertrain Joint Development Building

- **Integrated development office**
  1. Better coordination between R&D and production engineering
- **Full series of evaluations completed in the same building**
  2. Swift prototyping and evaluation
  3. Vehicle and unit evaluation assured at the single part and product levels

Maximize development efficiency

Tackle new R&D challenges

2 Toyota's Engine Development Objectives

Develop engines that can extract the greatest amount of work from each drop of fuel

Enhancing powertrain efficiency

- Better engine thermal efficiency
- Greater drivetrain transmission efficiency

Extracting the greatest amount of work from each drop of fuel

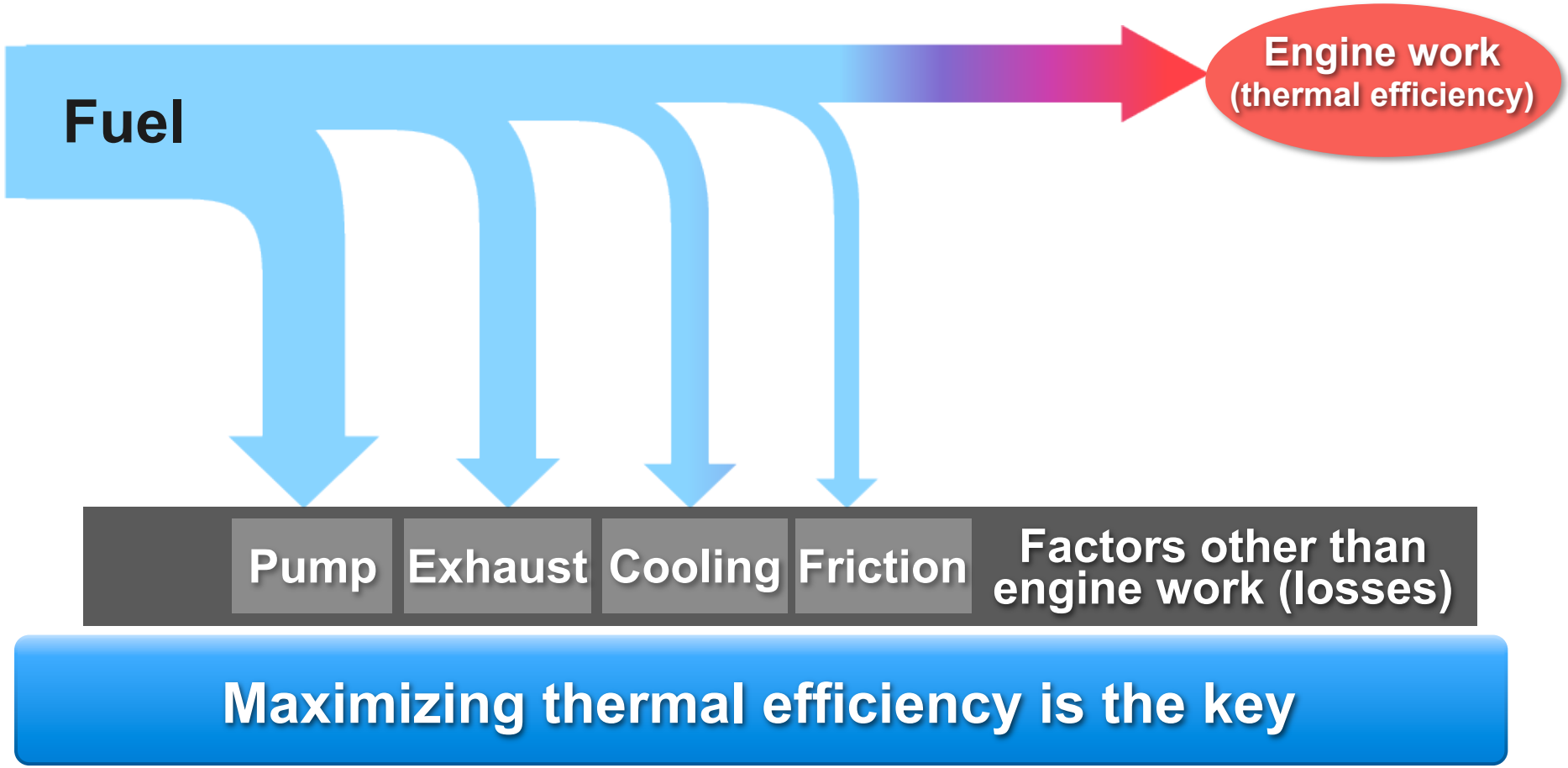
Reducing running resistance

Drag reduction

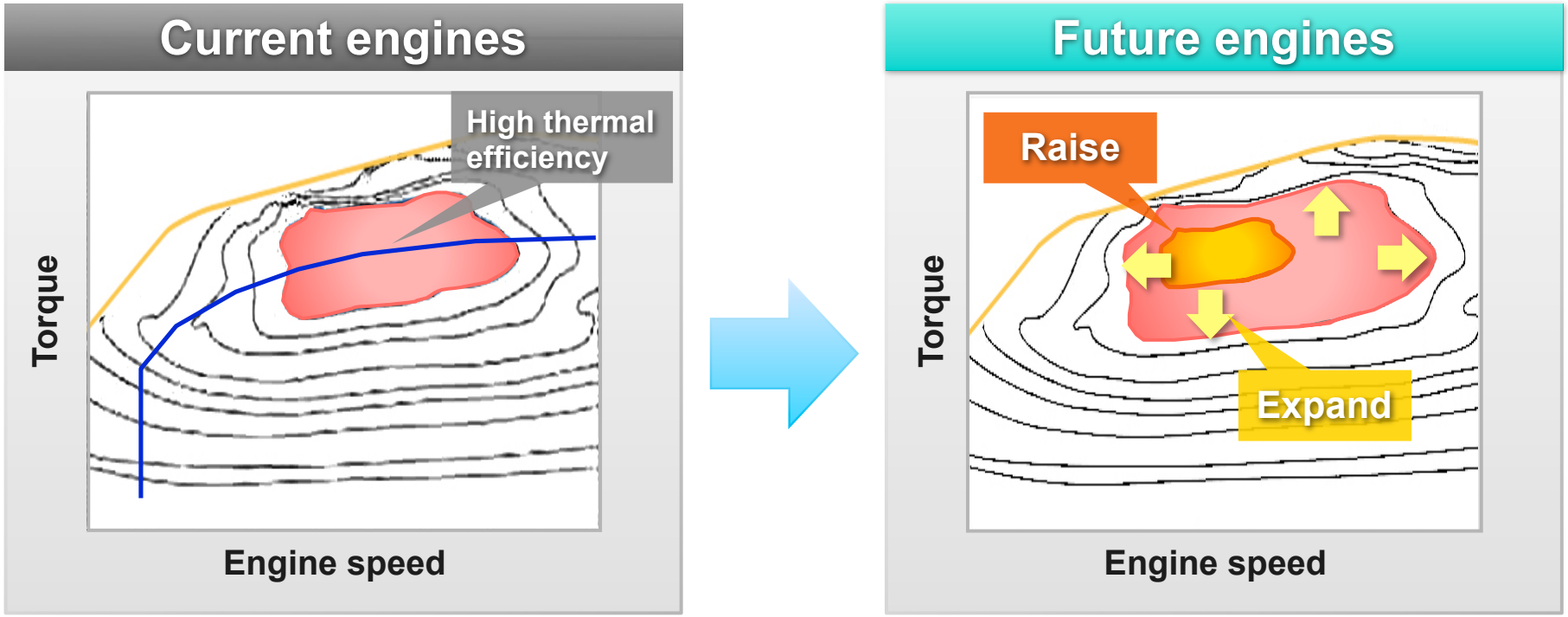
Weight reduction

Improve fuel economy by increasing engine thermal efficiency and drivetrain transmission efficiency

2 Toyota's Engine Development Objectives



2 Toyota's Engine Development Objectives



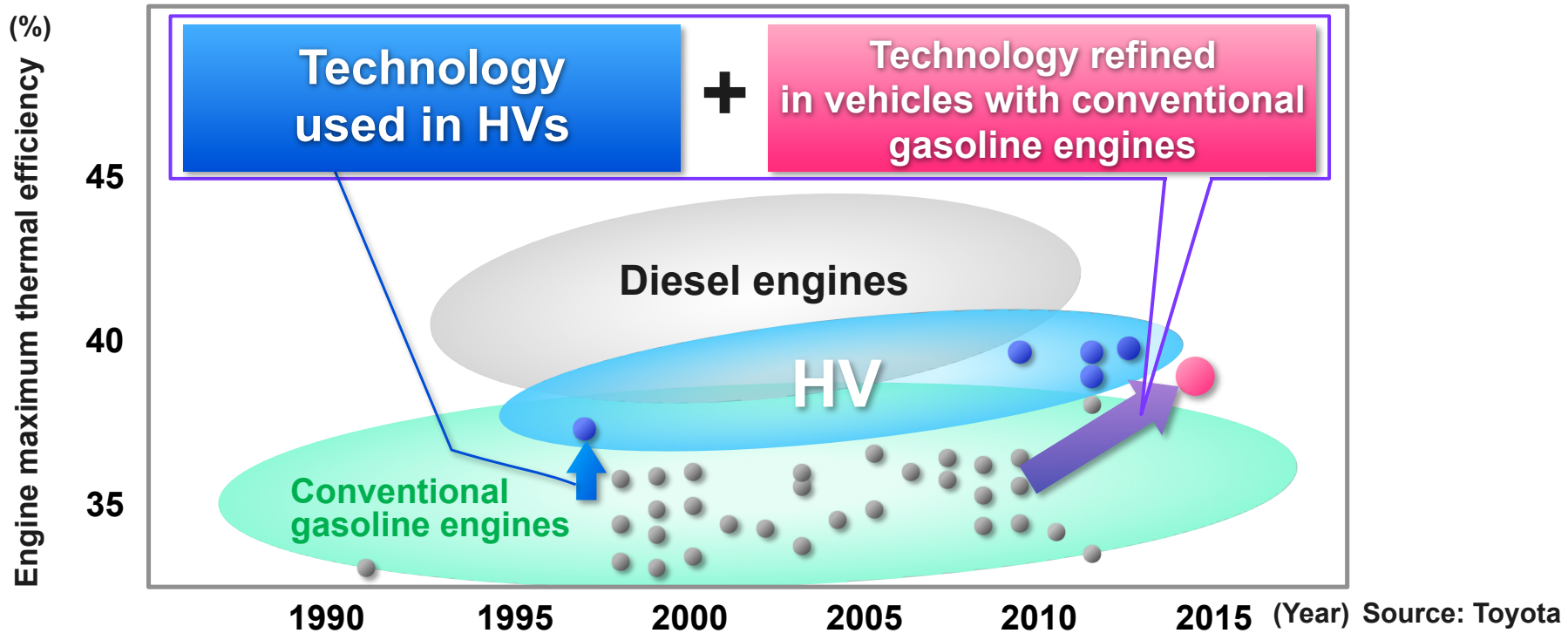
Raise and expand high thermal efficiency zones

Key achievements

Fuel economy improvement of 10 percent or higher compared to existing vehicles

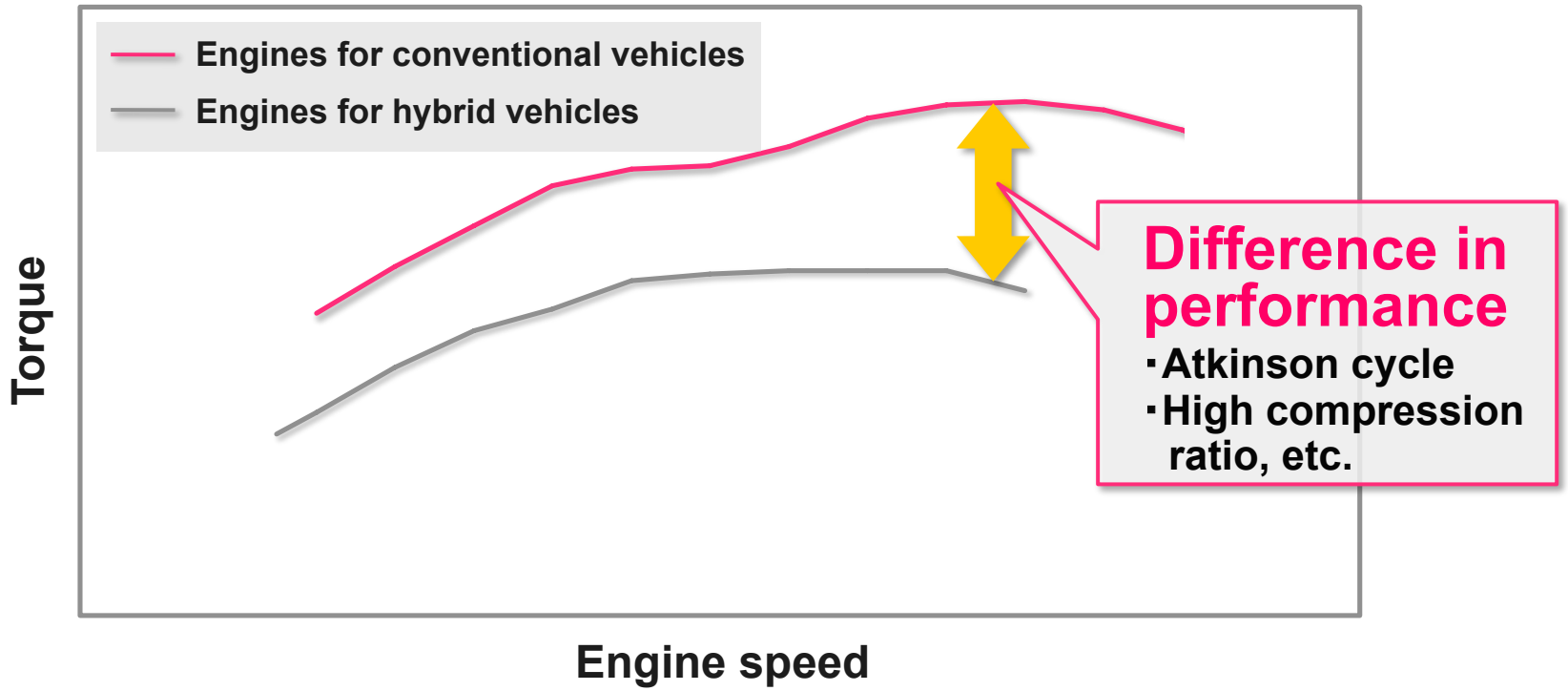
World-class maximum thermal efficiency

3 The New Engine Series

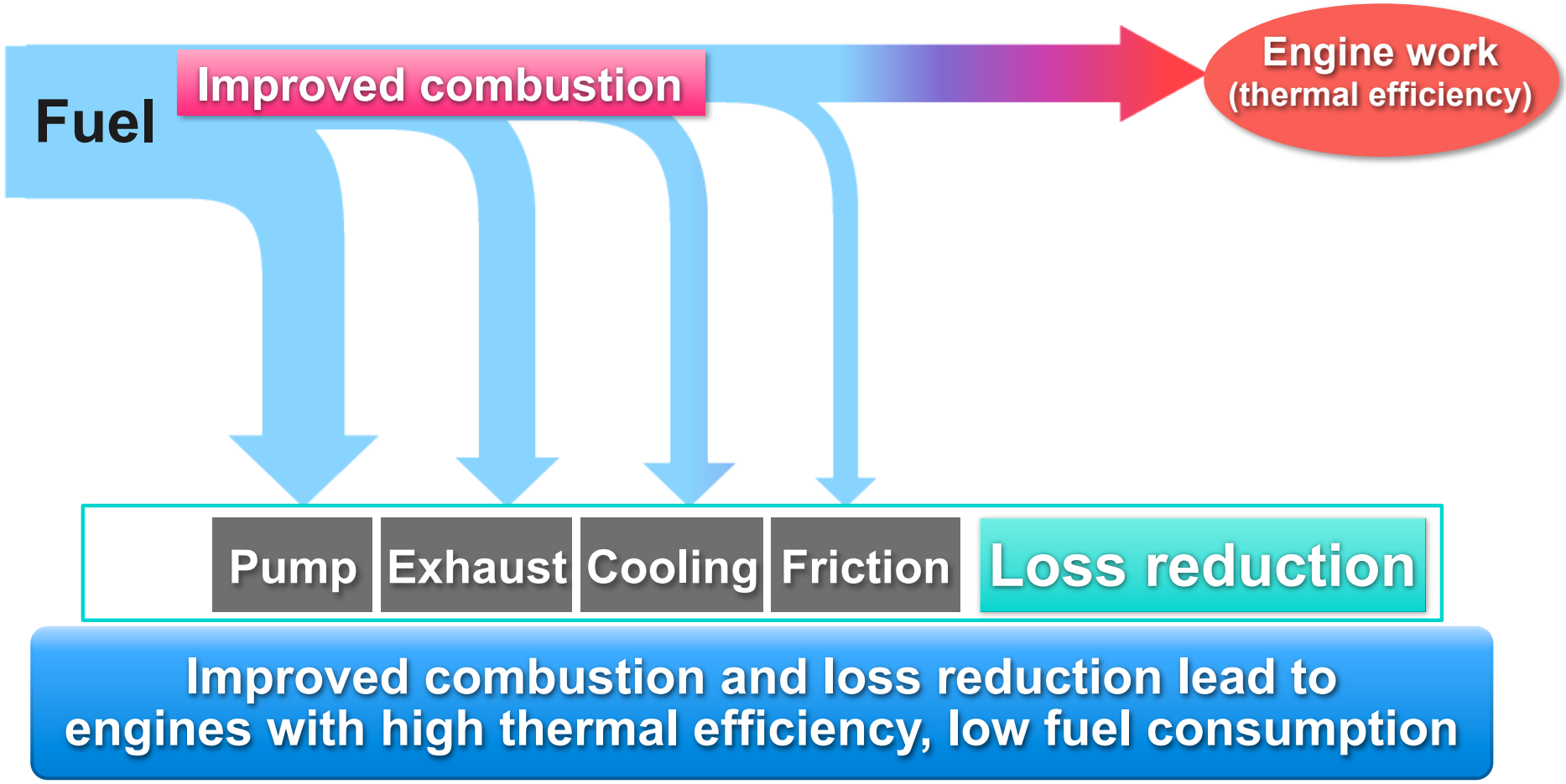


Achieve hybrid-like thermal efficiency in conventional vehicles

3 The New Engine Series



Performance differs between engines for hybrid vehicles and engines for conventional vehicles


Fuel
Improved combustion
Engine work
(thermal efficiency)
Pump
Exhaust
Cooling
Friction
Loss reduction
Improved combustion and loss reduction lead to
engines with high thermal efficiency, low fuel consumption

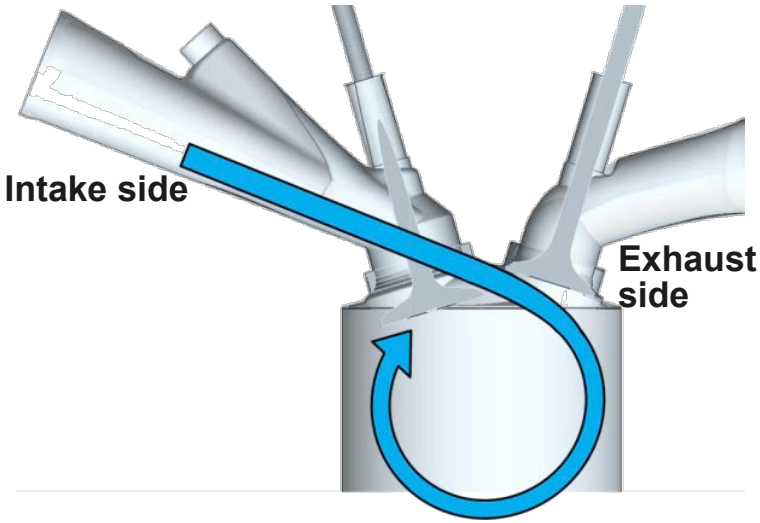
3 The New Engine Series

		HVs	Vehicles with conventional gasoline engines
Improved combustion	1 Rapid combustion		●
	2 Higher compression ratio	●	●
Loss reduction	3 Reduced pumping loss		
	1 Atkinson cycle	●	
	2 Large-volume cooled EGR	●	
	4 Low friction	●	●

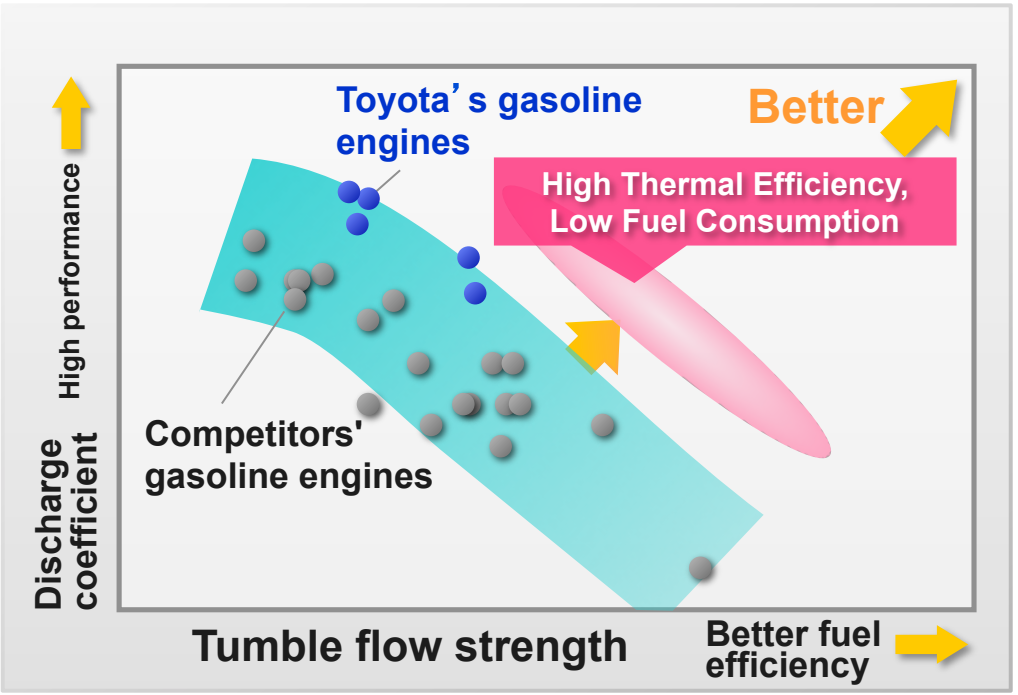
● : Technology used/refined

3 The New Engine Series

1 Rapid Combustion

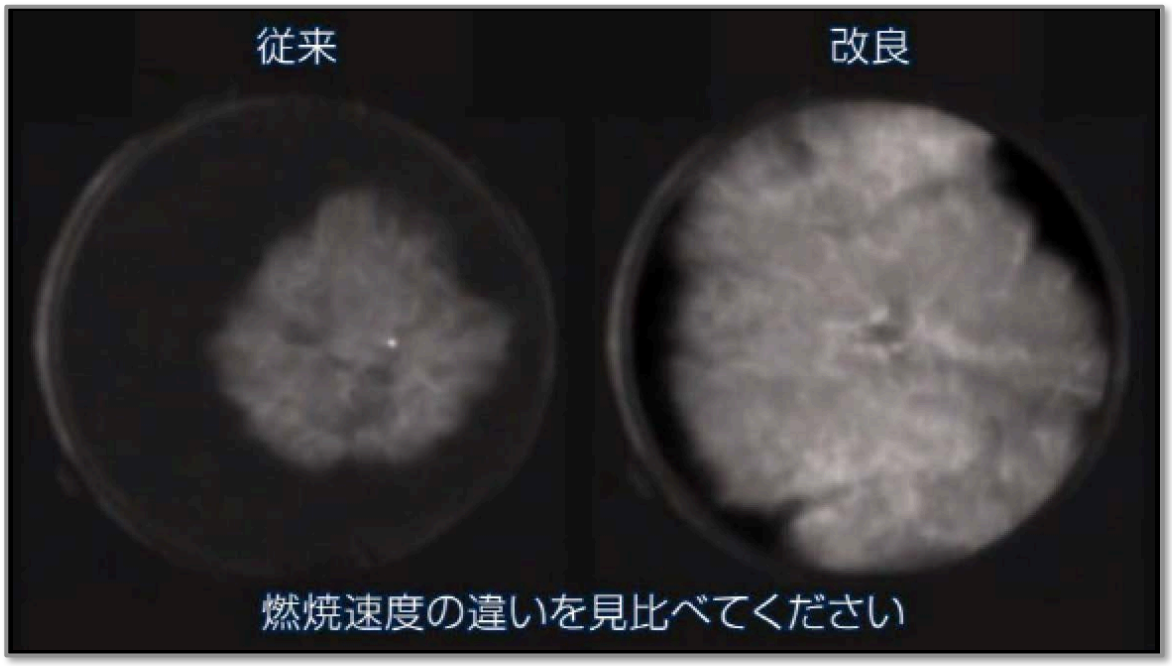


Tumble flow
(vertical vortex)



Achieve unprecedented efficiency and tumble

1 Rapid Combustion



Rapid combustion through higher tumble flow

2 Higher compression ratio

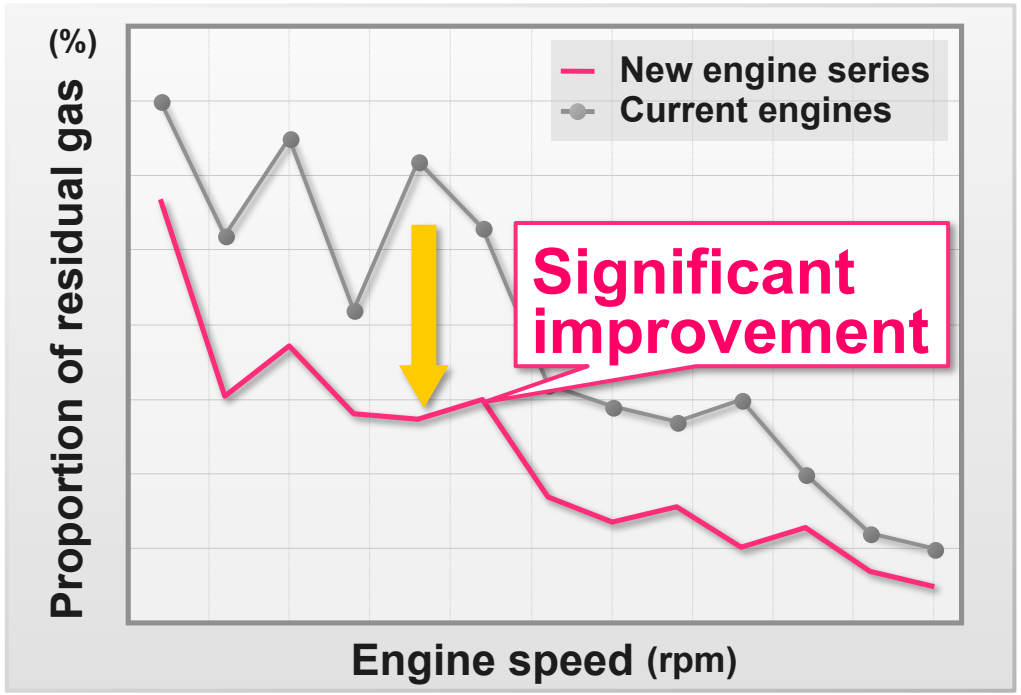
1. Rapid combustion
2. Scavenging in the combustion chamber
3. Control of combustion chamber temperature

Avoid knocking and maintain/improve power performance

2 Higher compression ratio

2 Scavenging in the combustion chamber

4-2-1 exhaust pipe

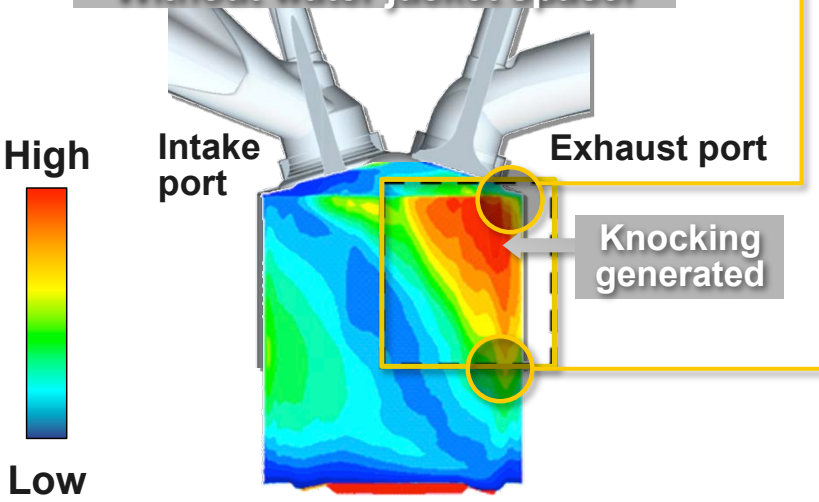


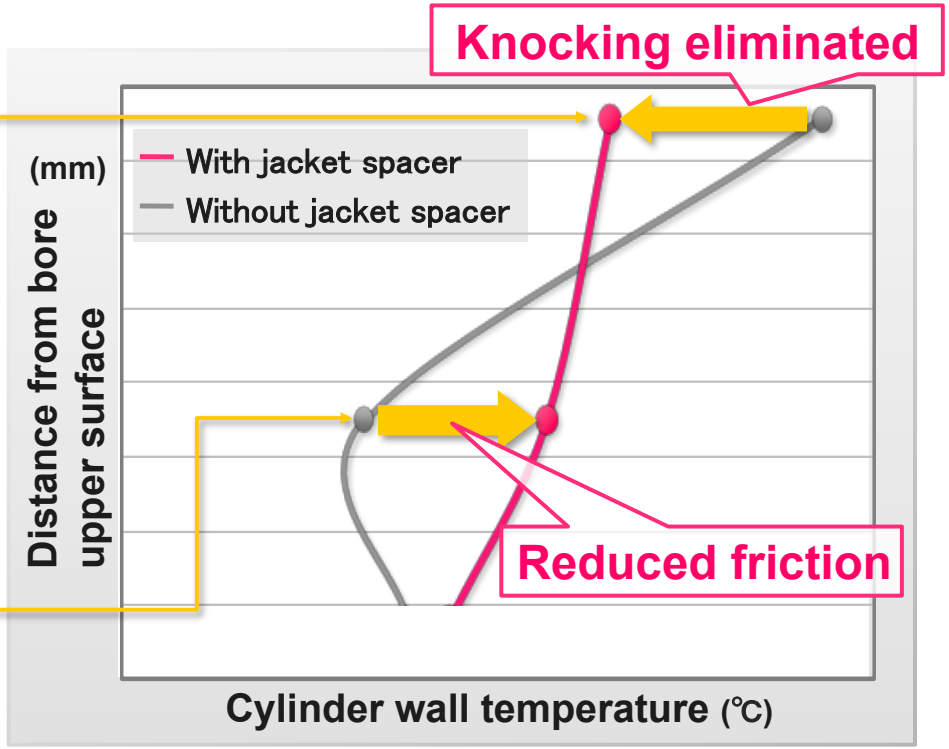
Even with a higher compression ratio, increasing scavenging efficiency prevents knocking

2 Higher compression ratio

3 Control of combustion chamber temperature

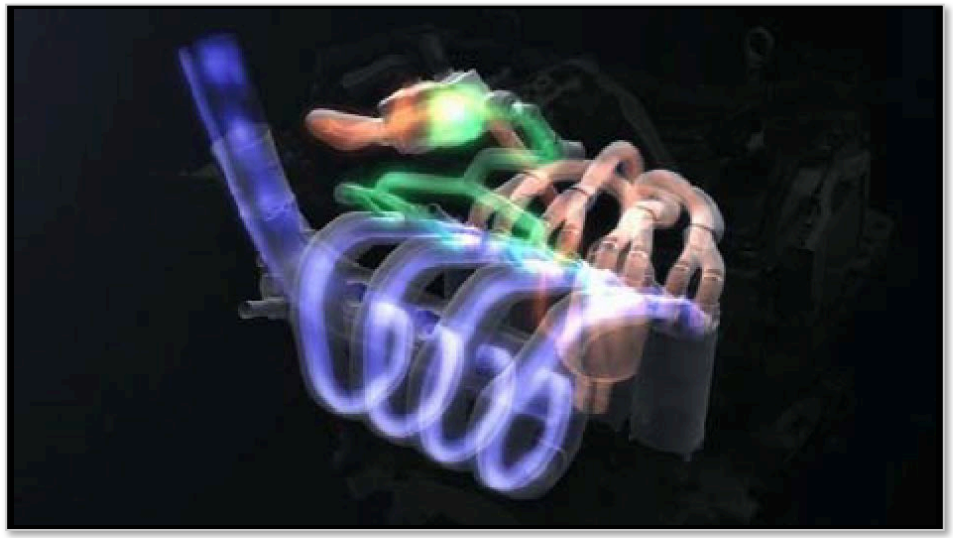
Without water jacket spacer





Knocking prevented by controlling the cylinder wall temperature

3 - 1 Atkinson Cycle



3 - 2 Large-Volume Cooled EGR

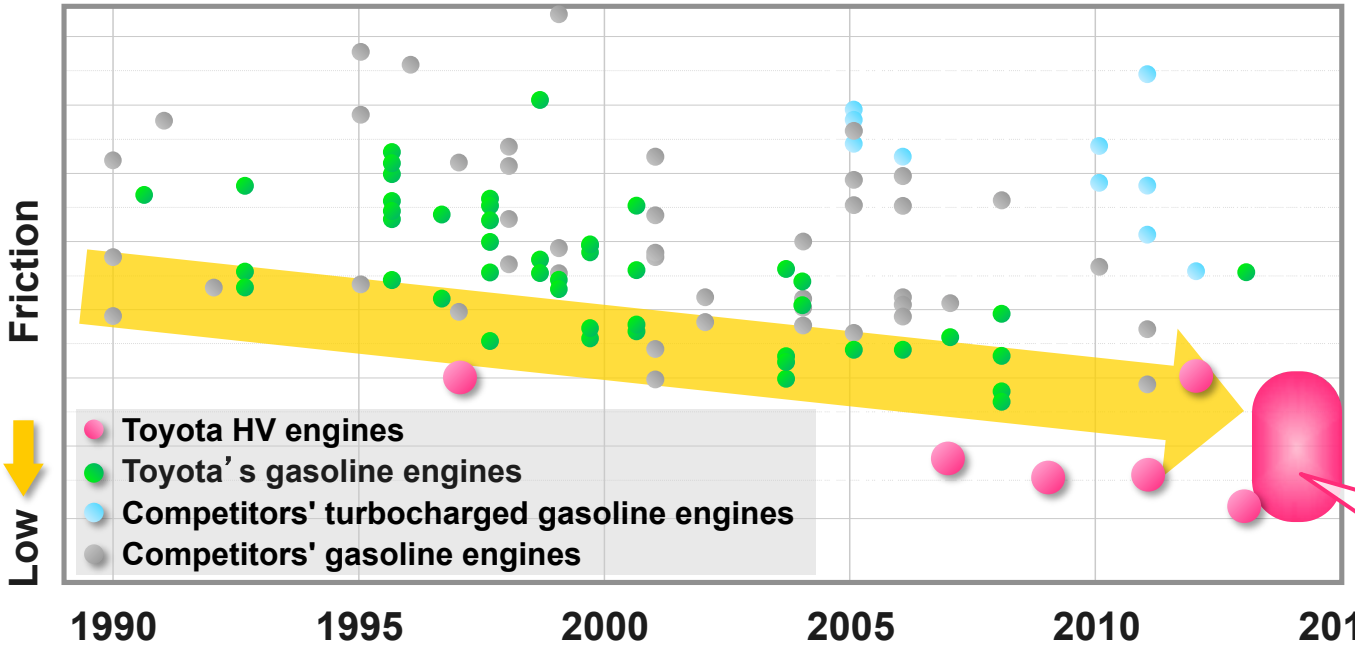
Variable valve system technology

- Expanded VVT operating angle
- Electronic VVT

Variable valve technology enables adoption of the Atkinson cycle in conventional vehicle engines

3 The New Engine Series

4 Low Friction



- Modified piston skirt surface
- Plastic-coated bearing
- New structure water jacket spacer
- Reduced capacity oil pump
- Auxiliary belt with reduced bending loss

High Thermal Efficiency,
Low Fuel Consumption Engines

Source: Toyota

Achieve world-class low friction

4 1.3- liter Engine

Better combustion

- **Rapid combustion**
  - High performance, high tumble port
- **High compression ratio(13.5)**
  - Reduced variation in compression ratio
    (Narrower tolerances for the compression chamber volume)
  - Large-volume cooled EGR
  - Water jacket spacer with EXPAD
  - 4-2-1 exhaust pipe

Loss reduction

- **Pumping and cooling loss reduction**
  - Atkinson cycle
  - Large-volume cooled EGR
  - Electronic VVT (intake side)
    (electronic variable valve timing mechanism)
- **Low friction**
  - Modified piston skirt surface
  - Water jacket spacer with EXPAD
  - Plastic-coated bearing
  - Low friction chain
  - Auxiliary belt with reduced bending loss

Max. thermal efficiency : 38%

4 1.0- liter Engine

Better combustion

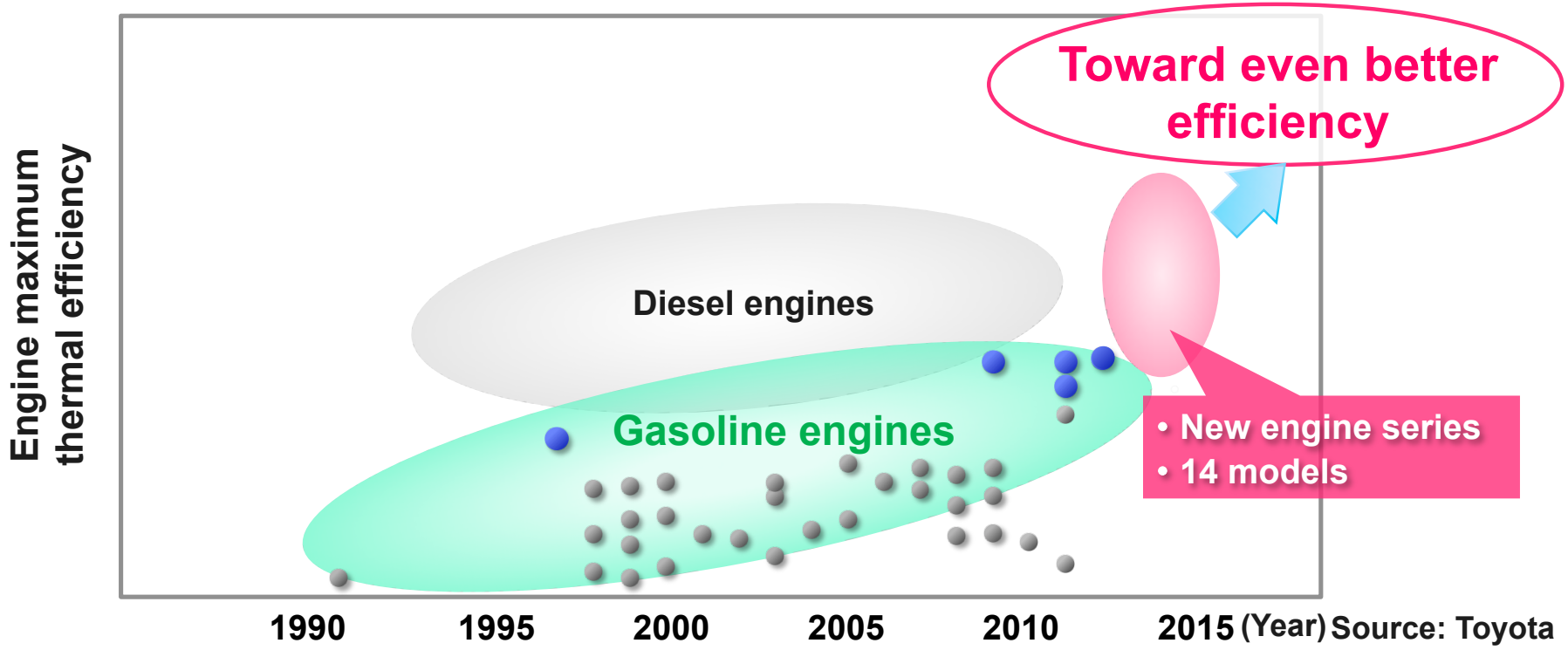
- **Rapid combustion**
  - High performance, high tumble port
- **High compression ratio(11.5)**
  - Large-volume cooled EGR
  - Water jacket spacer

Loss reduction

- **Pumping and cooling loss reduction**
  - Atkinson cycle
  - Large-volume cooled EGR
- **Low friction**
  - Modified piston skirt surface
  - Water jacket spacer
  - Low friction chain

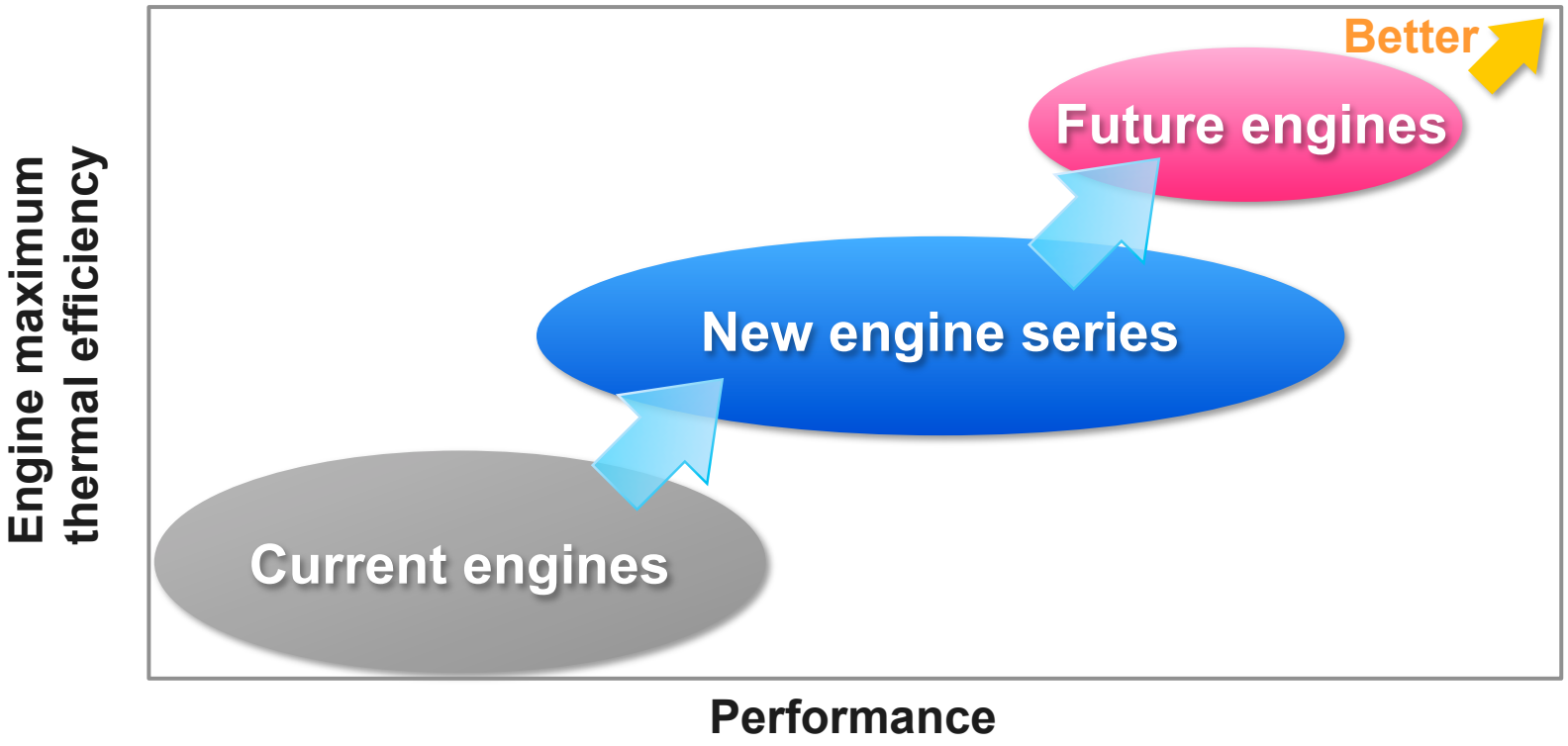
Max. thermal efficiency : 37%

5 Future Improvements

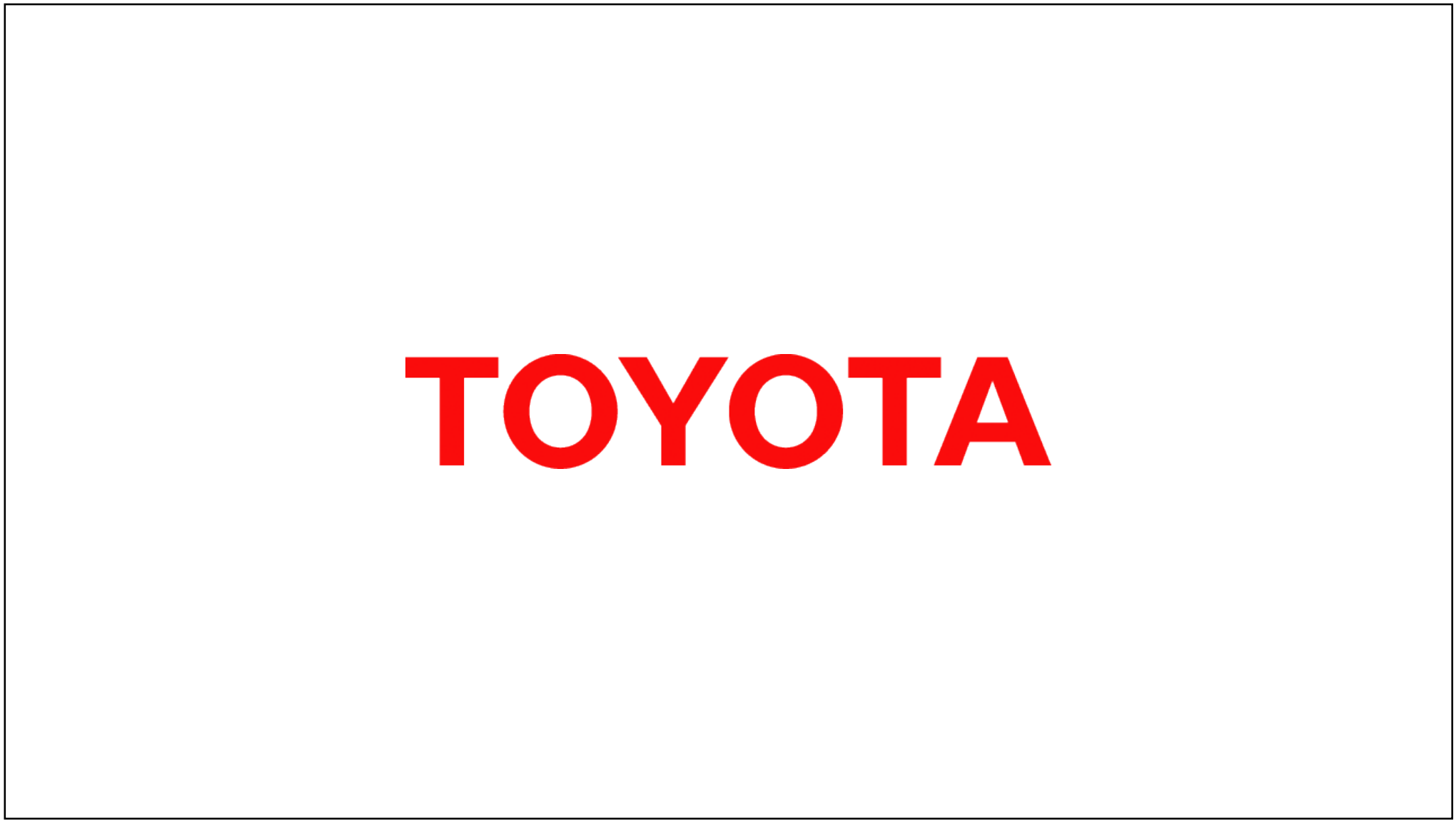


Introduce 14 models in the new engine series
Aim for even better efficiency in the future

5 Future Improvements



Continue to raise performance while increasing thermal efficiency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