The report of DPF installation, field test and its outcomes on Mitsubishi Fuso LDT products

Mayan Industrial and Manufacturing Co.

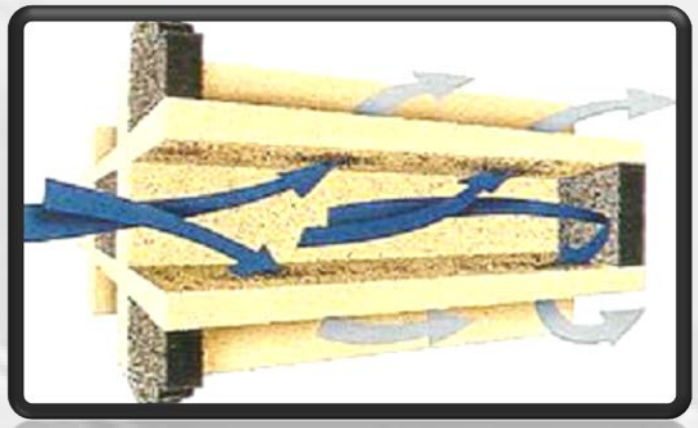
Introduction

- ✓ Mayan Industrial and Manufacturing Co is exclusive distributor of full range of Mitsubishi Fuso trucks in Iran.
- ✓ Mitsubishi Fuso belongs to Daimler Group.
- ✓ This company is manufacturer of full range of commercial products including 3.5 t to 40 t rigid trucks, 40t to 150 t tractor heads, vans, minibuses and buses.
- ✓ Mayan Ind. & Mfg. Co. installed proper DPF on its LDT products before their launch into the market in order to meet emission regulation.
- ✓ DPF performance and durability of its components under Iran's real conditions including varying fuel and poor oil quality had been examined via road test process that was defined by Fuso's R&D.
- ✓ This presentation is intended to introduce deployed DPF on Fuso LDT products and to report main outcomes of its test briefly.

The specification of deployed DPF in Fuso LDT's

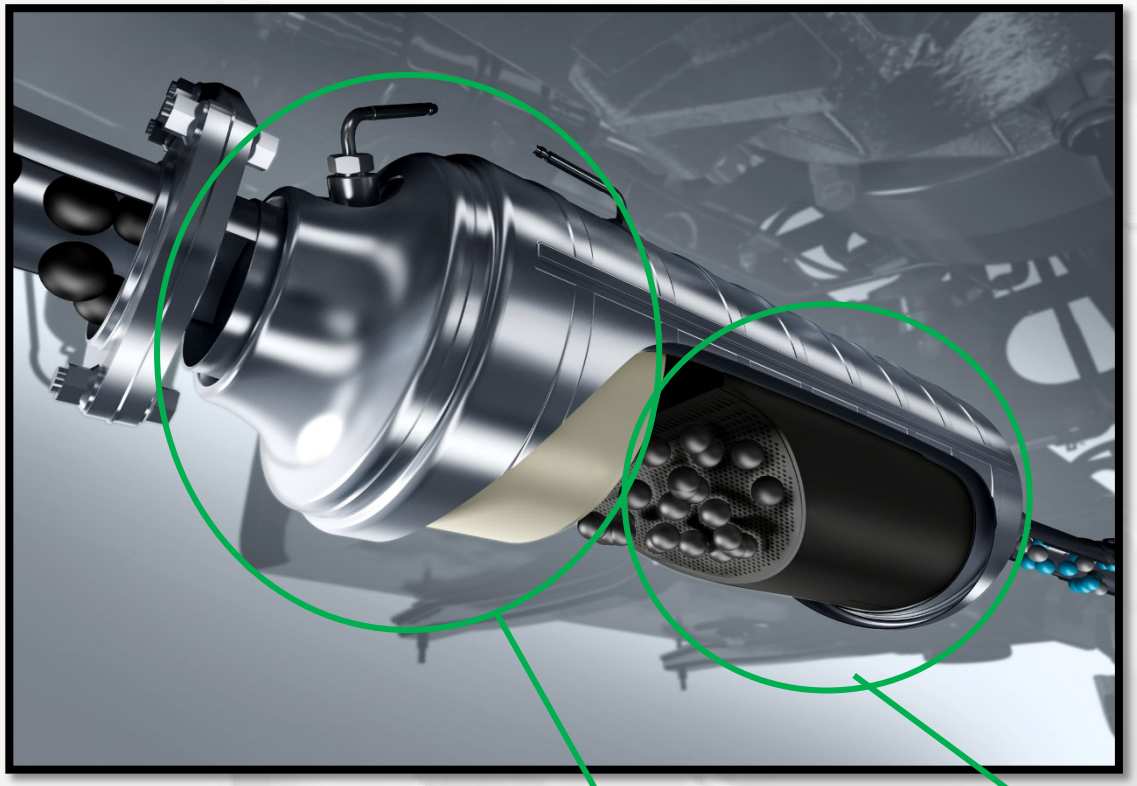
- Fuso is deploying DPF as ATS to reduce particulate numbers (PN).
- It is a full flow PM trap with wall filtration mechanism.
- Its substrate is Silicon Carbide
- Its mesh concentration is 400 cell/$inch^2$

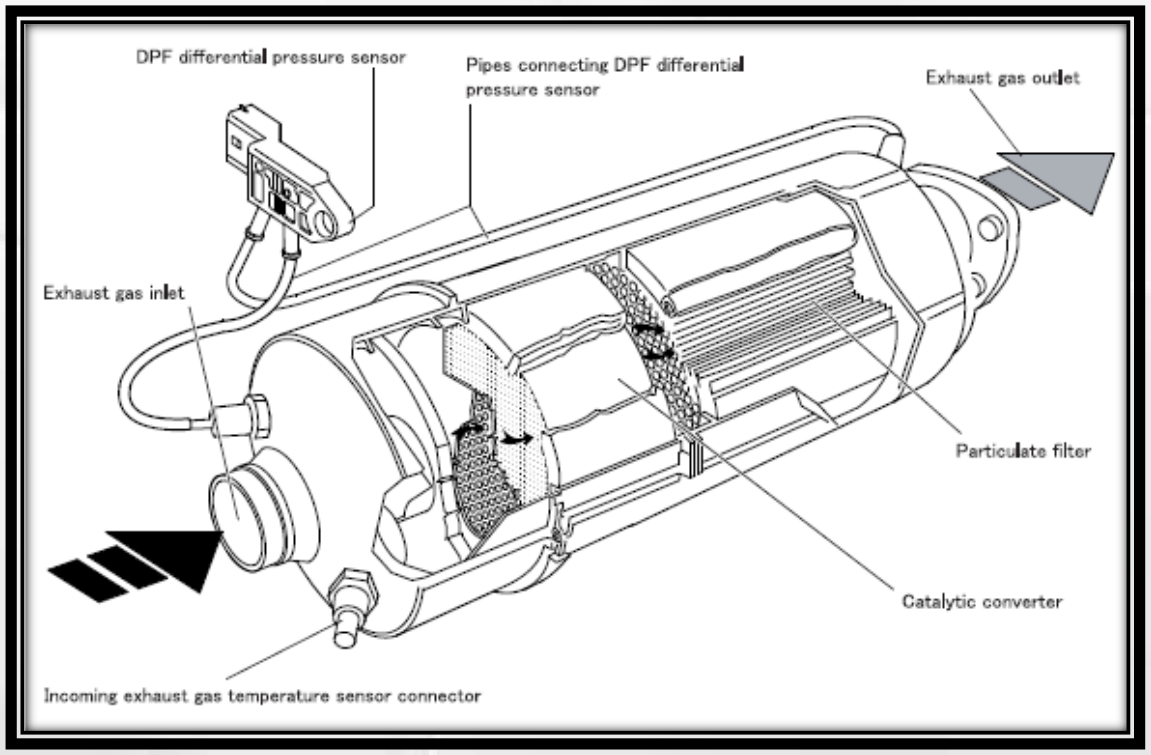
Segment	Length x Diameter (inch)	Volume (L)	OEM
DOC	4.0X6.77	2.3	Futaba-Italy
DPF	11.0X6.77	6.5	



The specification of deployed DPF in Fuso LDT's

- The regeneration process is a quasi passive one
- Its passive regeneration mechanism is DOC-CRT
- The upstream DOC converts NO to NO2 continuously to burn accumulated soot in real time





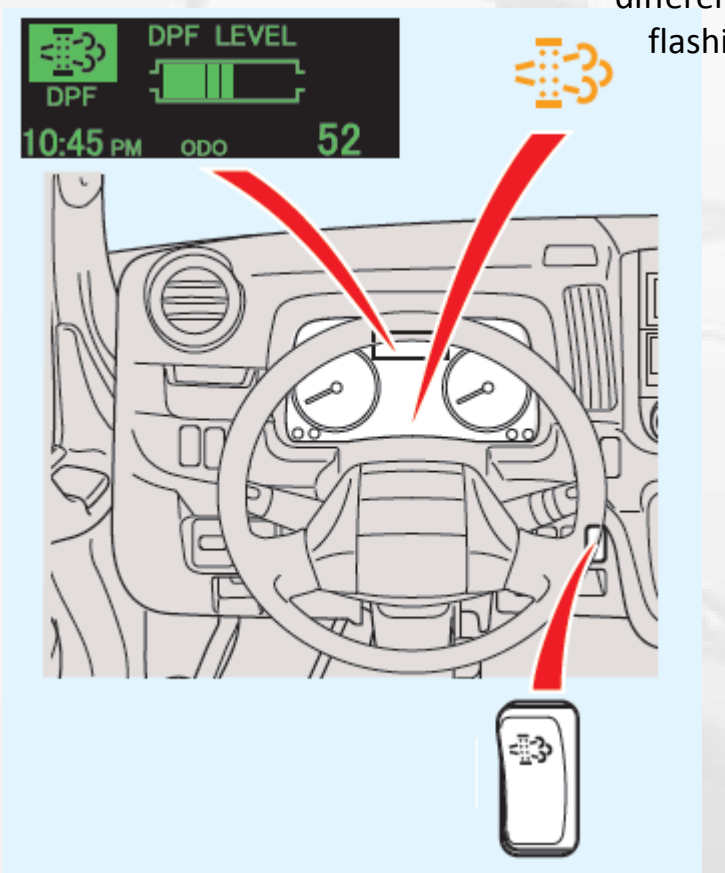
The specification of deployed DPF in Fuso LDT's

Real time monitoring of DPF in ICL

- ✓ All DPF related issues e.g. its filled level, regeneration modes and remaining time to clean it are being illustrated in digital display in ICL.

Digital display

DPF clogging indicator in different colors and flashing modes



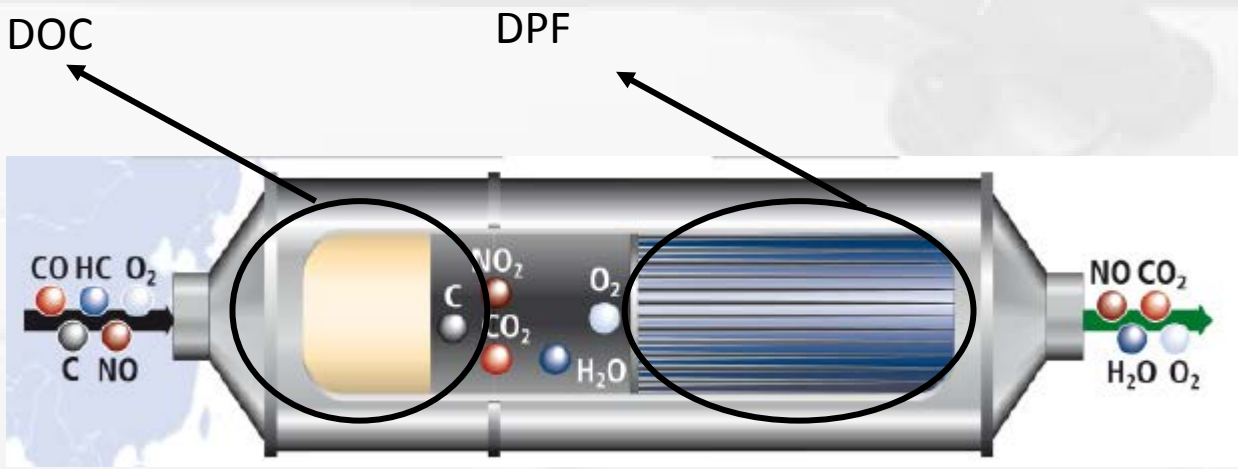
Manual Reg. switch

The specification of deployed DPF in Fuso LDT's

DPF regeneration steps

DPF regeneration in Fuso's LDT products in Iran consists of 3 main sequential steps:

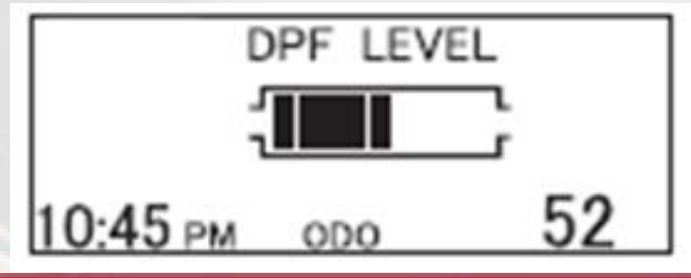
1- Continuous Automatic Regeneration: Is burning accumulated soot in filter continuously by oxidation reaction in DOC.



$2NO+O2 \rightarrow NO2+O2+N+$گرما

$NO2+C\ (soot) \rightarrow CO2+N$

✓ In this step, DPF indicator indicates 1 to 6 filled bars and no warning light is lightened.

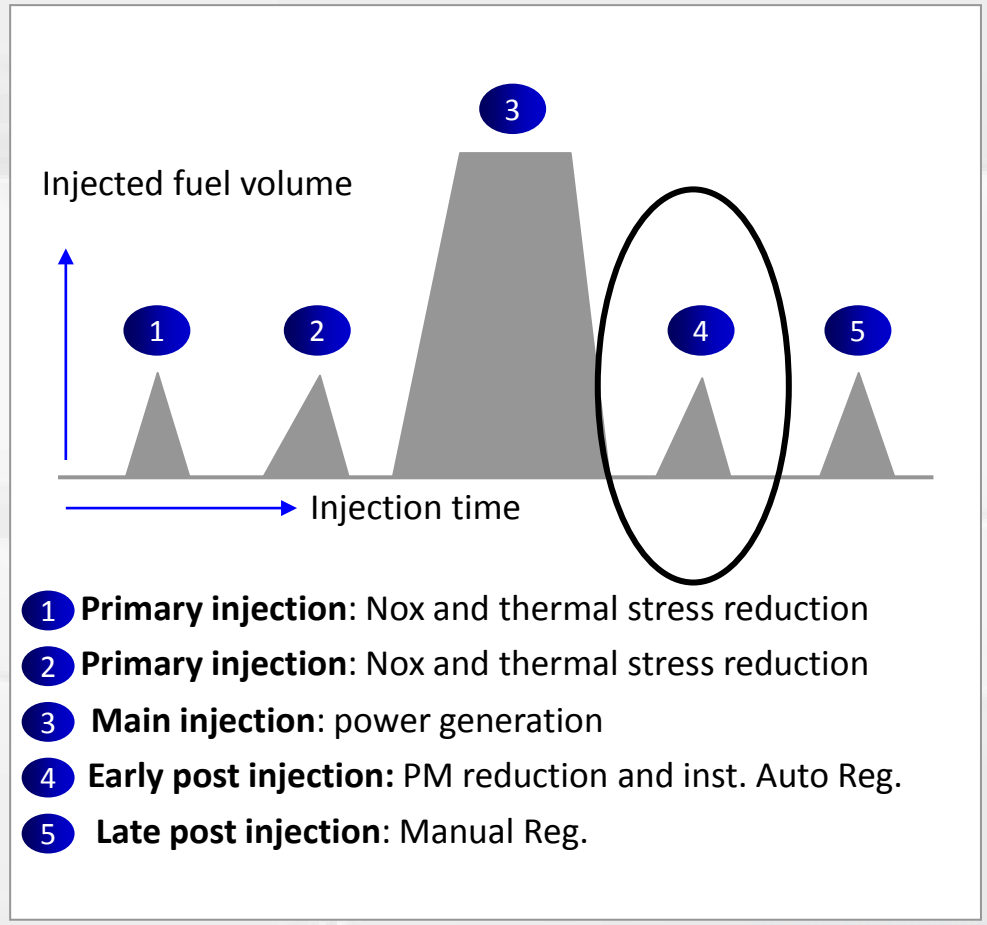


The specification of deployed DPF in Fuso LDT's

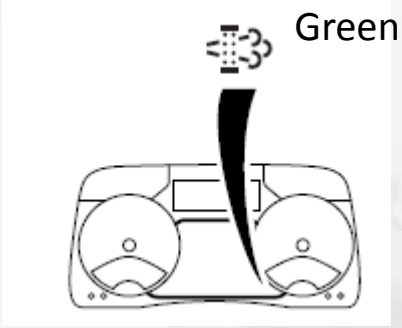
DPF regeneration steps

2- Instantaneous Automatic Regeneration: When 1st step is not enough to burn soot, this step triggers automatically by activating below items to increase exhaust temperature instantaneously.

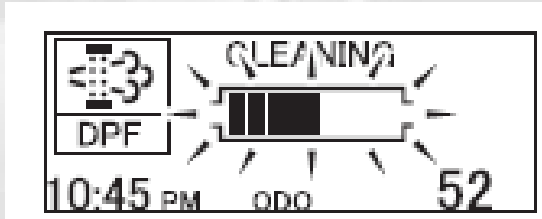
- Early post injection
- Temporary EGR deactivation
- Temporary increase of idle speed from 600 rpm to 800 rpm



1. **Primary injection**: Nox and thermal stress reduction
2. **Primary injection**: Nox and thermal stress reduction
3. **Main injection**: power generation
4. **Early post injection:** PM reduction and inst. Auto Reg.
5. **Late post injection**: Manual Reg.



✓ In this step, DPF indicator indicates 1 to 6 filled bars and green warning light is lightened.



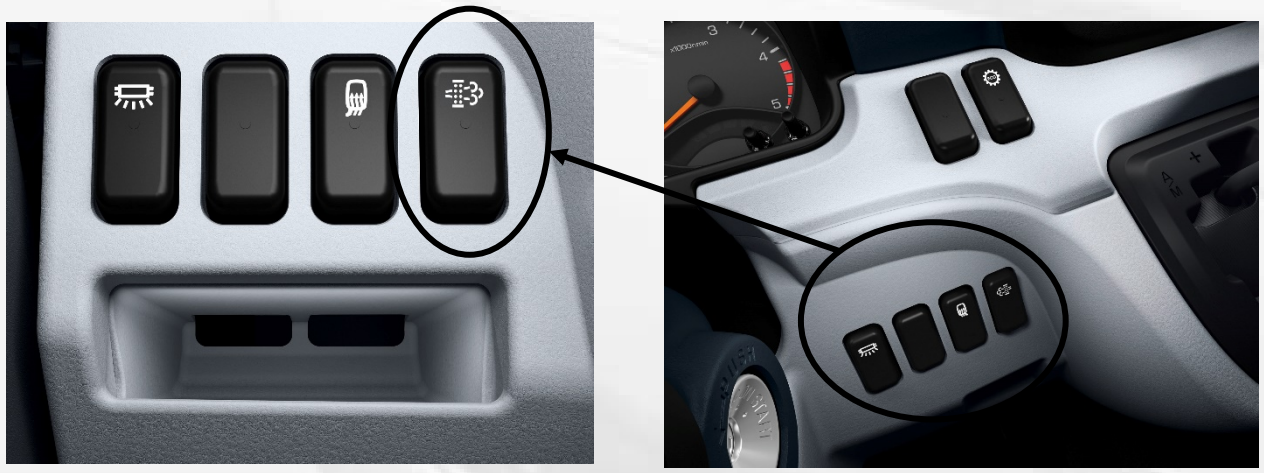
The specification of deployed DPF in Fuso LDT's

DPF regeneration steps

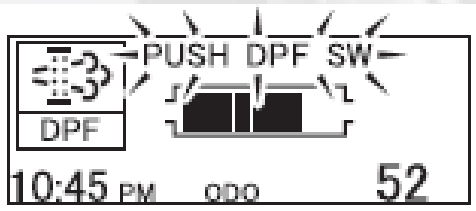
3- Manual Regeneration: In this step, DPF indicator indicates 7 to 8 filled bars and amber warning light is flashing.

✓ By triggering of this step by driver, late post injection will be also activated beside 3 items of 2nd step.

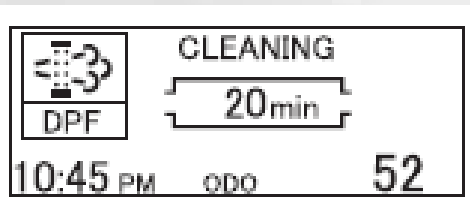
✓ This step be triggers by pushing a switch inside cab while engine is idling beside the road within 20 min.



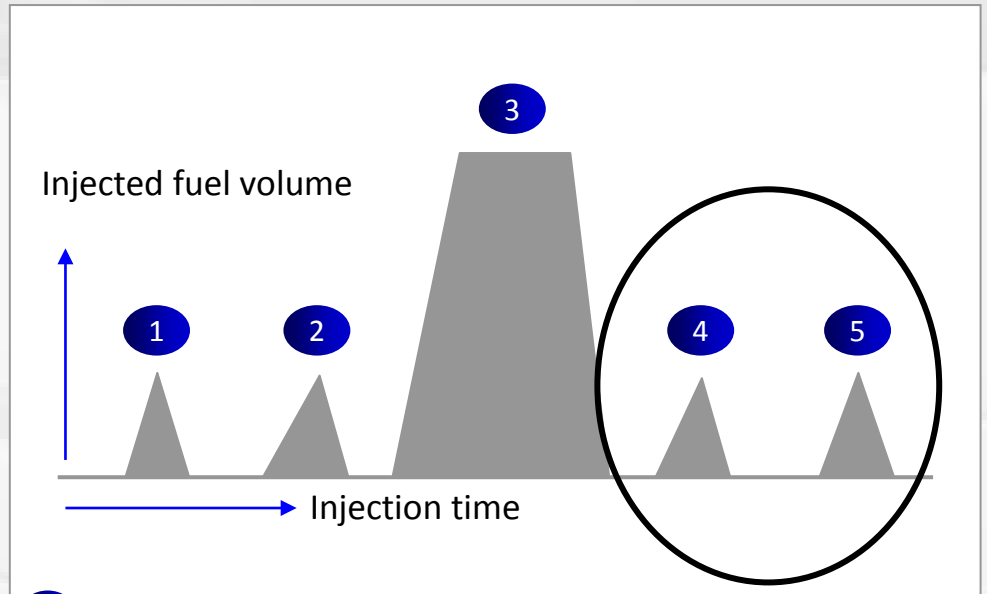
Manual Reg. activation switch



Illustrated info-just before triggering of manual Reg.



Illustrated info-right after triggering of manual Reg.



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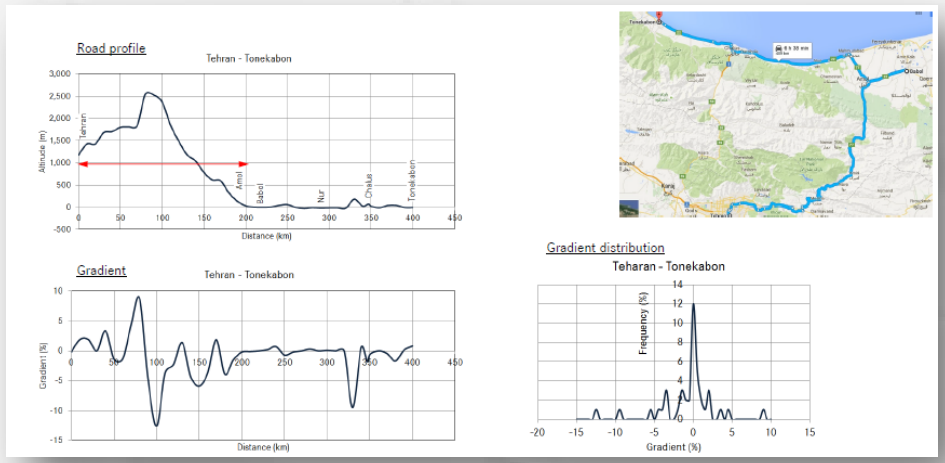
DPF performance examination

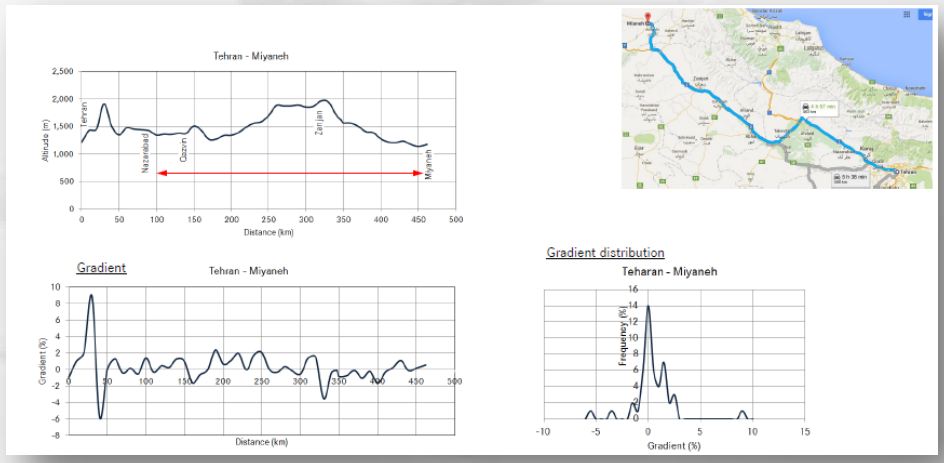
Road test under Iran real operational condition

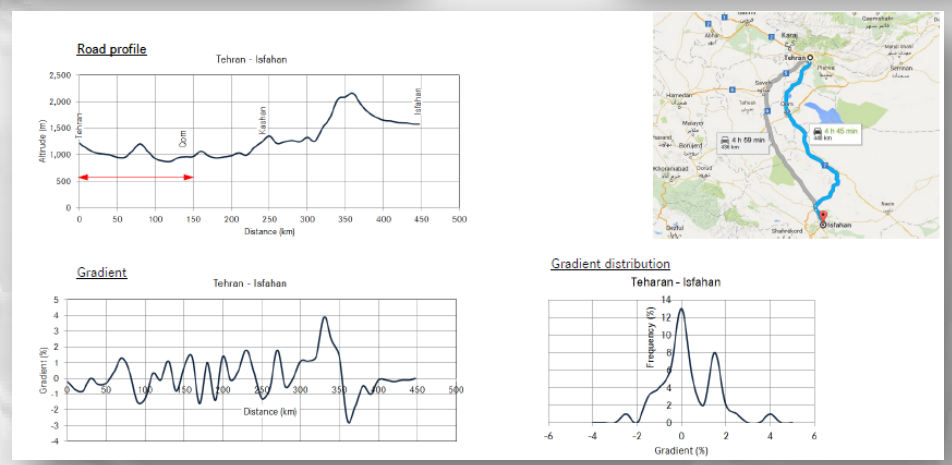
- ✓ DPF performance and durability of its components under Iran's real conditions had been examined via 50,000 km road test process.
- ✓ It was done on 2 sample trucks.
- ✓ Both 2 units were tested within almost 4 months in 3 different routes. Each rout represents different climate, humidity, altitude and topography conditions in Iran.

Rout 1: Tehran-Tonekabon



Rout 2: Tehran-Myaneh





Rout 3: Tehran-Kashan

DPF performance examination

Tested sample trucks

Test unit model	Tech. GVW (Tone)
FEB71GL4SA13	6
FECX1HL4SA13	8.55

Engine model	Engine volume	Engine output	Max torque	Emission level	Emission reduction Technologies
4P10-8AT4	3 L	110 kw (150 hp) @ 3500 rpm	370 N.m @ 1320-2800 rpm	Euro V+EEV	EGR+DPF

Test vehicle #1

Test vehicle #2

DPF performance examination

Fuel analysis results within 4 months of testing

- Within around 4 months of 50,000 km road test, diesel sampling and analysis has been done from versatile fuel stations across the test routs to cover diesel versatility nationwide.
- These sampling had been done several times from each station in order to monitor quality fluctuation per station too.
- Quality monitoring had been focused on sulfur content as it was proved that other quality attributes of diesel are not varying drastically and are almost in Euro IV level.

Item No.	Diesel attribute	Test method	Range of test results
۱	Kin. Viscosity@40°C	ASTM D445	2.25-2.99
۲	Density - Kg/m3 @15 °C	ASTM D4052	825-835
۳	Flash Point(Closed Cup)-°C	ASTM D93	around 60
۴	Cetane Index	ASTM D976	51-53
۵	Carbon Residue on 10% (V/V) Distillation Residue	ASTM D189	0.03-0.12

Diesel quality attributes-the range of variations in different stations

DPF performance examination

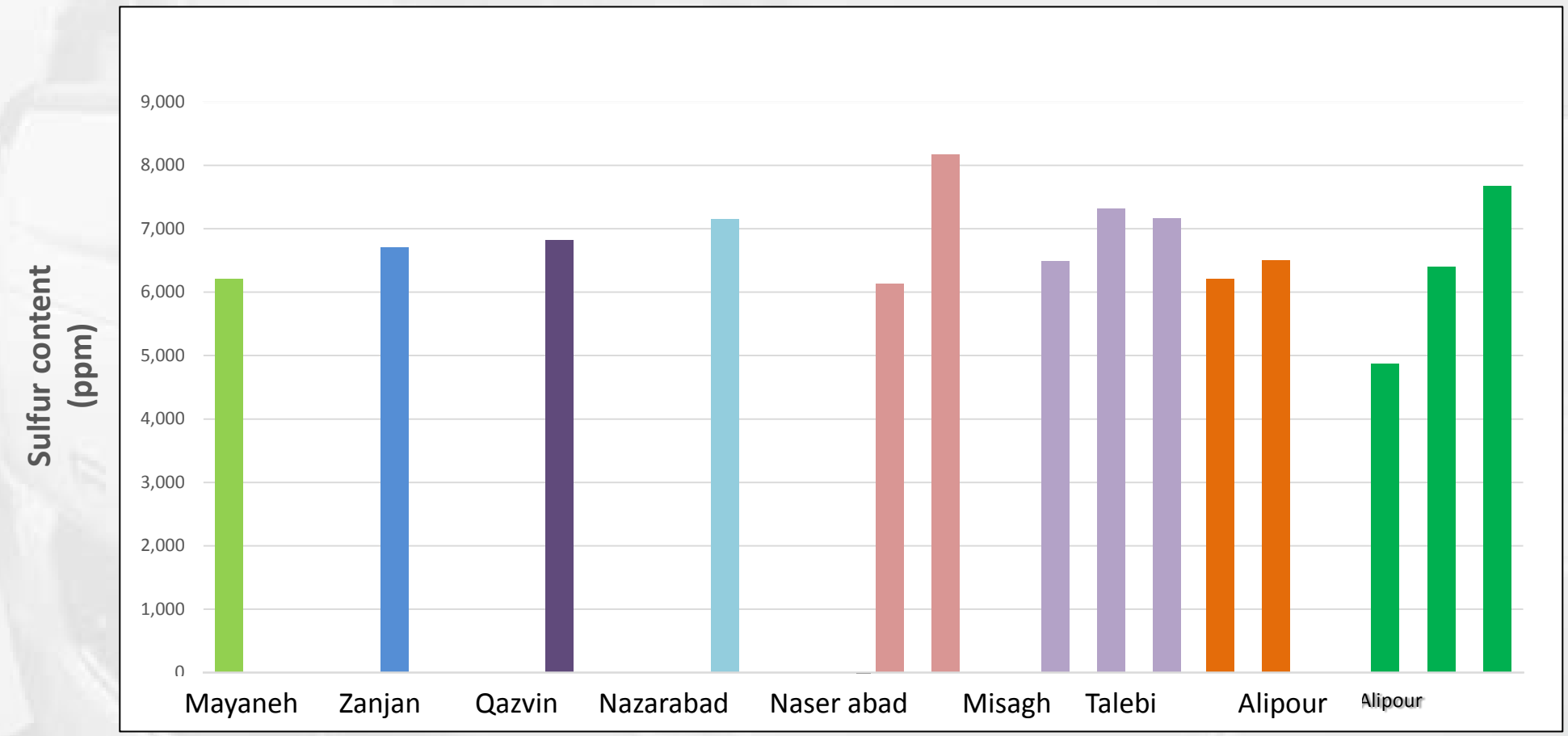
Fuel analysis results within 4 months of testing

- As it is illustrated in below map, sulfur content of diesel in Tehran stations are varying between 40-80 ppm but in stations far from Tehran is drastically high (up to 7,500 ppm).

Diesel sulfur content in different stations nationwide

DPF performance examination

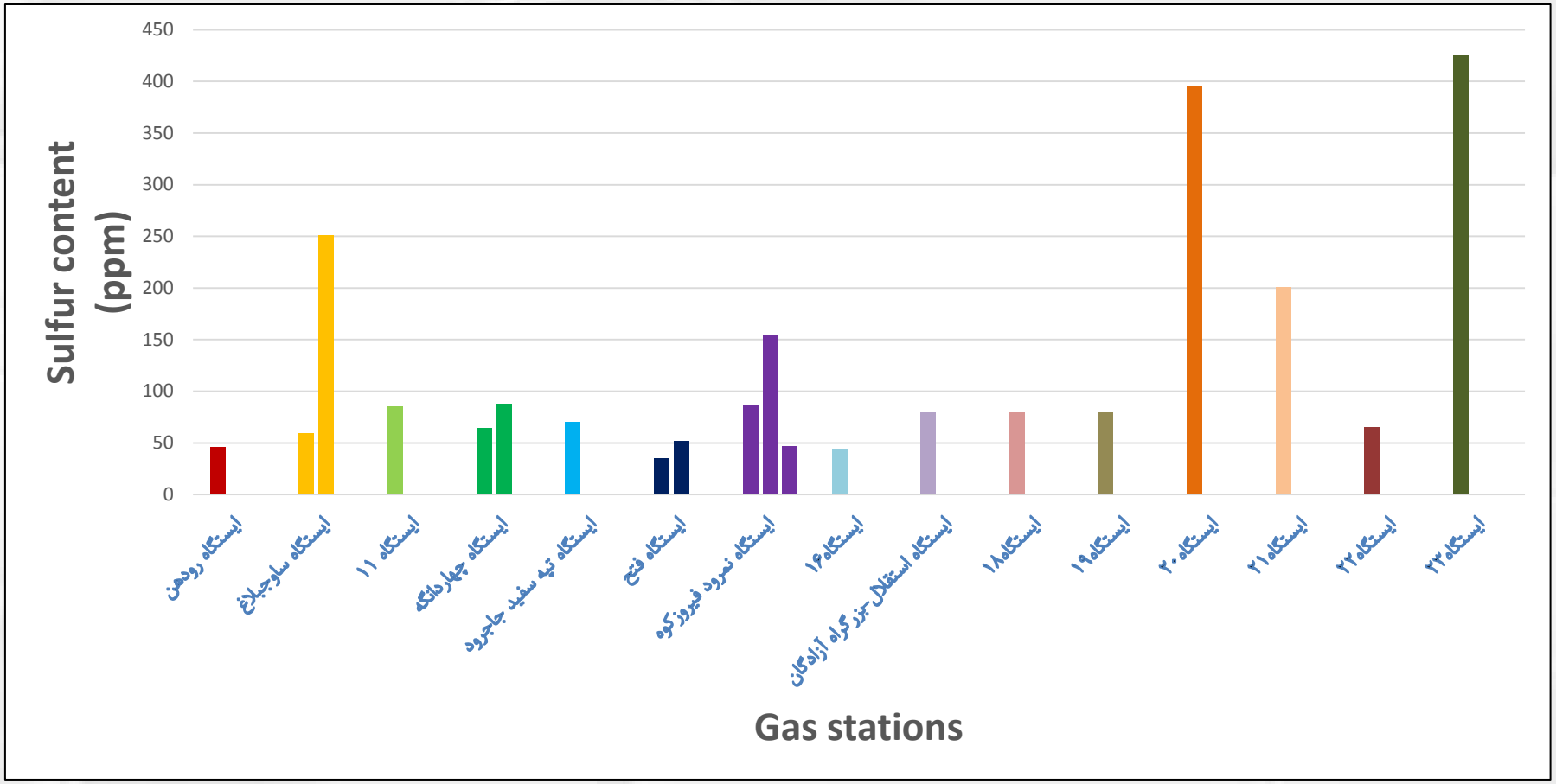
Fuel analysis results within 4 months of testing



Diesel sulfur content in stations far away from Tehran

DPF performance examination

Fuel analysis results within 4 months of testing



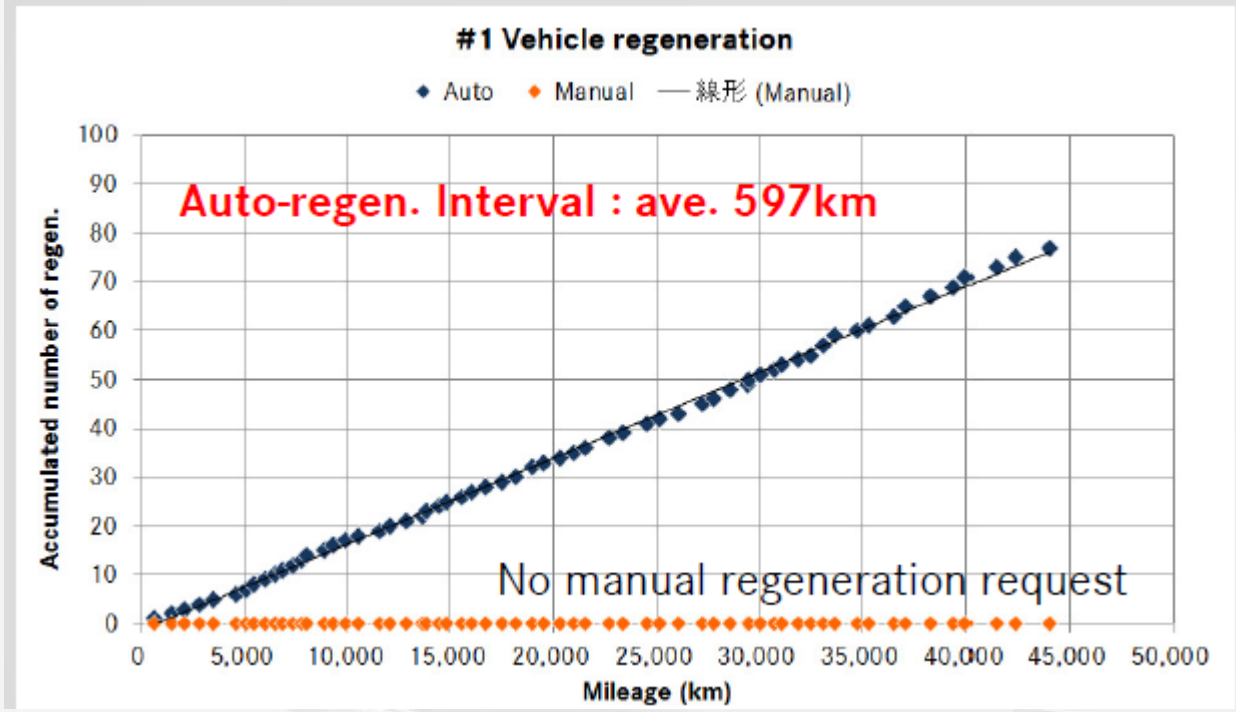
Diesel sulfur content in stations of Tehran and its suburb area

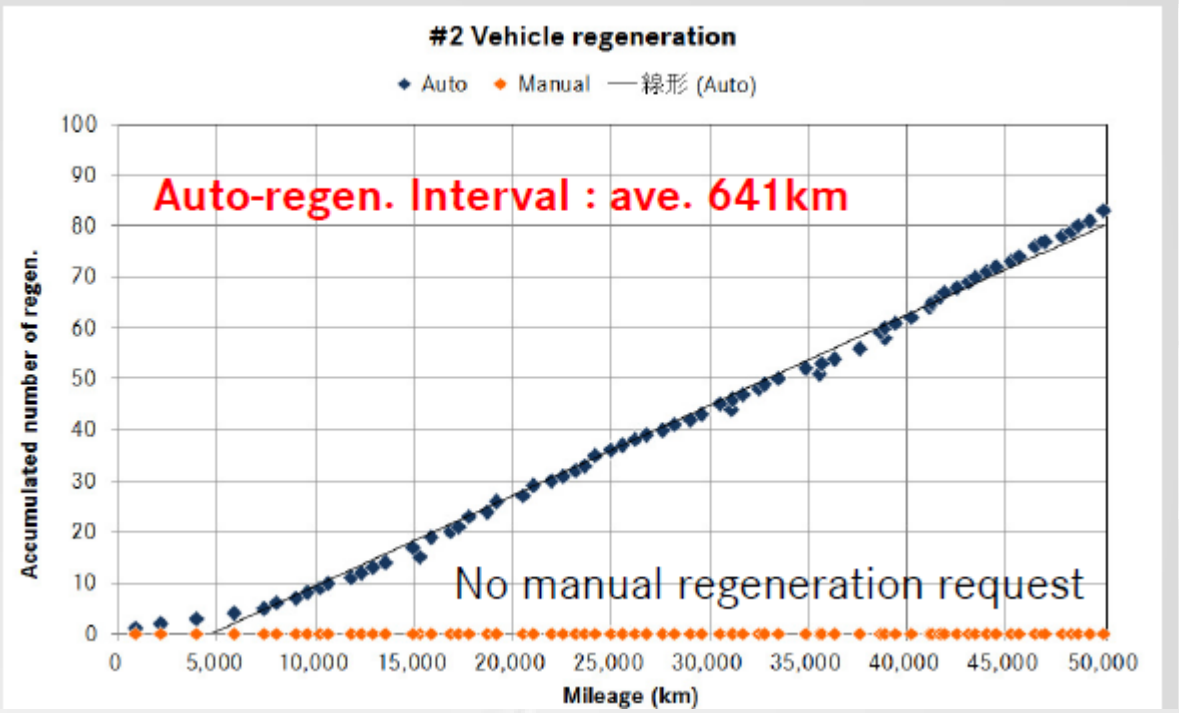
- So it is concluded that diesel quality aspects than sulfur content are almost in Euro IV level in spite of variations but its sulfur content is varying from this level up to hundreds times above.

DPF performance examination

DPF regeneration trend within 50,000 km

- No manual regeneration was required within 50,000 km road test.
- As average, instantaneous automatic regeneration had been deployed every 600 km.



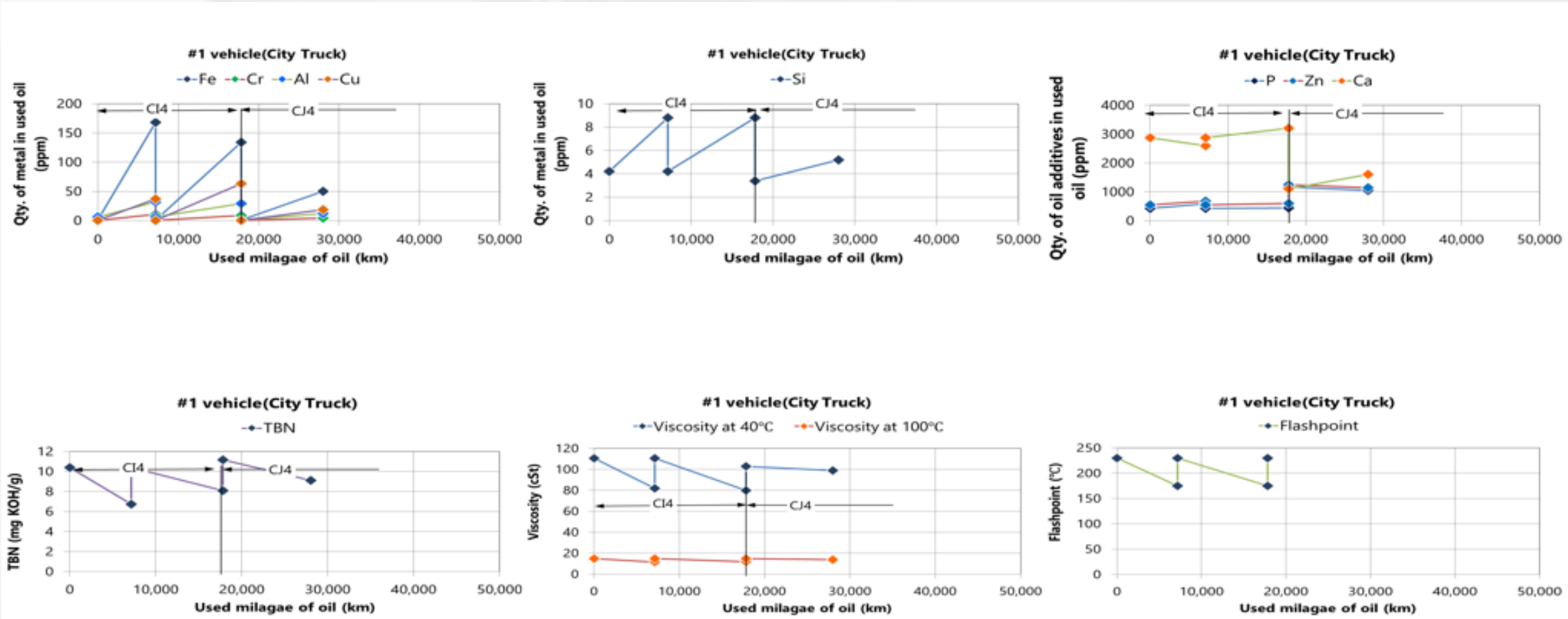


- This interval for instantaneous automatic regeneration is almost every 4,000 km, while operating with Euro IV diesel.

DPF performance examination

Oil Condition Monitoring

- Engine oil of both test units had been sampled and analyzed during 50,000 km road test.



Oil attributes test results

- In brief, in spite of using of highest oil quality level i.e. API CJ4 that is recommended for DPF equipped engines, oil had degraded considerably due to high sulfur content and dusty operational environment.

DPF performance examination

Oil Condition Monitoring

❖ The main reasons that high sulfur content can degrade engine oil can be summarized as below:

✓ Acidizing of combustion chamber by sulfuric acid formation and consequently TBN reduction.

✓ Frequent filter clogging due to lost regeneration efficiency that is caused by high sulfur content by sulfur toxic DOC and chemical deterioration of both DOC/DPF. This leads to higher back pressure exceeding levels and eventually penetration of turbocharger cooling oil into the intake manifold and its burning in chambers. So ash level will be increased by burned oil.

✓ Frequent DPF forced regeneration due to frequent clogging rate. So higher rate of post injection will leads to higher blow by effect in crankcase. This effect eventually leads to oil dilution by diesel that causes lost of flash point and viscosity of the oil.

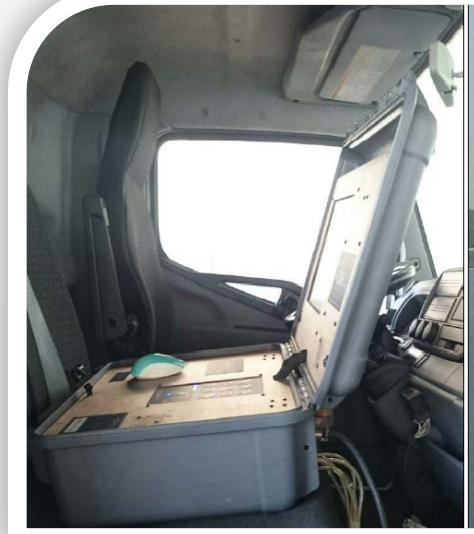
Based on bad effect of high sulfur content at the same time of using DPF on oil quality, level of metal elements increased considerably that is a clear sign of high corrosion and wear of engine components.

So in brief we can say that using DPF not only reflect in higher vehicle price but also in higher R&M costs, but this is something unavoidable that should be paid for improvement of air quality of our mega cities and healthiness of our citizens.

It is crucial to avoid from unbalanced landed cost in market's products by let some manufacturers to disobey from DPF installation

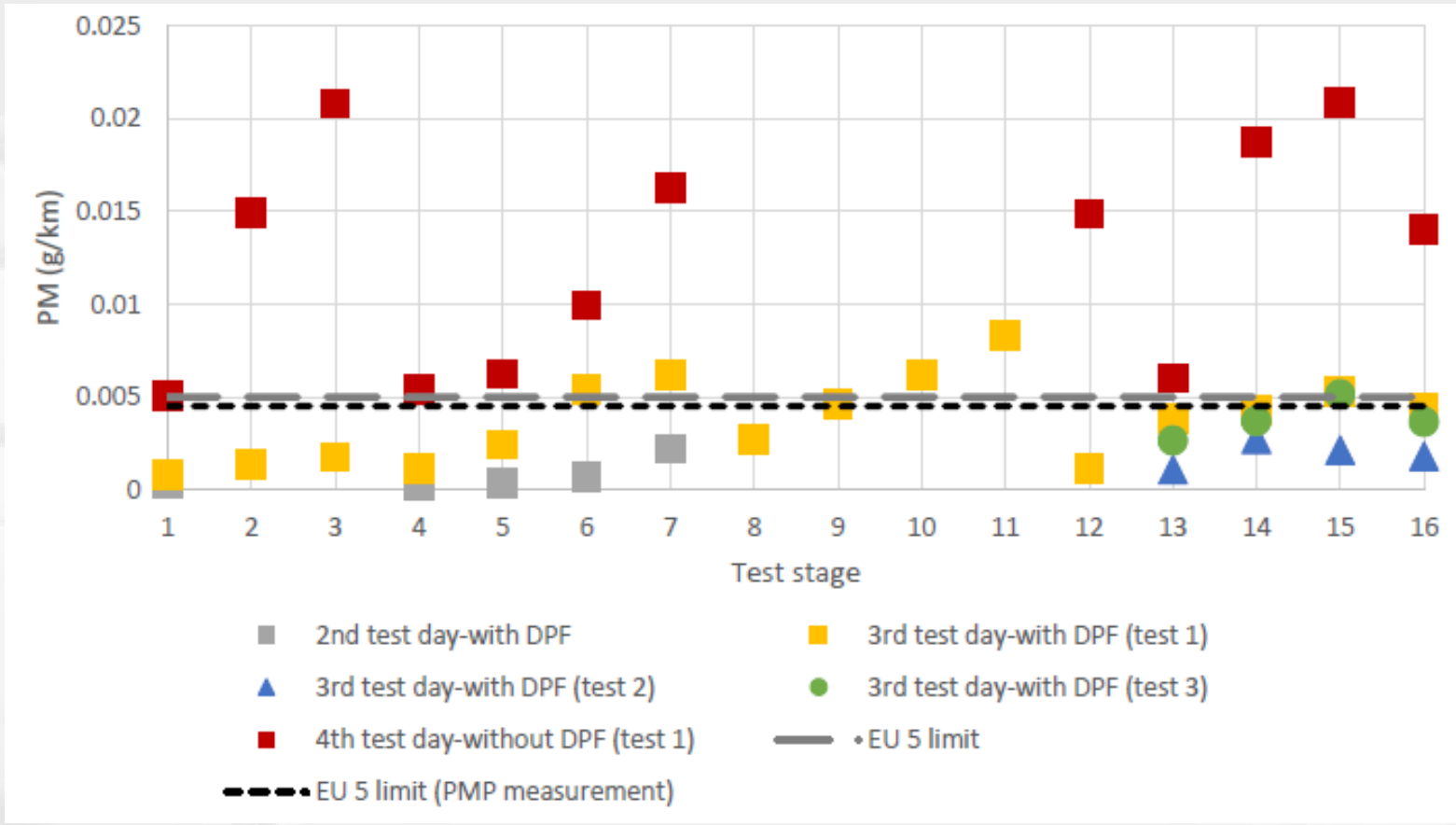
Examination of effectiveness and efficiency of DPF
By testing of 2 test units via PEMS

- At the end of 50,000 km road test, PM and opacity of exhaust gases of test units was measured using PEMS
- The intention was to observe DPF effectiveness on improvement of this element in exhaust gases.
- For this practice, DOC/DPF muffler was replaced with an simple pipe and PM and opacity was measured before and after this change.



Replaced pipe instead of DOC/DPF muffler

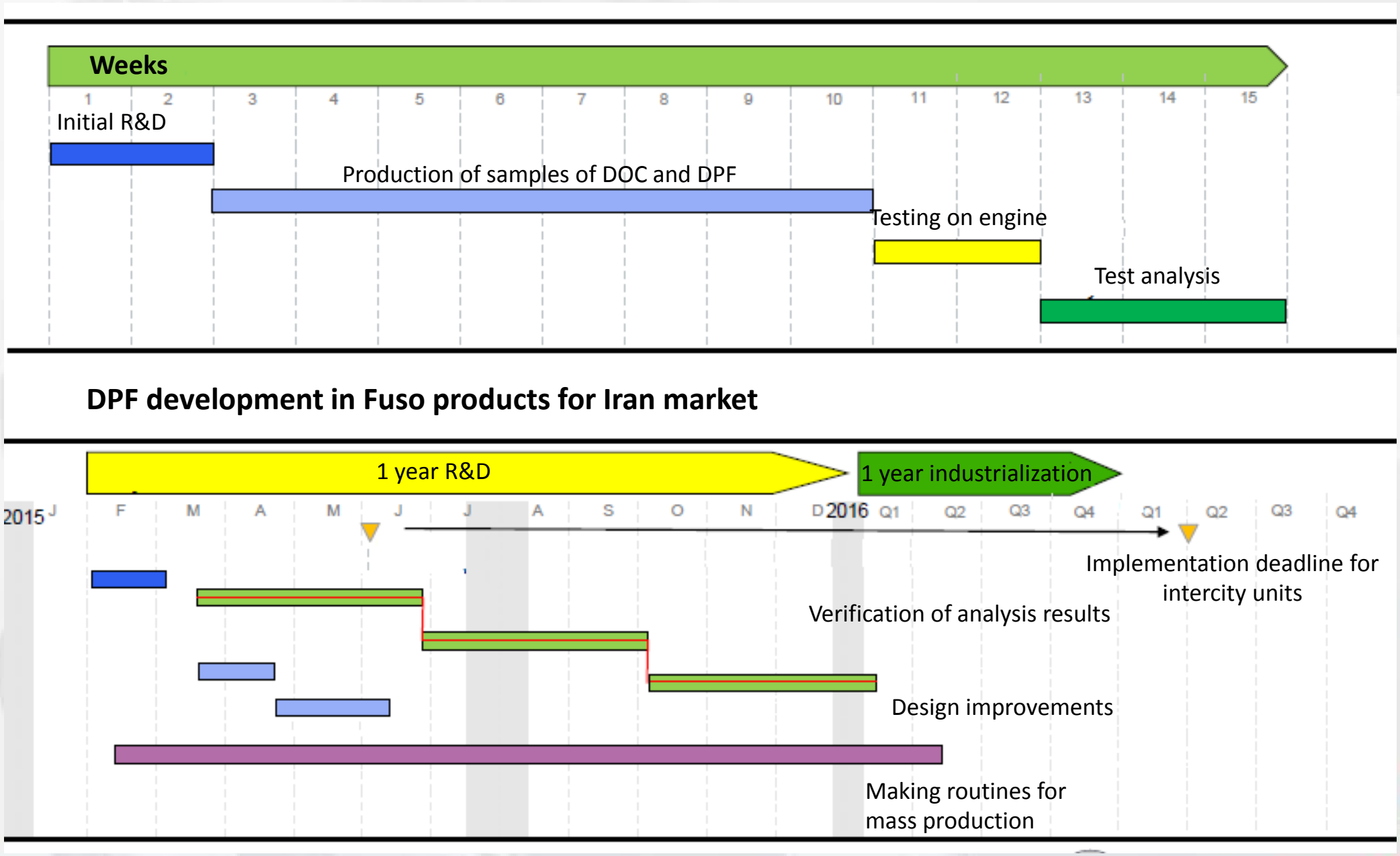
PEMS test results
with and without DPF



Smoke opacity	Average measured PM	
1.49 m^{-1}	0.0128 g/km	**Without DPF**
0.04 m^{-1}	0.0030 g/km	**With DPF**

The trend of DPF development in Mitsubishi Fuso Co.

- ✓ Development of this technology in Mitsubishi Fuso Co. to meet Iran law for DPF installation has been done within around 2 years including R&D, sample production, testing and finally industrialization for its mass production.



Mitsubishi Fuso's investment to implement Iran DPF law

- ✓ As it was implied in previous slide, implementation of OEM DPF on Fuso products in Iran lasted around 2 years.
- ✓ Huge investment was made to create knowhow of this technology in this organization.

«Estimated investment is around 2.5 million €»

This is investment that is made commonly by Mayan and Fuso based on trust on national demands and also respect and adhering on national missions beyond commercial intentions.

A question that needs serious answer here:

What are the consequences of failing to execute DPF law in Iran accurately?

What are the consequences of failing to execute DPF law in Iran accurately?

➢ The major aftermaths in country's future international relationships with others:

- Serious and essential questioning of country's regulations which are adopted by cabinet's of ministries
- Sending of destructive signal to foreign counterparts meaning that it is always possible to lobby to change most definite passed laws of the country which are driven by public concerns of nation
- Encouraging of law violators and discouraging of its followers
- Extending the red carpet for those foreign enterprises who left Iranian people alone during sanctions with lots of problems and are raising so many conditions to return to country's business after nuclear deal.

➢ The nationwide climate aftermaths:

- There is no doubt that country's major problem in megacities pollution field is PM2.5 issue.
- Diesel commercial fleets are major source of PM2.5
- The sole solution for this problem is deployment of DPF technology.
- Definitely no other technologies like SCR, EGR, Partial flow traps,… will not lead to considerable reduction of PM2.5 quantity.
- So bringing up of any alternative in which utilization of DPF is not a part of it means continuation of current situation in megacities that leads to grave environmental consequences and numerous impacts in terms of citizens' healthiness.

➢ The commercial aftermaths:

- Major and drastic hurt on those companies and manufacturers who tried to implement DPF law in their products.

What is achievement of Euro V+EEV in terms of PN reduction (if any)?

- ✓ One of disputing emission levels to be added as one of acceptable emission norms in Iran is Euro V+EEV
- ✓ The main issue that unfortunately is being neglected by Euro V+EEV proponents intentionally is that this norm has nothing to do with PN that has been the core of passing of DPF law by cabinet of ministries. So Euro V+EEV achieves nothing beyond Euro V, IV or even 3 in terms of PN.
- ✓ This norm never came into the force in EU and just was recommended for 2 years after obligation of Euro V in EU. Then in Euro VI norm it was the first time that PN has been added to evaluating items.
- ✓ So EEV is not something restricted to Euro V because this is a norm that has been proposed at the same time of effectiveness of each emission level to encourage manufacturers to achieve lower pollutant levels than obligatory norm at each period.
- ✓ Euro V+EEV has no limit for PN. It has just lower levers for UHC and Nox than Euro IV in ESC and also lower PM level in ETC.
- ✓ So as it is seen Euro V+EEV has even no intention to monitor PN levels as it has no PN limit.
- ✓ As Nox and UHC is not recognized as a major source of pollution disaster that we are facing with in our megacities it can be concluded that Euro V+EEV leads to absolutely no environmental achievement relative to Euro IV or even Euro III.

What is achievement of Euro V+EEV in terms of PN reduction (if any)?

Implementation date	Test cycle	Emission limits						Emission norms
		CO g/kwh	HC g/kwh	NOX g/kwh	NH3 (ppm)	PM g/kwh	PN #/kwh	
Oct. 2000	ESC	2.1	0.66	5.0	-	0.10	-	**Euro III**
Oct. 2005	ESC	1.5	0.46	3.5	25	0.02	-	**Euro IV**
Oct. 2008	ESC	1.5	0.46	2.0	25	0.02	-	**Euro V**
Oct. 2008	ESC	1.5	0.25	2.0	25	0.02	-	**EEV**

Emission limits in different norms in ESC test

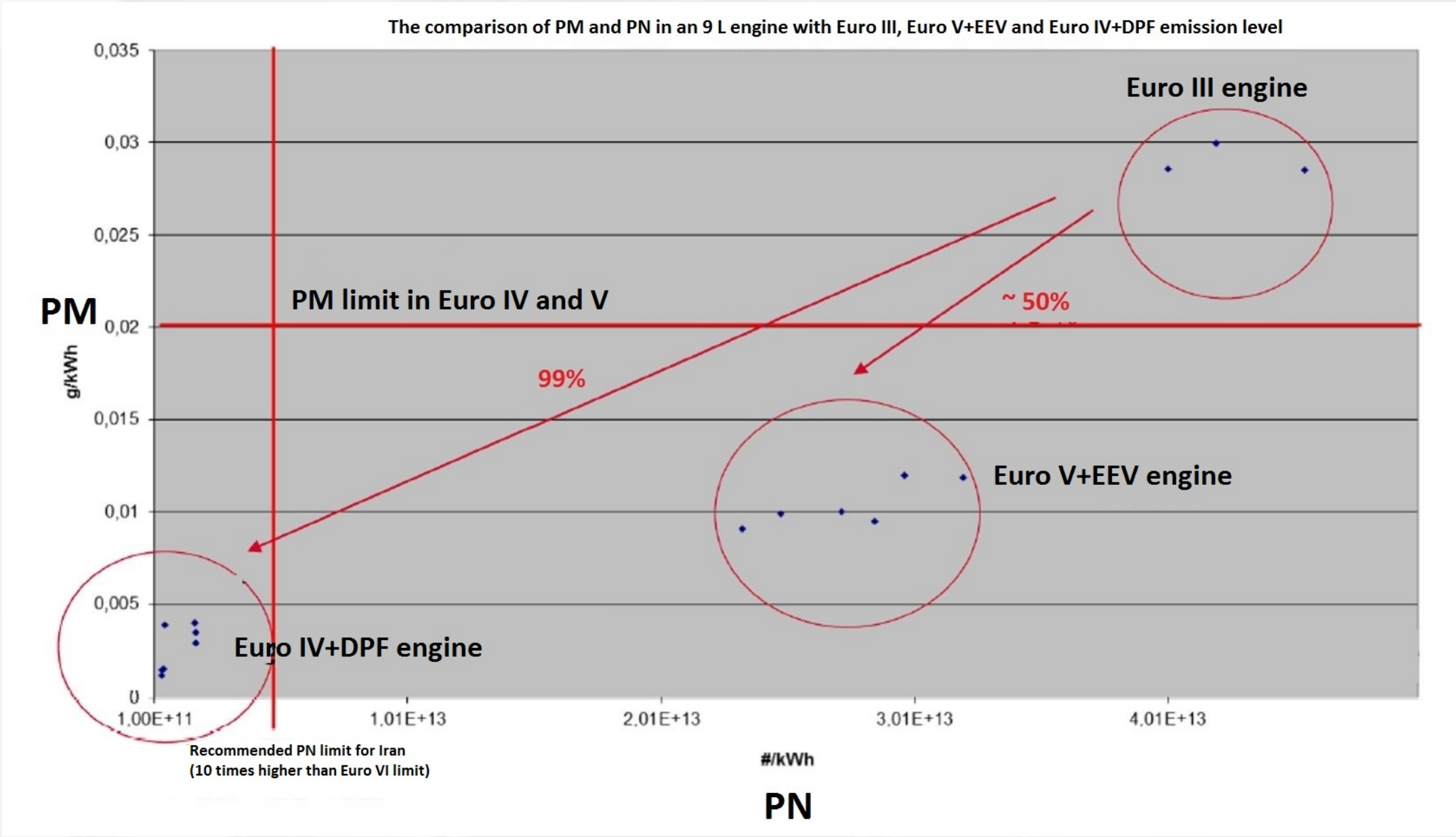
Implementation date	Test cycle	Emission limits						Emission norms
		CO g/kwh	NMHC g/kwh	NOx g/kwh	NH3 (ppm)	PM g/kwh	PN #/kwh	
Oct. 2000	ETC	5.45	0.78	5.0	-	0.16	-	**Euro III**
Oct. 2005	ETC	4.0	0.55	3.5	25	0.03	-	**Euro IV**
Oct. 2008	ETC	4.0	0.55	2.0	25	0.03	-	**Euro V**
Oct. 2008	ETC	3.0	0.40	2.0	25	0.02	-	**EEV**

Emission limits in different norms in ETC test

- As it is seen in above tables, Euro V+EEV has no PN limit, same as its predecessors, so eliminate no concern in current environmental situation in Iran

What is expected normal PN level in an Euro V+EEV engine?

- ✓ Now that it is cleared that Euro V+EEV has no intention to reduce PN level and practically an Euro V+EEV engine can produce same PN level as even Euro III, let's see theoretically how many PN is expected to be produced in an engine which is certified by this norm.



- As is seen, PN level of an typical Euro V+EEV is almost 50 times higher than a typical engine with DPF.

- It is notable here that a similar project for this one that is defined for LDT range of Fuso products has been defined for MDT and HDT series of Fuso for the sake of selection of most proper DPF model that be sulfur tolerant, but this project is suspended now by strengthening of some rumors on acceptance of Euro V+EEV !

Photos of Fuso MDT and HDT series

12T MDT cargo truck

26T HDT tipper truck

Disobey of some European manufacturers from DPF demand
In spite of obeying the same in EU countries !

- ✓ As is seen in the left map, there are more than 70 cities in EU zone that are deploying DPF in commercial vehicles other than Euro VI ones (retrofit) to meet special demands in LEZ areas.
- ✓ There are around 30 cities just in Germany where hundreds of vehicles from those manufacturers are equipped with DPF by retrofit that are opposing the same plan with same goal in Iran !!

The possibility of abuse from lack of executional instruction for implementation of DPF demand

- ✓ The executional instruction for DPF law is not unfortunately passed and officially introduced so far.
- ✓ This means that there is no clear info on some essential issues like PN limit, test method, test cycle, measuring equipment characteristic and the process for homologation of new engine and vehicle.
- ✓ It is not clear that what are accredited bodies for issuance of test report and/or certificates. Whether or not the test report alone is acceptable or certificate is also required? Is EC type approval certificate is required as there is no reliable test bench for emission measurement of HD diesel engines specially for PN measurement in transient cycles in Iran? And some other vague points.

These sorts of un-clarities and lack of essential requirements for implementation of DPF demand makes it possible for some manufacturers to assert that their products are equipped with DPF and to get relevant approvals without following the rule practically.

Moreover, lack of any COP measure to monitor mass produced vehicles and impossibility of identification of presence of DPF inside the muffler by visual inspection makes it quite simple for abusers to act illegally.

So it is crucial to take necessary measures very soon in order to avoid from these illegal acts, otherwise the goal of this law will not come into the reality.

Indirect imposed costs on DPF equipped vehicles due to poor fuel quality

As it was implied in previous slides, using of DPF not only leads to higher initial cost of product due to high price of this equipment, but also imposes some indirect costs that increases R&M costs considerably that is mainly caused by poor fuel quality in Iran. Some of these costs are listed below:

Cos			
€x41			s
30X5			R) ear rage
			g oil

It is necessary to invest on improvement of fuel quality with top priority either by improvement of local production or importation of high quality fuels by ministry of oil and other organizations in order to avoid from wasting of such a huge cost in the country.

In add uch as
EGR v s cost
estima

So indirect cost that will be imposed on an DPF equipped vehicle due to poor fuel quality is around 220 million IRR per vehicle per year

So assuming 50,000 units (LDT up to HDT) that is being supposed to be equipped with DPF next year, can estimate that more than around **10,000 billion IRR** cost just due to poor fuel quality will be imposed on country.

1. Based on road test results of Fuso products.
2. Assuming average hauling of each truck as 100,000 km per year and DPF price as of 2,500 € as average.

Thanks for your time and attention!