Briefing on Mazda's Long-Term Vision for Technology Development

Technical Overview of SKYACTIV-X

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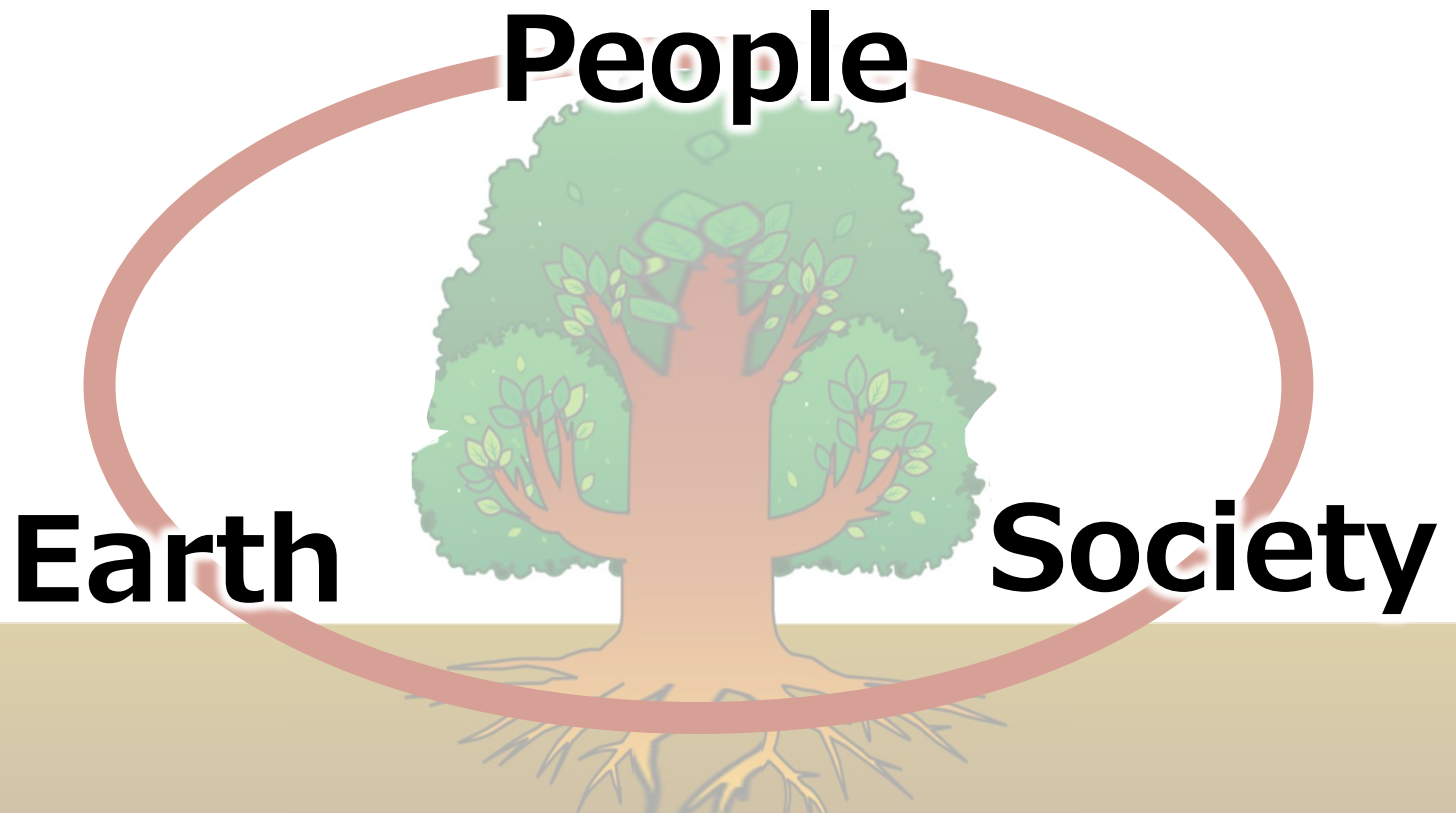
Mazda Motor Corporation

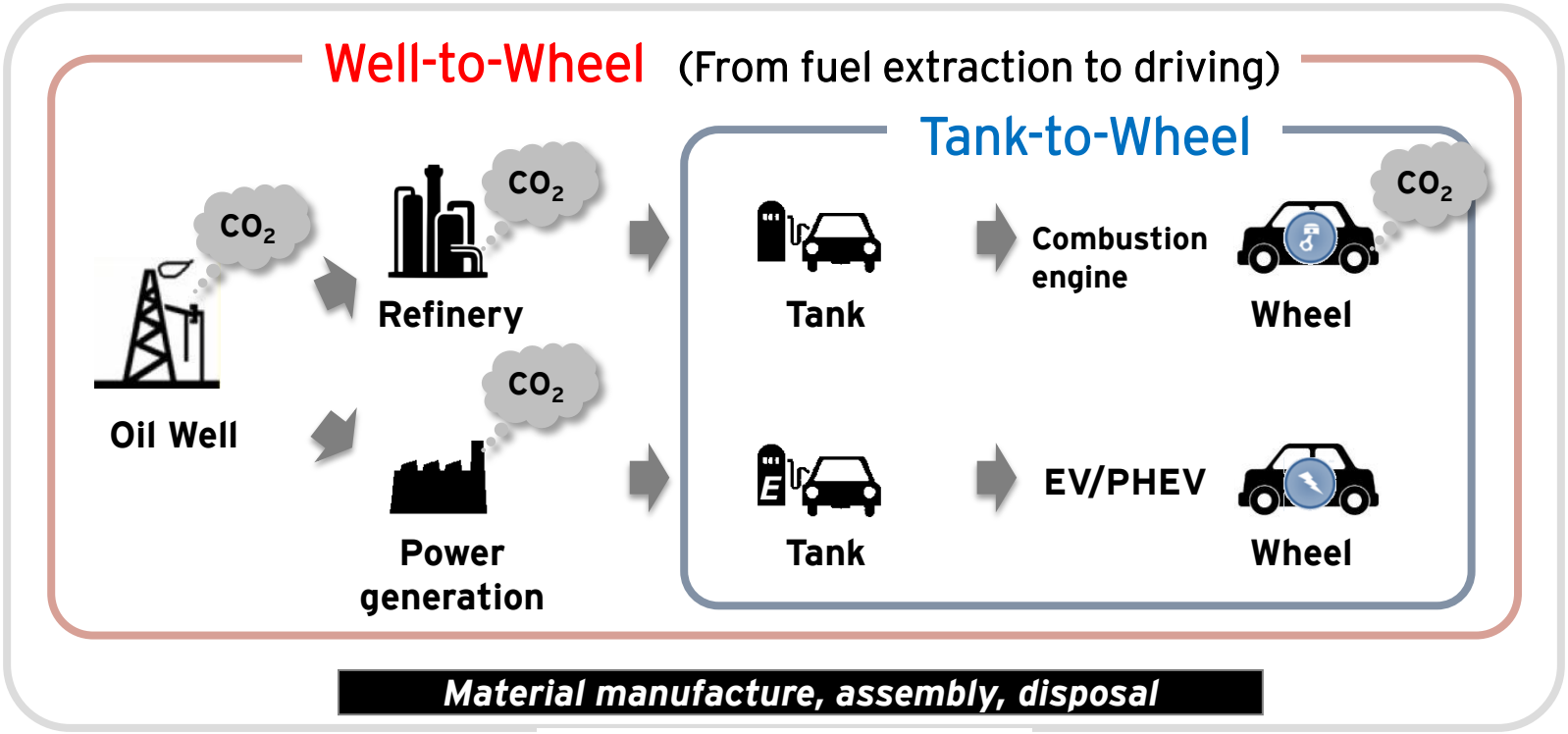
Sustainable Zoom-Zoom 2030

At Mazda, we see it as our mission to bring about a beautiful earth and to enrich people's lives as well as society. We will continue to seek ways to inspire people through the value found in cars



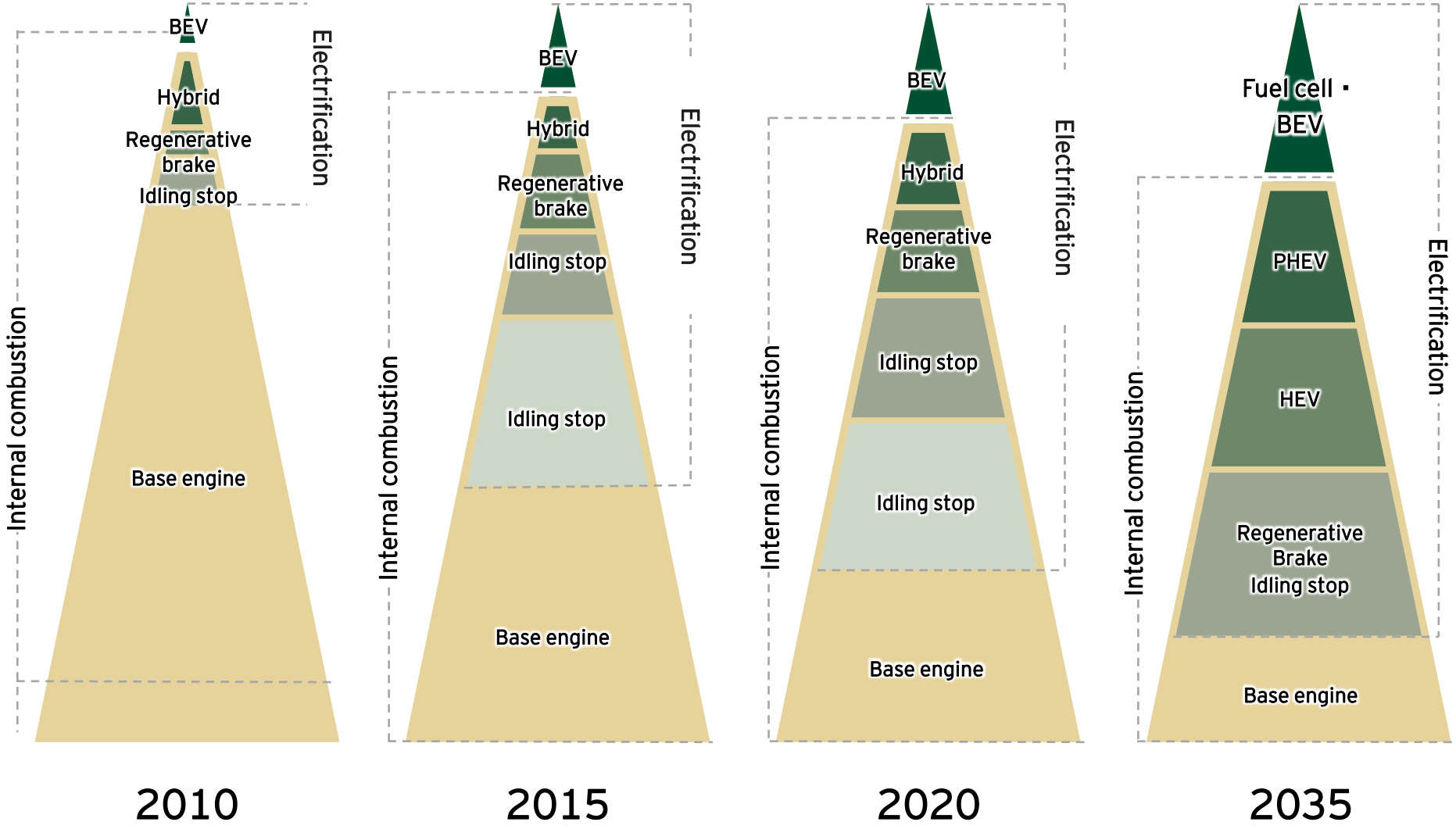
Mazda's Approach to Issues Facing the Earth

Approach CO2 reduction from a well-to-wheel perspective to reduce CO2 emissions throughout the vehicle's life cycle

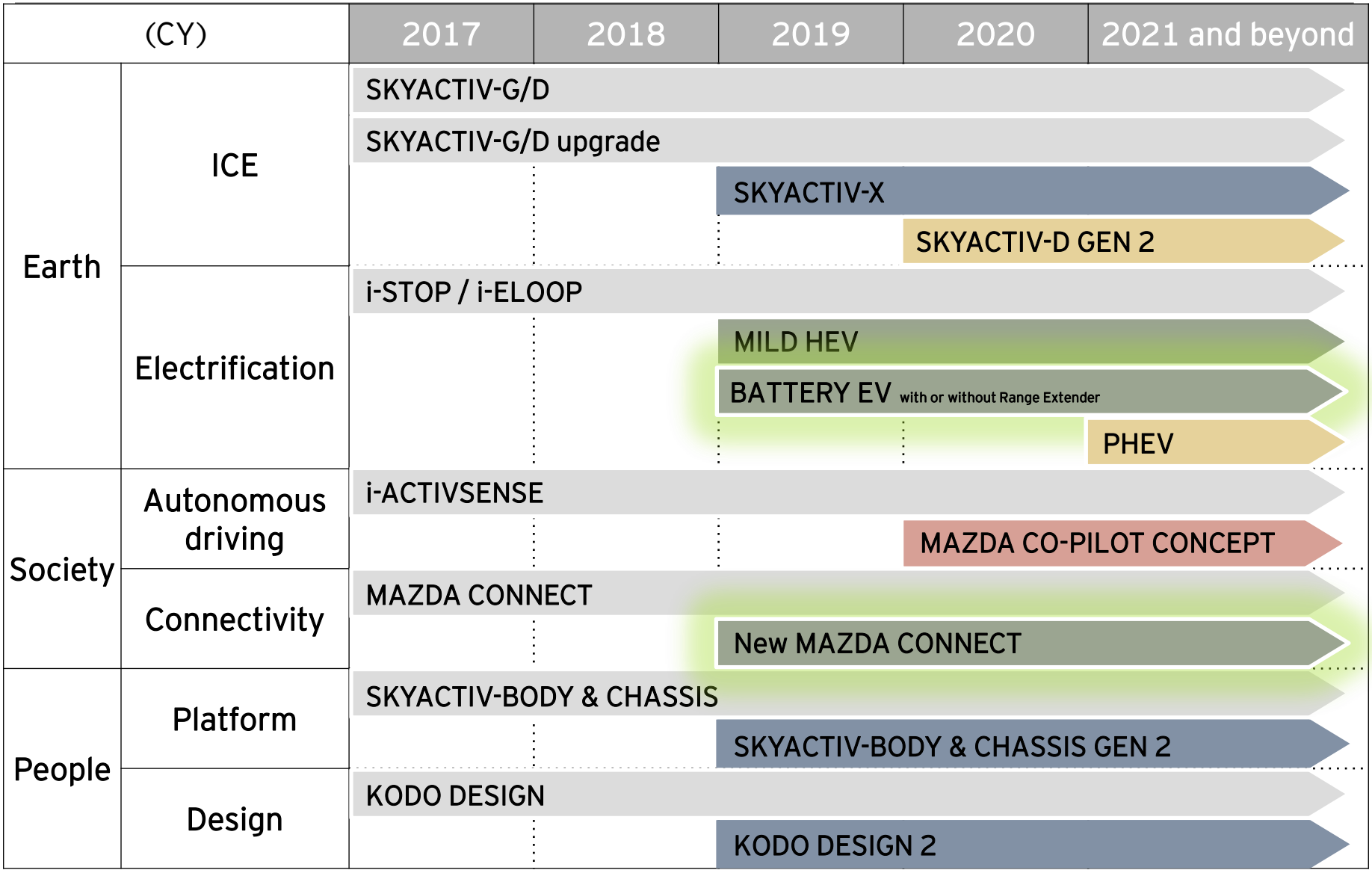


Life Cycle Assessment

Forecast Expansion of Environmental Technologies



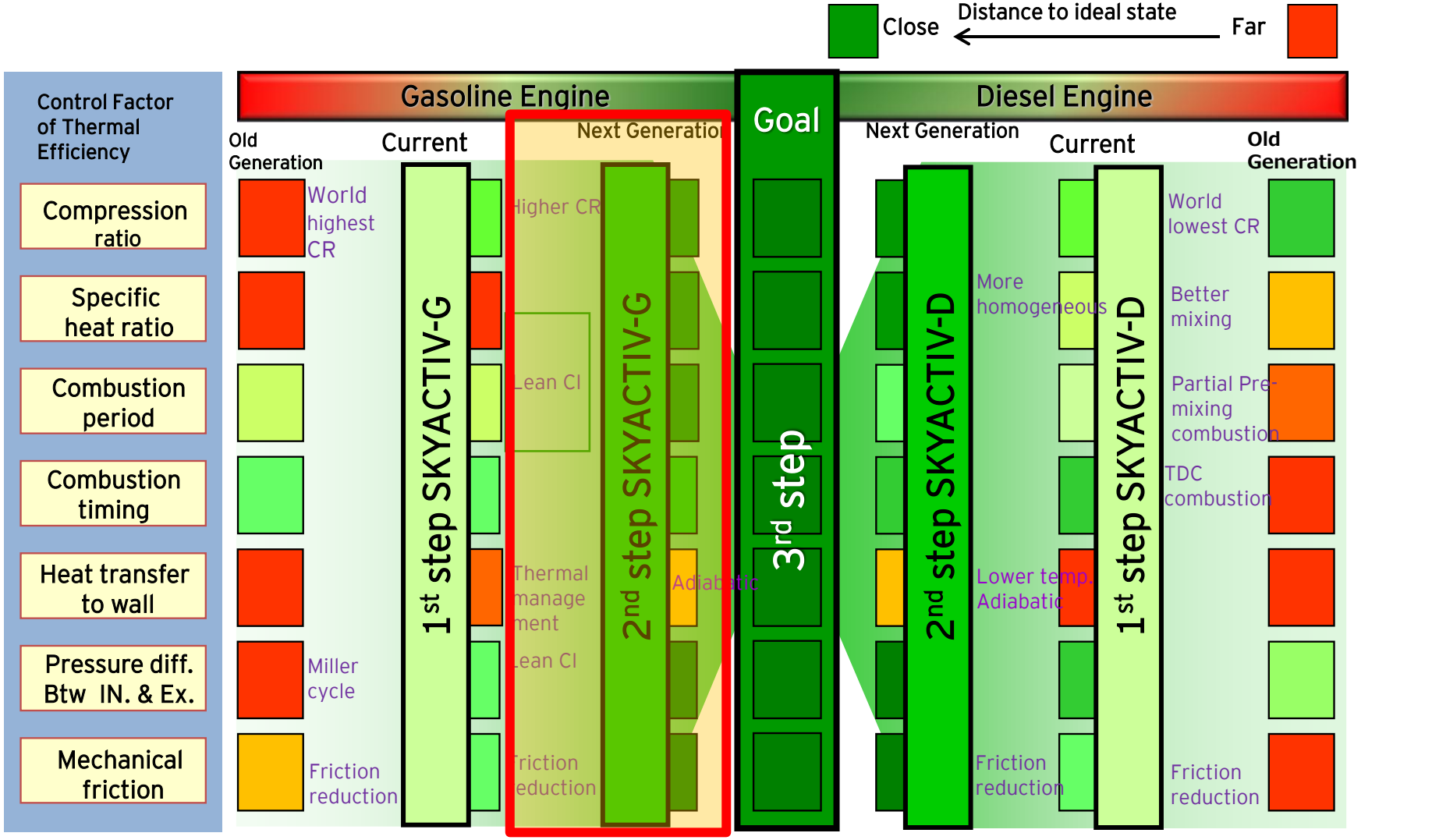
Launch plan for next-generation technologies



Year a briefing to be 2017 2018 2019 2020

Next-Generation Gasoline Engine SKYACTIV-X

Road Map to Ideal Combustion



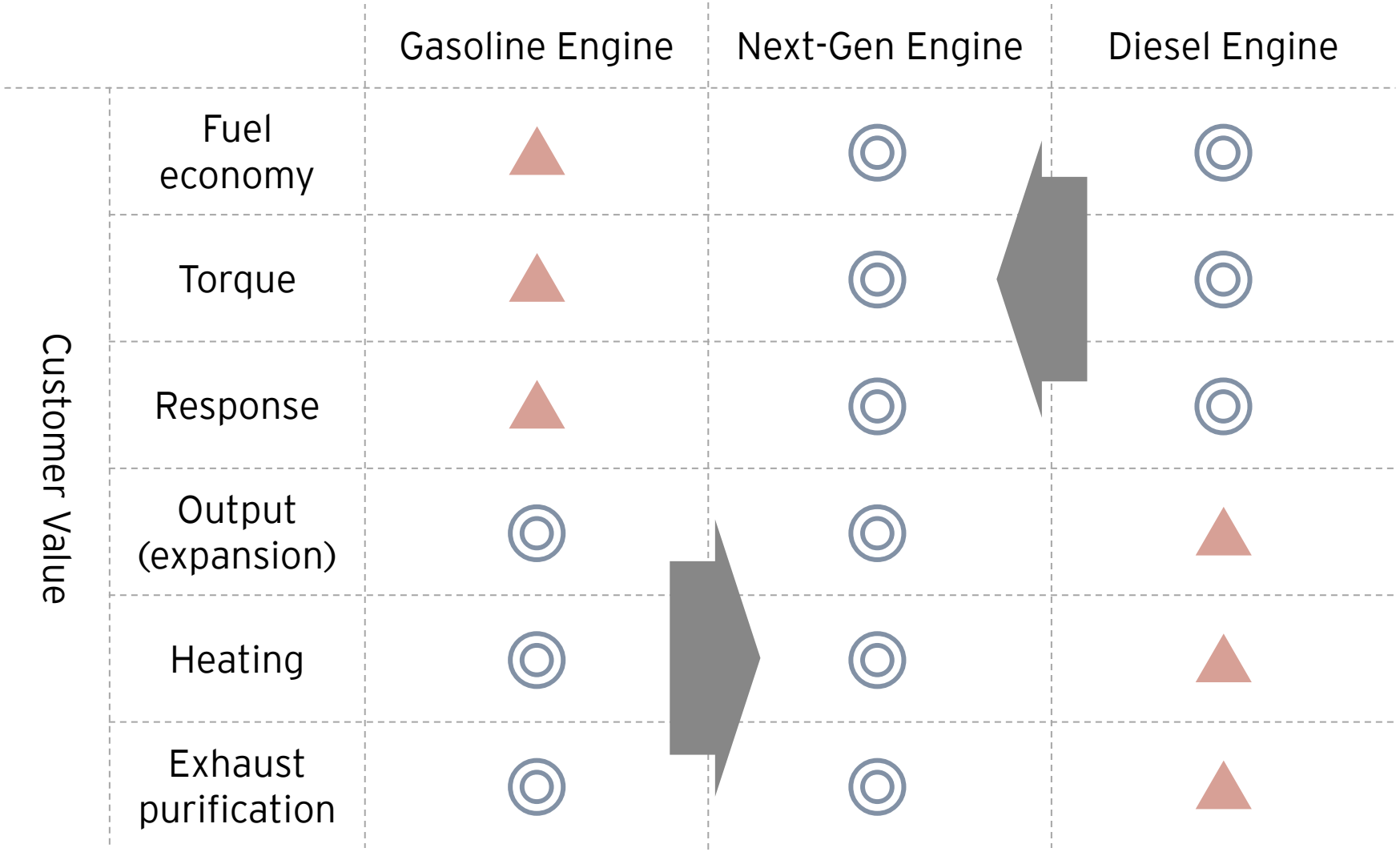
Features of SKYACTIV-X

SKYACTIV-X

A gasoline engine using compression ignition

Fuel Type : Gasoline
Combustion Method : Diesel

Features of SKYACTIV-X



‘CCI’ is our target for ideal combustion

CCI （Controlled Compression Ignition）

＝ Completely “controlled”
compression ignition combustion

‘CCI’ is our target for ideal combustion

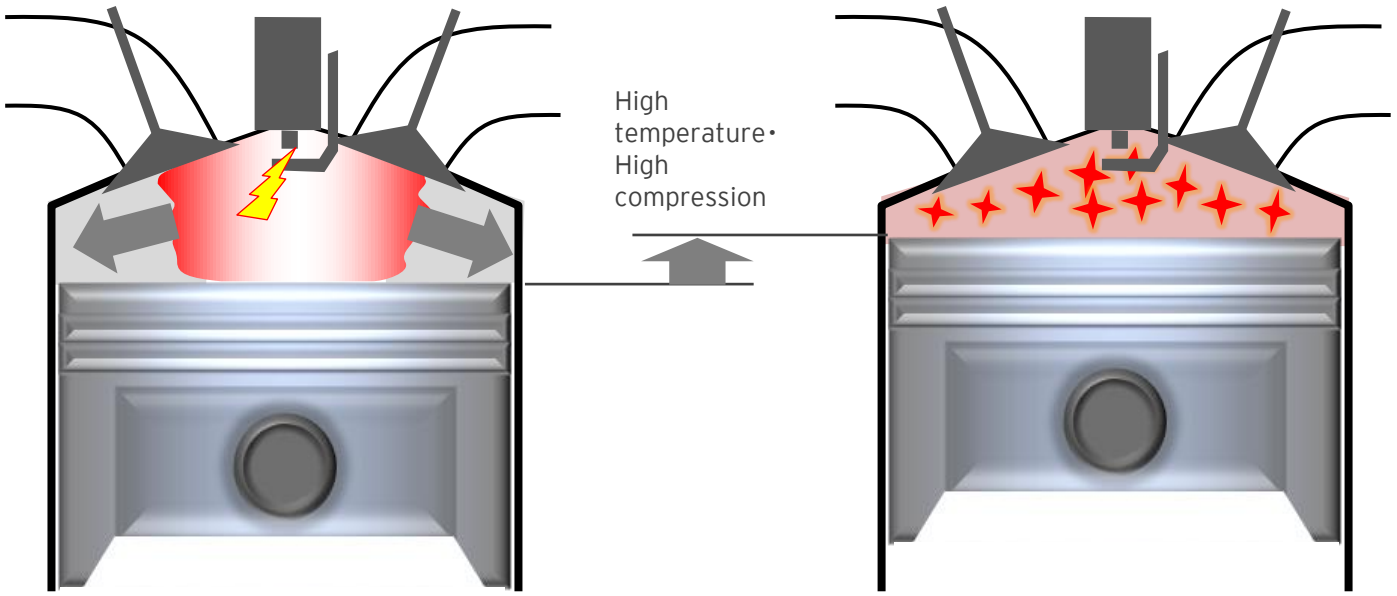
CCI (Controlled Compression Ignition)

= Completely “controlled”
compression ignition combustion

Difference between SI and HCCI

Spark Ignition (SI)

Homogeneous Charge Compression Ignition (HCCI)



- Ignition by plug
- Combust by flame propagation
- Air/Fuel＝Const.

- Compression ignition
- Combust at multiple points
- Air>>Fuel　: leaner

Why is Compression Ignition Significant?

Aiming to improve fuel economy with spark ignition, we try to achieve lean combustion.

⇩

But if we increase the amount of air or gas

the flame will not propagate

Can't we ignite gasoline by compression, as we do with diesel?

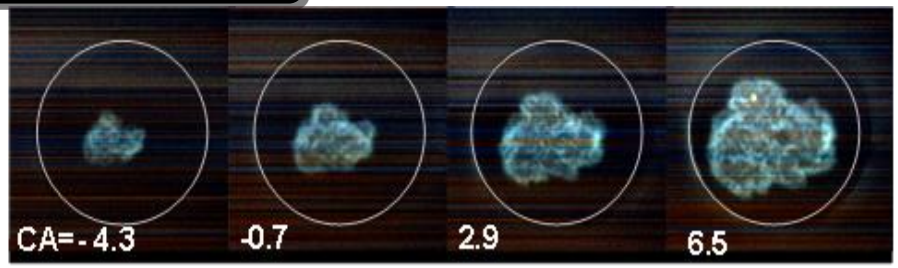
⇩

Combustion ignition enables a super lean burn at twice the ideal air/fuel ratio

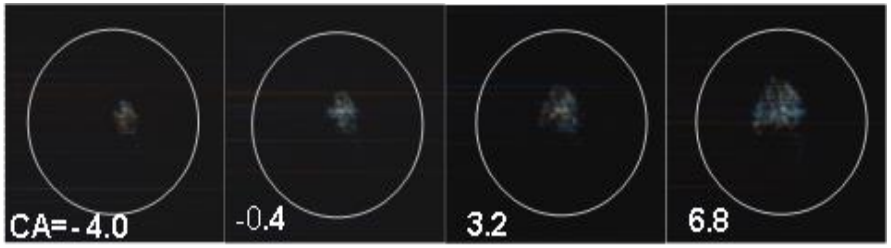
Even lean air/fuel mixtures will ignite and burn in many places simultaneously if highly compressed

SI Combustion

Ordinary SI combustion@750rpm:
air fuel ratio of 14.7:1

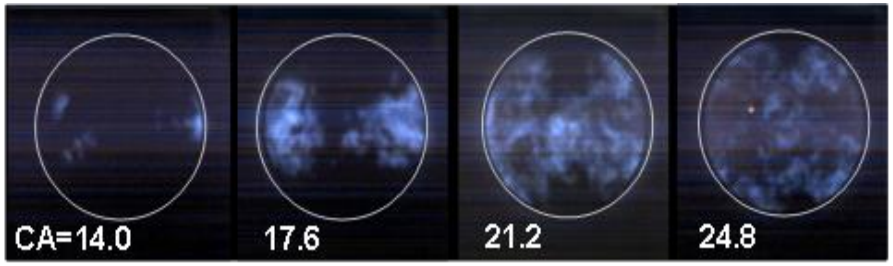


Challenge:
Lean, spark ignition combustion : air fuel ratio of 29.4:1



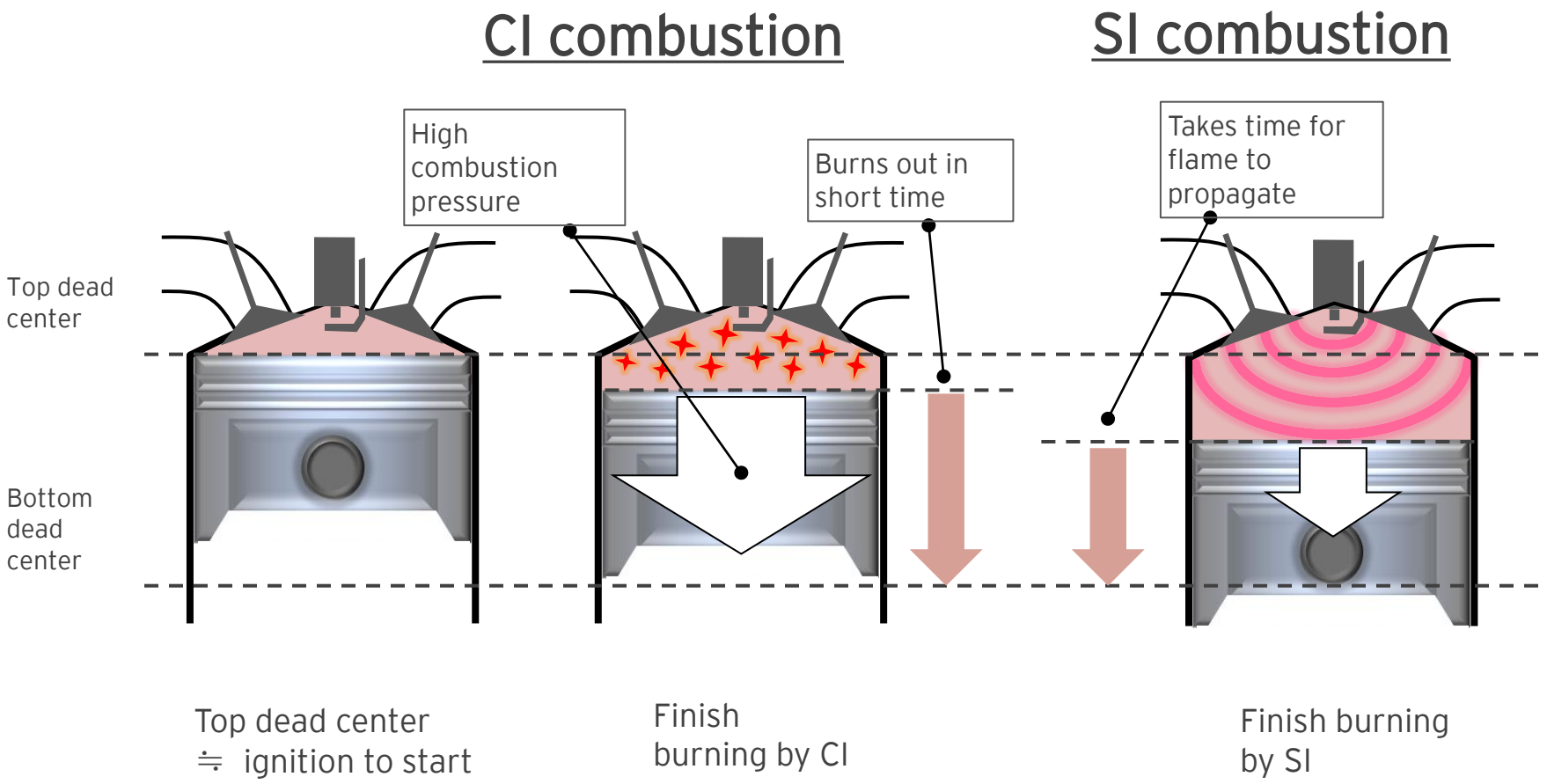
CI Combustion

@750rpm :
air fuel ratio of 36.8:1



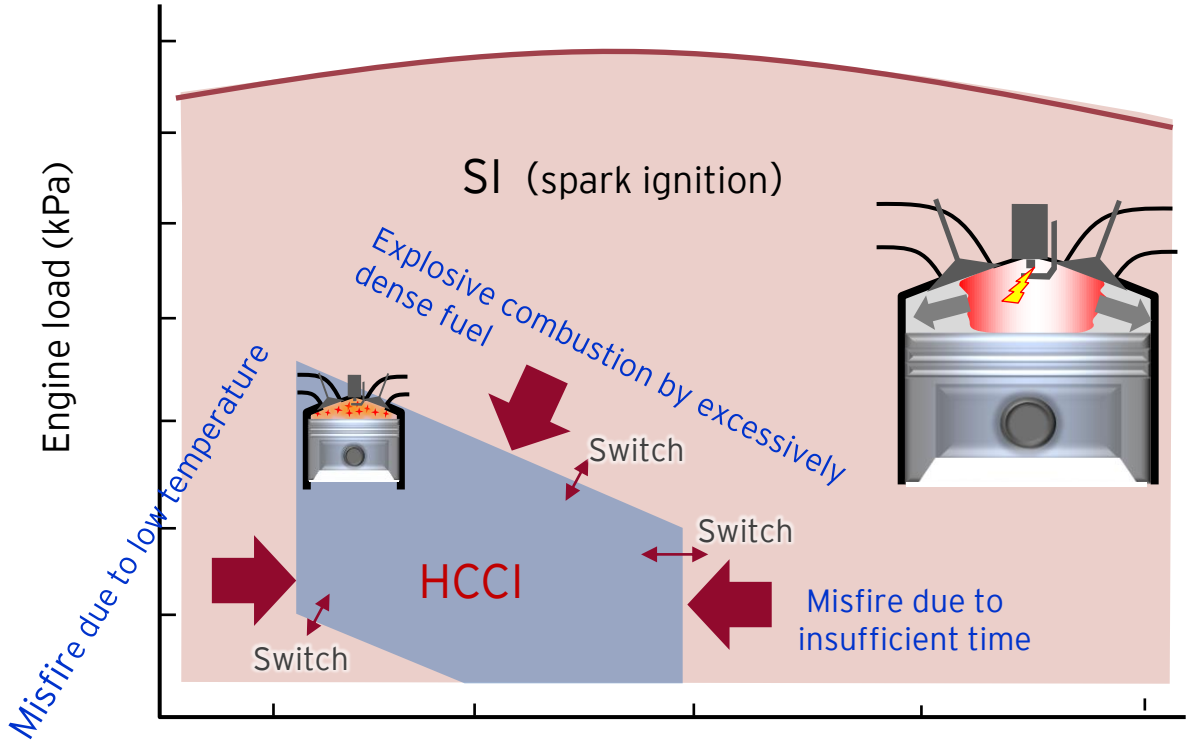
Why is Compression Ignition Significant?

<CI and thermal efficiency>



Issues with Conventional HCCI

Other OEMs/research institute



Data under development as Aug. 2017

Compression Ignition ⟷ **Spark Ignition**

Very difficult to achieve stable switching

Breakthrough

Breakthrough Point

(Mazda original technology)

||

Technique to completely control the switch between combustion types and expand the operating region of compression ignition

Breakthrough

‘CCI’ is our target for ideal combustion

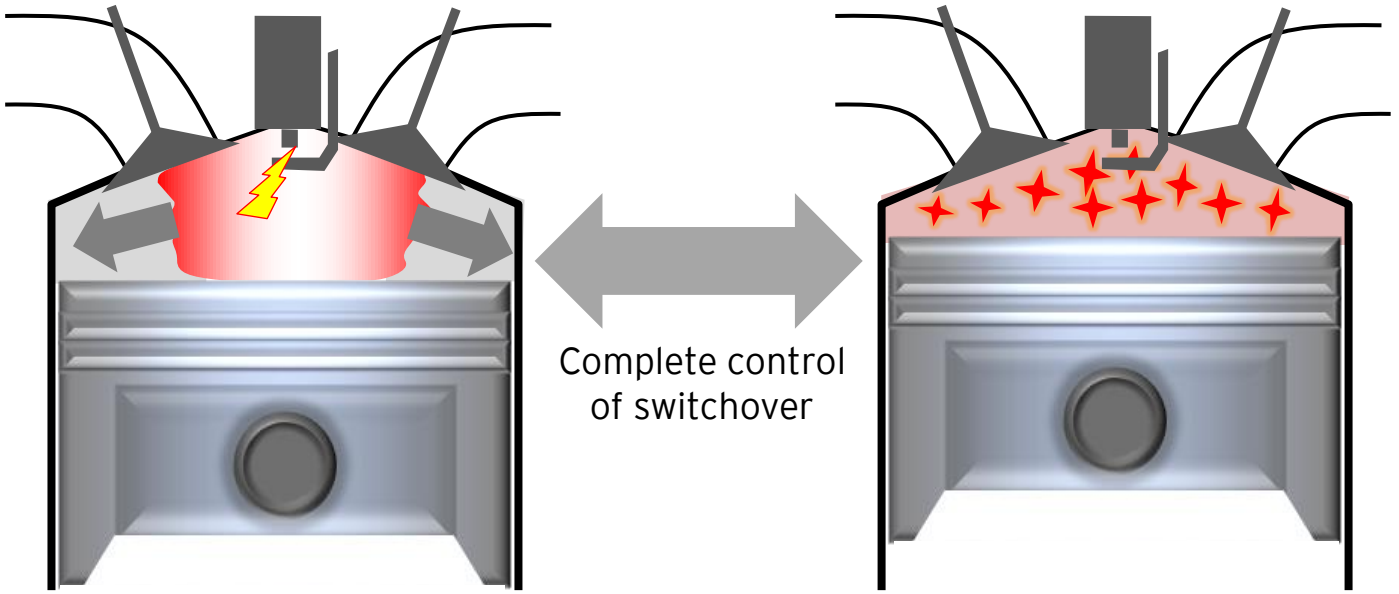
CCI （Controlled Compression Ignition）

＝ Completely “controlled”
compression ignition combustion

Breakthrough

Spark Ignition (SI)

Homogeneous Charge Compression Ignition (HCCI)

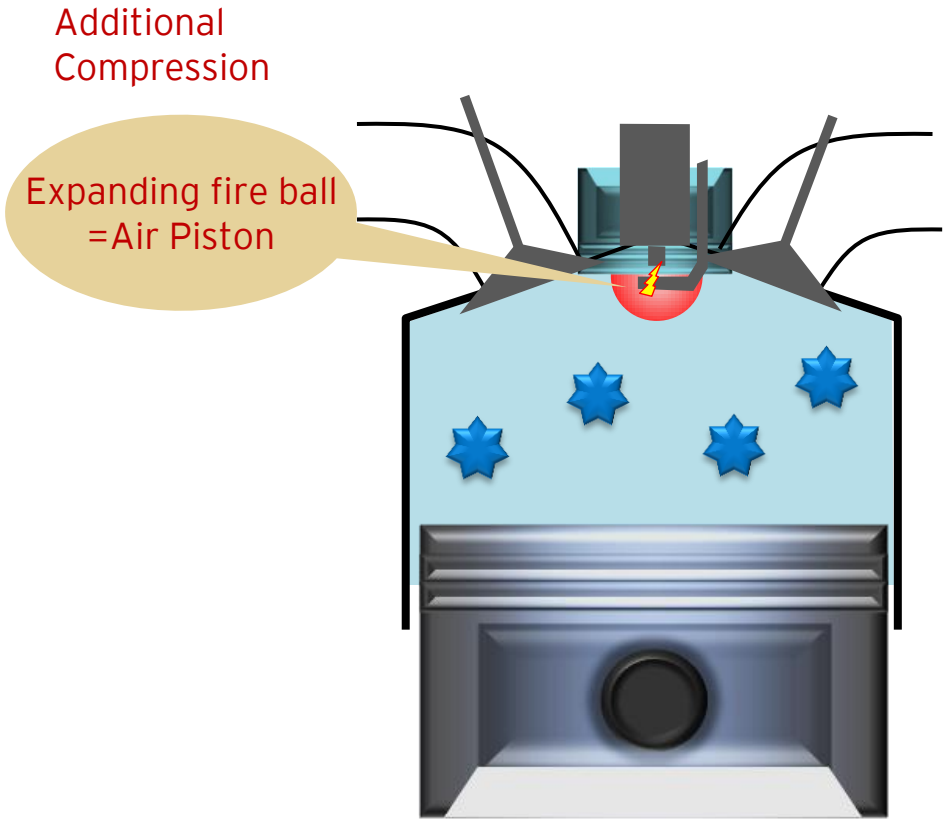


A spark plug is necessary

Use spark plug as a control factor

Breakthrough

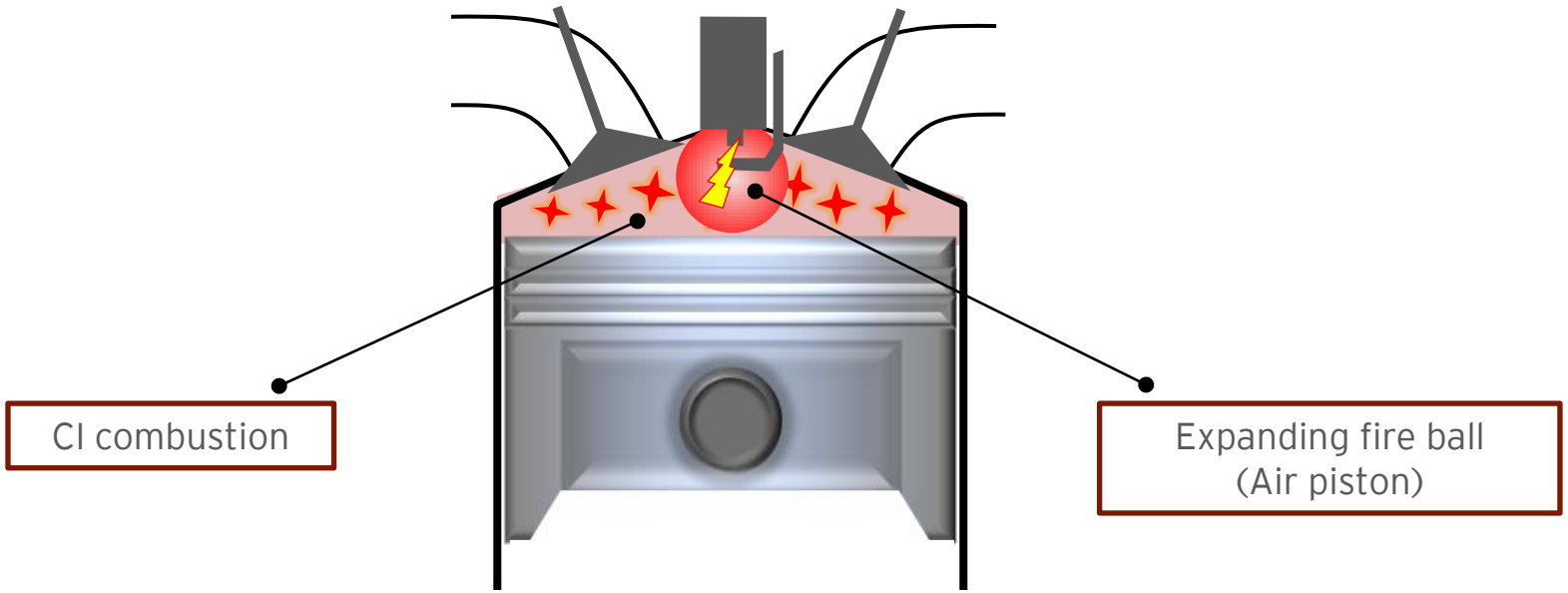
<Compression ignition using spark plug as control factor>



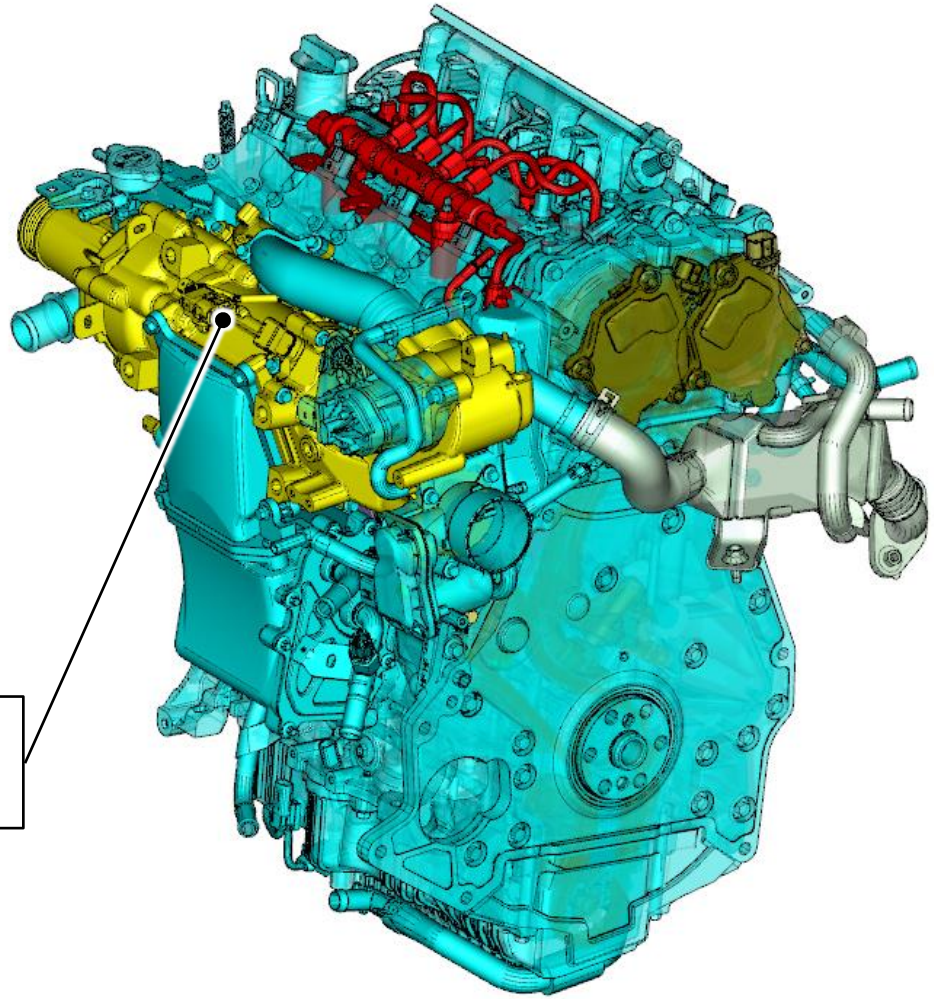
SPCCI Combustion

“SPCCI”

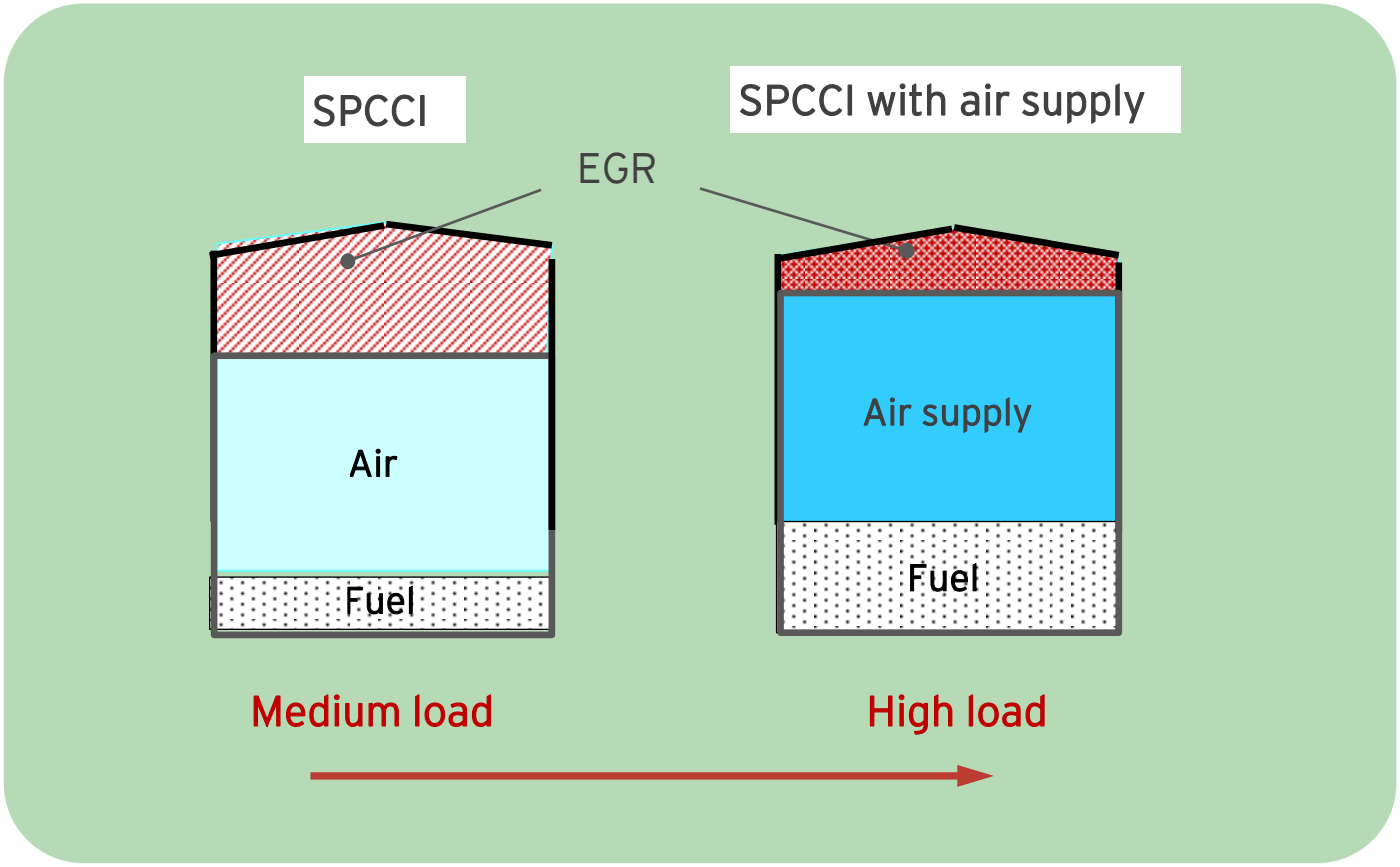
(Spark Controlled Compression Ignition)



Air Supply Unit

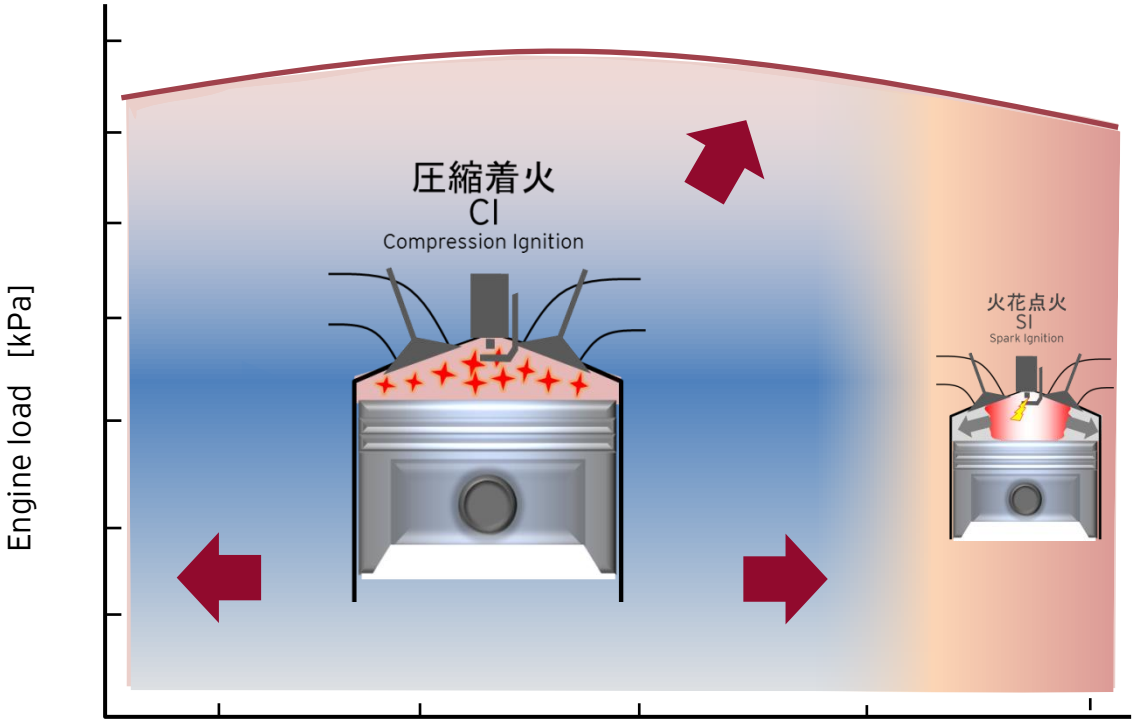


Air Supply Unit



SPCCI Combustion

< Spark Controlled Compression Ignition is seamless over a wide region >



Data under development as Aug. 2017

SPCCI works over a wide range of rpms and engine loads
and allows stable switching between HCCI and SI

Value Provided by SKYACTIV-X

Ⅰ Performance

Ⅱ Fuel Economy

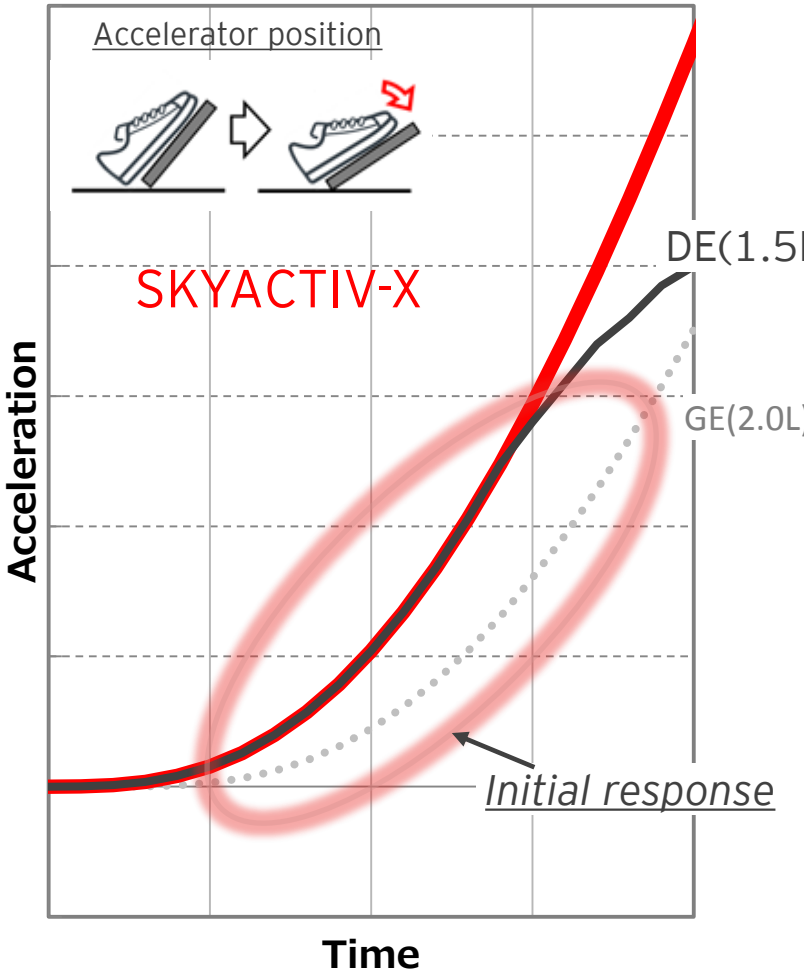
Ⅲ Driving pleasure that comes from the combination of performance & efficiency

Ⅰ Performance

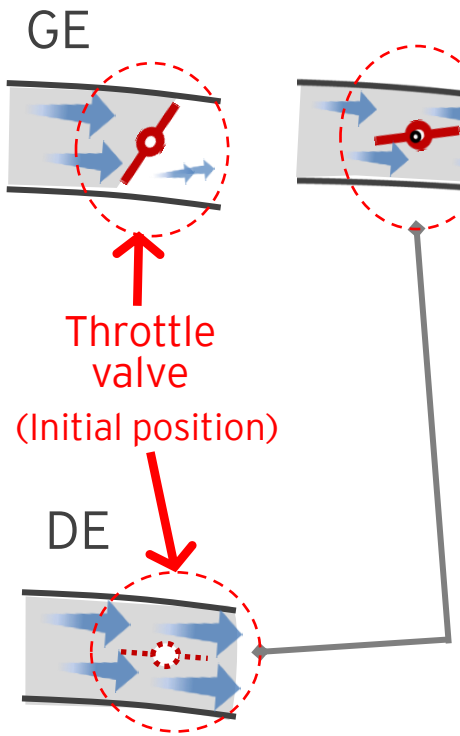
① Responsiveness

① Responsiveness (launch response)

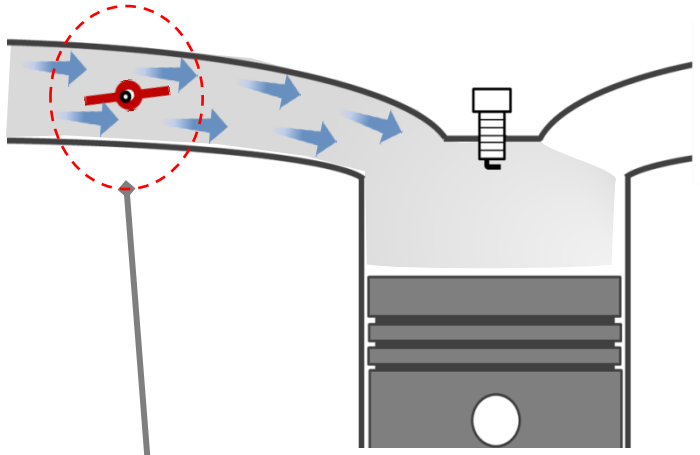
<Improved launch response to throttle pedal operation>



〈Conventional〉



〈SKYACTIV-X 〉



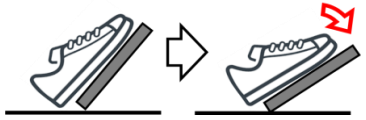
Intake air enters cylinders without delay thanks to low resistance of throttle valve, providing good launch response

Data under development as Aug. 2017

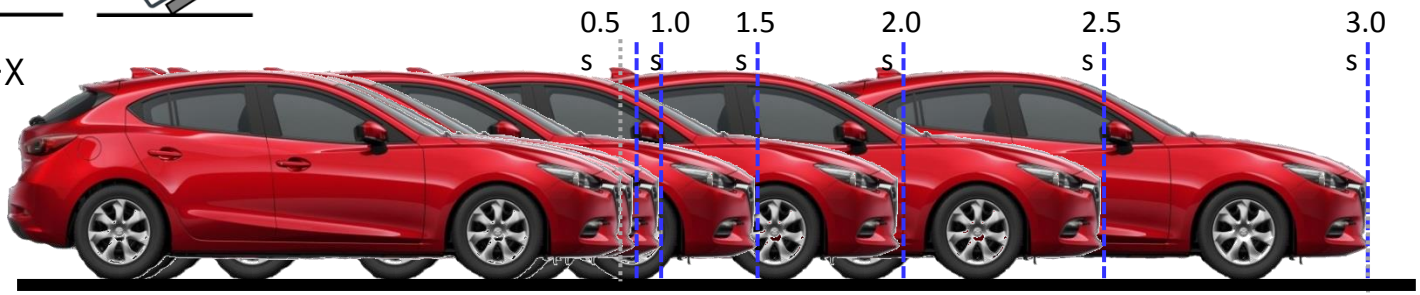
① Responsiveness (launch response)

Initial vehicle response when accelerating from 40 km/h

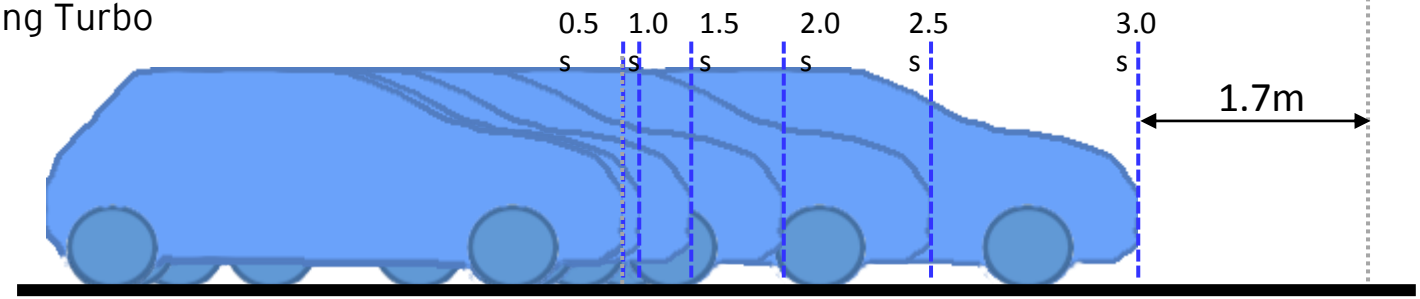
Good launch response essential for responsive driving → Peace of mind and safety



SKYACTIV-X



Competitors
Downsizing Turbo

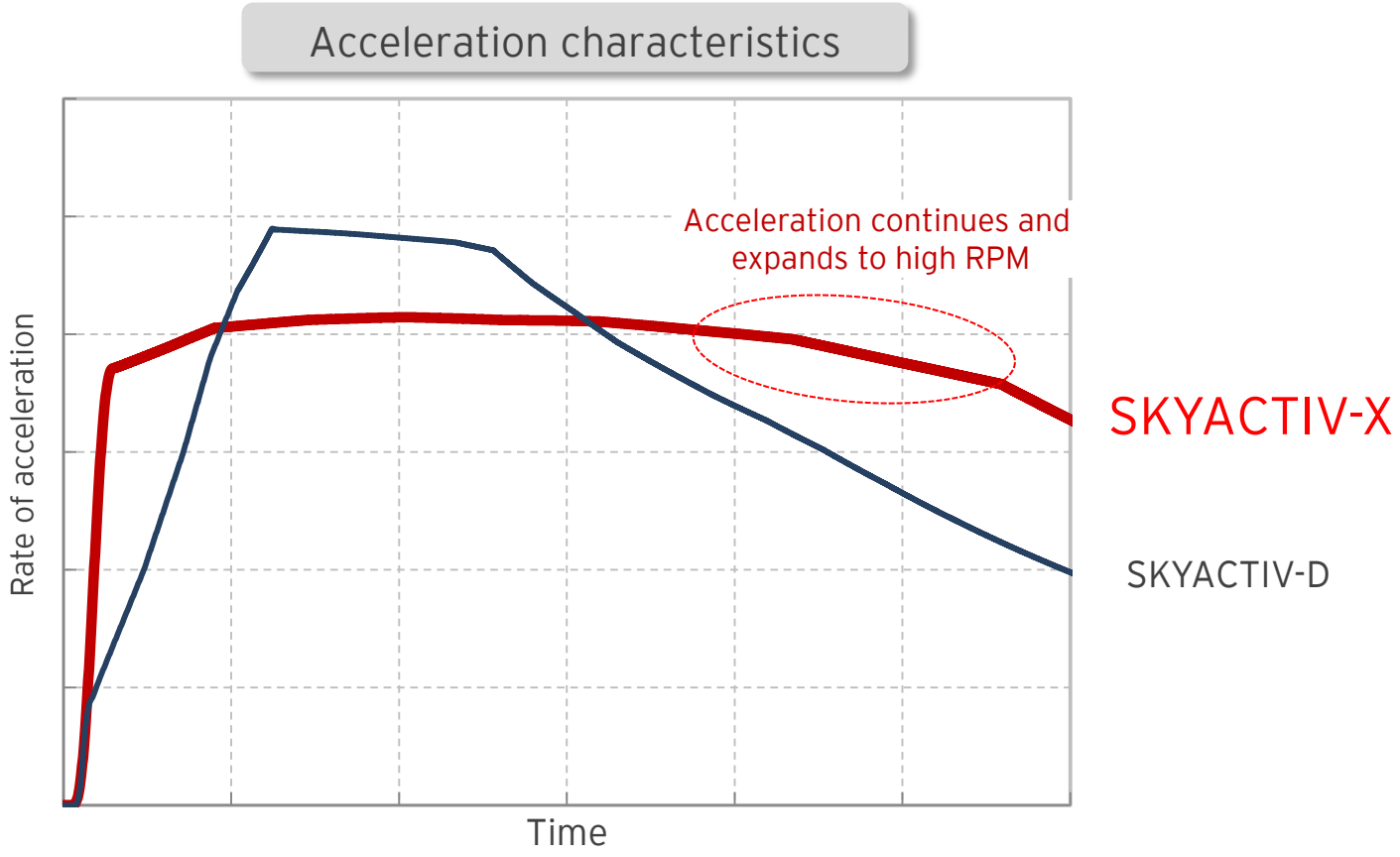


Data under development as Aug. 2017

Ⅰ Performance

②Expansive at high RPM

Expansive at High RPM



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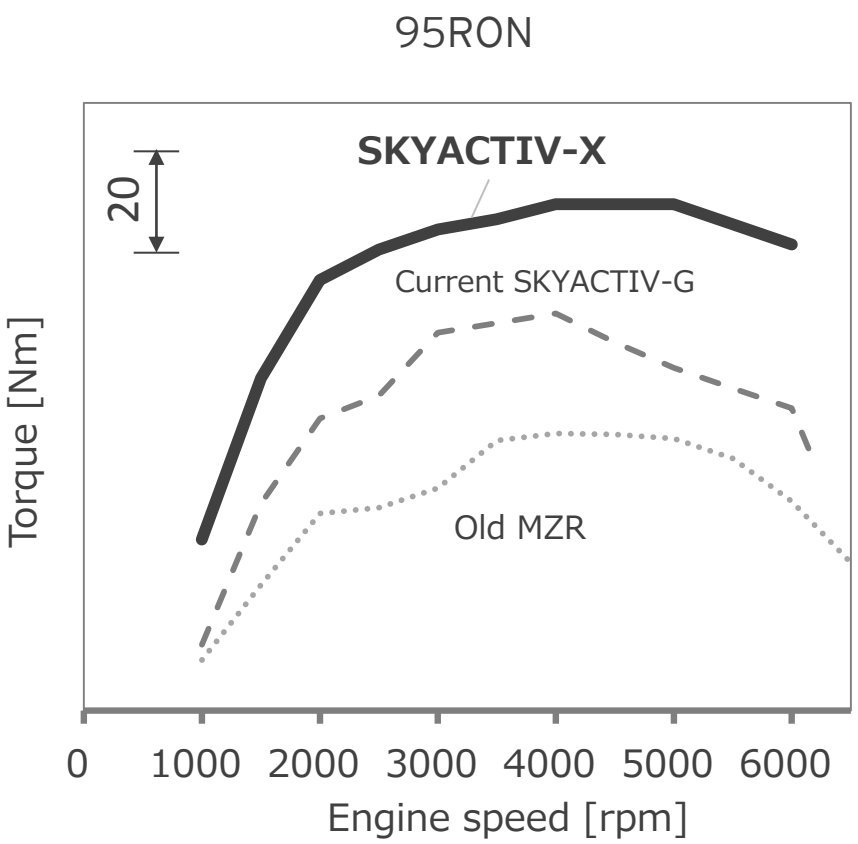
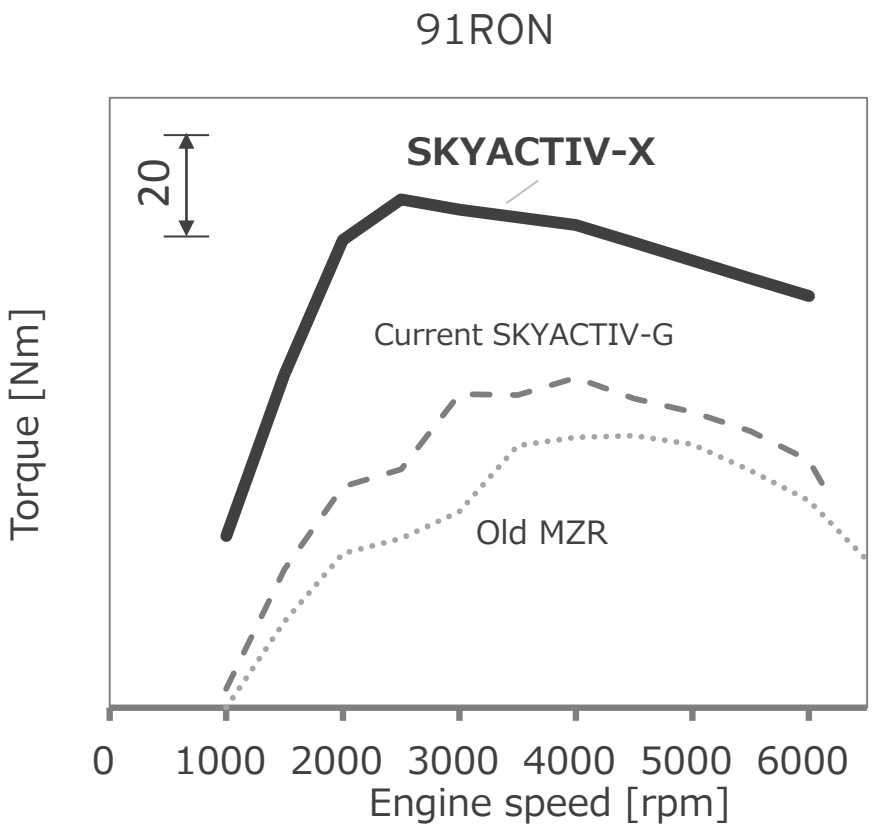
Power Output





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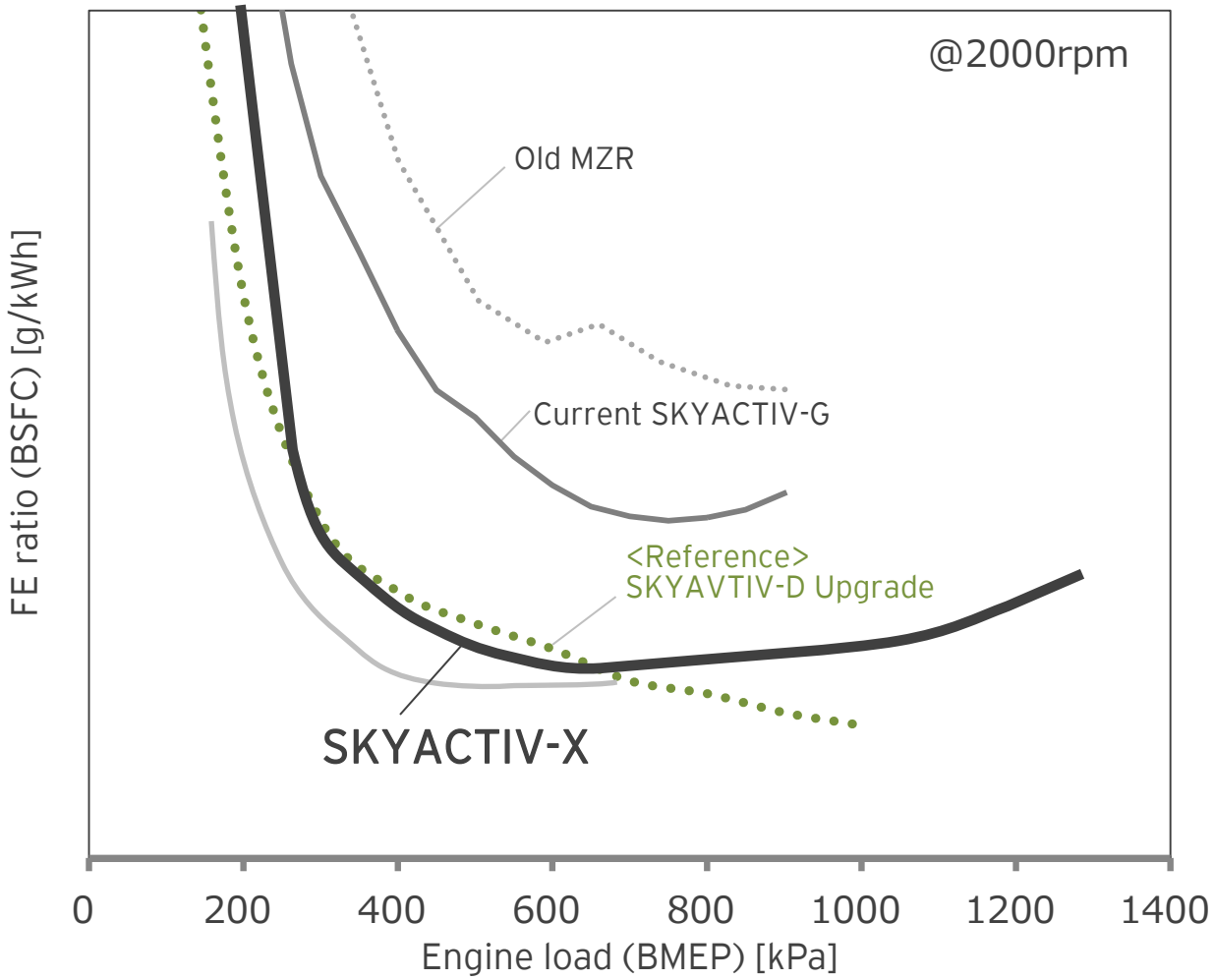
Ⅱ Fuel Economy

① Drastic improvement in fuel consumption rate

Drastic improvement in fuel consumption rate



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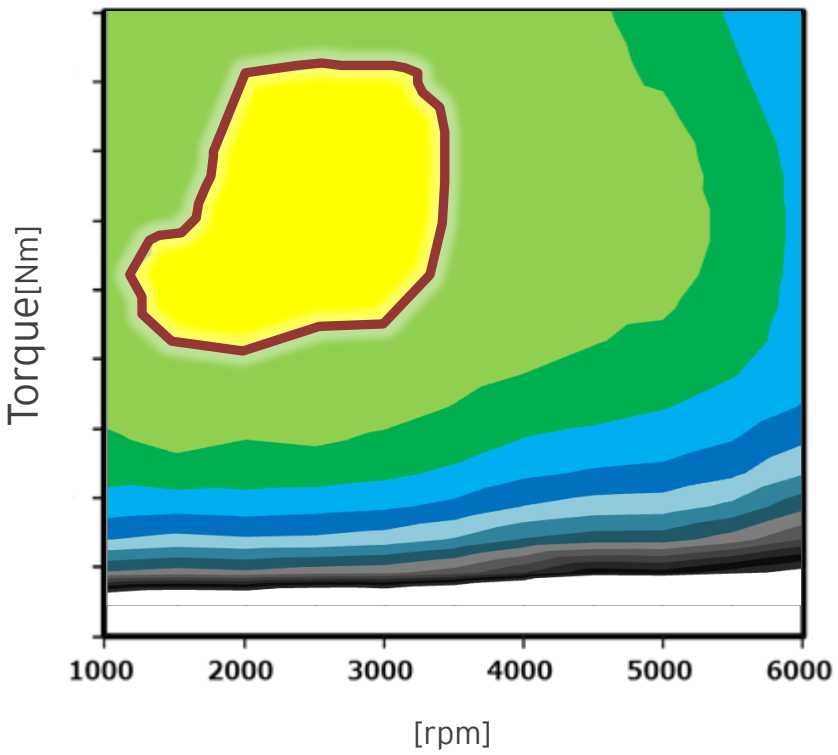
Ⅱ Fuel Economy

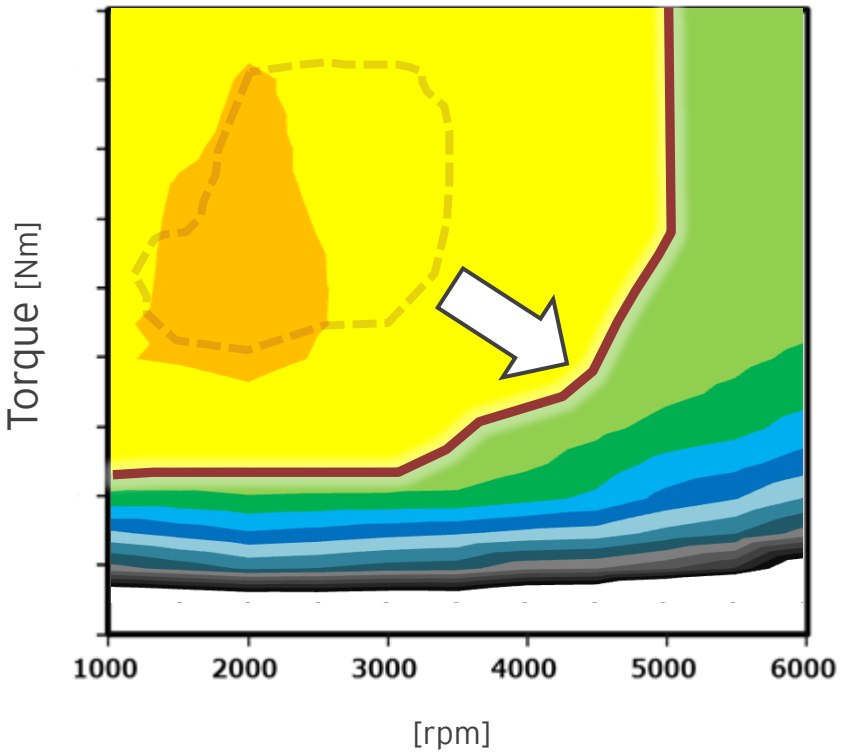
② A flat fuel consumption curve means little difference in fuel economy performance in the real world

② Flat Fuel Consumption Curve

〈Conventional Engine〉



〈SKYACTIV-X〉



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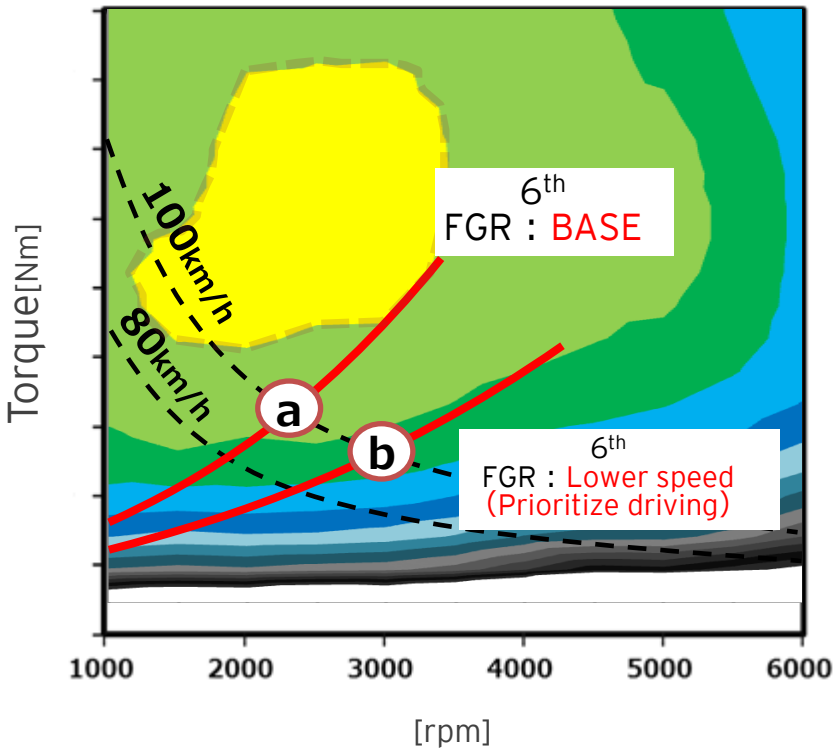
Value Provided

Ⅲ Driving pleasure that comes from the combination of performance & efficiency

Ⅲ Driving pleasure

〈Conventional Engine〉



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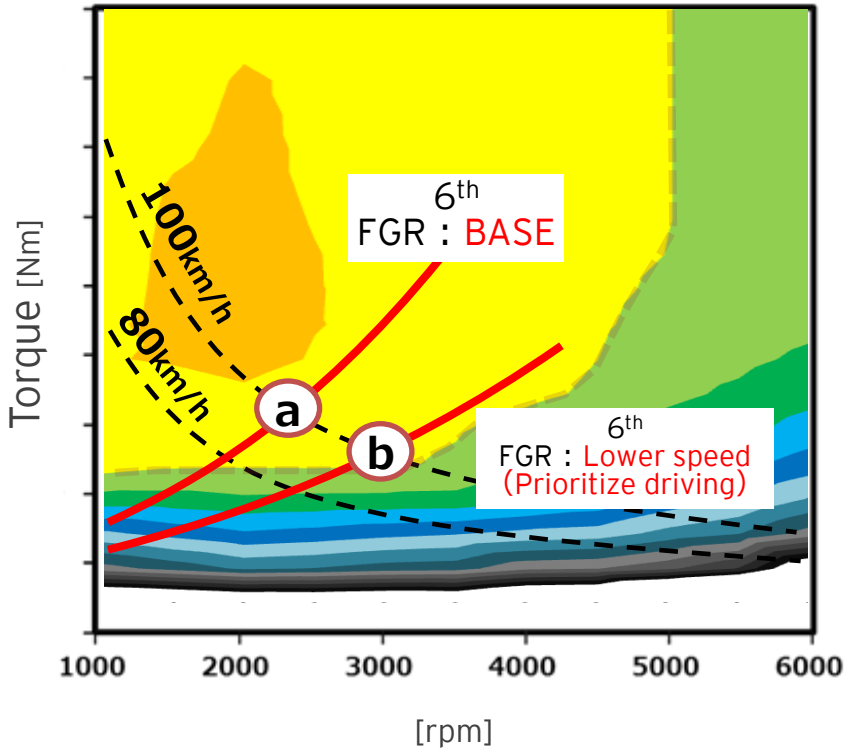

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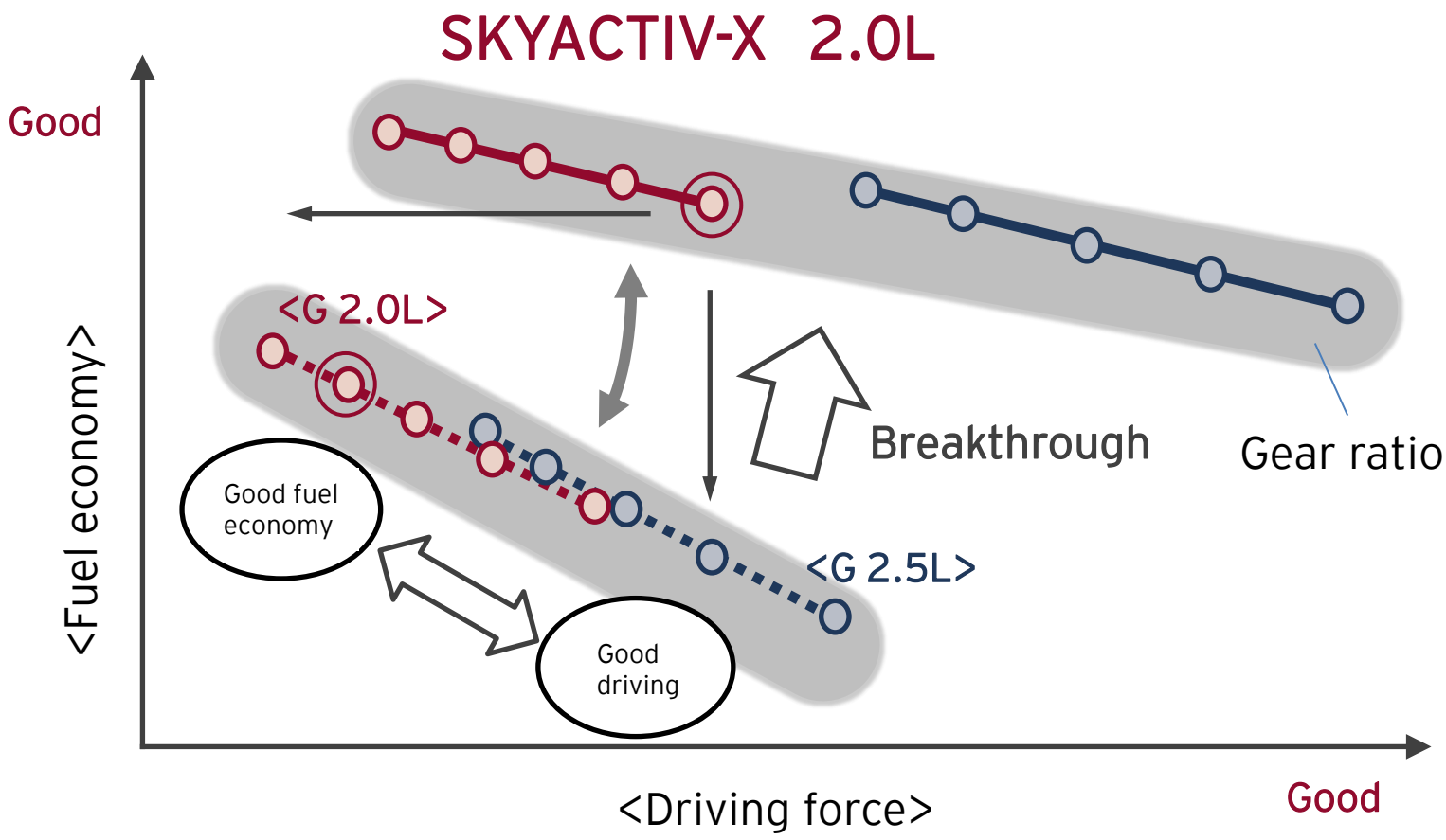
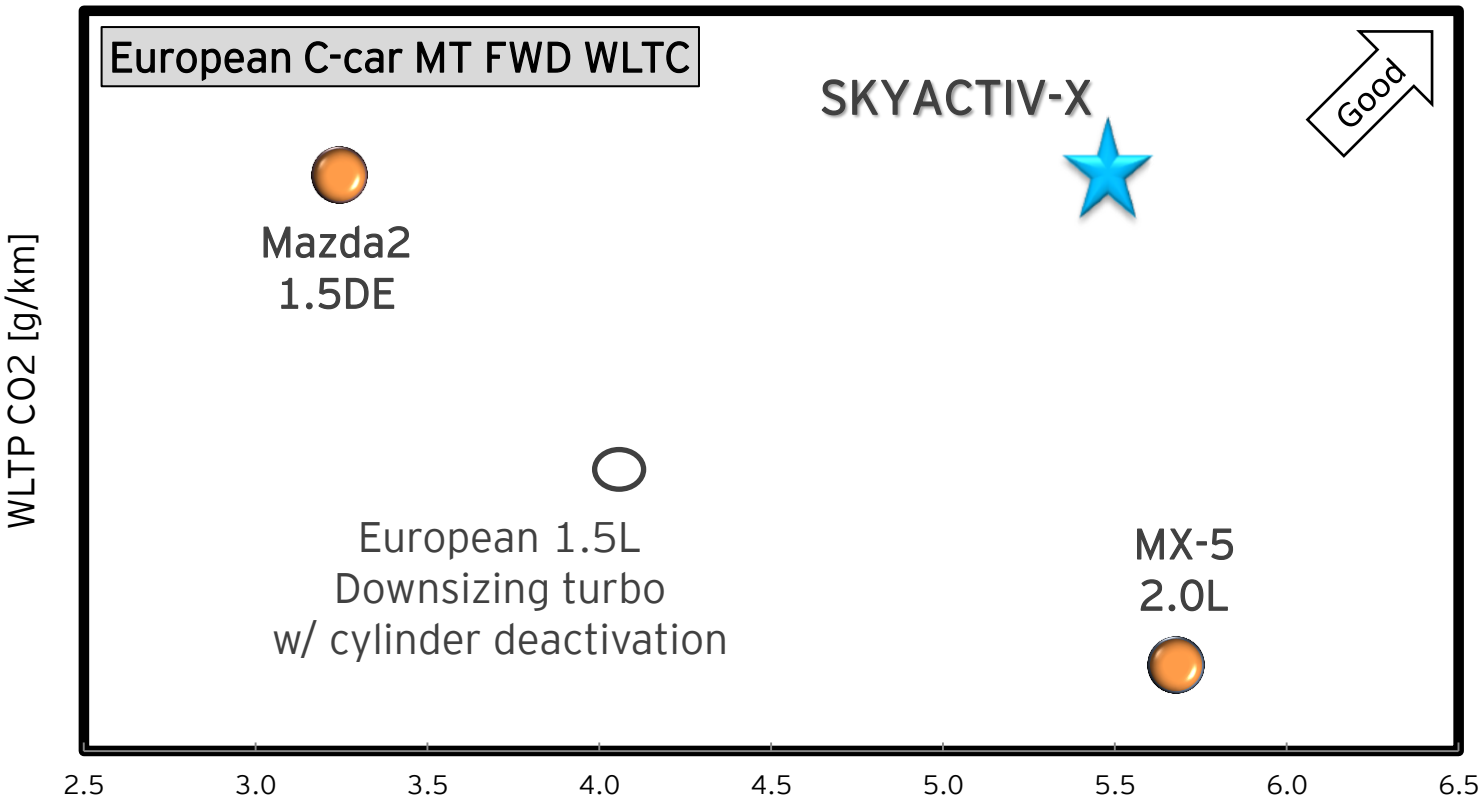
Ⅲ Driving pleasure

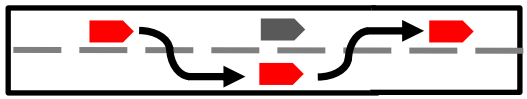


Data under development as Aug. 2017

Ⅲ Driving pleasure



40km/h→Acceleration



Acceleration position

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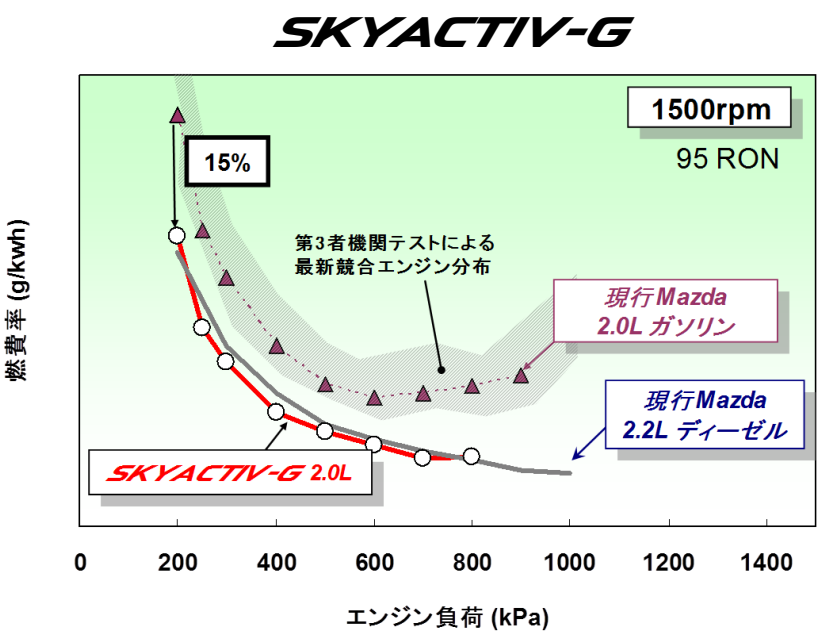
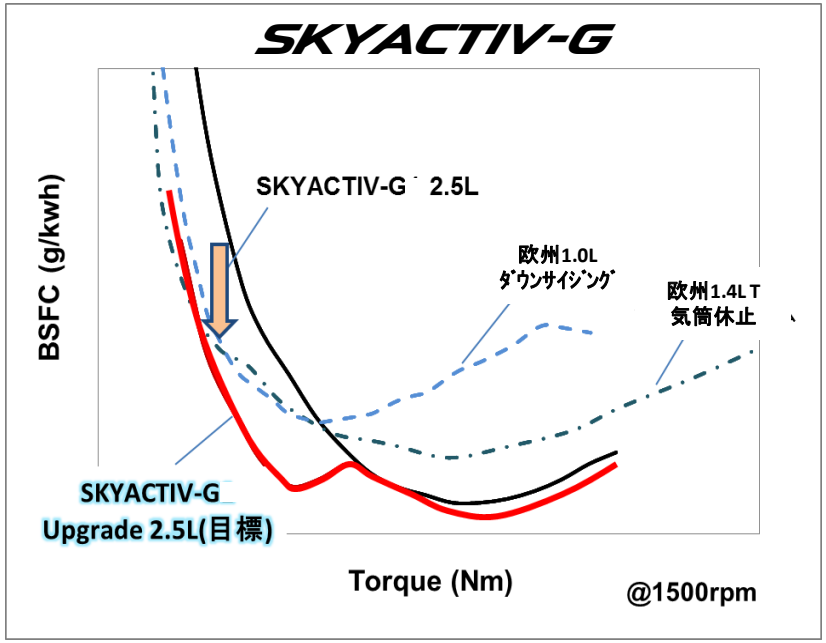
Positioning in Product Strategy

Feedback on SKYACTIV-G and Upgrade





Data under development as Aug. 2017

Feedback on SKYACTIV-G and Upgrade

Benchmarking and Hardware-in-the-Loop Operation of a 2014 MAZDA SkyActiv 2.0L 13:1 Compression Ratio Engine

2016-01-1007
Published 04/05/2016

Benjamin Ellies, Charles Schenk, and Paul Dekraker
US Environmental Protection Agency

CITATION: Ellies, B., Schenk, C., and Dekraker, P., "Benchmarking and Hardware-in-the-Loop Operation of a 2014 MAZDA SkyActiv 2.0L 13:1 Compression Ratio Engine," SAE Technical Paper 2016-01-1007, 2016, doi:10.4271/2016-01-1007.

Abstract

As part of its technology assessment for the upcoming midterm evaluation (MTE) of the 2022-2025 Light-Duty Vehicle Greenhouse

support the MTE, EPA has been conducting a series of engine benchmarking and development activities at its National Vehicle Fuel and Emissions Laboratory in Ann Arbor, MI.

Air Flow Optimization and Calibration in High-Compression-Ratio Naturally Aspirated SI Engines with Cooled-EGR

2016-01-0565
Published 04/05/2016

SoDuk Lee, Charles Schenk, and Joseph McDonald
US Environmental Protection Agency

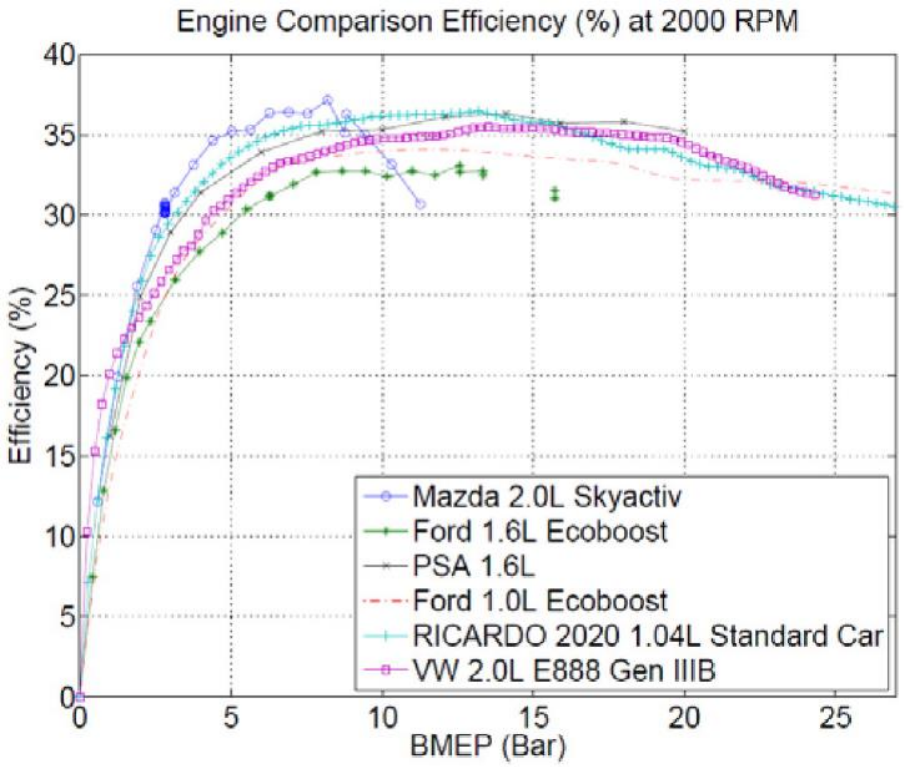
CITATION: Lee, S., Schenk, C., and McDonald, J., "Air Flow Optimization and Calibration in High-Compression-Ratio Naturally Aspirated SI Engines with Cooled-EGR," SAE Technical Paper 2016-01-0565, 2016, doi:10.4271/2016-01-0565.

Abstract

As part of the U.S. Environmental Protection Agency (U.S. EPA) "Midterm Evaluation of Light-duty Vehicle Standards for Model Years 2022-2025 [1]", the U.S. EPA is evaluating engines and assessing the effectiveness of future engine technologies for reducing CO2 emissions. Such assessments often require significant development time and resources in order to optimize intake and exhaust cam variable valve timing (VVT), exhaust gas recirculation (EGR) flow rates, and compression ratio (CR) changes. Mazda SkyActiv-G spark-ignition (SI) engines were selected by EPA for an

Introduction

As part of analyses in support of the 2017-2025 Light-duty Vehicle GHG standards, EPA contracted with Ricardo PLC to project future CO2-reduction effectiveness for specific engine technologies. One of the most effective spark ignition engine technologies evaluated by Ricardo used a combination of sequential turbocharging, engine downsizing, engine friction reduction measures, variable valve lift and valve timing, and the use of cooled, high- and low-pressure loop EGR [3]. This particular package was referred to within the analysis as EGRB (EGR-boosted). The best BSFC of the Ricardo EGRB



SAE 2016-01-1007:<https://www3.epa.gov/otaq/climate/documents/mte/2016-01-1007-benchmark-hil-operat-2014-mazda-skyactiv-2.0l.pdf>
SAE 2016-01-0565: <https://www3.epa.gov/otaq/climate/documents/mte/2016-01-0565-air-flow-optim-calib-nat-asp-eng.pdf>

Product Strategy ~ Enhance SKYACTIV Lineup

Gasoline engine lineup

SKYACTIV-X

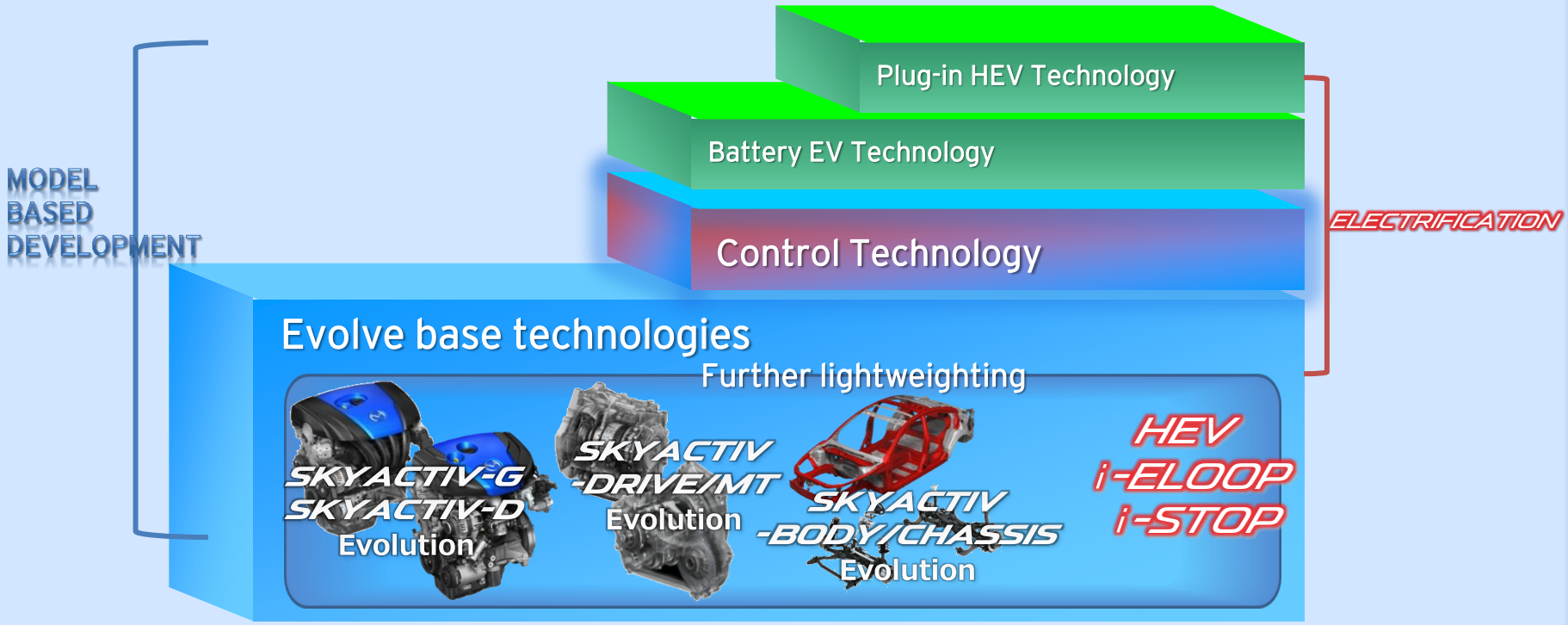
Diesel engine lineup

Building Block Strategy and Process Innovation

Provide unique, world-leading products with the most appropriate technologies for each market

Process Innovation

・Monotsukuri Innovation (Common Architecture & Flexible Production)



Building Block Strategy

Toward Mazda's 100th Anniversary in 2020