Powertrain Calibration Optimisation

Optimisation

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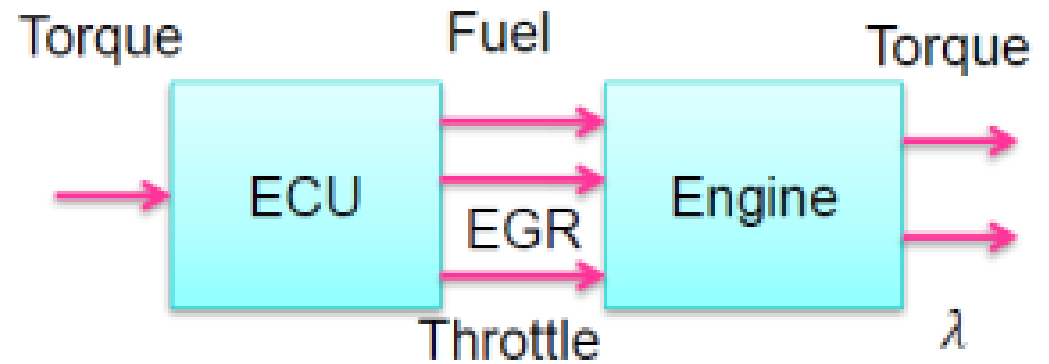
Aim

❑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
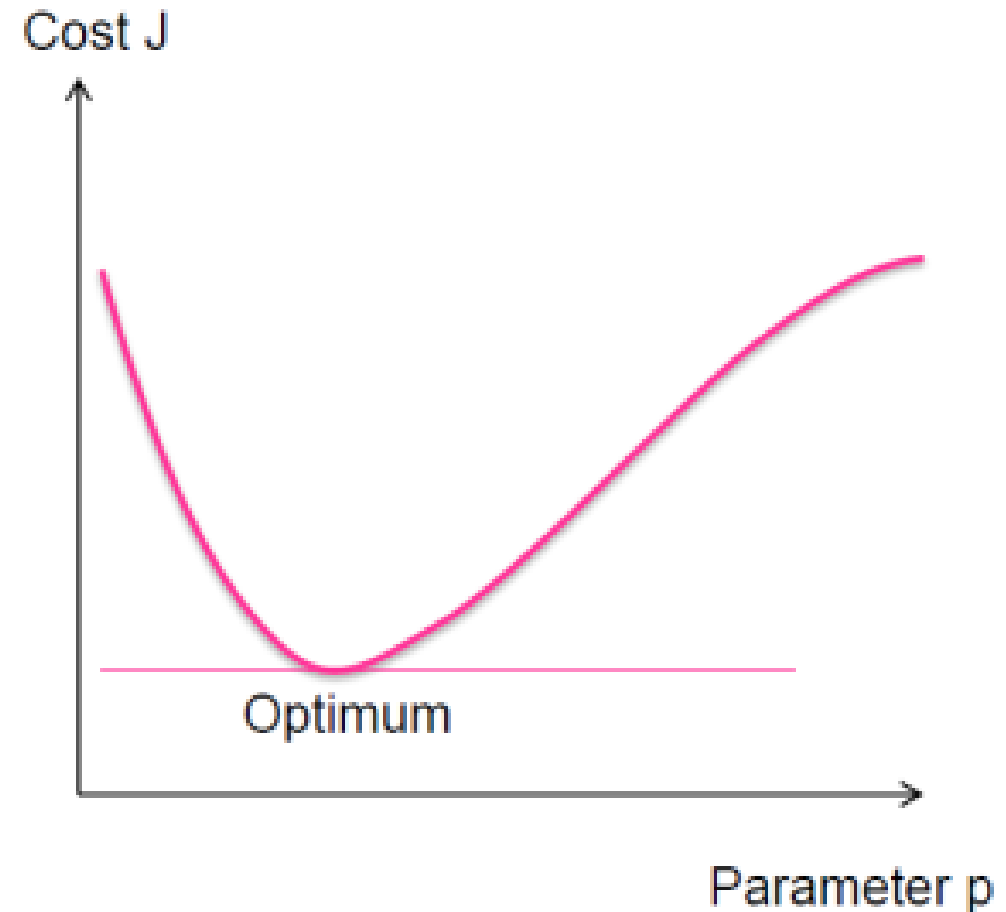

Obtain the desired torque

Multiobjective Optimisation

☐ Model all the relevant factor – responses

- Fuel consumption
- Emissions
- Driveability

Create a weighted cost function:

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

Optimisation

☐ Use an algorithm to find the best compromise - the lowest total cost.

☐ Lots of dimensions to consider
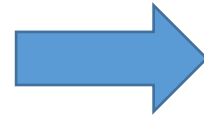
☐ How to find this?

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
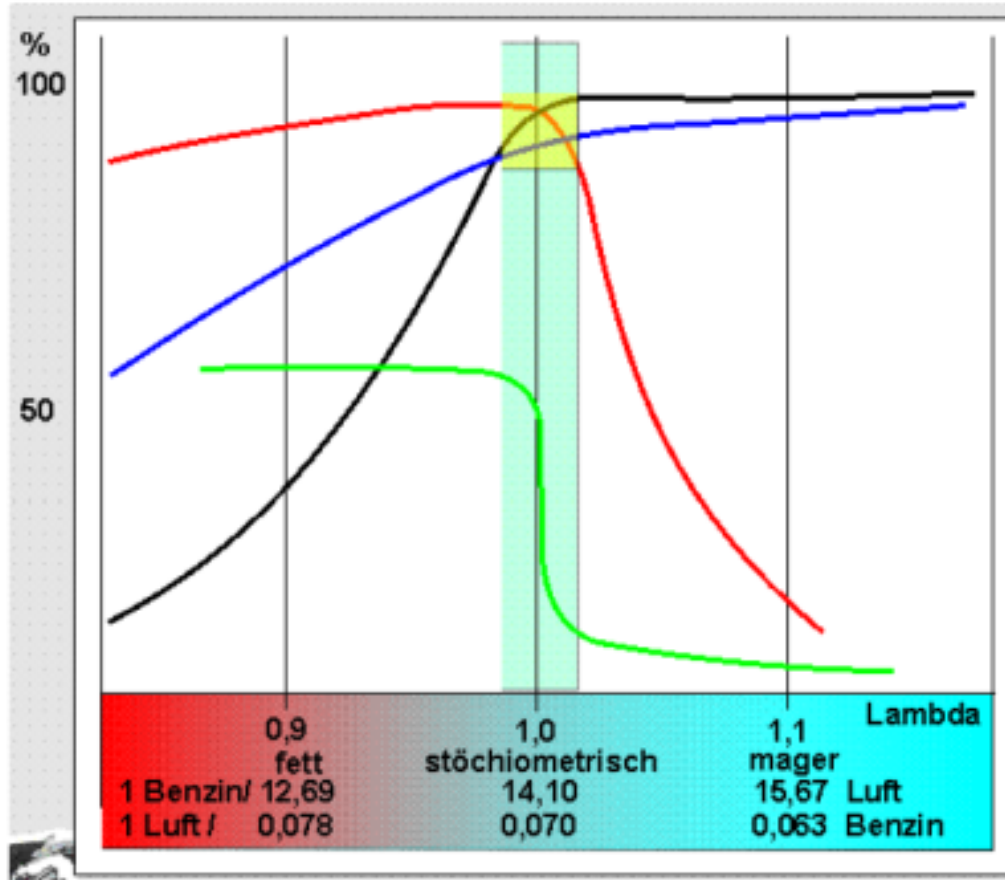- p is the decision variable (a vector)

Engine Model
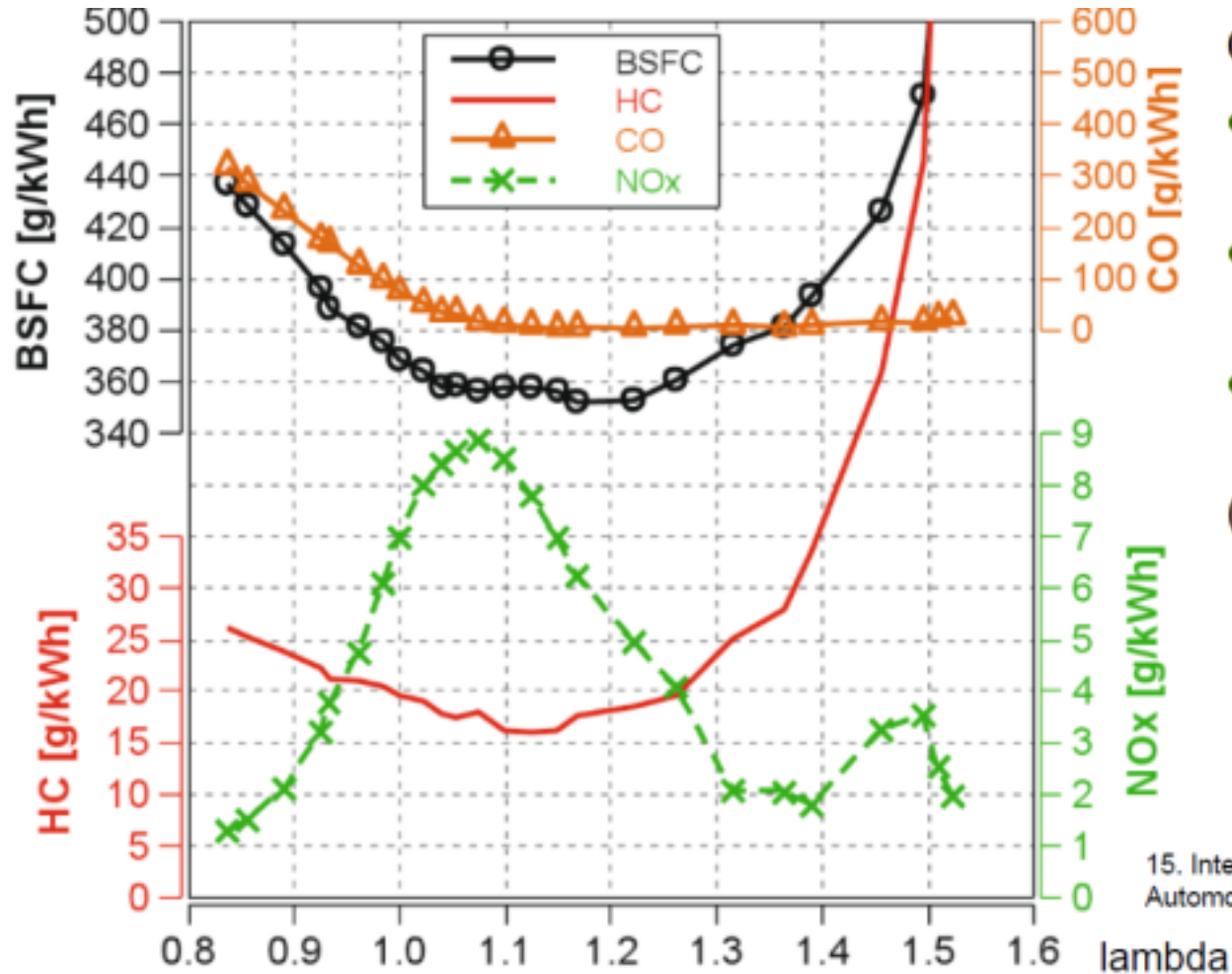
Observations:

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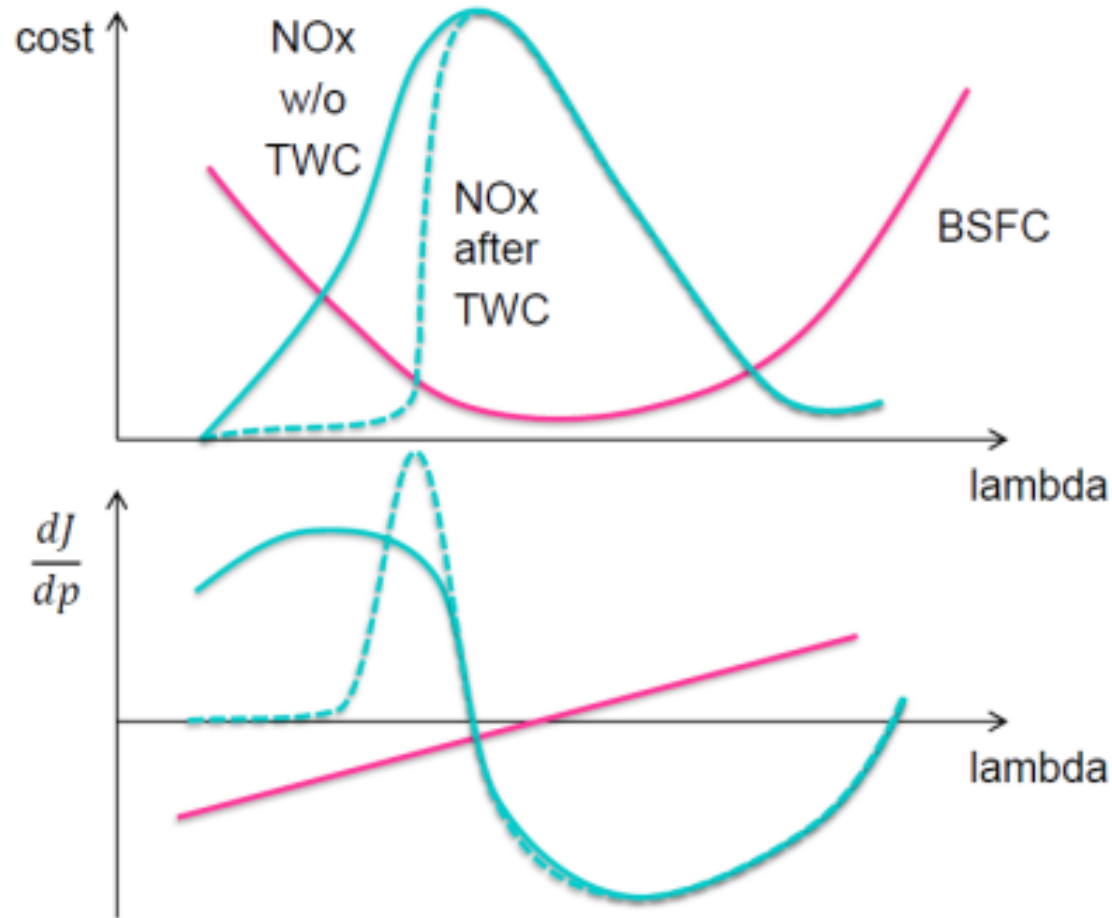- NOx is bimodal, max at 1.1

(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
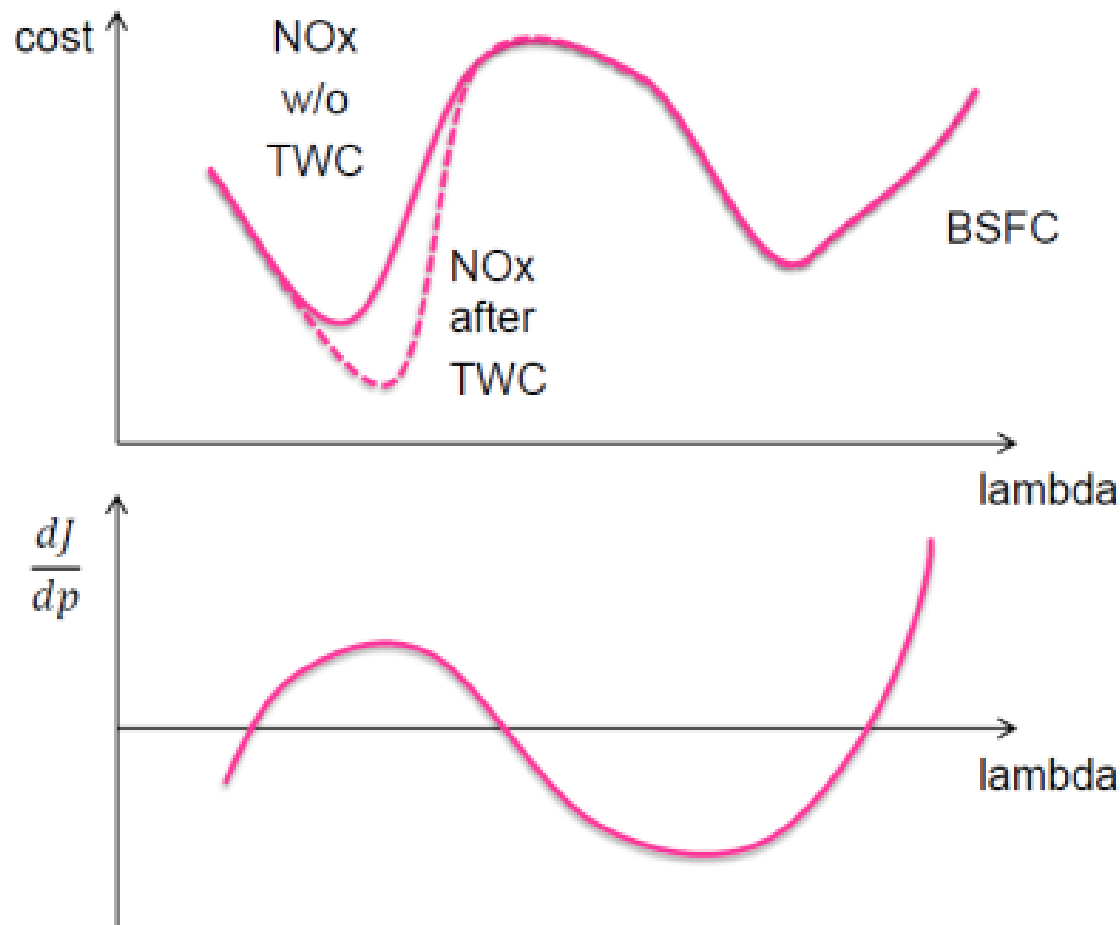

Critical point:
$$\frac{dJ}{dp} = 0$$

Or

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

BSFC is:

- Convex
- → One optimum
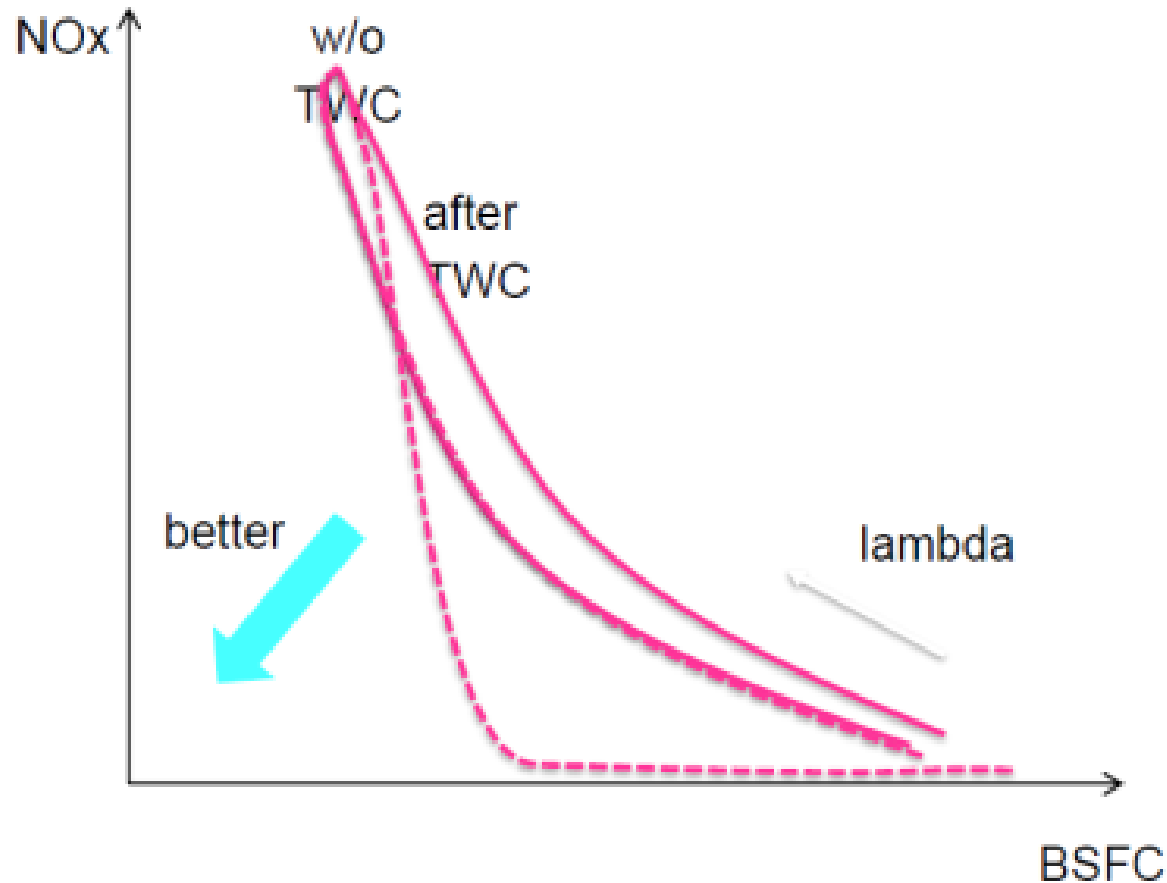- → Easy to solve

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
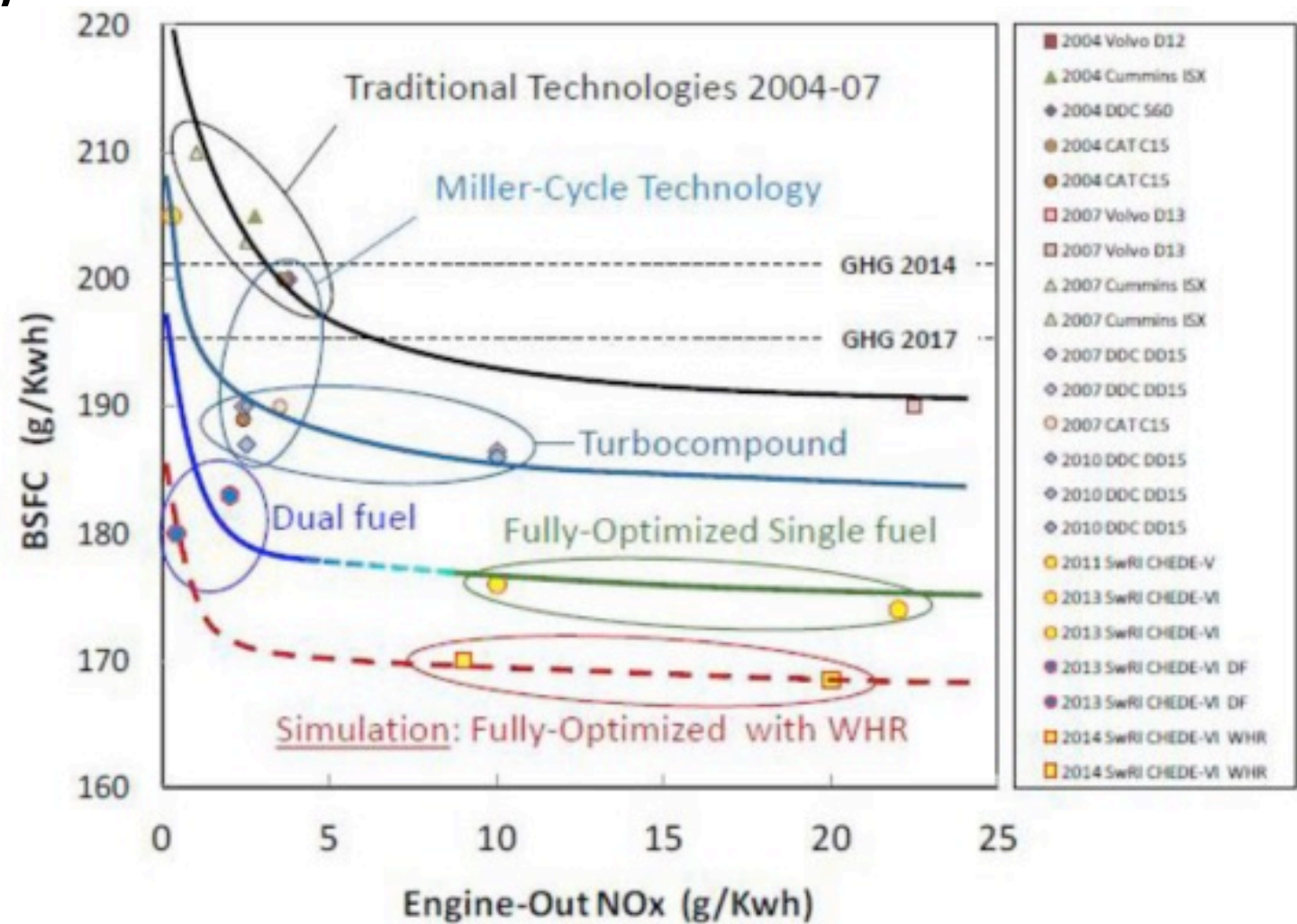
Disadvantage:
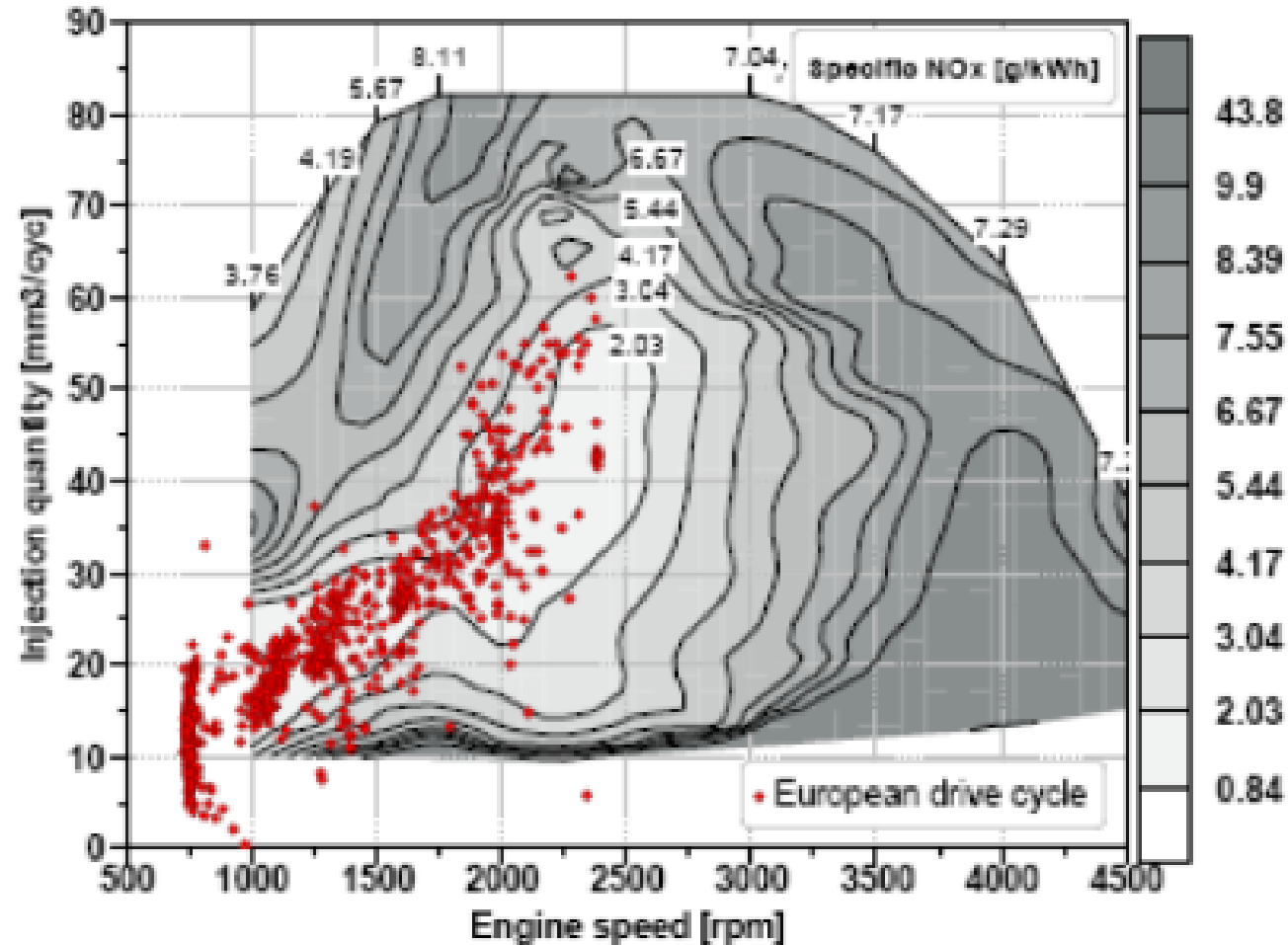
lambda is not visible

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.