Powertrain Calibration Optimisation

Optimisation

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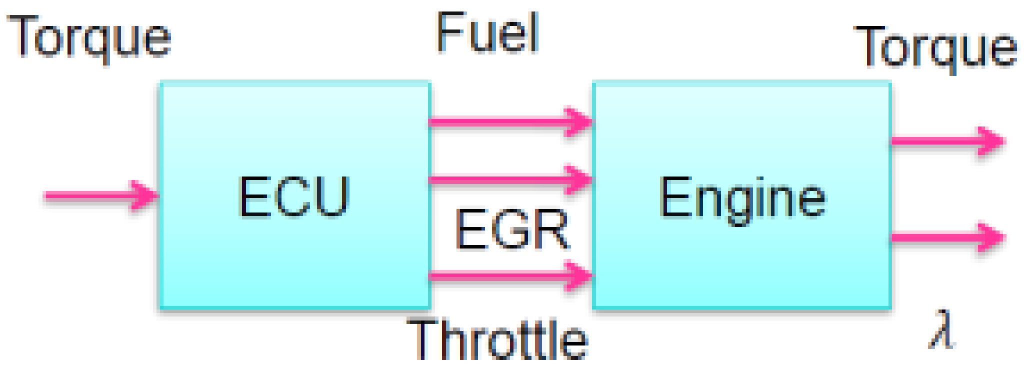
Aim

- ❑Overview of the calibration objectives
- ❑What is optimisation
    - ❑Objective function
    - ❑Algorithm – finding the minimum
    - ❑Constraints
- ❑Pareto curve and the NOx tradeoff

Calibration Goal: Model Inversion

Access the desired reference via

- ❑Inversion of the static non-linear model
- ❑Inversion of the dynamic model
- ❑Or control



Obtain the desired torque

Multicriterial Optimisation

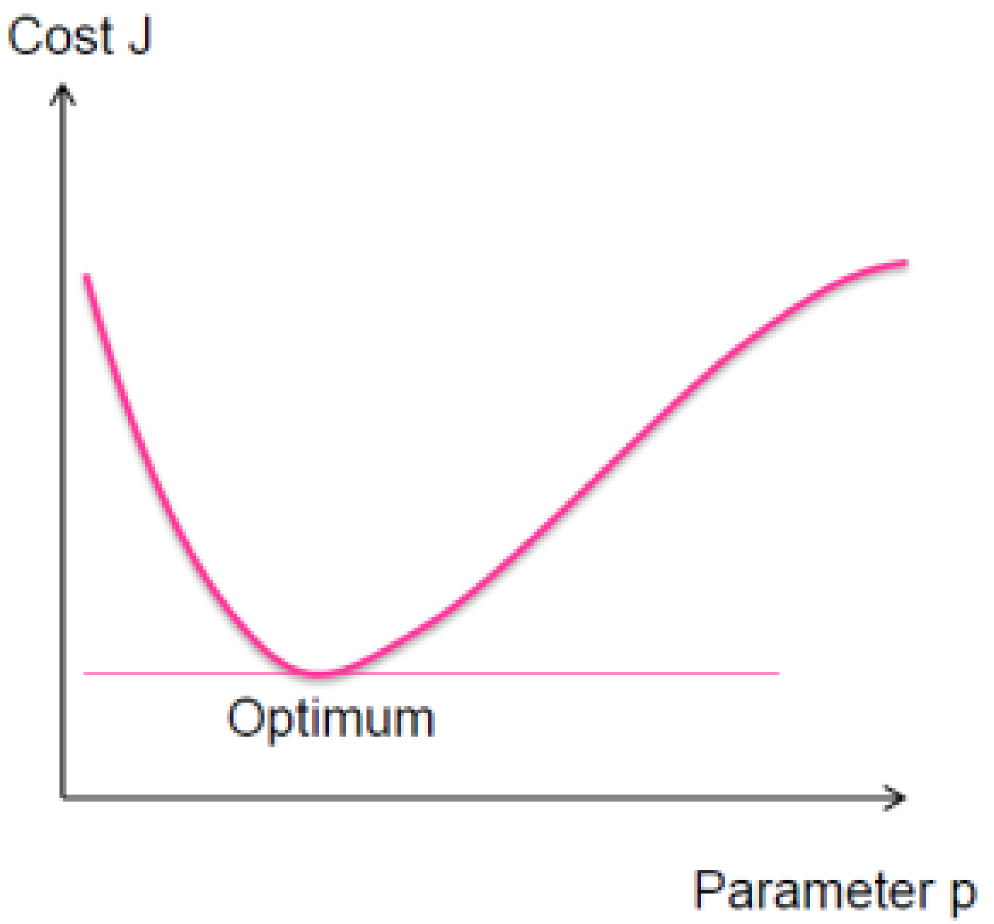
- □Model all the relevant factor – responses
  - Fuel consumption
  - Emissions
  - Driveability

Create a weighted cost function:

$$J = \alpha J_{fuel} + \beta J_{emissions} + \dots$$

Optimisation

- Use an algorithm to find the best compromise - the lowest total cost.
- Lots of dimensions to consider
- How to find this?



Limits

□Physical limits

- Cylinder pressure
- Fuel flow
- Valve range
- VGT range

□Legal limits

- Emissions
- Power
- Noise

Limits

- Limits are difficult. Hard limits;
  - Active limit: equality constraint
  - Inactive limit: not relevant
- Soft limits
  - Cost penalty

Handling differs by algorithm and tool.

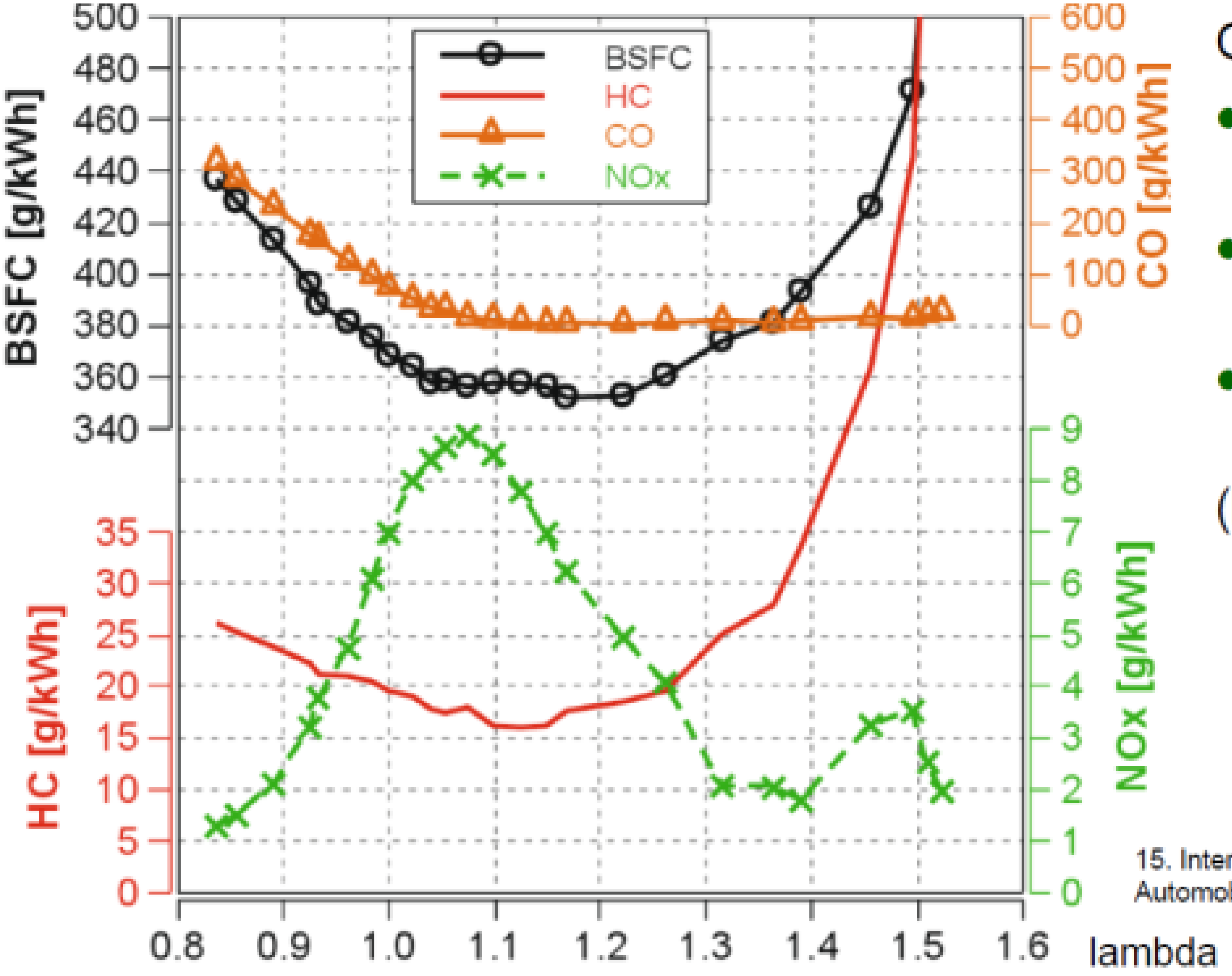
Optimisation with weighted Objectives

- Optimisation is the process of finding the best combination of controls to meet a specified task.
- In an optimisation process a cost function is formulated and minimised.
- The Cost function contains quantities to be minimised.
- The **weighting** is essential

$$\min_{p \in P} J(p) \ \text{with} \ J = \sum_i \alpha_i f_i(p)$$

- f_1 may be a measure of fuel consumption
- f_2 may be a measure of NOx emissions etc
- p is the decision variable (a vector)

Engine Model



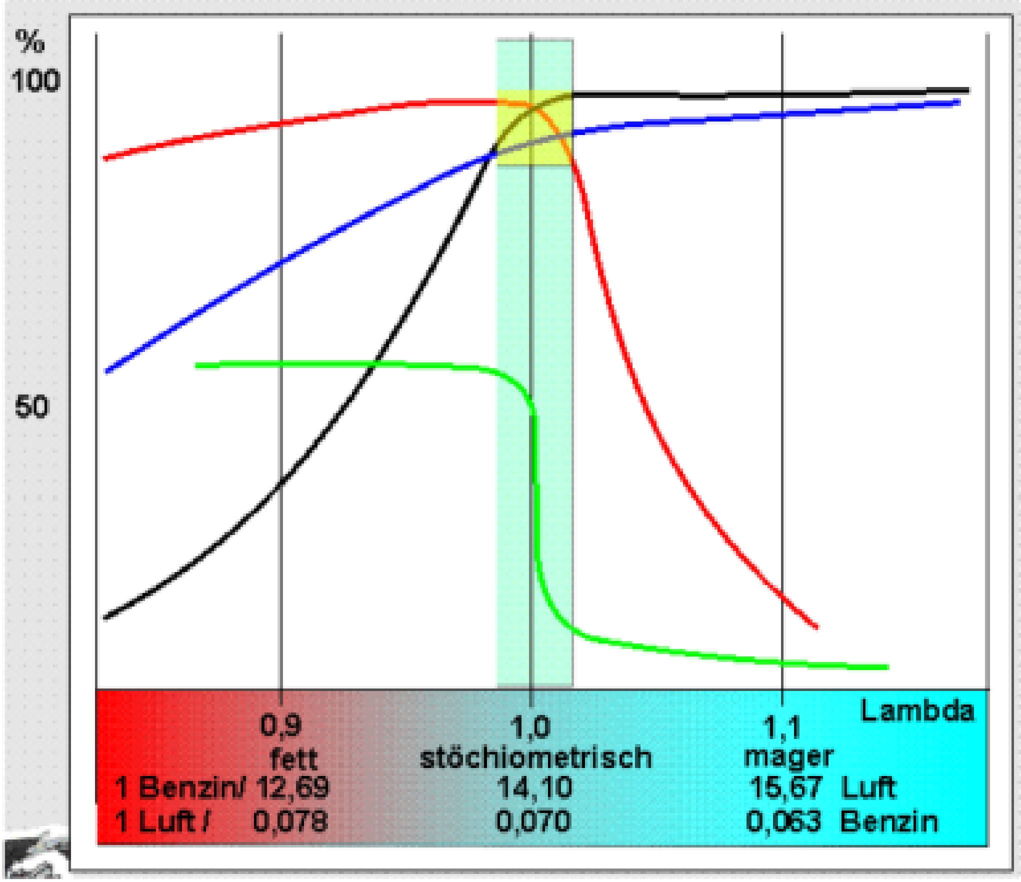
Observations:

- BSFC is convex, min at 1.2
- CO is convex, min at 1.1
- NOx is bimodal, max at 1.1

(but mind the TWC)

15. Internationales Stuttgarter Symposium: Automobil- und Motorentechnik, p252

Catalyst Performance

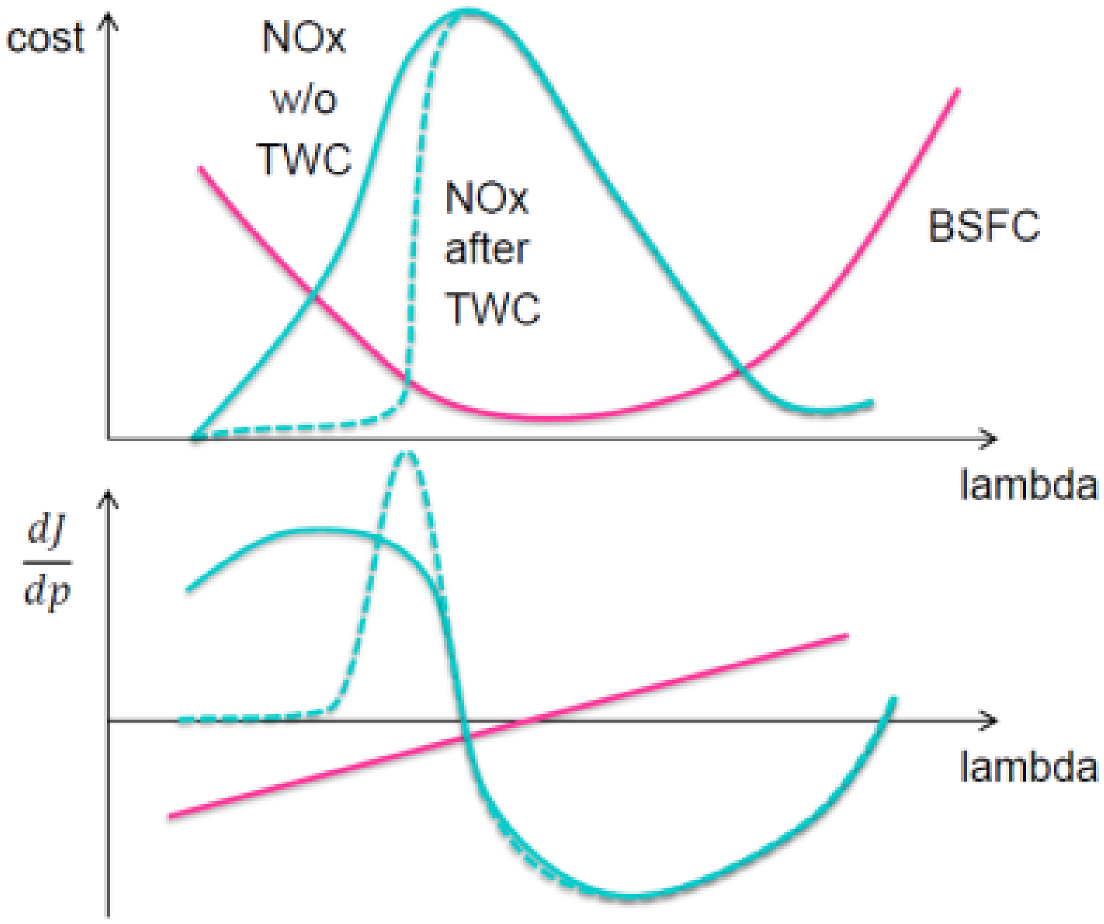


Observations:

- HC conversion from 1.0
- NOx conversion up to 1.0
- Very narrow operating window

http://www.powerboxer.de/auspuff/29-lambdasonde-und-kat

Finding the Optimum



Critical point:

$$\frac{dJ}{dp} = 0$$

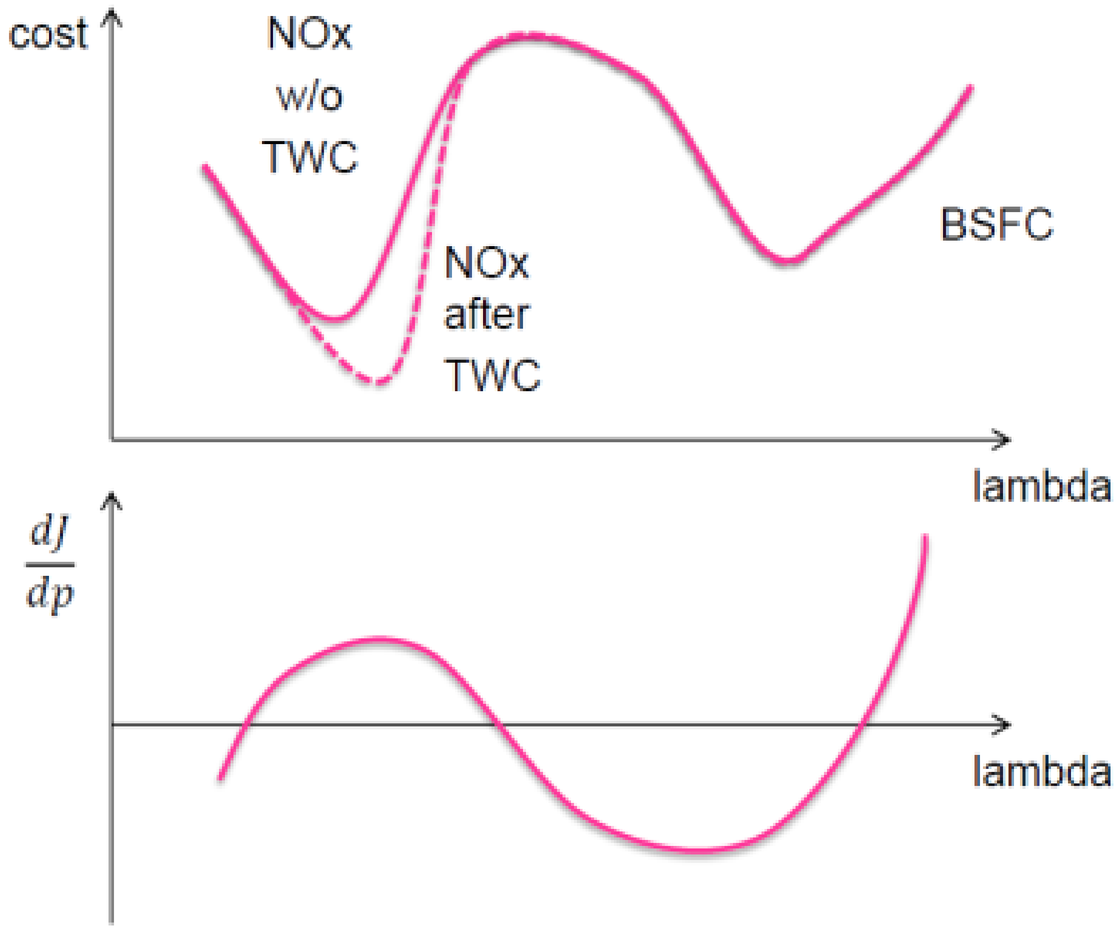
Or

$$\alpha_1 \frac{dJ_1}{dp} + \alpha_2 \frac{dJ_2}{dp} = 0$$

BSFC is:

- Convex
- → One optimum
- → Easy to solve

Finding the Optimum



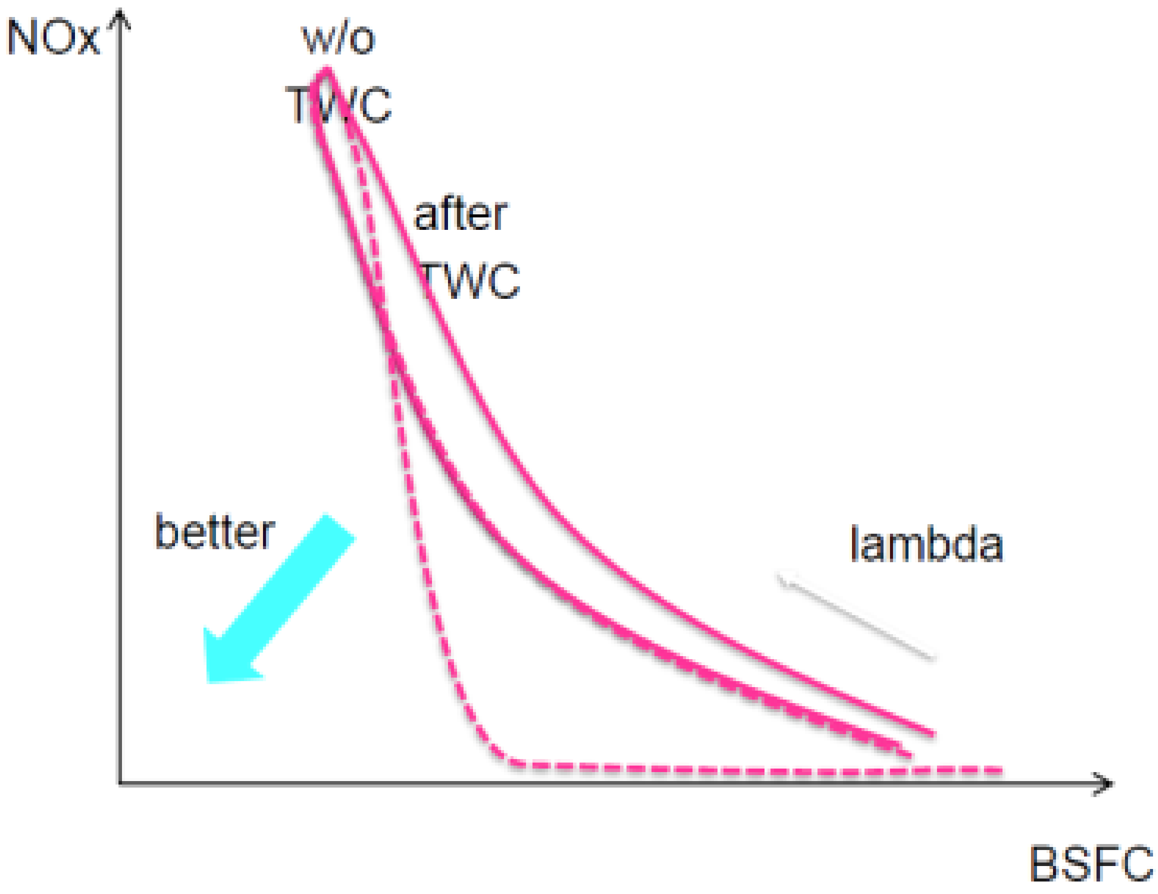
Total cost is:

- Bimodal
- Not convex
- Has a maximum

Derivative shows

- Sign reversal
- Three roots

Pareto Curve



Shows the trade-off

Slope corresponding to the ratio of weights defines the optimum

Disadvantage:

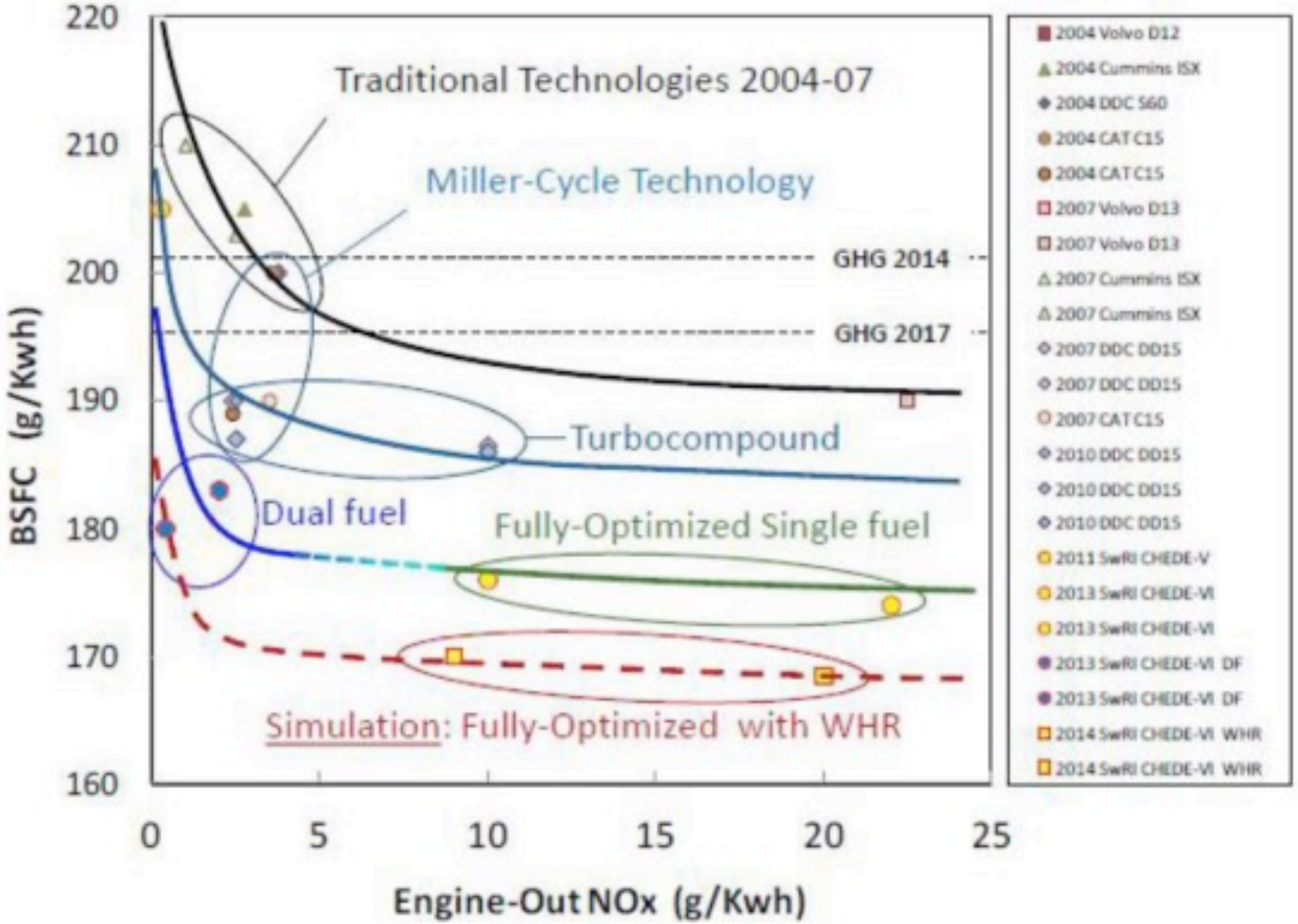
lambda is not visible

Conclusion:

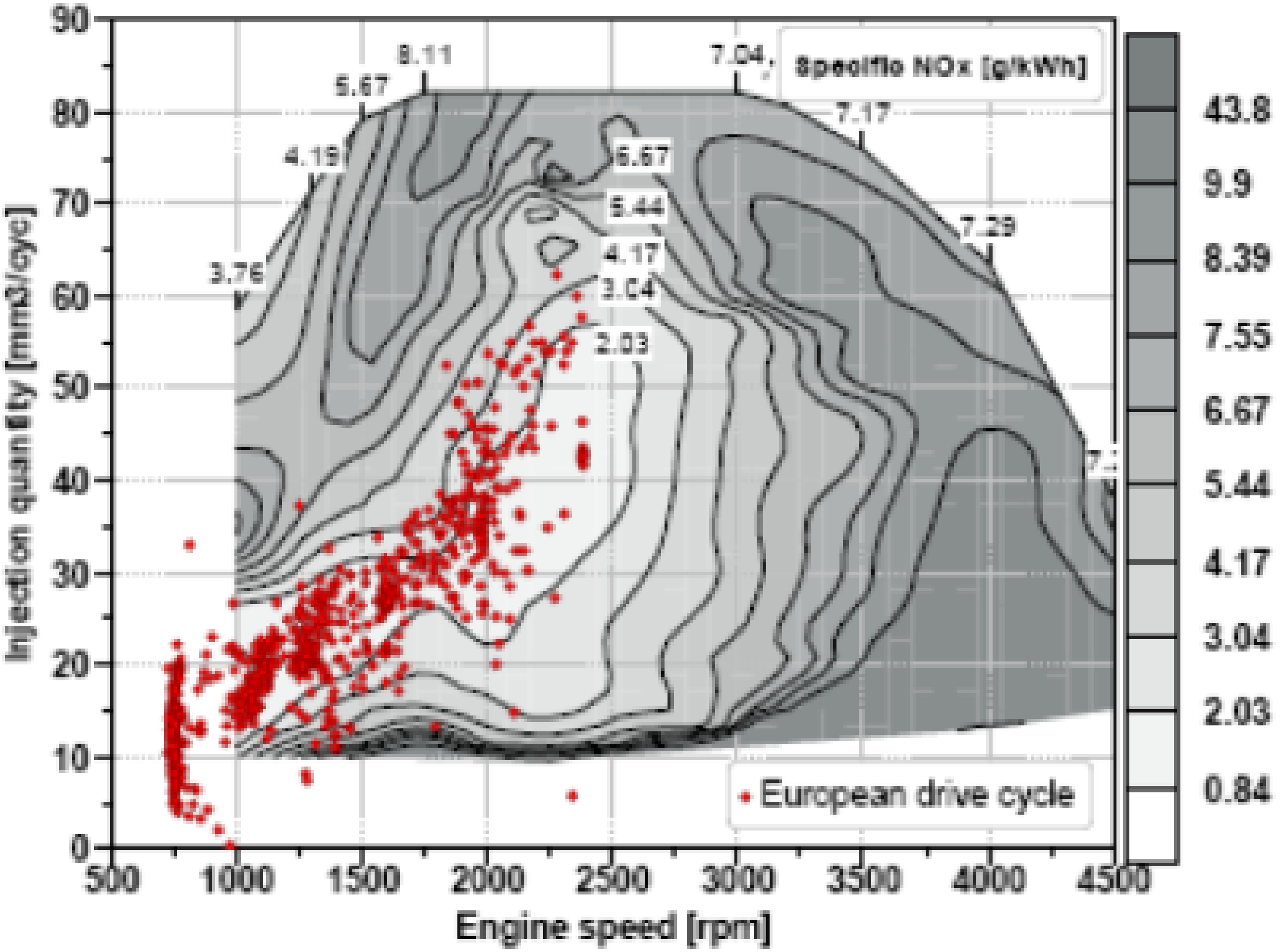
With TWC, lambda=0.99.

W/o TWC: lambda≈1.2

NOx Tradeoff (CI)



Typical Calibration Results: NOx



Emissions are

- good on the NEDC
- bad elsewhere

Note the scale!

Conclusion

- Calibration is the structured selection of parameters
- Optimising a cost function vs finding a compromise
- For all environmental conditions / speed / load
- Software support is essential and available
- Parameters have to be considered together.