KUALA LUMPUR 2012 WORLD GAS CONFERENCE

25th world gas conference

"Gas: Sustaining Future Global Growth"

The Innovation behind the CNG/PETROL Bi-fuel-hybrid vehicle

In pursuit of the ultimate eco-friendly car

By: Akihiro Yamada, Naoko Fukutome

Date: 6 June, 2012

Venue: Convention Center Hall 403

Patron

IGU
INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Host

MALAYSIAN Gas ASSOCIATION

Host Sponsor

PETRONAS

1. Background: Why did we develop this car?

- In Japan, the transportation is responsible for about 20% of total CO_2 emissions.
- "Act on the Rational Use of Energy"

  Car makers have been developing fuel-efficient vehicles such as the petrol-fueled hybrid, and introducing them to the market one after another.
- The number of NGVs in Japan is almost saturated.

"How to break this situation?"

CNG/Petrol Bi-fuel Hybrid vehicle!

Aims: "NGV" - for a Low Carbon Society!

- Further improvement in CO_2 emissions reduction

  Mathematics shows ---

  Petrol-fueled cars : CNG cars = 100 : 80

  Petrol-fueled cars : Petrol hybrid cars = 100 : 50

  ➡ Petrol-fueled : Petrol hybrid : CNG hybrid
  = 100 : 50 : 40

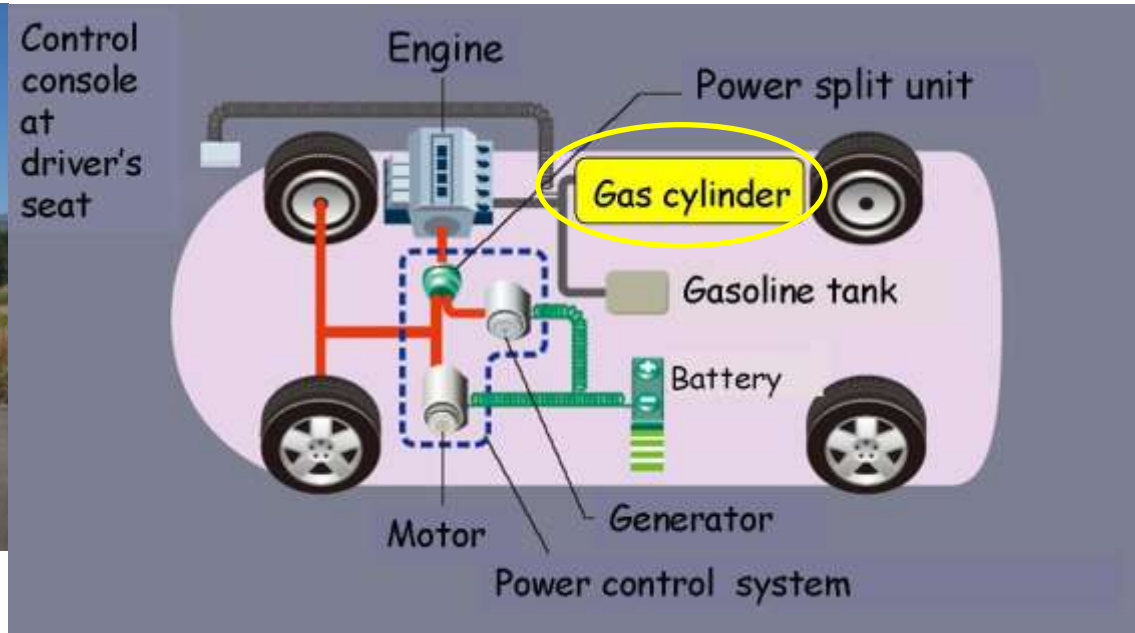
- Driving comfort-ability
  - Longer cruising distance

    ➡ Utilise natural gas and petrol as a bi-fuel
  - Overcome disadvantages in CNG-fueled vehicles

2. What did we do to realize this car?
Base Vehicle:

- "SAI" - TOYOTA
- Petrol hybrid system, 2.4-liter engine
- 23.0 km/L (by catalogue)
- CNG cylinder: 77.7 liter x 1

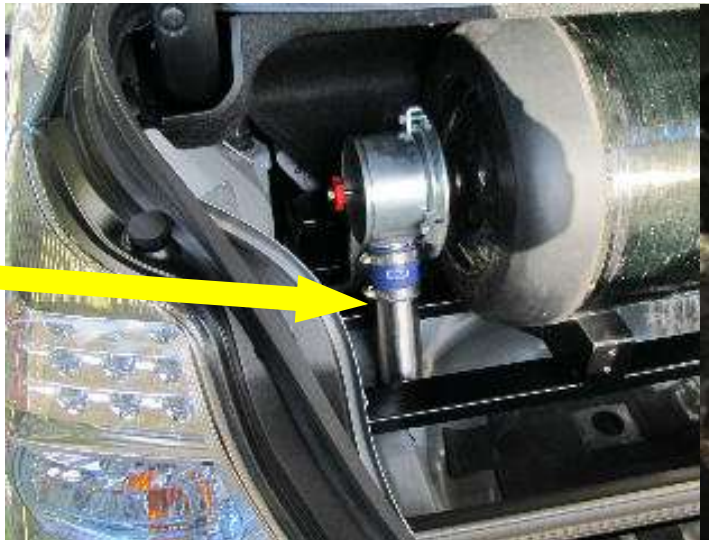
Add the great performance of CNG vehicle on the base car's high performance



CNG cylinder

- Filled volume: 15.5m^3
- Structure: Aluminum alloy reinforced by carbon fiber with plastics coating
- Weight: 25.7 kg
- Container Screen: prevents both damages for the cylinder and from condensation on the cylinder

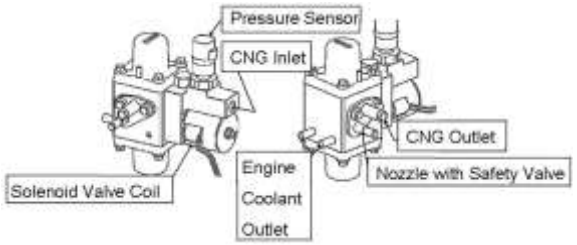
- To prevent gas inflow to the inside of the vehicle; in case of gas leak from the gas cylinder valve, the gas is released through this duct.



Remodeling of the vehicle

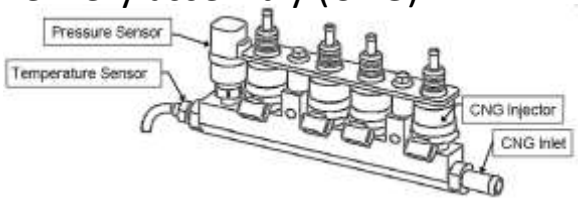
Receptacle (CNG)

Regulator (CNG)

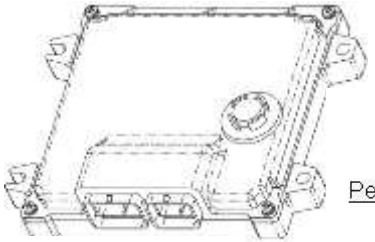


Controller (Bi-fuel)

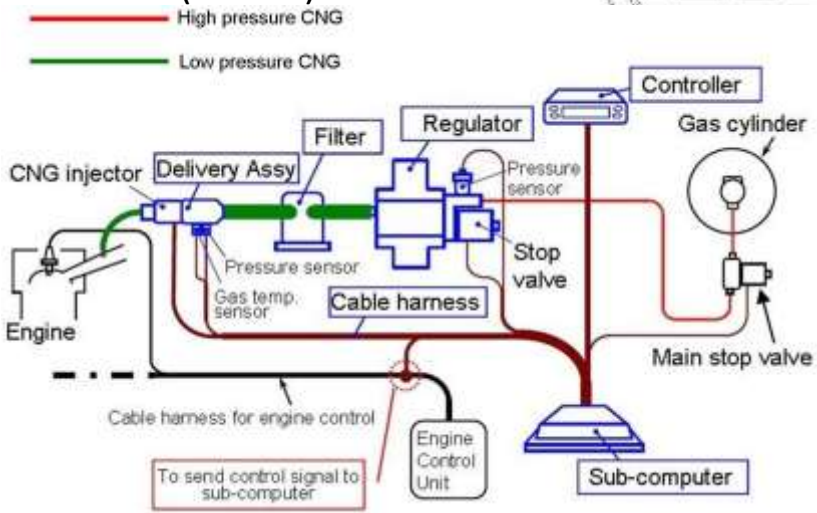
Delivery assembly (CNG)

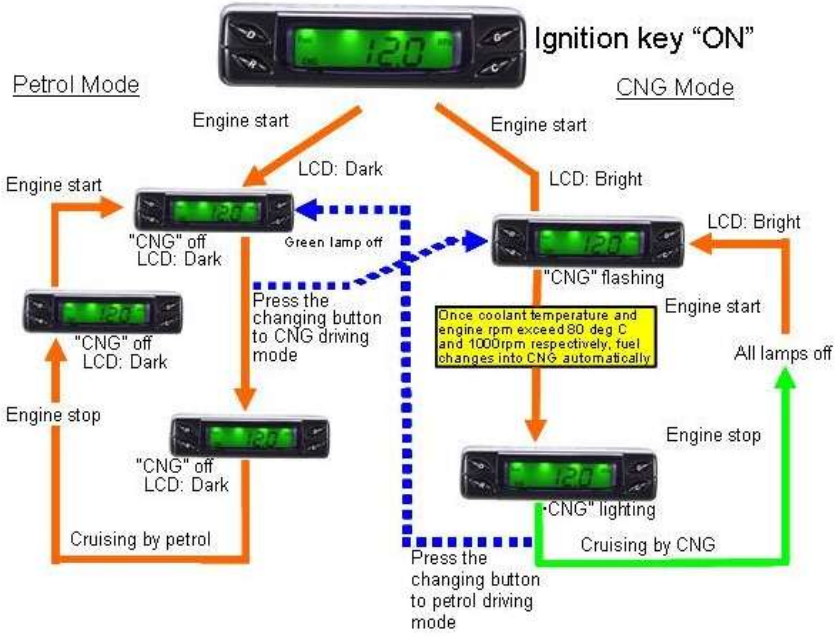


Sub computer (Bi-fuel)



Wire harness kit (Bi-fuel)





Estimated vehicle capability

- CO_2 reduction effects

	Petrol-powered	'SAI': Petrol Hybrid	'SAI': CNG Bi-fuel Hybrid
Fuel efficiency	11.5 km/l	23.0 km/l	29.8 km/m^3
CO_2 emissions coefficient	2.32 kg/l	2.32 kg/l	2.29 kg/m^3
CO_2 emissions / 1km cruising	202 g	101 g	77 g
% of CO_2 emissions	100	50	**38**

- Cruising distance of Bi-fuel

	CNG	Petrol
Fuel efficiency	29.8 km/m^3	23.0 km/L
Fuel consumption	15.5 m^3	55 L
Calculated value for cruising distance	461 km	1,265 km
Total calculated cruising distance	1,726 km	

3. Result: How was the result?

- Driving-ability:
  - CNG-fueled vehicles' disadvantage: acceleration

    The engine and the motor work together to provide the power to pick up speed.

    ⇨ **The driving feeling has been improved**

- CO_2 emissions reduction:
  - Lowered the set temperature of the coolant → 40 degrees C
  - The engine starts by petrol → within a few seconds the vehicle shifts to CNG operations → the total length of driving with CNG increases

    ⇨ **Longer CNG driving achieves less CO_2 emissions**

Test Results

Fuel	Driving section	CNG filled volume	Petrol filled volume	Driving distance	Volume of energy consumption	Volume of CO_2 emissions	% of CO_2 emissions
		m^3	L	km	MJ/km	kg/km	%
Bi-fuel hybrid	General roads	24.44	9.92	618	2.34	0.128	86.5
	Motorways	34.52	7.1	895	2.01	0.107	87.3
Petrol hybrid	General roads	—	11.65	183	2.20	0.148	100
	Motorways	—	23.14	439	1.82	0.122	100

- **Bi-fuel** mode achieves **less CO_2** emissions versus petrol mode; although it consumes more energy, CNG and petrol.
- **Bi-fuel** hybrid achieves **13% reduction** (average) versus petrol hybrid, and should achieve **56% reduction** versus usual petrol-fueled vehicle.

< Petrol-fueled V : Petrol HV : CNG Bi-fuel HV = 100 : 50 : 44 >

Remaining challenges of the CNG/Petrol bi-fuel hybrid car

- Improve the compression ratio
  - Because this vehicle is driven with the original base car's engine; driven at the compression ratio set for a petrol-fueled engine.

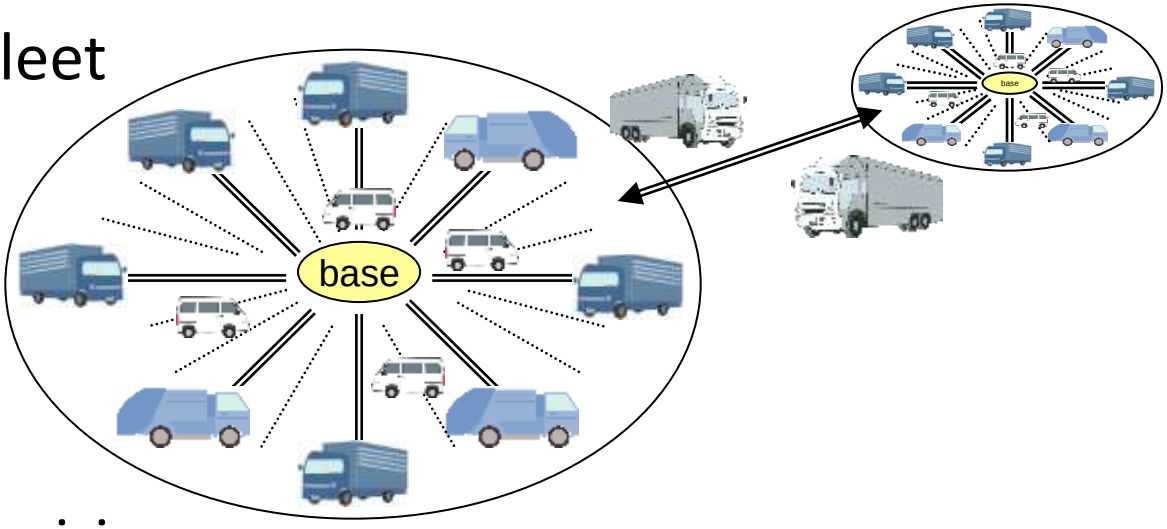
    ⇒ the efficiency cannot be achieved higher as expected as a CNG vehicle

- Durability of the main valve
  - To improve fuel consumption, this vehicle has a system to stop the engine when the accelerator is released even while driving; thus, the main valve also repeats opening and closing numerous times.

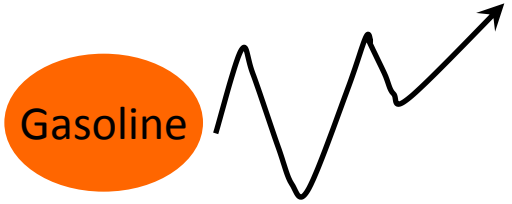
    ⇒ the main valve should require a super-high durability or more frequent maintenance

4. Conclusion: Which direction is the road ahead of us?

- NGV market in Japan: fleet



- Economic potential
  - Worldwide economic crisis
  - Natural Gas price: "***Japan Premium***", yet less volatile and almost always cheaper than Petrol
  - Highly volatile Petrol price, and often it hikes

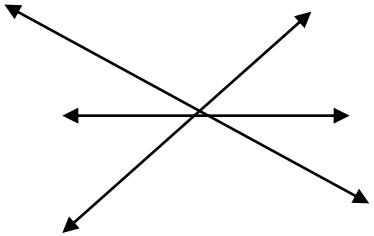


- Energy Security
  - What did we learn from "March 11"?

Types and Performance in the fleet market

Expand or Narrow the choice?

- Types
  - Heavy Duty Truck : 25t (total weight)
  - Truck : 2t, 3t, 4t
  - Garbage truck
  - Automobiles: van, station wagon, etc.



- Performance
  - CNG HV
  - Bi-fuel HV
  - Bi-fuel
  - CNG

Thank you very much for your precious time!