

# **Evaluation of Hybrid System and Plug-in Hybrid System In Japanese Fuel Efficiency Regulation**

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## **1. Top Runner Approach for FE regulation**

## **2. Fuel Efficiency regulation for HDVs**

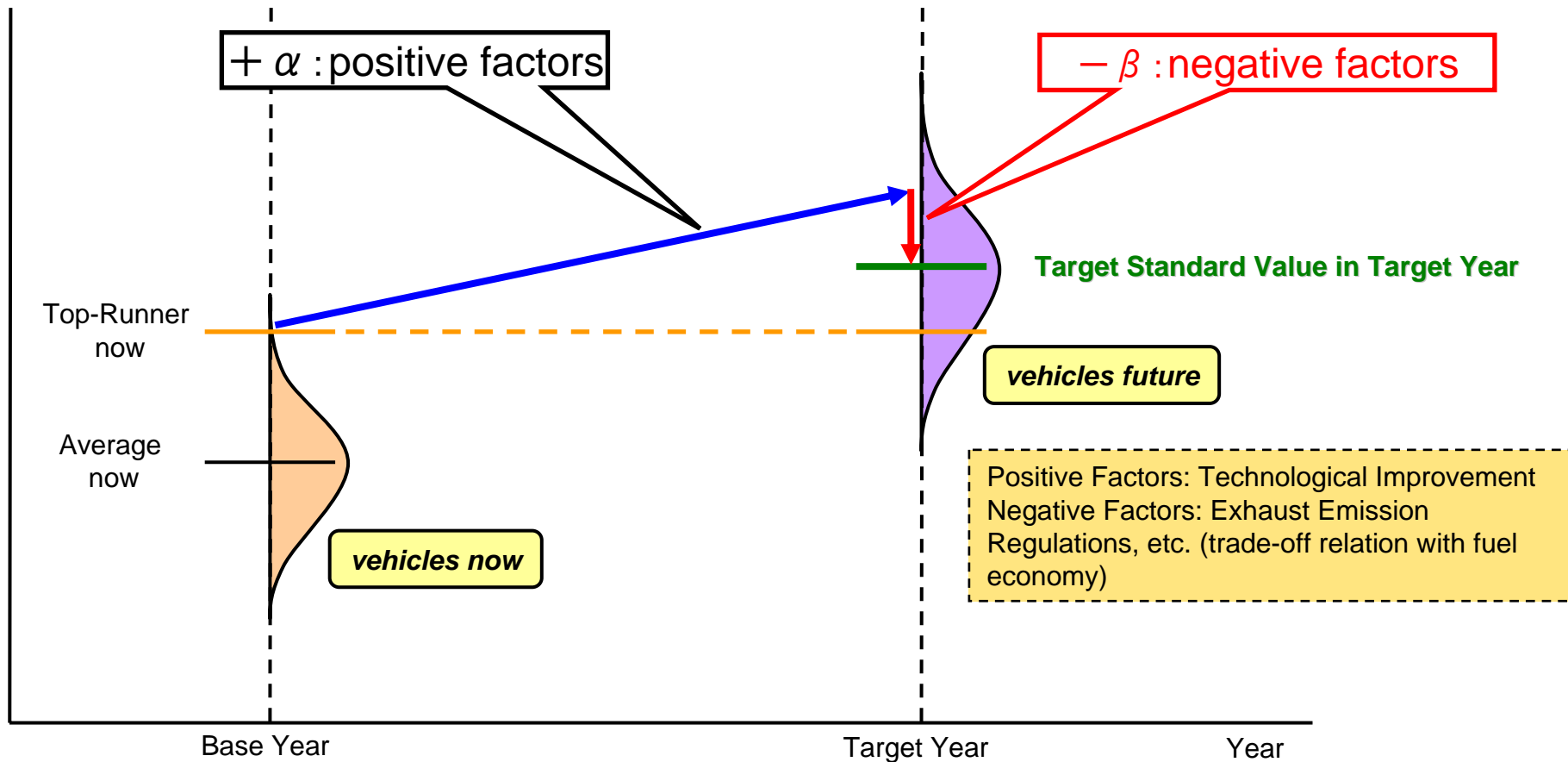
- Simulation Test Method
- for HD HEV Test

## **3. Fuel Efficiency Regulation for LDVs**

- Conventional Test Method
- for LD HEV Test
- Challenge for PHEV Evaluation

## **4. IPT Bus : PHEV for HDVs**

- By target year, average fuel consumption must be higher than the best fuel efficiency in the base year.
- Standard should be high but reachable because target values are already achieved by actual vehicles in the base year.
- Particular types of cars such as HEVs and MT mounted cars are excluded from top runner



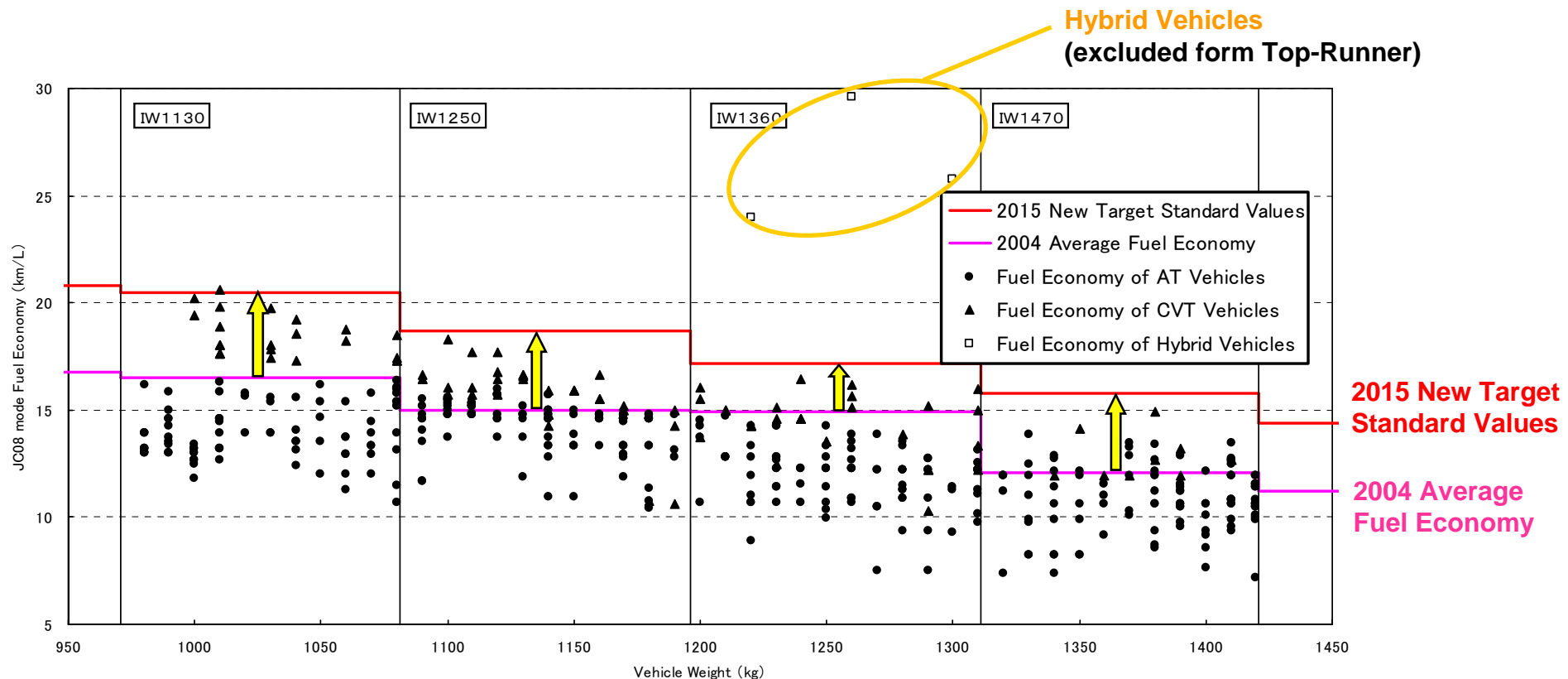
- Conventional fuel efficiency improvement technologies (2 – 4 % in total)
  - Engine compression ratio increase, Friction reduction, Weight reduction,
  - Reduction of vehicle travel resistance, Low rolling resistance tires
  - Optimizing overall control of engine
- Engine improvement [Gasoline engine]
  - 4 valves (1%), 2 valves and 2 ignitions (2%), Variable valve system (1 – 7 %)
  - Direct-injection stoichiometric engine (2%), Direct-injection lean-burn engine (10%)
  - Variable cylinder (7%), Miller cycle (10%)
  - High volume EGR (2%), Roller cam follower (1%), Offset crank (2%), Variable compression ratio (10%)
- Engine improvement [Diesel engine]
  - 4 valves (1%) , Electronically controlled fuel injection device (1.5%) , Common rail (2.5%), Direct-injection diesel engine (8%), High pressure injection (1%), Supercharger and supercharger efficiency improvement (2 – 2.5%), Intercooler (1%), EGR (0.5 – 1%), Roller cam follower (1.5%), Offset crank (2%)
- Auxiliary equipment
  - Electric power steering (2%), Charge control (0.5%)
- Driving system improvement
  - Idle-neutral control (1%), AT with more gears (1 – 4%), Switch to CVT (7%), Switch to automated MT (AMT/DCT) (9%), Switch to MT (9%)
- Introduction of fuel-efficient vehicles
  - Hybrid vehicles (15 – 70%), Diesel vehicles (20%) , Idling stop vehicles (4 – 7%)

β)

- Exhaust emission regulations (▲3 to ▲7.5% in total)
  - Caused by technologies used on diesel vehicles and direct-injection lean-burn vehicles in response to the 2009 exhaust emission regulations.
  - Technologies considered were engine body improvement (NOx reduction by improving EGR, PM reduction by high pressure injection, etc.) and aftertreatment devices such as NOx occlusion reduction catalyst and continuous regeneration type DPF, etc.
- Safety regulations (▲0.1 to ▲1.4% in total)
  - Caused by increased weight and travel resistance as a result of measures against/for offset crash, pedestrian protection, ISO-FIX, etc.
- Noise regulations(▲0.1% in total)

## Current Fuel Economy Performance and Level of 2015 Target Standard Values

\* Example (passenger vehicle: 4 weight categories between 971kg and 1420kg)



\* Fuel economy values on this table are measured by JC08 mode.



- For N1 vehicles, segments are defined by “several other features” in addition to “vehicles weight”, taking into consideration:
  - Market of each vehicle type
  - Applied technology for each vehicle type
  - Specification/Vehicle structure of each vehicle type

Type	Fuel		Vehicle structure	Transmission		Weight category
1. Passenger car	Gasoline or diesel oil		—	—		16 categories
2. Small bus	Gasoline	Diesel oil	—	—		—
3. Mini freight vehicle	Gasoline or diesel oil		A   B	MT	AT	2 – 4 categories
4. Light-weight freight vehicle	Gasoline or diesel oil		—	MT	AT	2 – 3 categories
5. Med-weight freight vehicle	Gasoline	Diesel oil	A   B1   B2	MT	AT	1 – 8 categories



## 1. Top Runner Approach

## 2. Fuel Efficiency regulation for HDVs

- Simulation Test under JE05
- HD HEV Test

## 3. Fuel Efficiency Regulation for LDVs

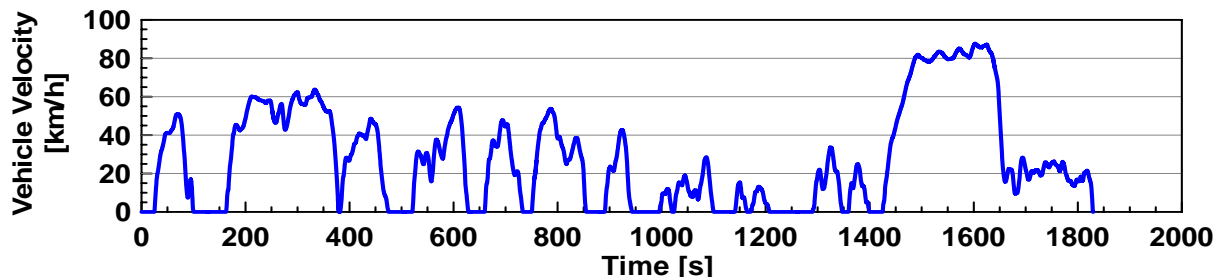
- Conventional Test Method
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## 4. IPT Bus : PHEV for HDVs

# Japanese test mode for HDVs (JE05)

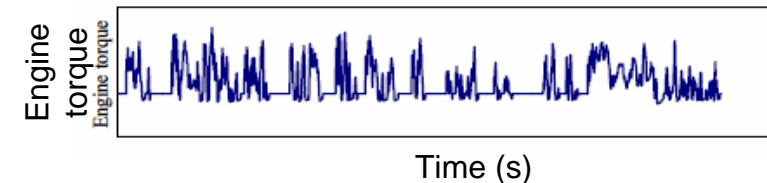
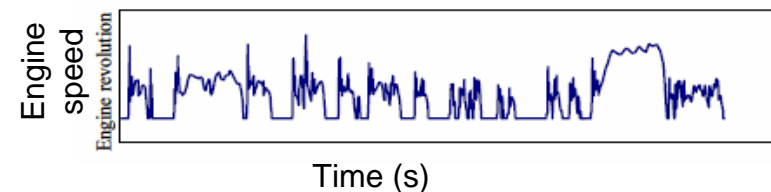
Combination of Urban Driving Mode (JE05) and Inter-urban Driving Mode

Urban Driving Mode = JE05 Mode (Emission Test Mode)

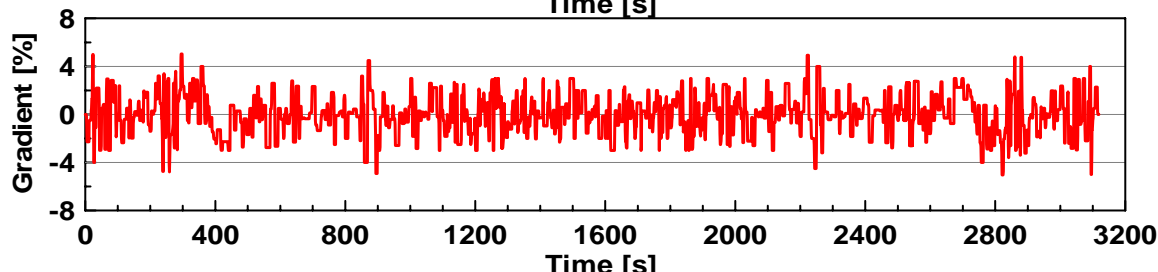
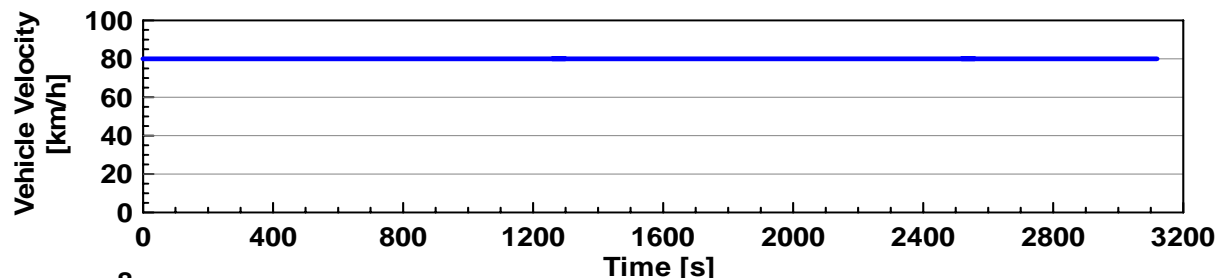


- Stand-alone Engine Measurement Method
- Including Transient Operating Points

Conversion to Histories of Engine Speed and Engine Torque




Interurban Driving Mode: 80km/h Constant Speed Mode with Road Gradient



## Actual Engine Test of Fuel Efficiency by JE05 Mode is NOT feasible and effective.

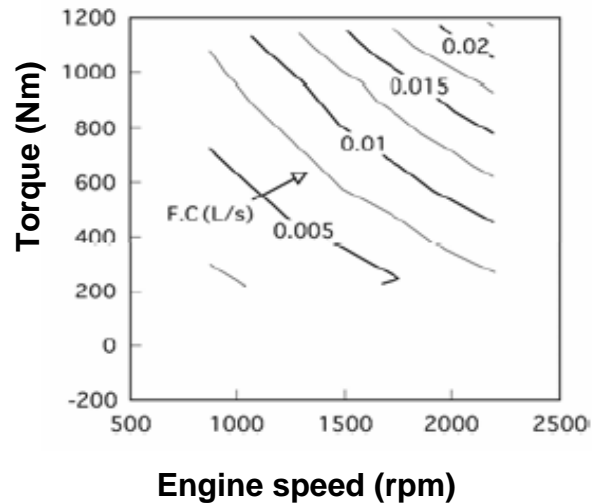
**Stand-alone engine test of fuel efficiency by JE05 mode may require a large number of different engine types.**

**The manufacturers spend large resources (time, labor and money) for constructing the testing facility and performing measurements.**

 Evaluation of Fuel Efficiency by *Simulation Method*

- Using real vehicle and engine specifications

## Real Fuel consumption map

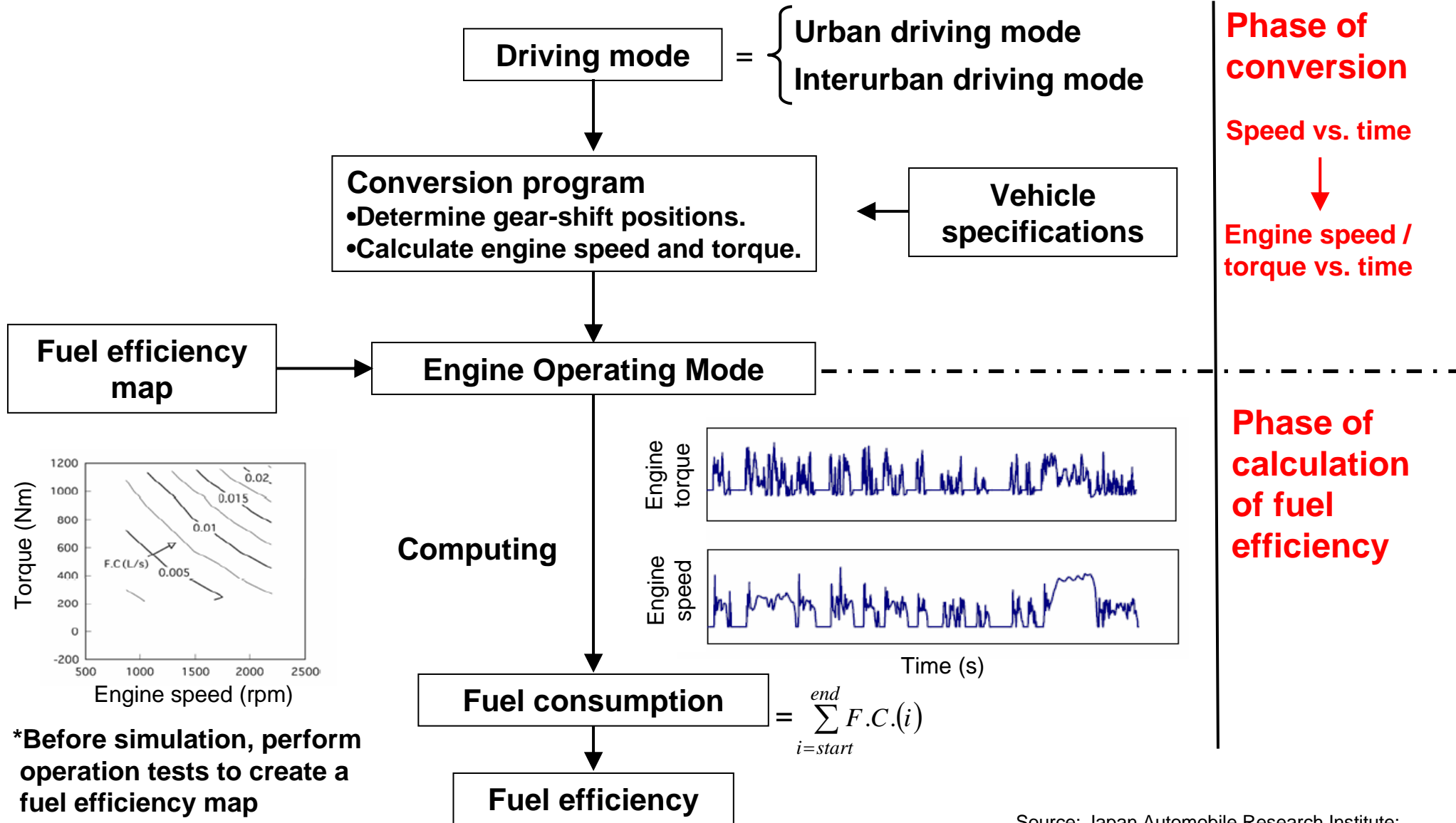


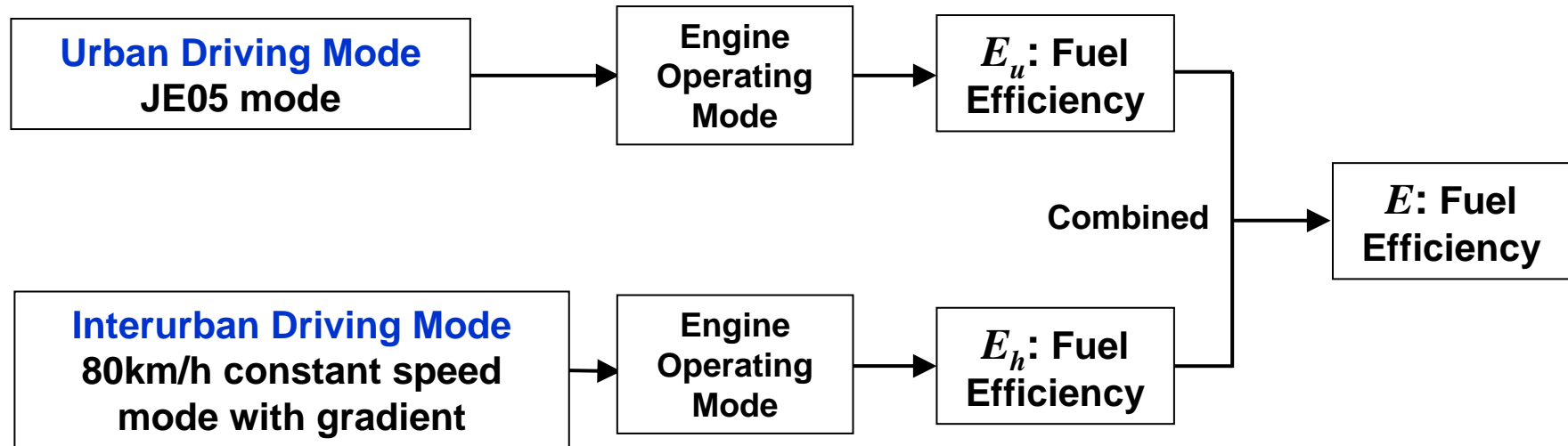
Engine parameters

Drive train parameters

- The method is an extension way of the emission test.

- Low cost and Hi test efficiency
- Problems of reproducibility of driving resistance





$$E = 1 / (\alpha_u / E_u + \alpha_h / E_h)$$

**$E$** : Heavy vehicle mode fuel efficiency (km/L)

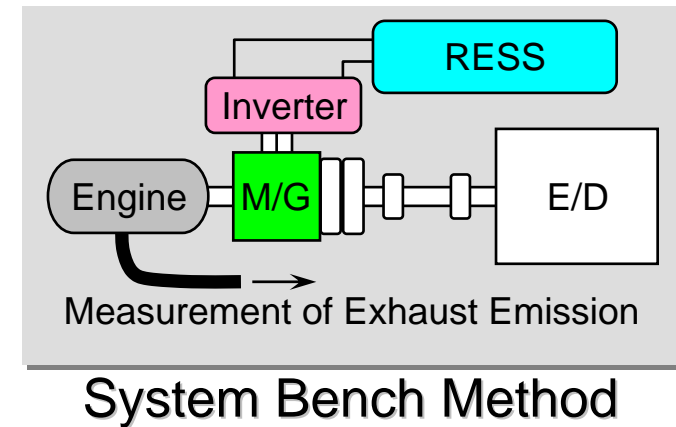
**$E_u$** : Urban driving mode fuel efficiency (km/L)

**$E_h$** : Interurban driving mode fuel efficiency (km/L)

**$\alpha_u$** : Proportion of urban driving mode

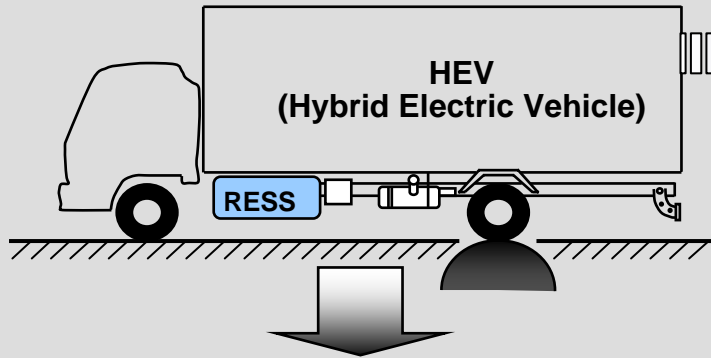
**$\alpha_h$** : Proportion of interurban driving mode

- **Fuel Efficiency Test**  
⇒ desired simple method: **Simulation Method**
- **Emission Test**  
⇒ desired dynamo test with only engine: **without electric system**
- **System Bench Method for HEV**
  - **Structurally-complex system**
  - **Need multiple E/D for 4-wheel drive vehicles**

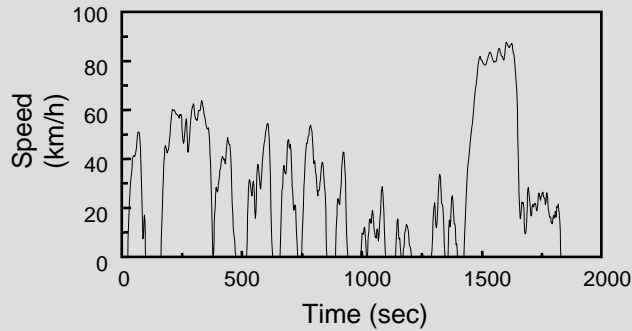


**Hardware-In-the-Loop Simulator (HILS) Test Method**  
was developed

## Chassis Base



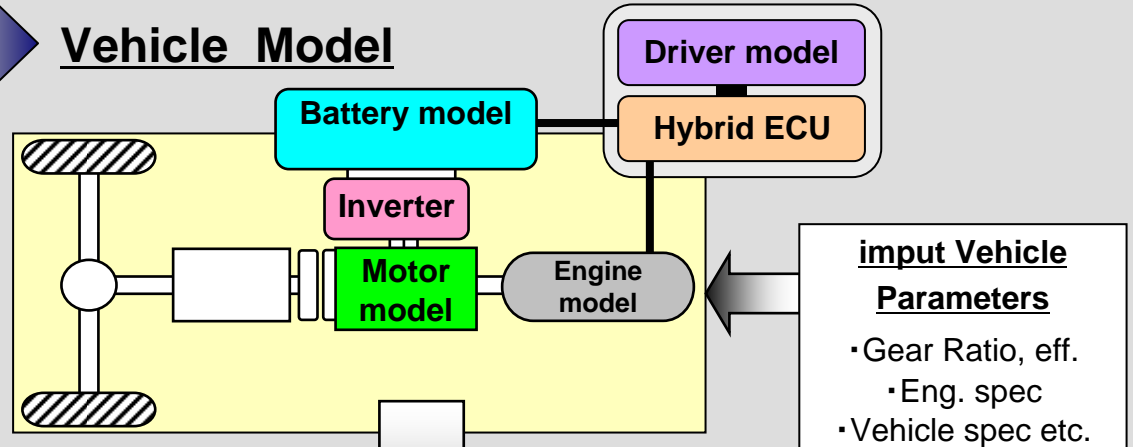
Run JE05



Fuel Consumption Ratio

## HILS (Hardware In the Loop Simulator)

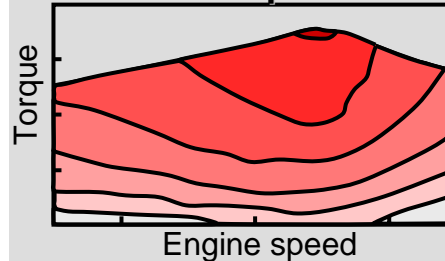
### Vehicle Model



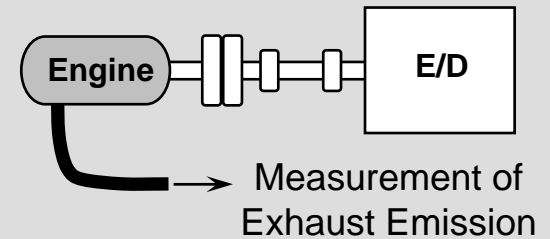
Virtual JE05 Running on CPU

Get E/G rpm, E/G Torque

Fuel Consumption



Exhaust Emission

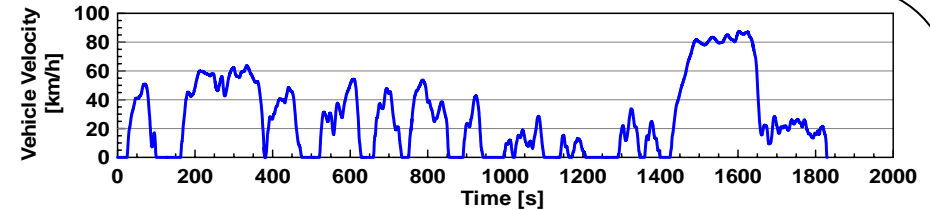




## 1st Step

HILS

Urban Driving Mode  
Interurban Driving Mode



Simulated driving  
by HILS Program  
to determine  
Engine Torque &  
Engine Speed

Input

Vehicle Specification

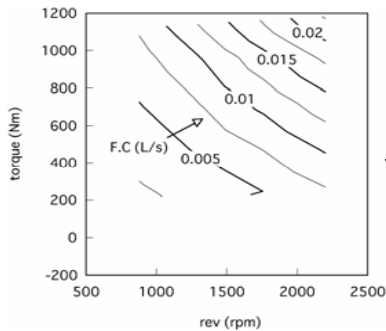
Vehicle weight, Driving Resistance,  
Full load engine torque, Motor  
characteristics, Battery characteristics,  
etc.

Connect

Hybrid ECU (Real)

## 2nd Step

Engine Operating Mode



Input

Fuel consumption

$$= \sum_{i=start}^{end} F.C.(i)$$

Fuel efficiency

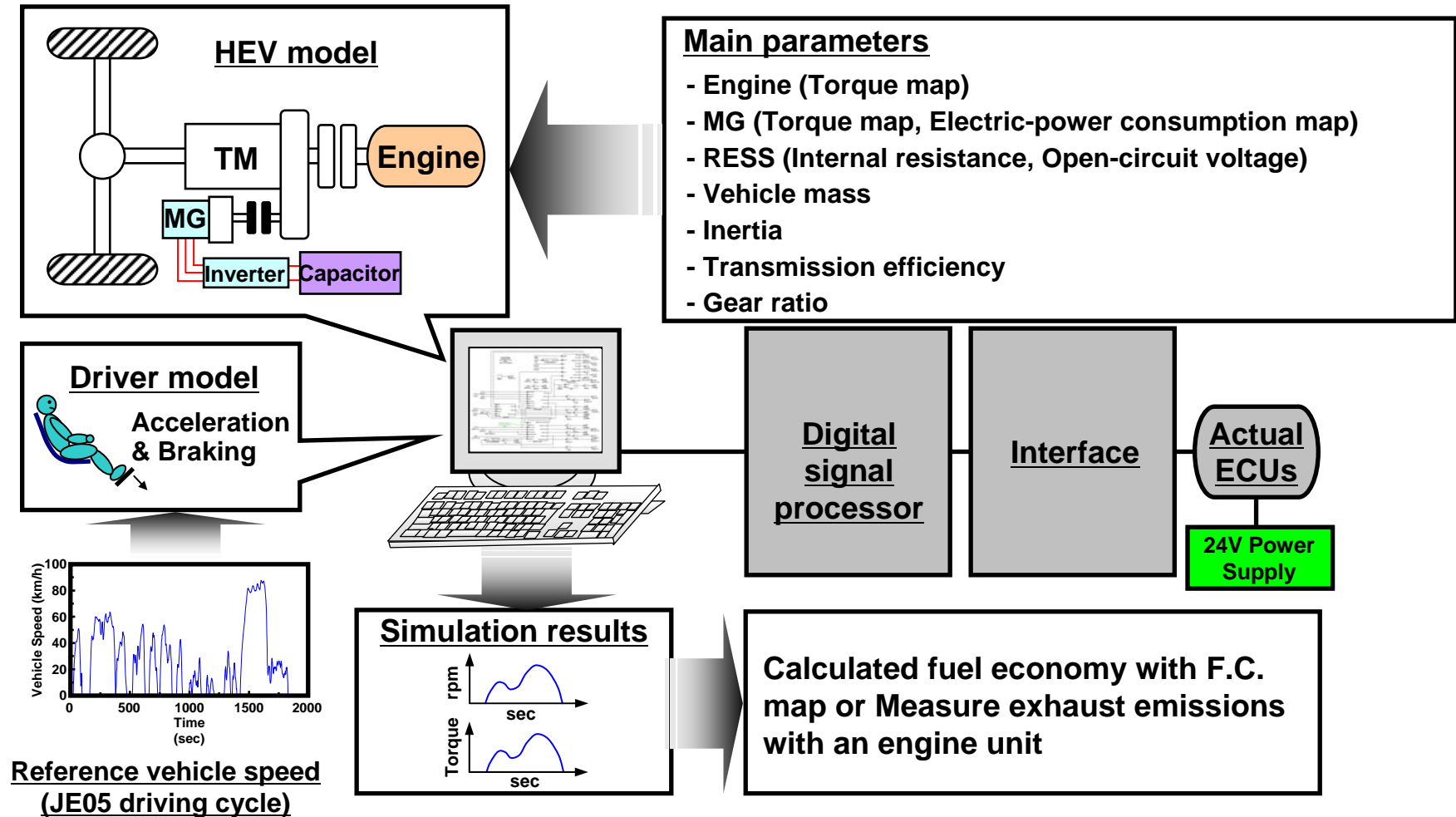
Engine  
torque

Engine  
speed

Time (s)

\*Before simulation, perform  
operation tests to create a  
fuel efficiency map

2nd step is same as  
Simulation Method



## 1. Top Runner Approach

## 2. Fuel Efficiency Standard for HDVs

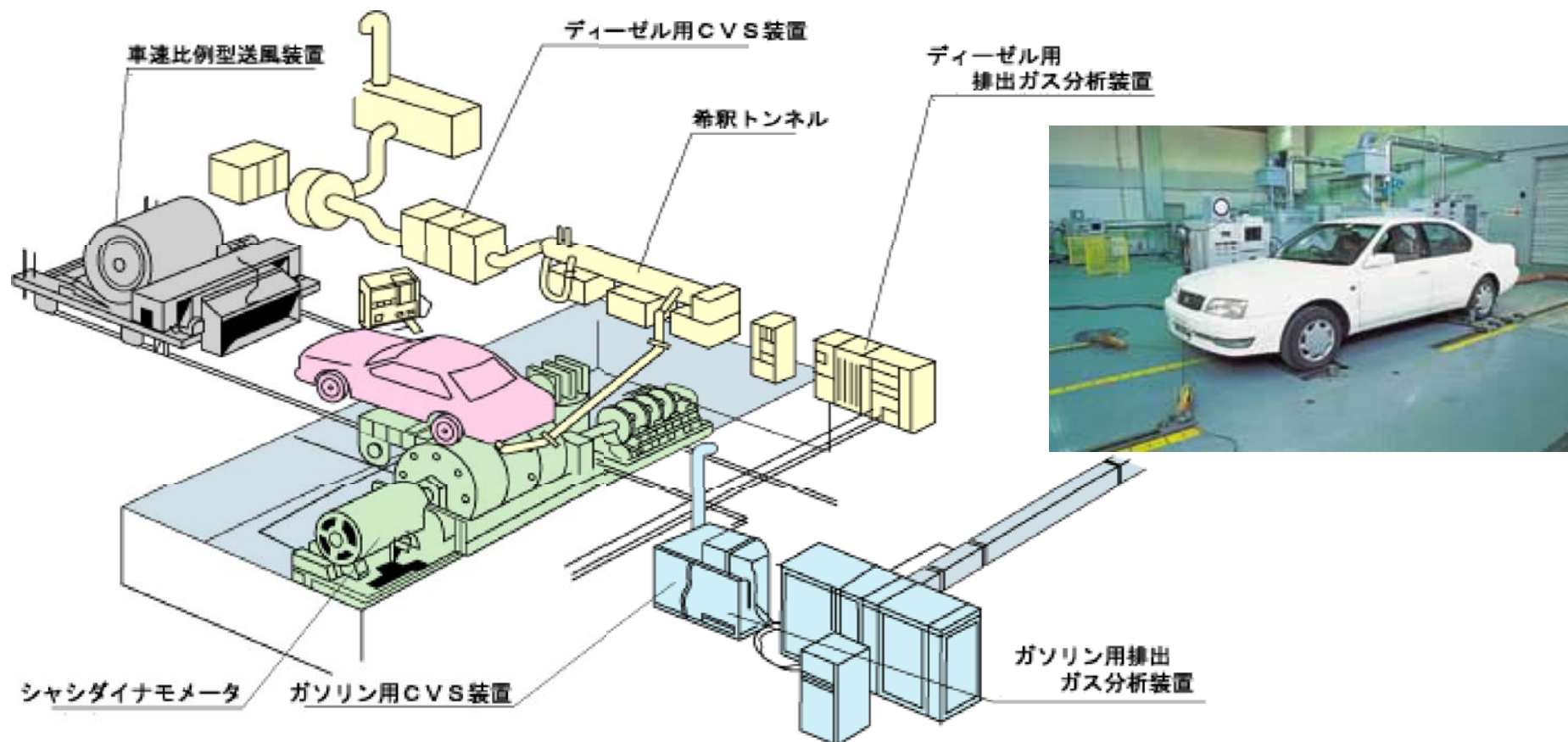
- Simulation Test Method
- for HD HEV Test

## 3. Fuel Efficiency Standard for LDVs

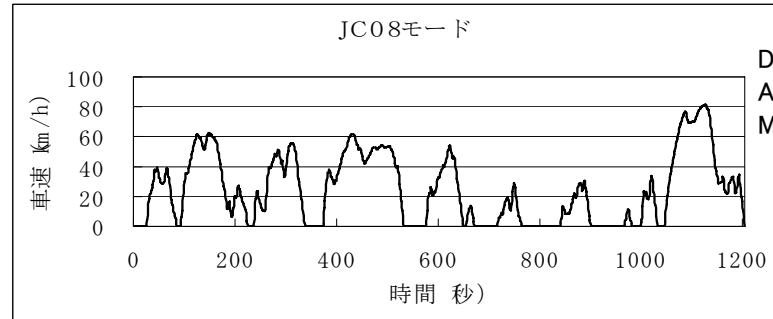
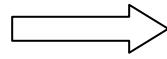
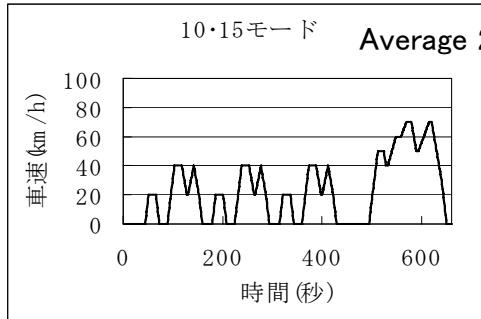
- Conventional Test Method
- for LD HEV Test
- Challenge for PHEV Evaluation

## 4. IPT Bus : PHEV for HDVs

-Vehicle's driving wheels placed on virtual road surface (rollers).  
Exhaust emission and fuel economy measured when operating vehicle in fixed pattern.

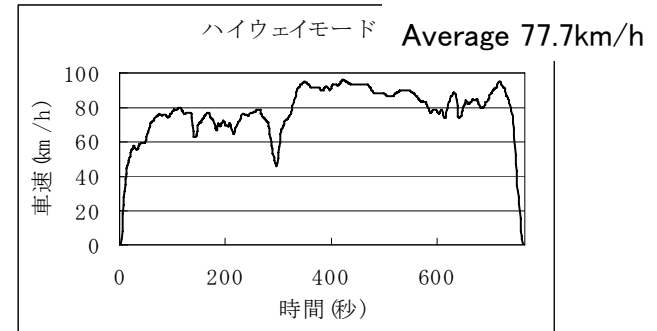
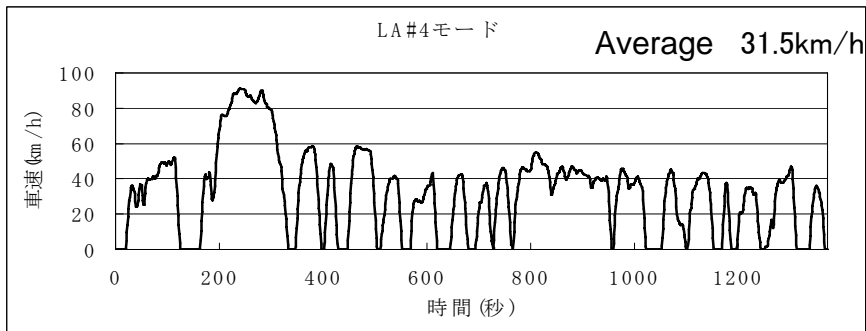


【Japan】

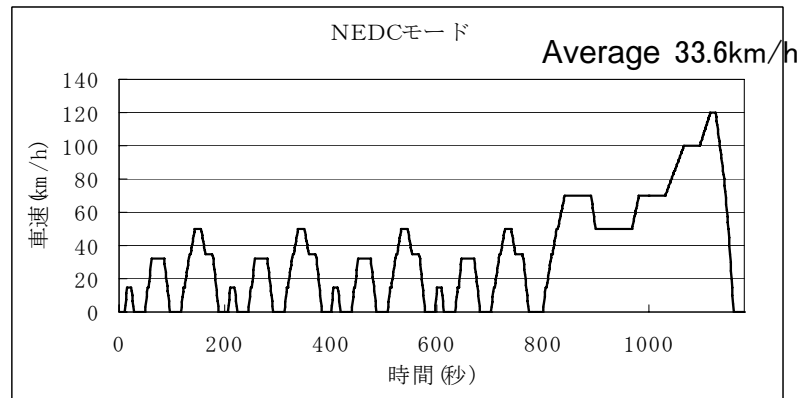


Distance traveled: 8.172km  
Average speed: 24.4km/h  
Maximum speed: 81.6km/h

【US】



【Europe】



Tests corresponding to traffic conditions of the respective areas and operation modes are conducted.

## Correction of current balance

The **current balance is corrected to zero** based on relational expression with  $\Delta$  SOC, considering effects by battery's state of charge (SOC).

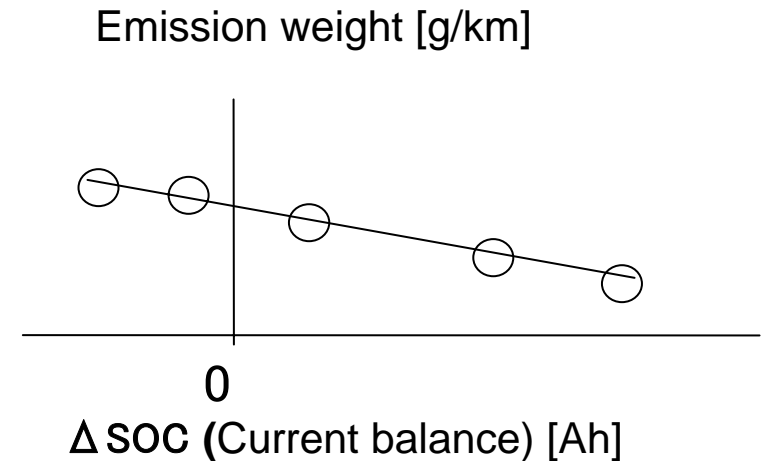
### (1) Exhaust emission measurement

#### [Technical Standard (Attachment 42)]

- ① Mode test is conducted several times. Relation between current balance ( $\Delta$  SOC) and exhaust emission weight are obtained.
- ② When statistical significance can be recognized for each exhaust emission component, exhaust emission weight of the prescribed tests shall be corrected to an exhaust emission weight corresponding to a current balance of zero, based on the inclination of the linear regression formula (correction factor).
- ③ When there is no statistical significance, corrections do not need to be made.

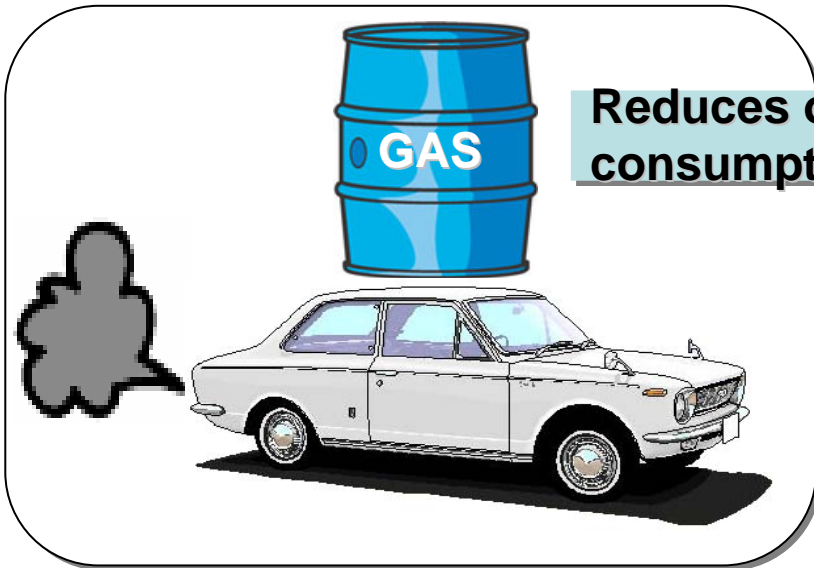
### (2) Fuel consumption measurement [TRIAS (5-9-2007)]

- ① Fuel consumption shall be calculated by carbon balance method using exhaust emission value corrected to a current balance of zero, similar to exhaust emission.



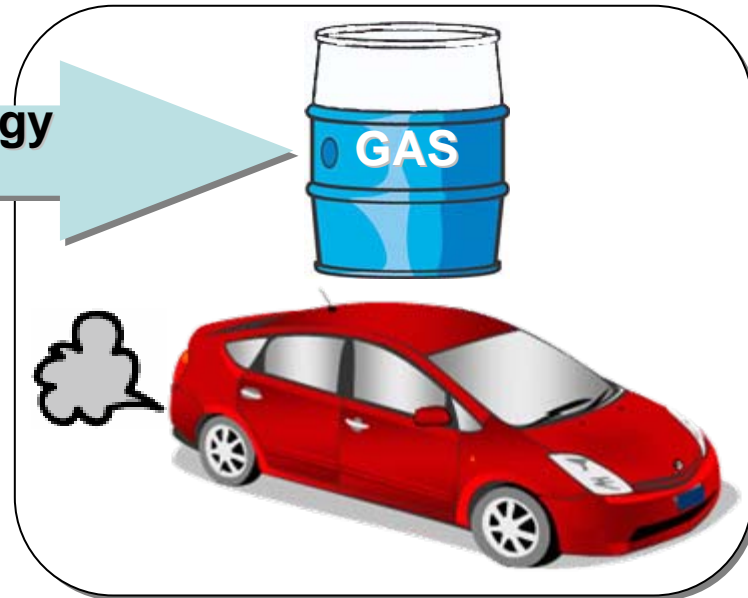
# From vehicle with internal combustion engine to HEV, in HEV 国土交通省

## Vehicle with internal combustion engine

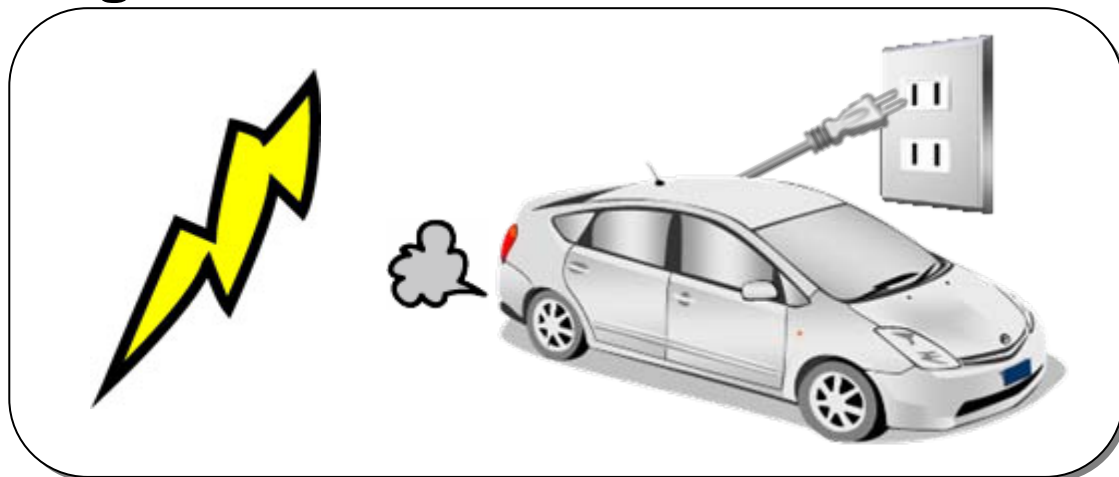


Reduces of petroleum energy consumption

## HEV



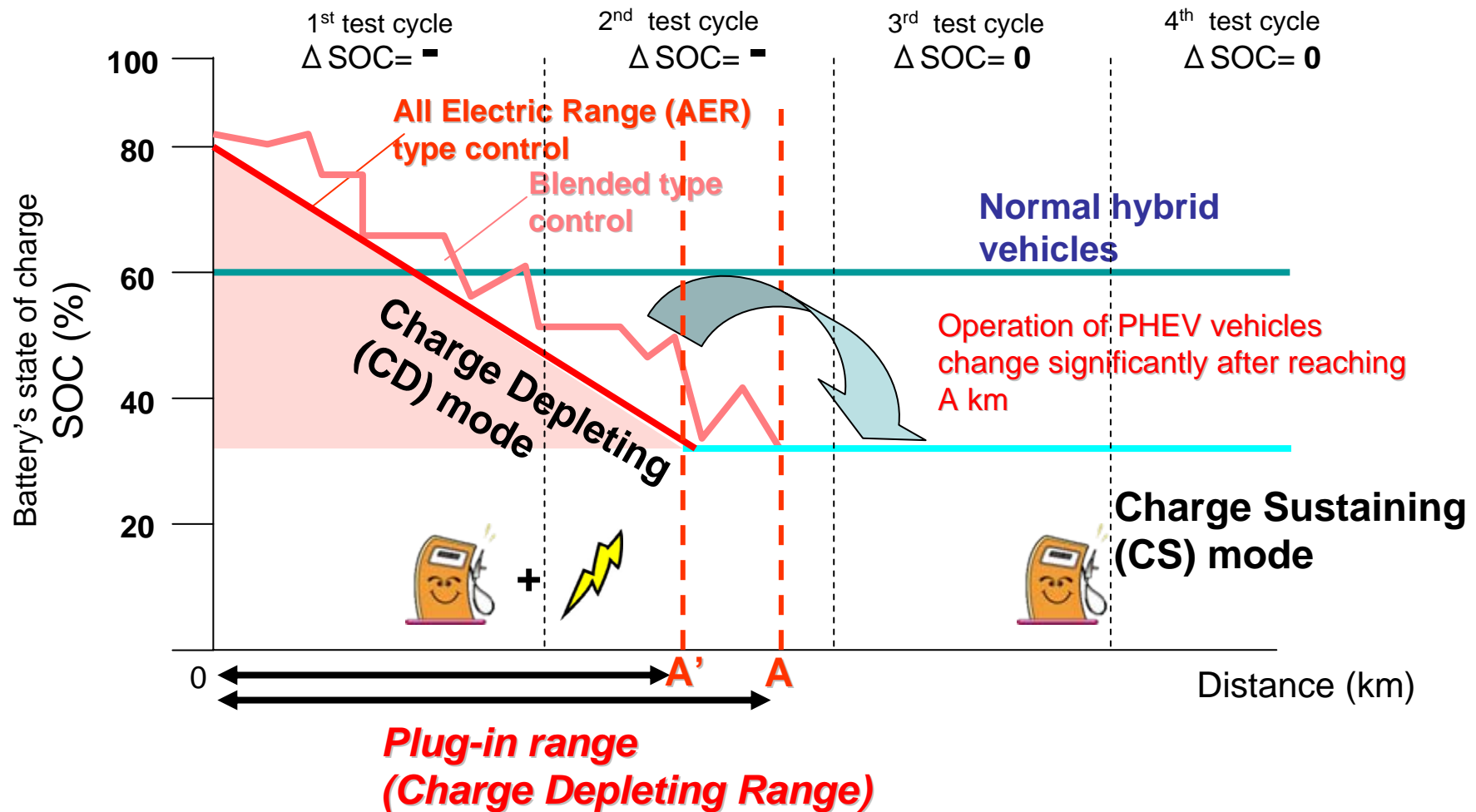
## Plug-in HEV



Replaces petroleum energy with electricity



# Characteristics of Plug-in Vehicles



Charge Depleting (CD) mode: Vehicle is operated by consuming electric energy supplied from external source (while reducing battery's state of charge (SOC))

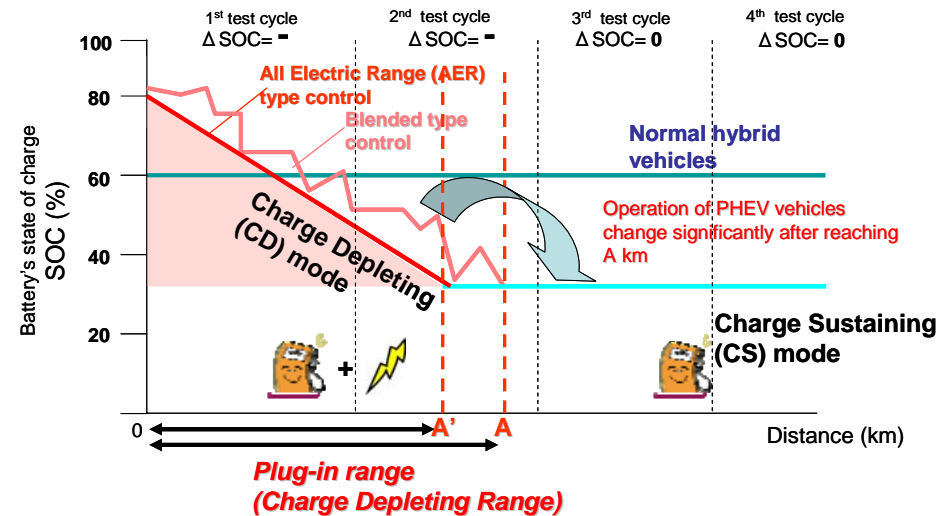
Charge Sustaining (CS) mode: By fossil combustion power (Engine + regenerated electric energy), operation of the vehicle is controlled so the SOC value remains constant.



## 1. Definition of Plug-in range (CD range)

- Plug-in range (CD range) does not always show the total work of charged electric power (How can we define capacity of electricity?).

- How can we estimate the changing point (A or A') from test result?



## 2. Combination of two different performances of CD mode/CS mode)

-How can we incorporate utility factor in the process of combination of two different performance of ?

-How can we accommodate further and rapid improvement of Plug-in performance in the near future (mainly achieved by new technology on battery power intensity or cost down)?

## 3. Consumer Information

- How can we inform consumers of the multi-layered performance of Plug-in HV without confusion?

- The actual performance differs depending on ways of use.

## 1. Top Runner Approach

## 2. Fuel Efficiency Standard for HD Vehicle

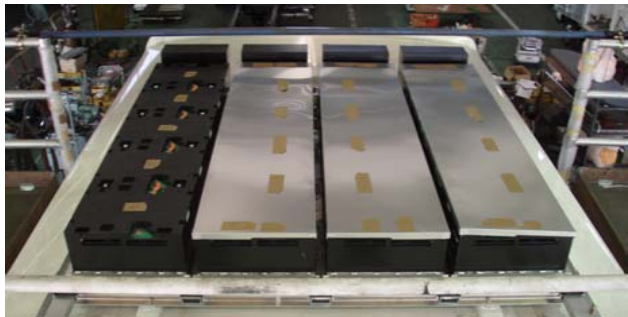
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## 3. Fuel Efficiency Standard for LD Vehicle

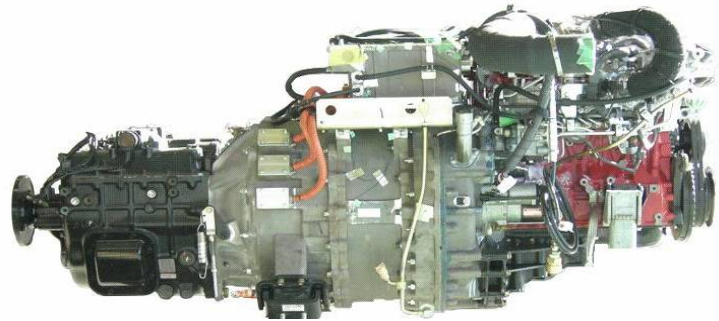
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## 4. IPT Bus : PHEV for HD Vehicle

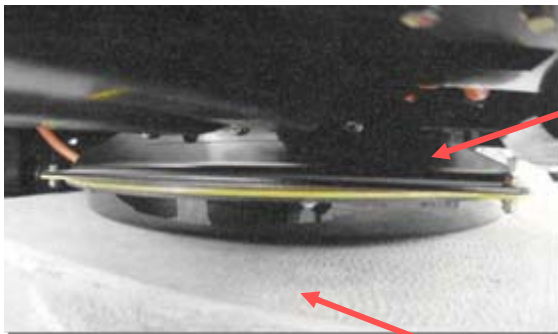
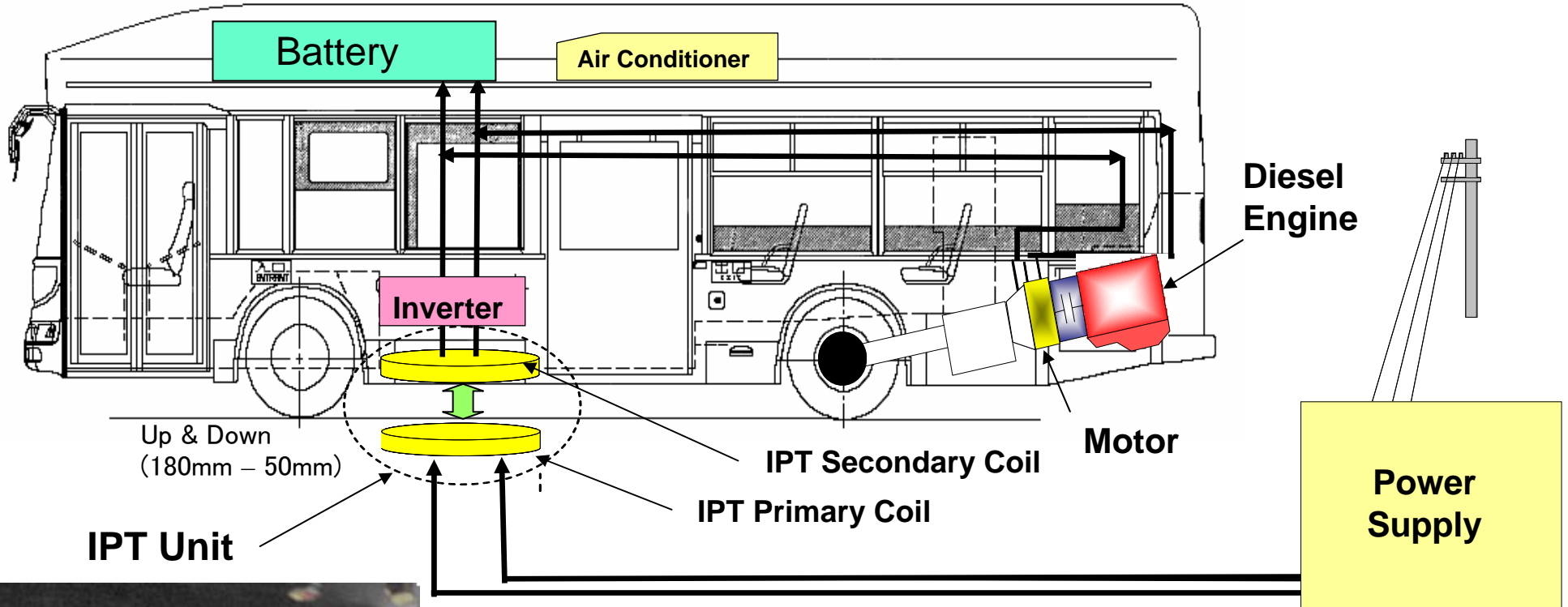
# IPI Hybrid Bus: "Plug-less" Plug-in for HD Vehicle



Lithium Ion Battery Unit



Power Unit



On Board Secondary Coil

**Big Power Quick Charge**

Concrete-covered Primary Coil





## Haneda Airport Shuttle Bus



Now

## Internal Combustion Engine Vehicle

Gasoline  
Diesel  
Etc.

Near Future

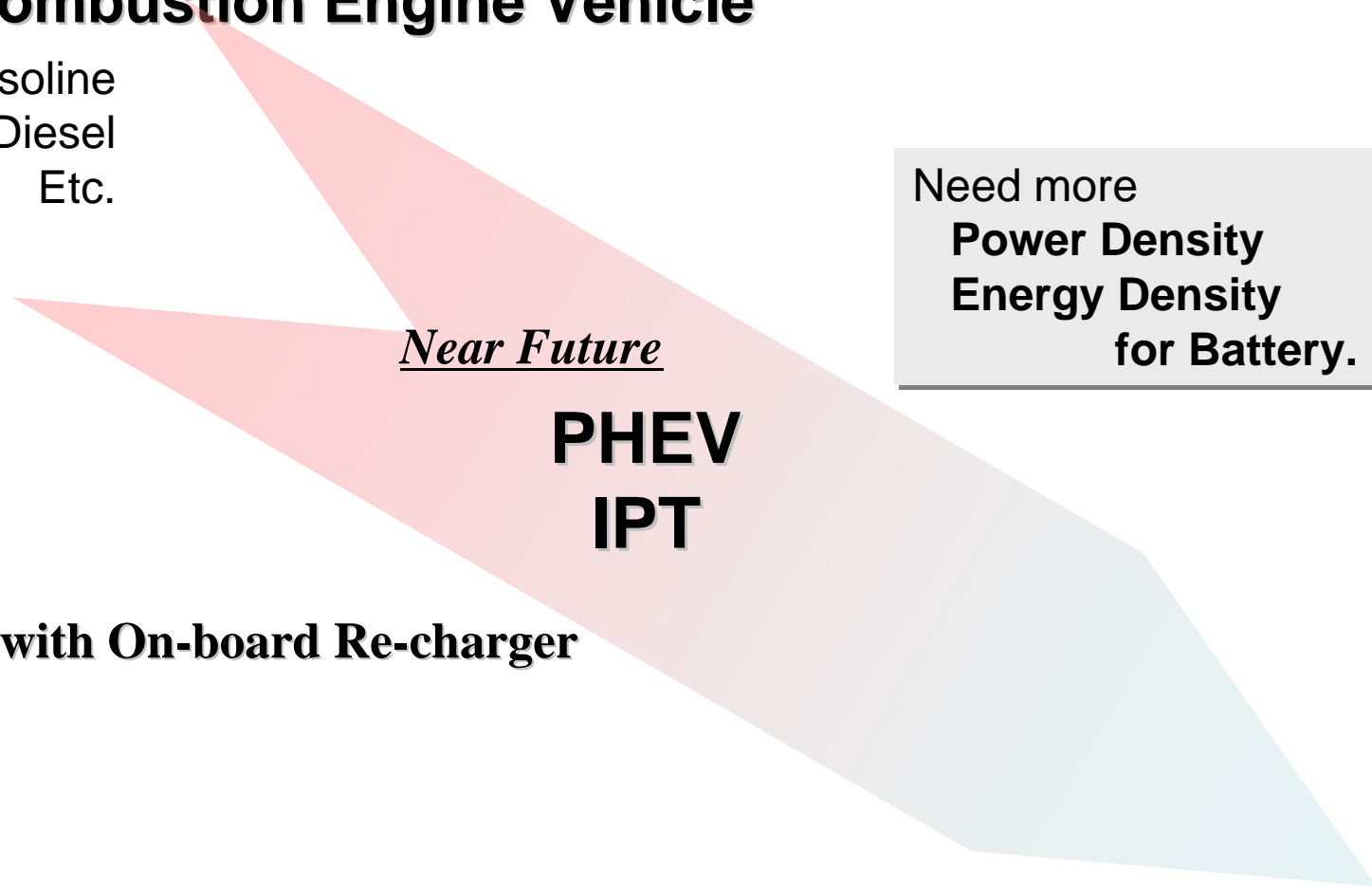
**PHEV**  
**IPT**

**PHEV is EV with On-board Re-charger**

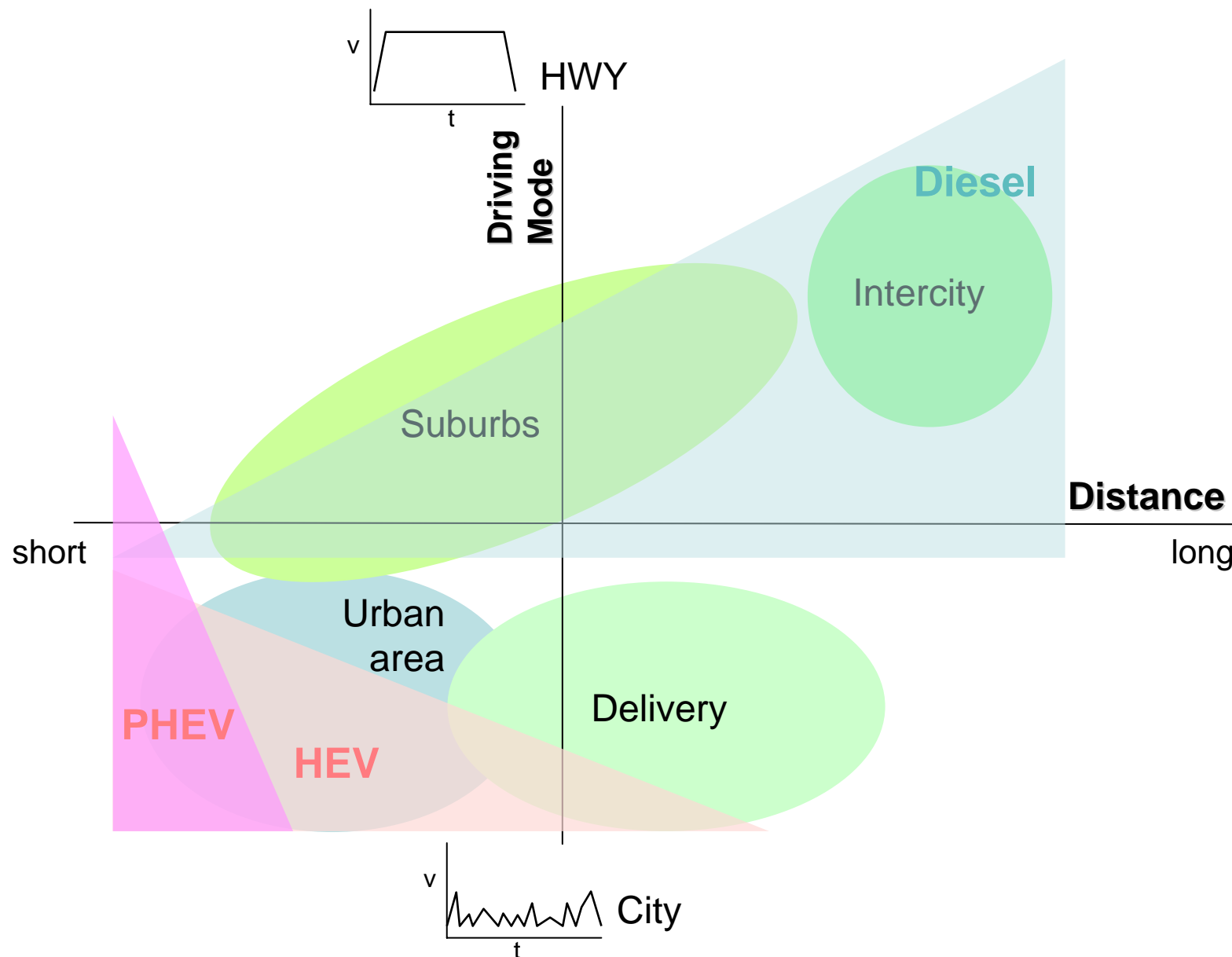
Need more  
**Power Density**  
**Energy Density**  
for **Battery.**

Far Future

**Full Electric Vehicle**



# Right Vehicle to Right Place



*Thank you all for listening so attentively*

For further questions:

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