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5 & 6 April 2006
The Hague, Netherlands

Joint Research Centre

Evaluation of WNTE and Alternative Options

Plenary Meeting of the Off-Cycle Informal Working Group

Zoetermeer, the Netherlands
5-7 April 2006

On-going European regulatory developments

- Heavy-duty EURO V stage
- In-use conformity checking introduced
- Elements in 2005/55/EC
- On-board measurement with PEMS is seen as the main 'route'
- IUC 'Pass/Fail' options: Oriented towards 'WNTE type' methods (i.e a pass-fail method based on a control area), but other methods are being evaluated.
- *Definition of the test protocol and evaluation work conducted by the EU-PEMS group.*

Future European regulatory developments

- Heavy-duty EURO VI stage
- Off-cycle provisions introduced
- In-use conformity checking kept
- An issue is to keep a consistency and to prepare a transition between EURO V/IUC and EURO VI/OCE/IUC

Existing approaches…

To evaluate the in-use data, a link to the homologation data must be established.

Approaches are sorted in 3 categories:

1. "Control area" (WNTE, US-NTE)

2. Work-based (could also be Fuel-based)

3. Compliance Factor (or BSFC based)

1. Control Area Approaches

Principle of the Control Area Approaches

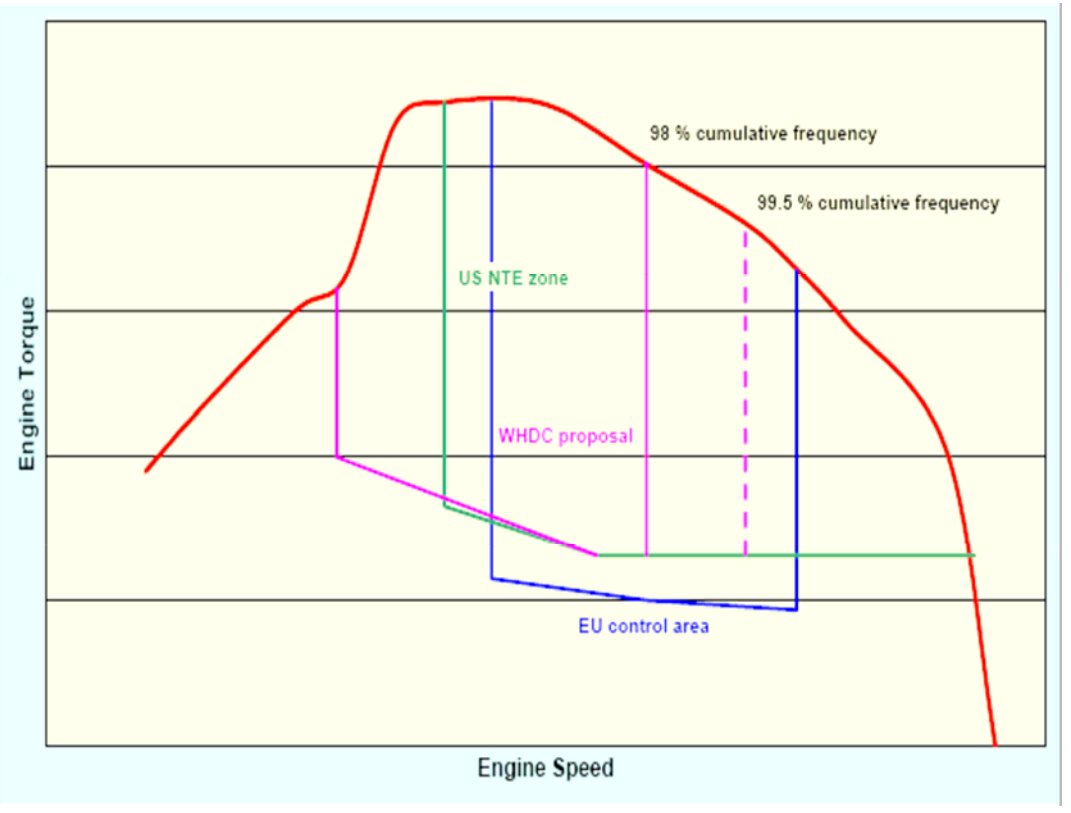
Not based on entire engine operation but rather on a "control area" that can match – to a certain extent – the control area from homologation cycles.

1. US-NTE

2. WNTE

3. "Simplified" to eliminate the operating points that should not be considered (cold start, idling)

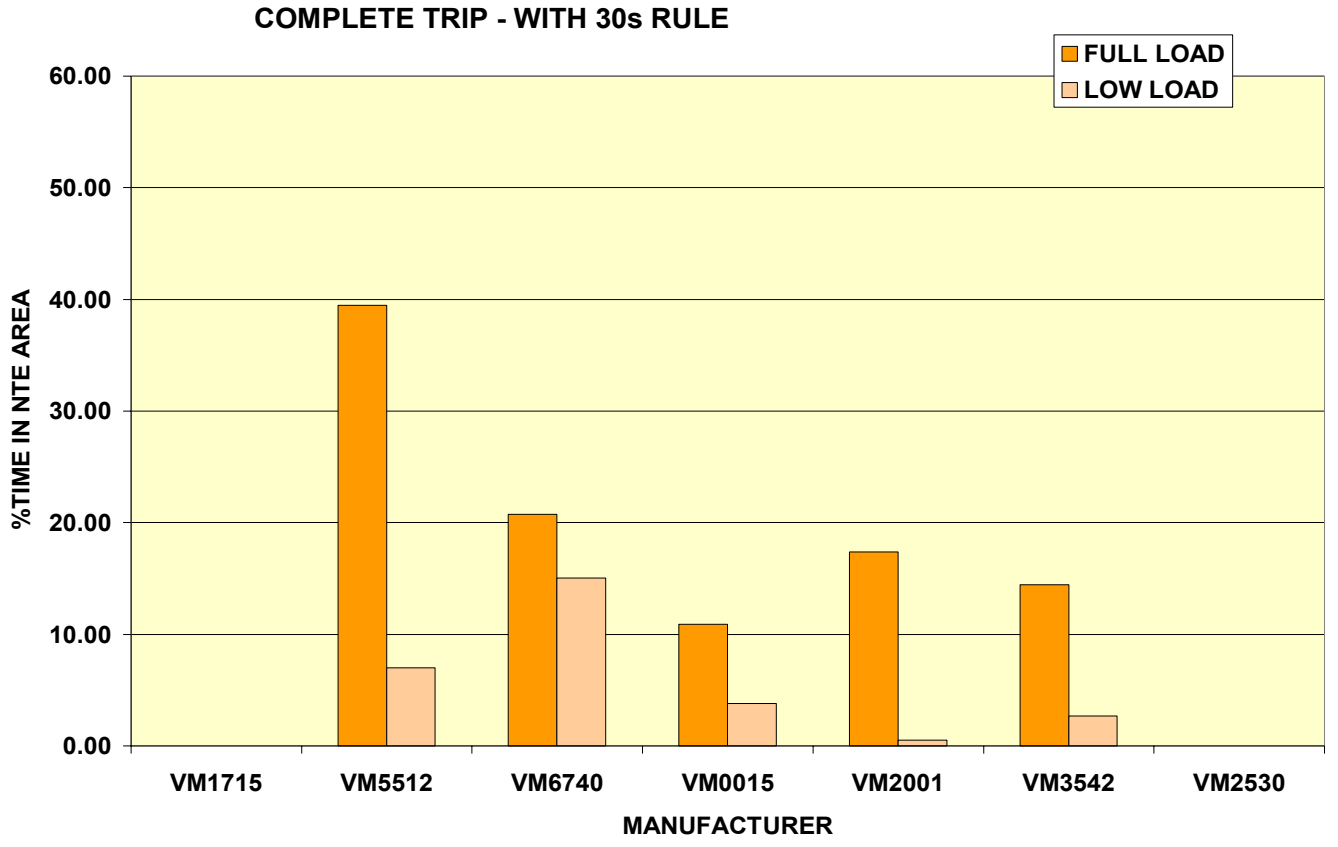
Existing control areas (OICA May 2005)



Does it fulfill the needs?

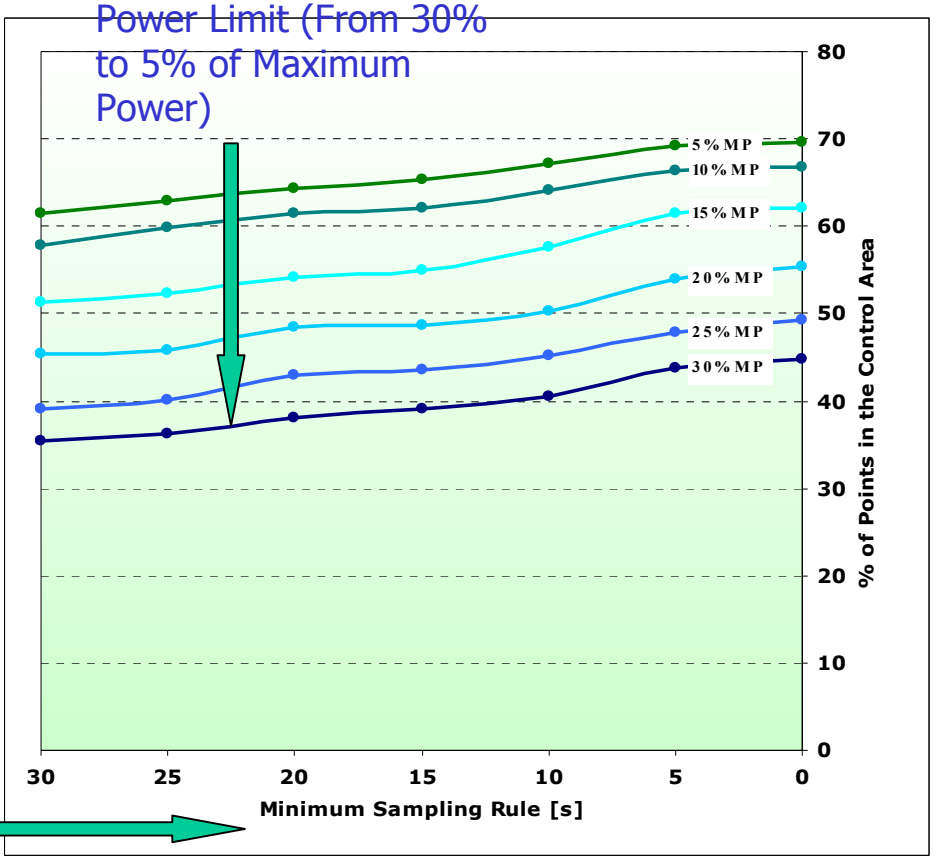
- Questions raised:
  - Are the 'control area approaches' (in particular the WNTE) suitable for any kind of engine/vehicle operation?
  - If not, how far can it be improved? Shall we modify the control area? The minimum sampling rule?
  - What are the rationale behind the definition of the US-NTE and WNTE (Size of the control area and minimum sampling rule in particular)?

- Amount of 'NTE data' collected for 5 Trucks - Highway and extra-urban operation: 38% maximum, for a fully loaded vehicle, operated with a cruise-control at maximum speed on the motorway….otherwise below 20%



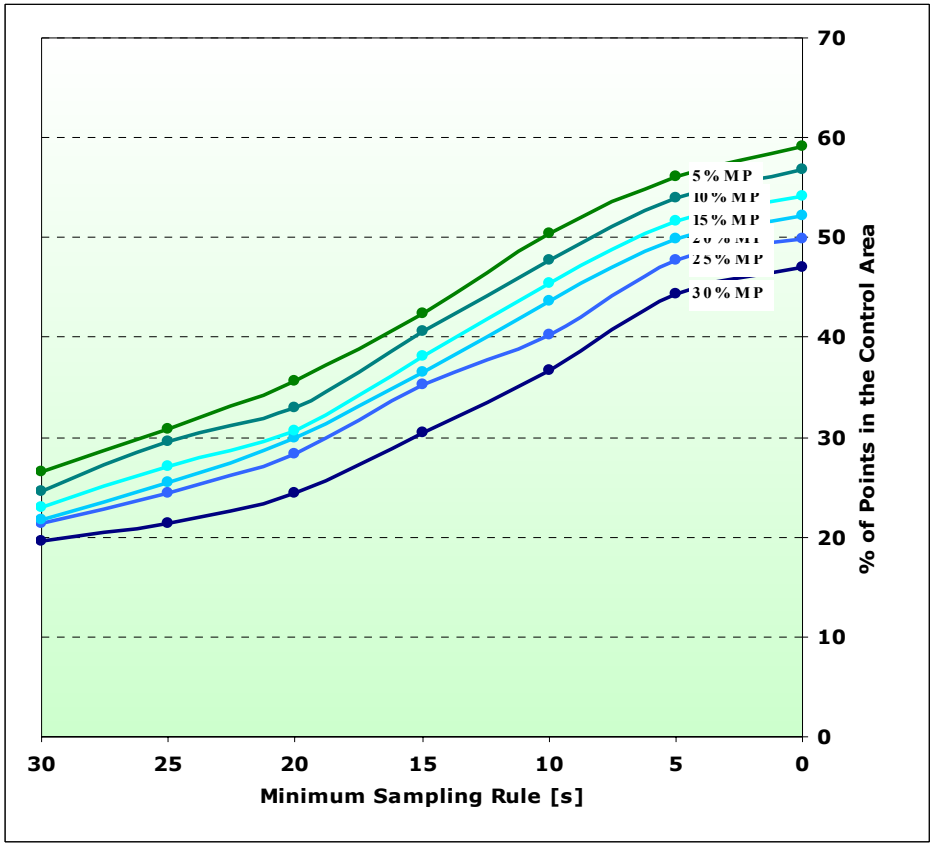
- Is it possible to capture more data?
- **Vehicle 1**

Modifying the Low Power Limit (From 30% to 5% of Maximum Power)

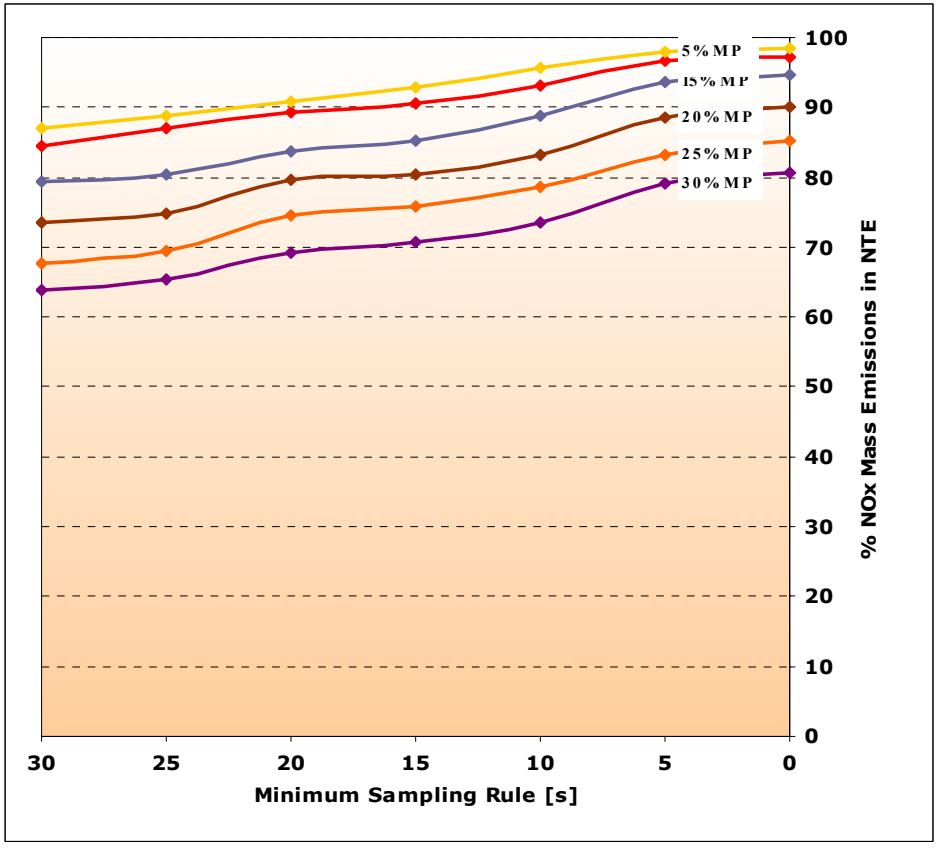


Modifying the Minimum Sampling Rule (From 30s down to 0s)

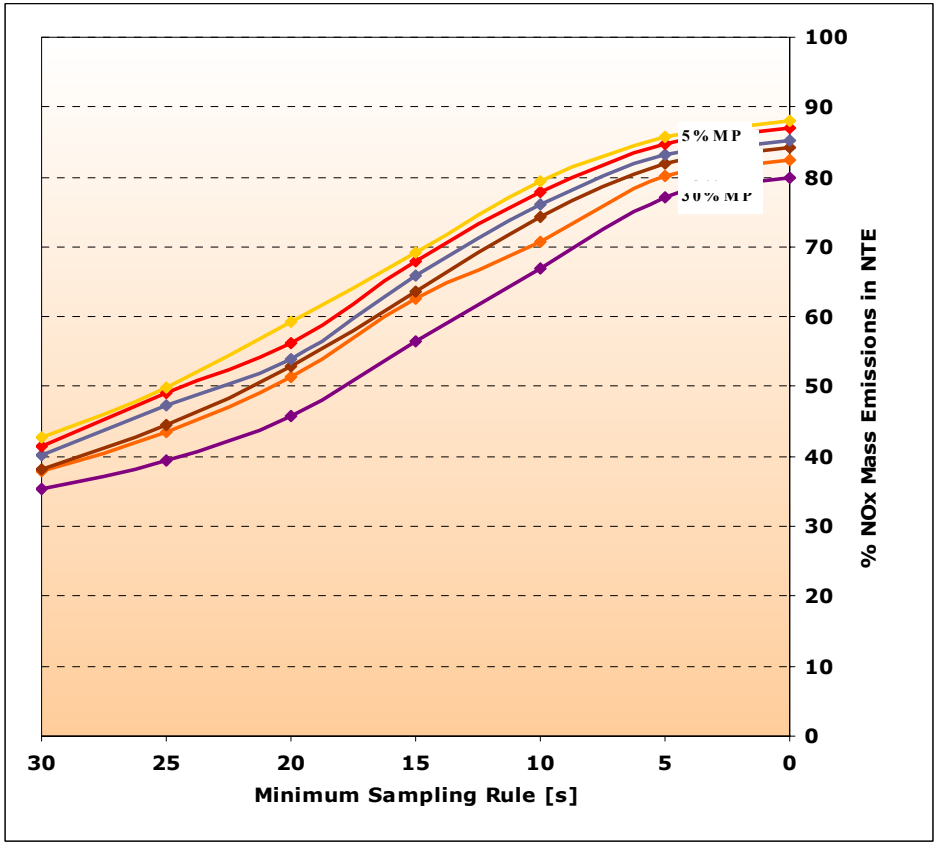
- Is it possible to capture more data?
- **Vehicle 2**



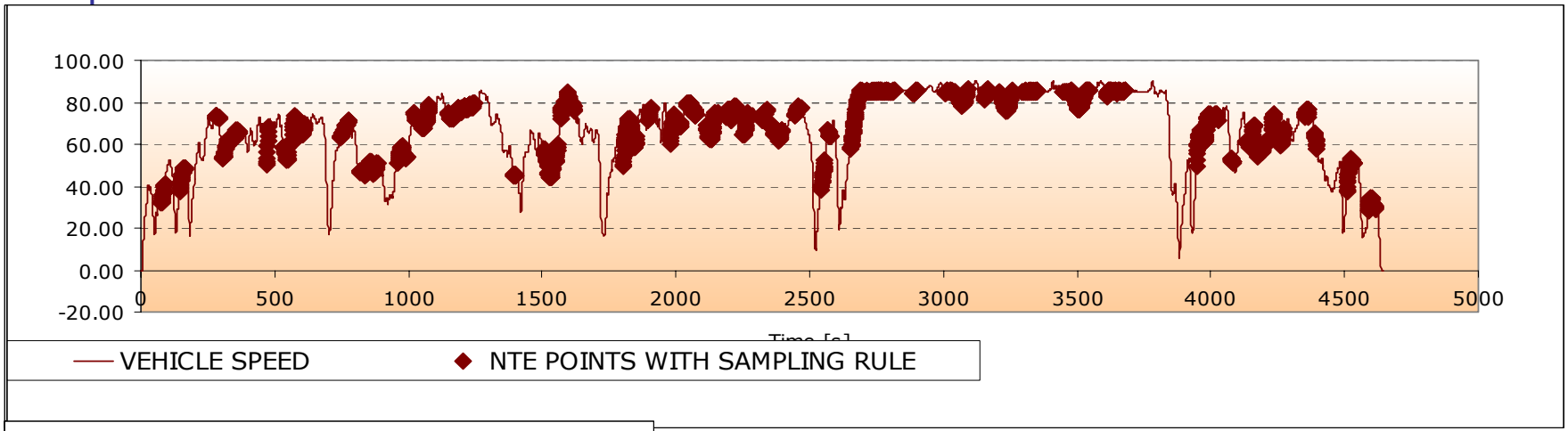
- Are most of the mass emissions captured?
- **Vehicle 1**, Highway operation with cruise control (40% of operation in NTE with full load)

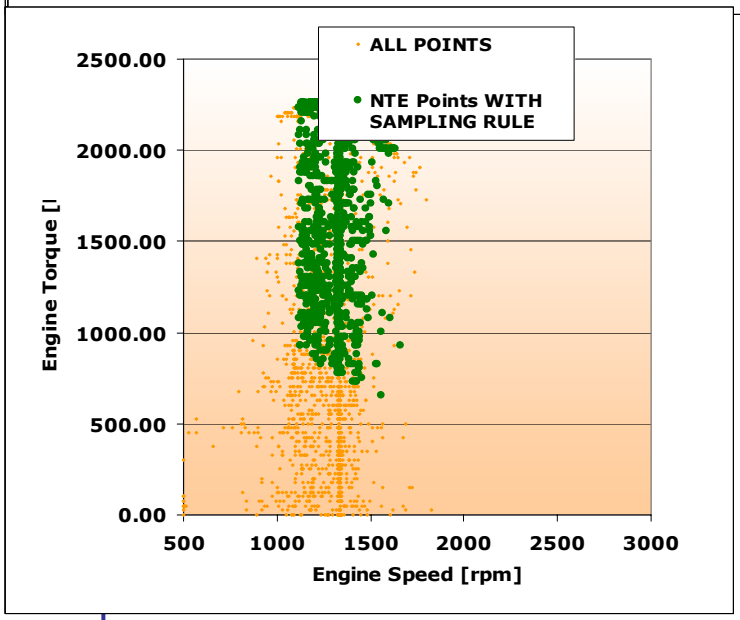


- Are most of the mass emissions captured?
- **Vehicle 2**, Less highway operation with cruise control (20% of operation in NTE with full load)



Effect of the Minimum Sampling Rule (Example)





10s

- The sampling rule removes a lot of the transient operation...

Control Area Approaches: Preliminary conclusions

- The "Control Area" approaches are a very efficient tool to capture random operation of the engines in a definite control area
- With the current definitions (US-NTE or WNTE) and a 30s minimum sampling rule, it provides a very good tool to capture the operation of "long-haul" HD vehicles, (in particular if operated with a cruise control), which is typical of the US heavy-duty long haul operation
- What about the other types of operation?
- European long-haul operation has a different character from the US and Japanese operations
- Delivery trucks? City buses?
- **The size of the "Control Area" and the associated rule could be adjusted to reflect wider regulatory needs**

2. Work-based Approach

Work (or fuel based) Approach

- Brake Specific Emissions are calculated for a defined work value.
- The "work window" is moved throughout the data set
- The size of the window depends on the time needed to reach the defined work value.

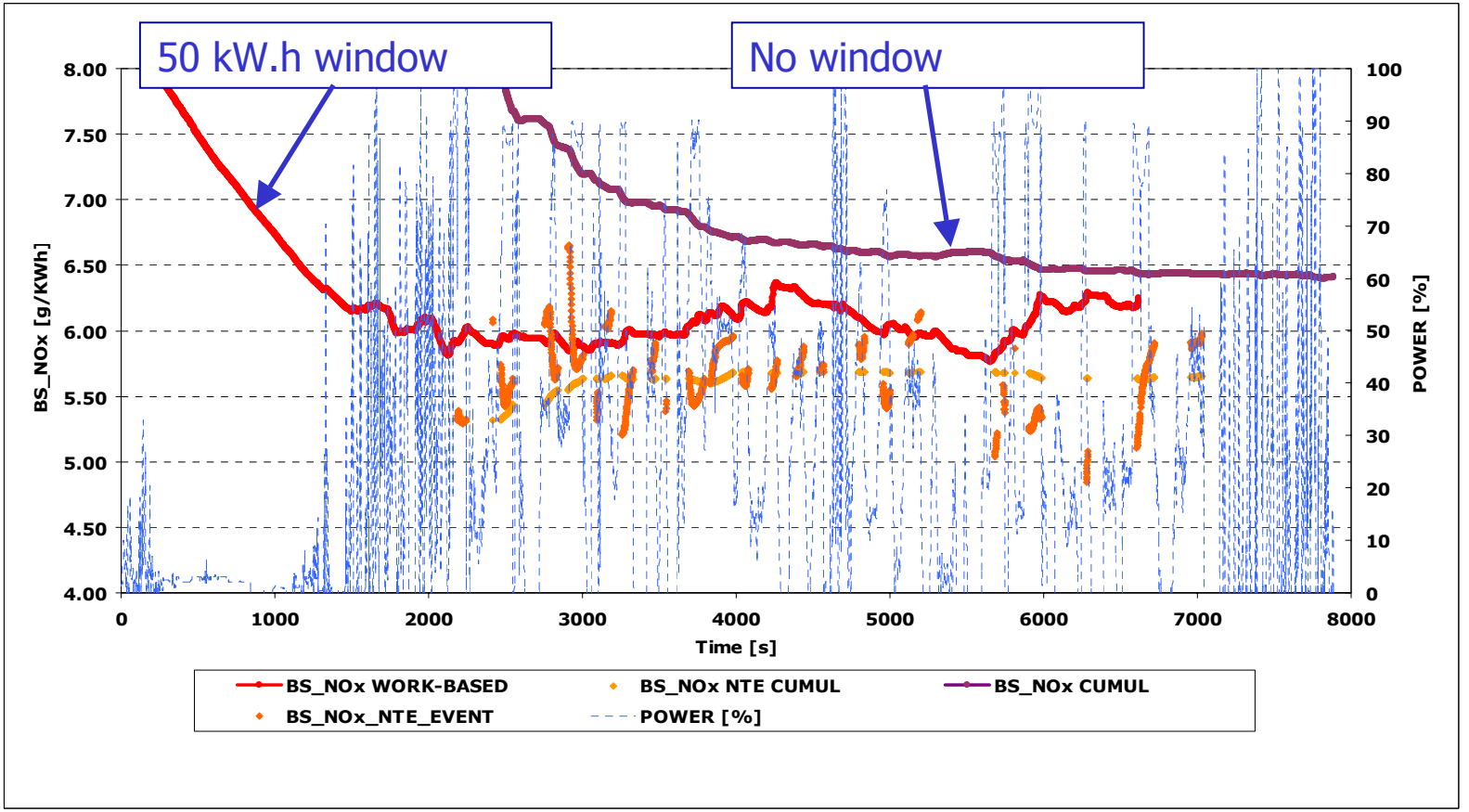
Work (or fuel based) Approach

Starting from the work W_{lab} [fuel consumption FC_{lab}] expressed in kW.h [liters] during a laboratory (homologation) test, one calculates for the road PEMS data the brake specific emissions at every data point for the corresponding amount of work W_{road} or fuel FC_{road}

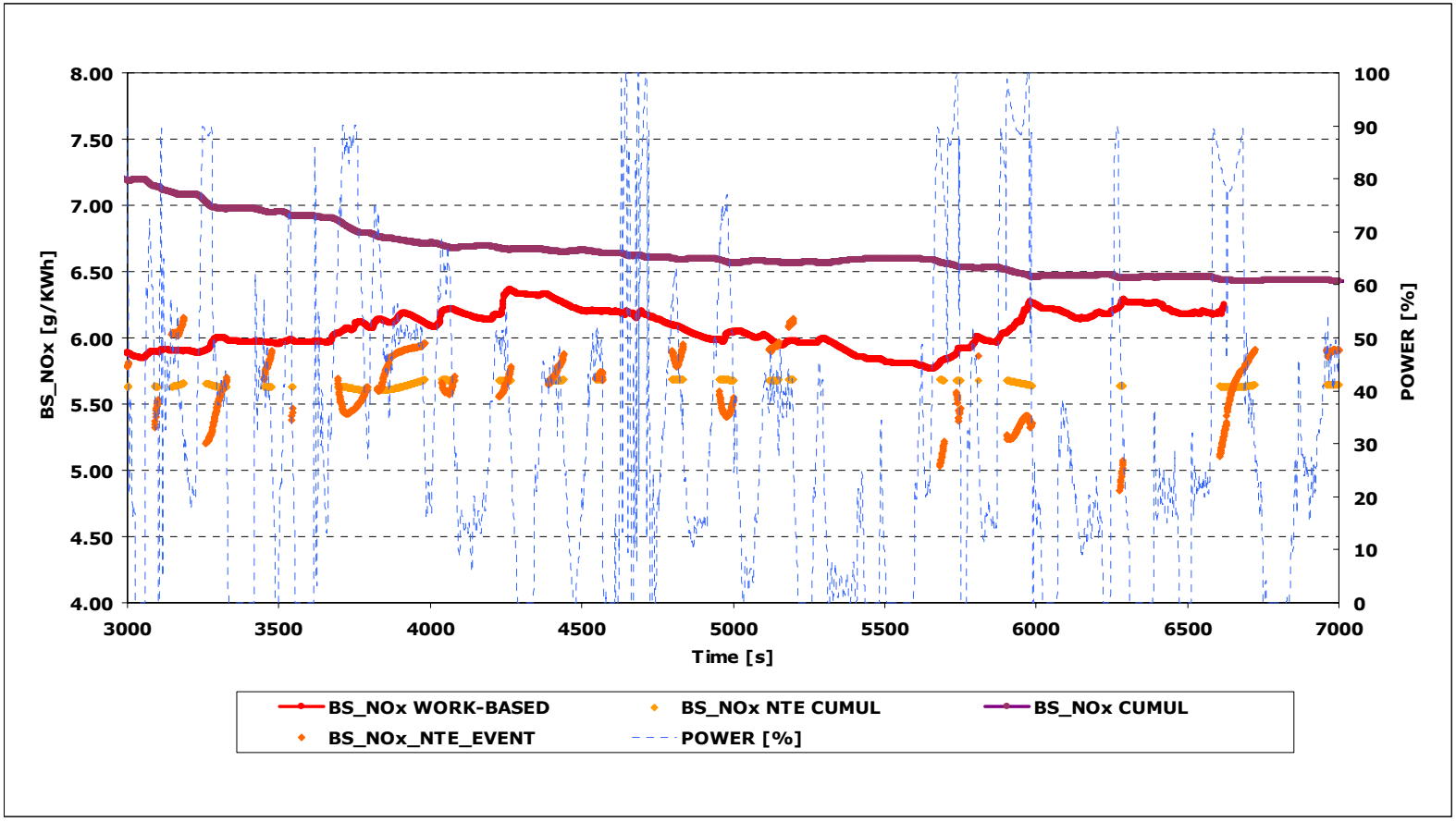
Algorithm:

At each time t1 of the road PEMS data, one looks for t2 such as $W_{road}=W_{lab}$ (or fuel $FC_{road}=FC_{lab}$)

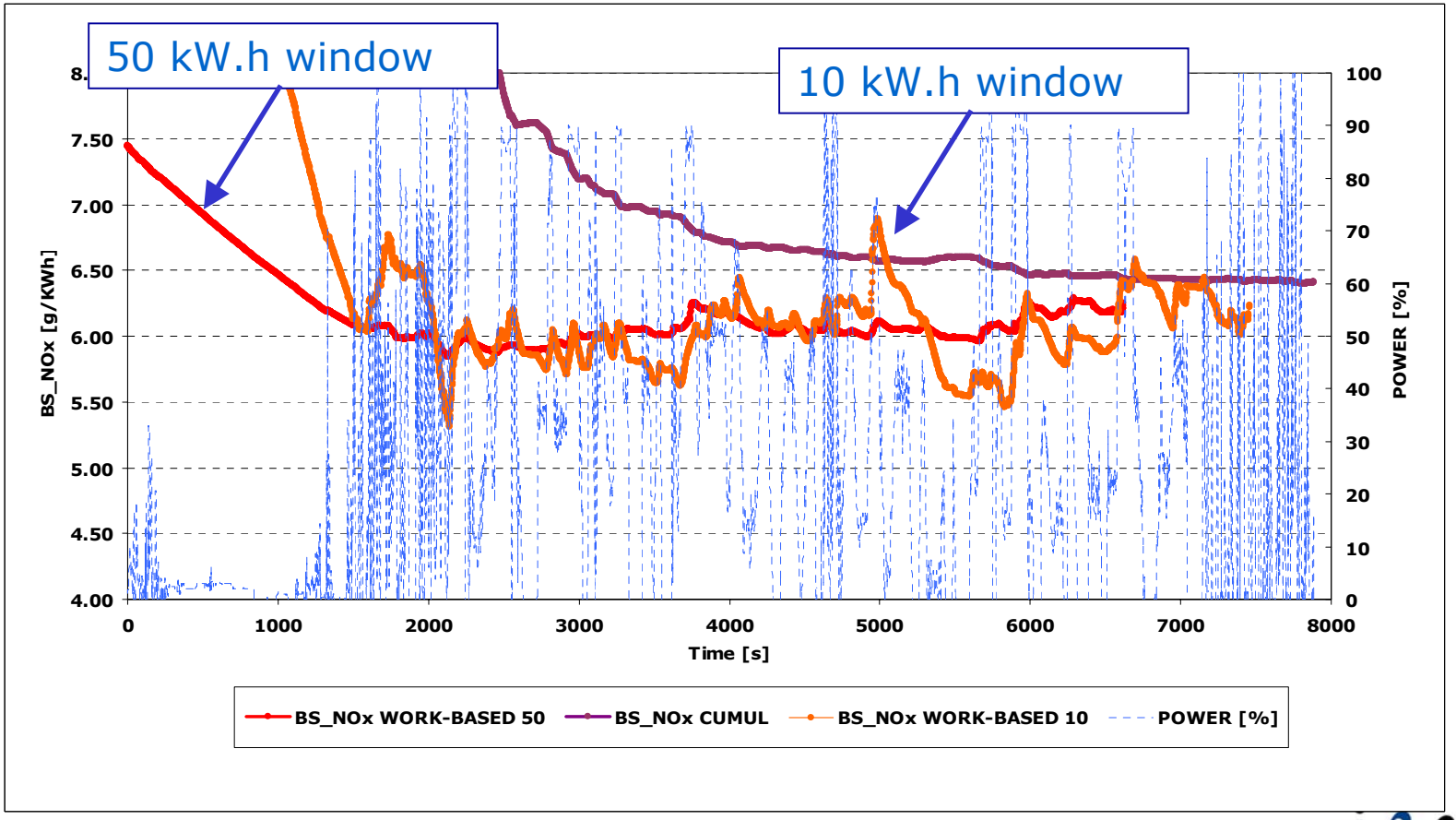
Work-based window (NOx)



Work-based window (NOx)



Work-based window (NOx) – Effect of window size



3. Compliance Factor Approach

Approach Type 3: Compliance factor (1)

In the test-cell, from the certification data, one calculates the "Certification" ratio C1:

$$C_1 = \frac{BS_{NO_x,lab}}{BS_{CO_2,lab}} = \frac{M_{NO_x,lab}/W_{lab}}{M_{CO_2,lab}/W_{lab}} = \frac{M_{NO_x,lab}}{M_{CO_2,lab}}$$

As the work is identical for both species, it can be eliminated from the above ratio and therefore:

$$C_1 = \frac{M_{NO_x,lab}}{M_{CO_2,lab}}$$

BS: Mass emissions

M: Mass

Approach Type 3: Compliance factor (2)

A similar ratio I1 can be calculated for in-use data:

$$I_1 = \frac{BS_{NO_x,road}}{BS_{CO_2,road}} = \frac{M_{NO_x,road}}{M_{CO_2,road}}$$

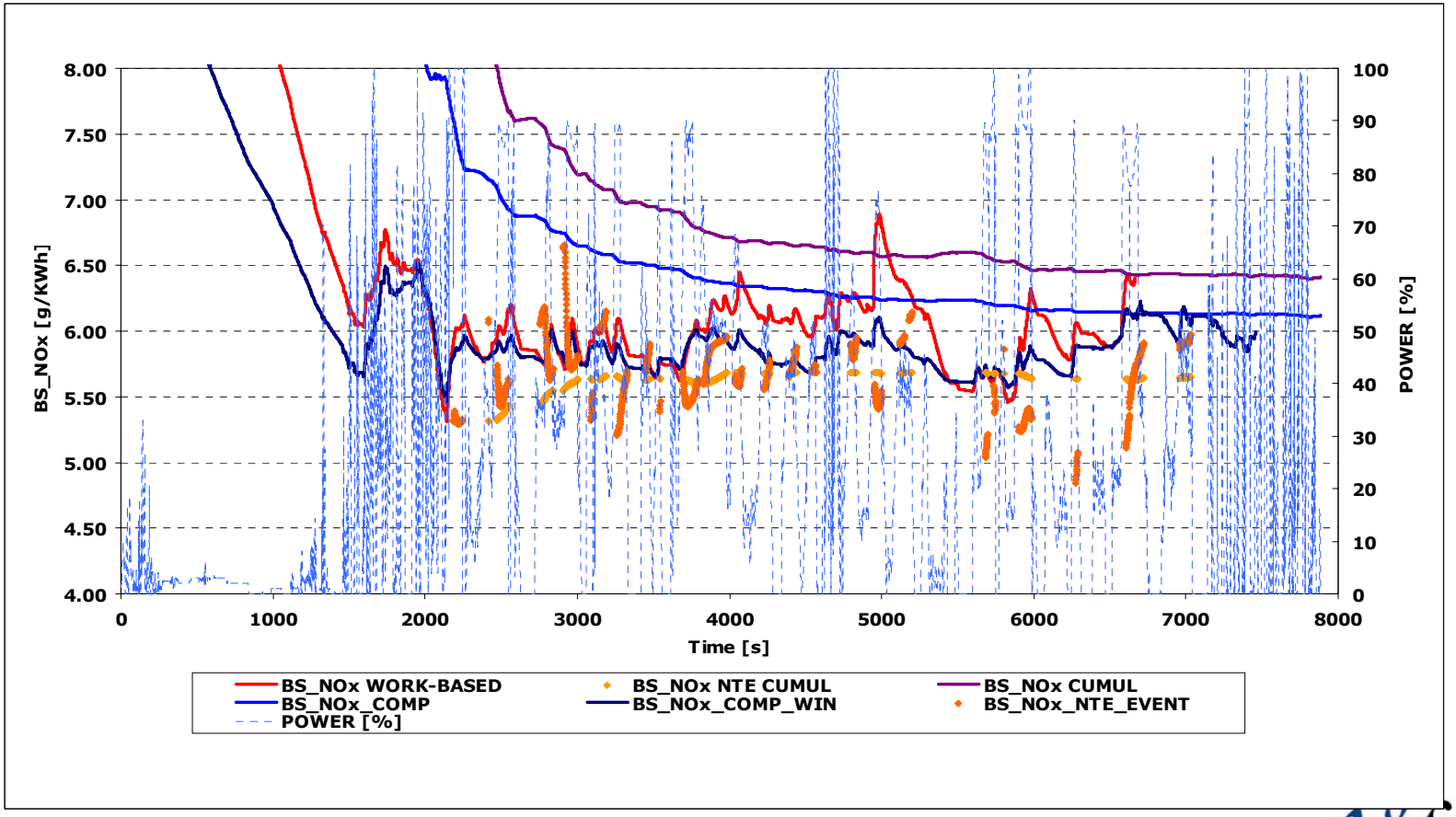
And the "compliance factor" can then be defined as:

$$F = \frac{I_1}{C_1}$$

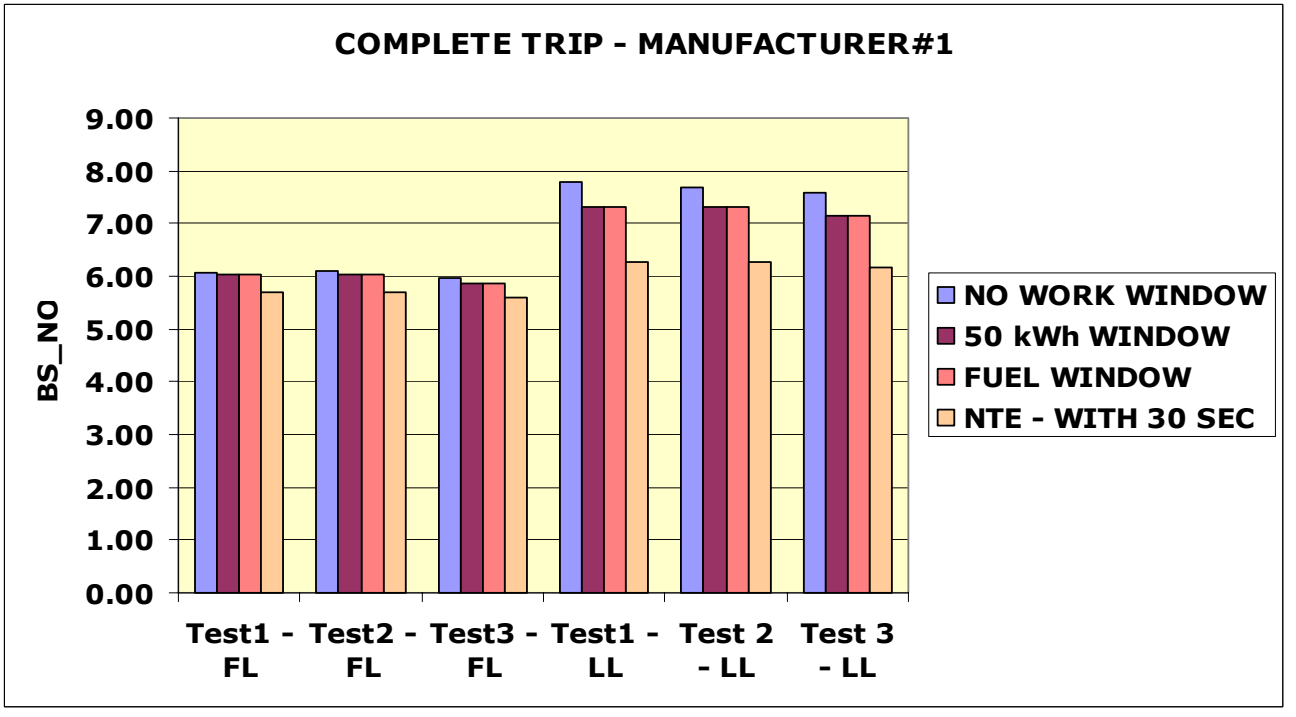
- Amount of road data to be considered?
- Homologation data needed (masses)

Comparison Of Approaches

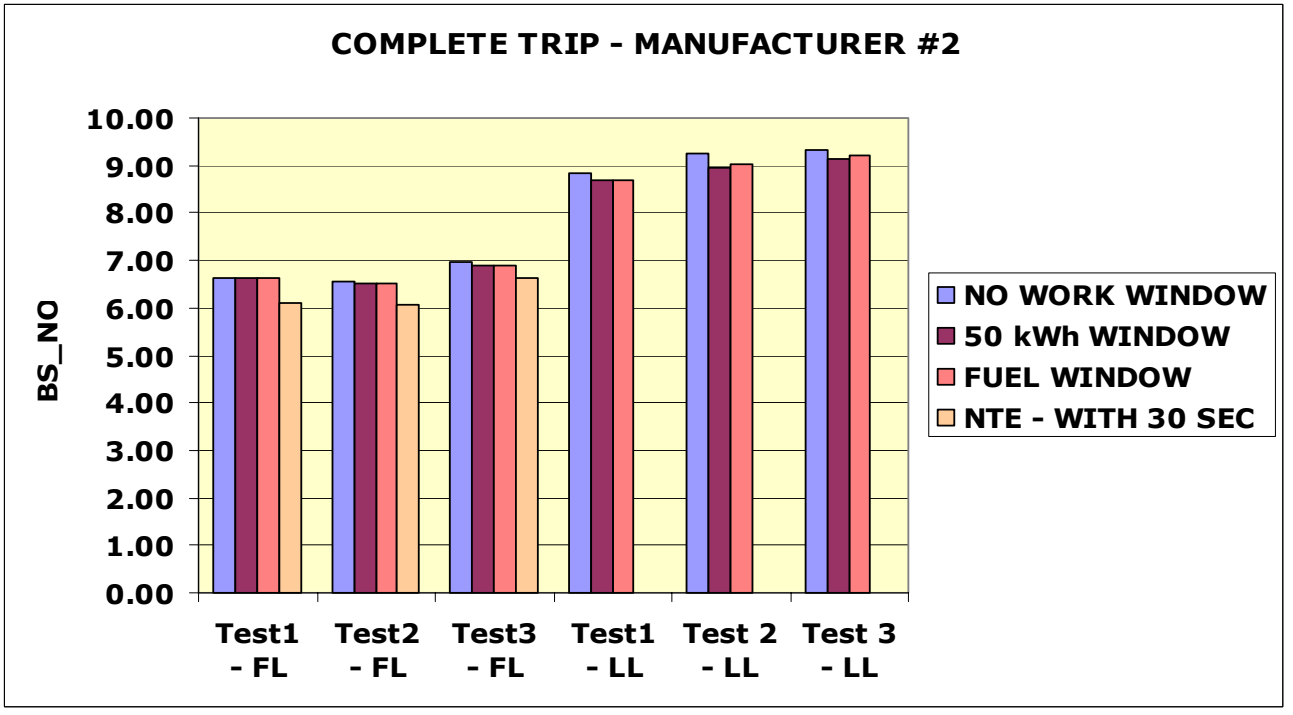
Instantaneous data



Comparison of approaches – Vehicle 1



Comparison of approaches – Vehicle 2



Comparison of approaches (In-use testing)

Data needed for the different approaches

Approach	Engine data	Certification data	On-board Data
1. Control Area	- Maximum power curve	- None	- All (1)
2. Work (Fuel) Based	- None	- Work (Fuel) on homologation cycle	- All (1)
3. Compliance Factor / BSFC	- None	- All (2)	- All but Engine torque and speed

(1) CO, CO2, THC, NOx concentrations, Exhaust Mass Flow, Engine Speed and Torque
(2) Homologation CO, CO2 (BSFC), THC, NOx masses

Advantages and drawbacks

Approach	Advantages	Drawbacks
1. Control Area	- Recognised approach, already established as regulatory tool - Clear link with existing control areas from the STATIONARY test cycles	- Minimum Sampling rule and other selection rules - Does not account for transient operation - Not Applicable to some operating conditions (City Buses) - No clear link with TRANSIENT test cycles.
2. Work (Fuel) Window	- Accounts for all road operation data (TRANSIENT), with the probable exceptions of idling and cold start (to be further investigated) - Provides excellent estimation of scatter of on-road emissions / certification emissions	- Cannot easily be linked to a "Control Area"
3. Compliance Factor / BSFC	- No Engine Torque needed on board	- Based on BSFC… which BSFC?