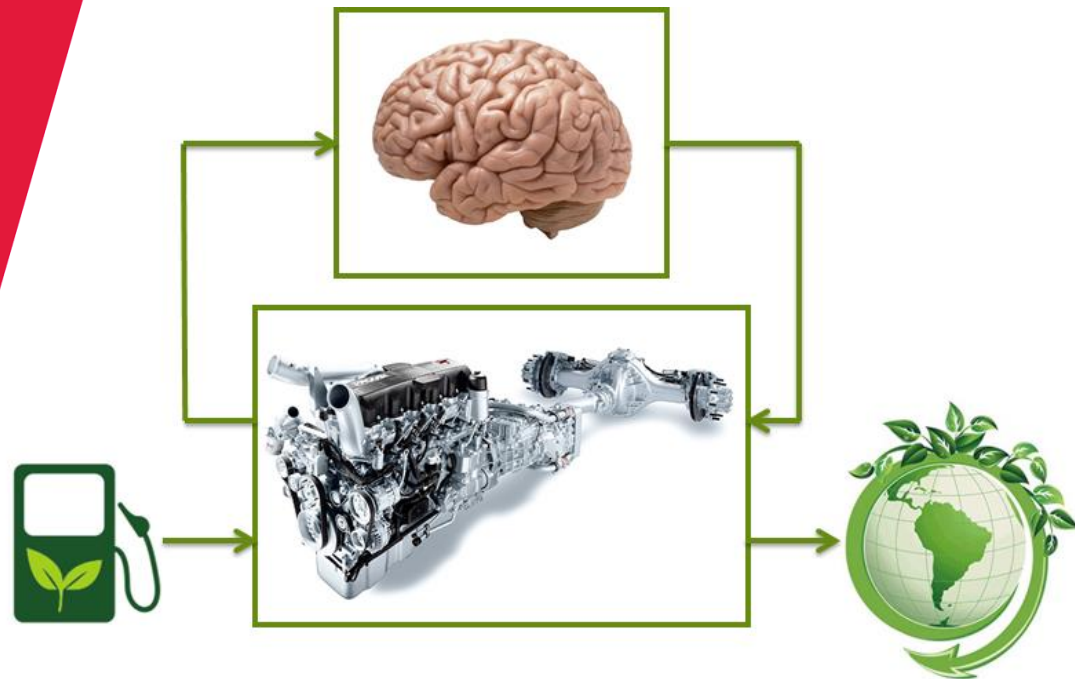


The Self-Learning Powertrain: towards smart and green transport

*LINK-SIC Workshop 2019
ABB CRC, Västerås
19 November 2019*

Frank Willems



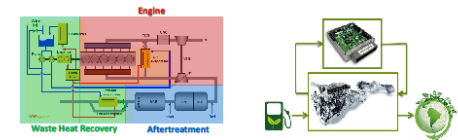
My activities in LINK-SIC

- Visiting professor LiU ISY/Vehicular Systems
– *August – November 2019*
- Collaboration with Prof. Lars Eriksson, Kristoffer Ekberg, Robin Holmbom, Olov Holmer
- Guest lectures on Model-based powertrain control
- Company visits:
 - Scania (Erik Höckerdal)
 - Atlas Copco (Nils Dressler)

ISY guest lectures on Model-Based Powertrain Control

Outline

This sequence of ISY guest lectures will give an introduction into modeling and model-based control design for advanced combustion engines with aftertreatment system and with waste heat recovery system. The aim is to give those who are interested in or work with powertrain control systems a common reference frame. The sequence consists of five interactive lectures, which highlight the applied modeling and control methods. The presented approaches are illustrated with relevant, practical case studies. Note that the lectures also can be followed on a stand-alone basis. No registration is required.



Who should attend?

The guest lectures are intended for automotive and control engineers that have a basic background in physics-based modeling and control. Especially, PhD students are encouraged to attend. By following these lectures, the attendees get an introduction into the state-of-the-art in modeling, virtual sensing and model-based control approaches for future powertrains.

Lecturer



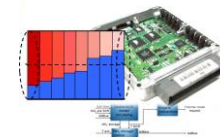
Frank Willems is visiting the Vehicular Systems group at the Department of Electrical Engineering (ISY) during September-November. As a Gastprofessor, he will collaborate with Prof. Lars Eriksson within the competence center LINK-SIC.

Frank obtained his MSc (1995) and PhD (2000) in Mechanical Engineering from Eindhoven University of Technology (TU/e). He subsequently joined the Powertrain group of TNO Automotive, where he currently is a senior technical specialist in powertrain control. Over the years, Frank has been involved in a wide range of industrial research projects on clean engine technologies. Since 2007, he has been a part-time staff member of the Control System Technology group, Department of Mechanical Engineering at TU/e. In this group, Frank holds a position as Full Professor. His main research interests are control-oriented modeling of internal combustion engines and aftertreatment systems, cylinder pressure-based combustion control, and integrated energy and emission management.

INVITED LECTURE SCANIA TECHNICAL CENTER

SCR Modeling and Control

Frank Willems
Senior Research Scientist – TNO Automotive
Professor – Eindhoven University of Technology



TNO innovation
for life

TU/e Technische Universiteit
Eindhoven
University of Technology

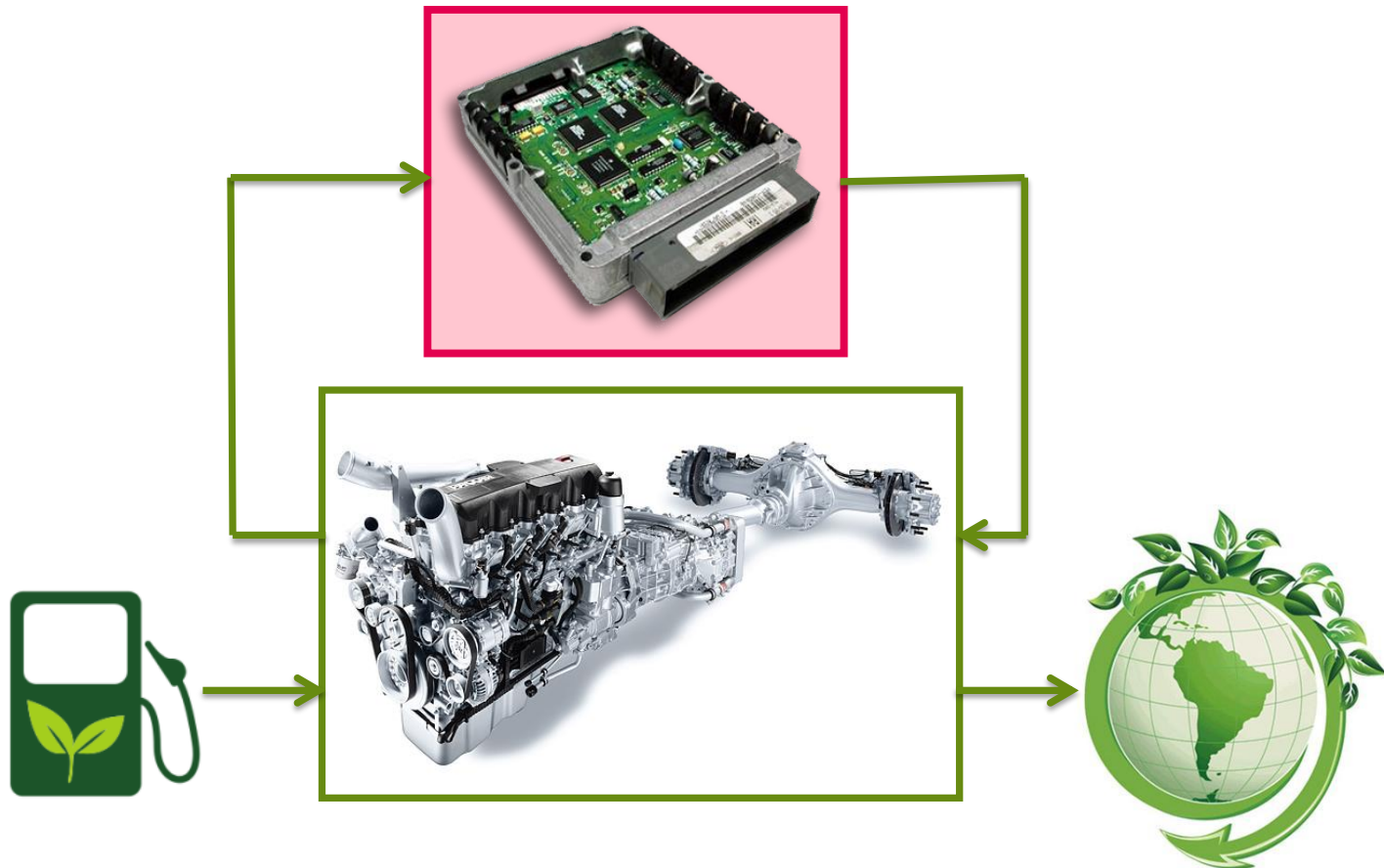
Invited lecture ATLAS COPCO

**MODEL-BASED CONTROL DEVELOPMENT
LESSONS LEARNED FROM POWERTRAIN APPLICATIONS**

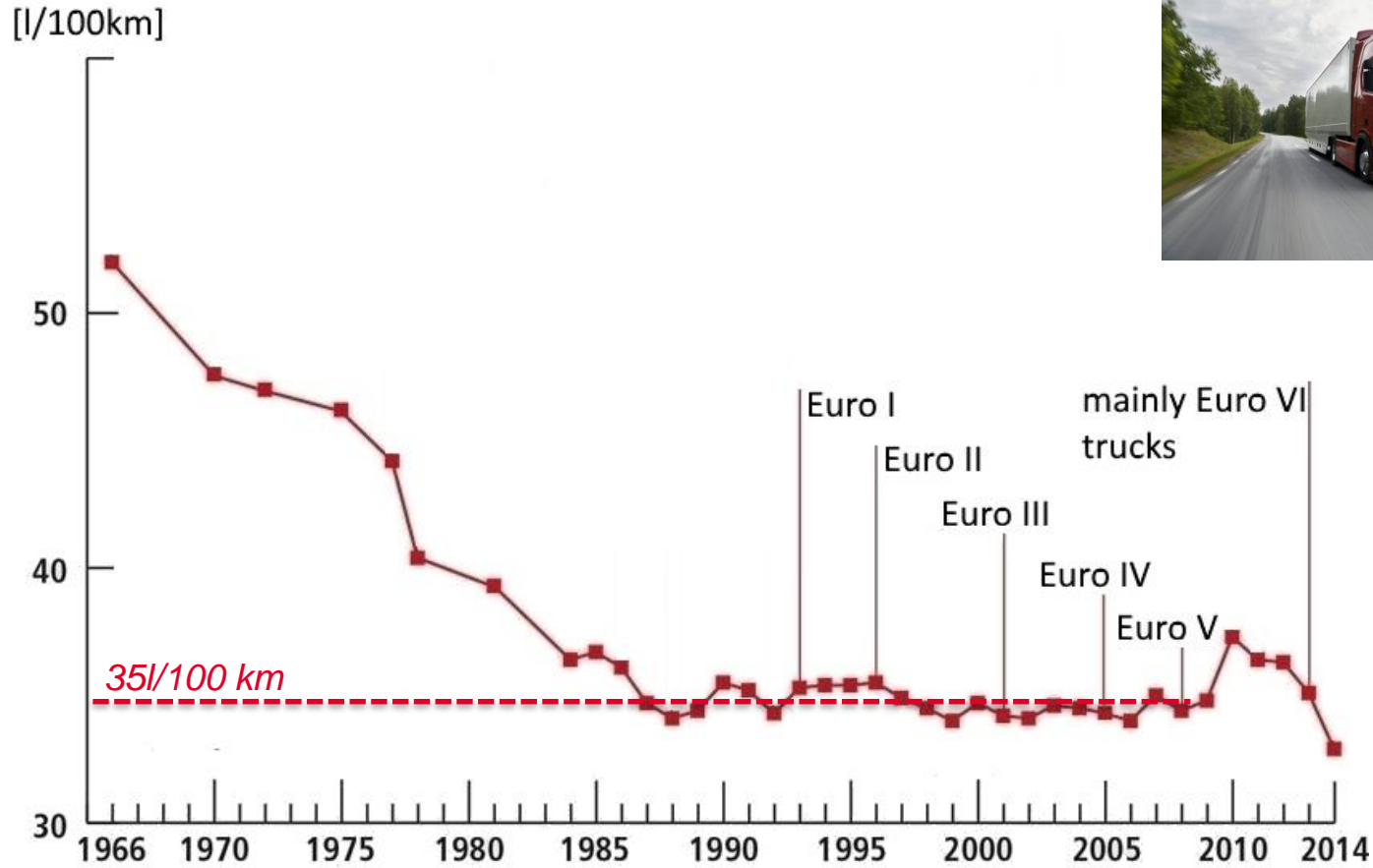
Prof. Frank Willems
TNO Automotive
Eindhoven University of Technology (TU/e)

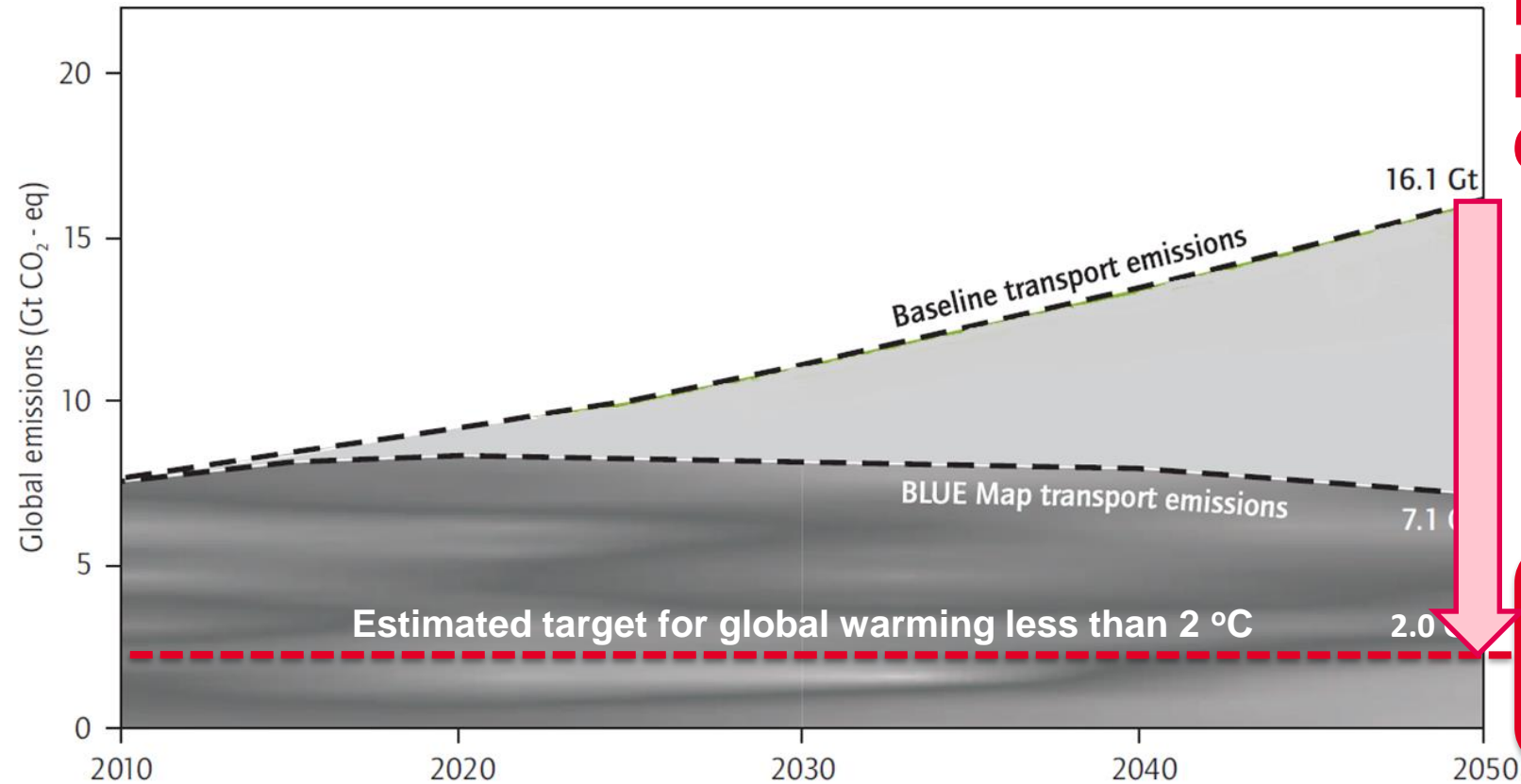
TNO innovation
for life

Still research to be done on powertrain control?



Historic real-world fuel consumption



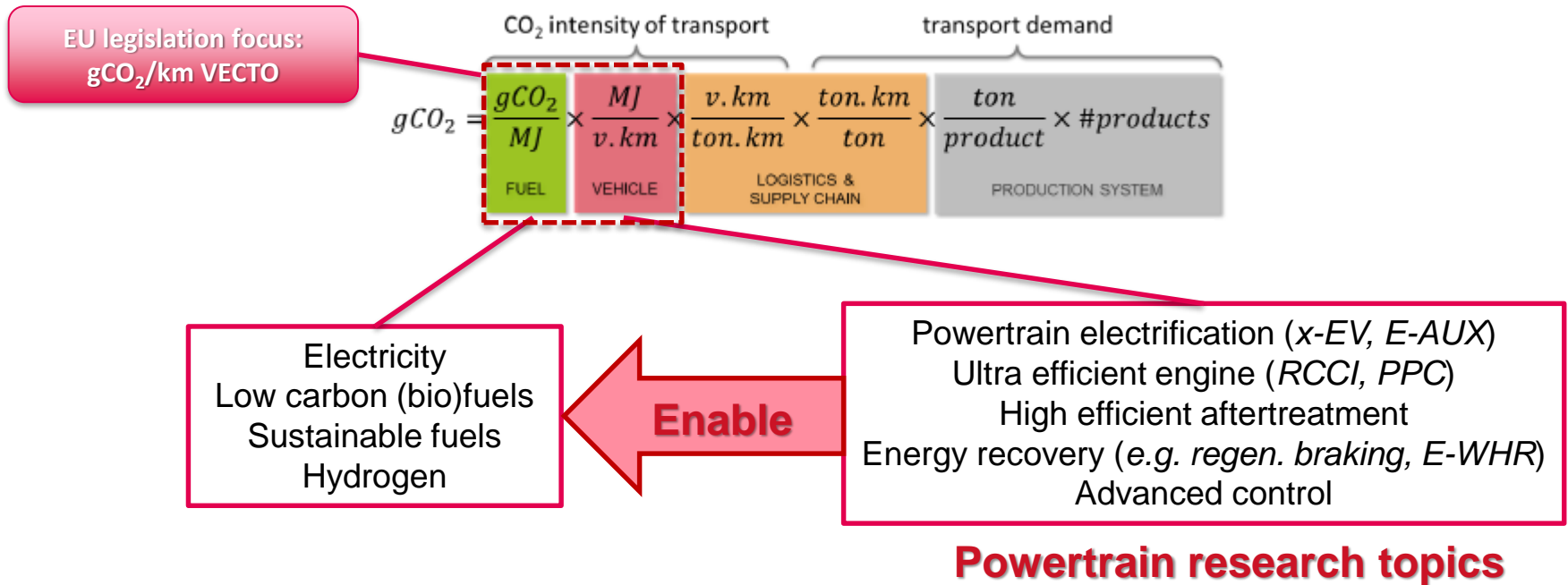


How to bridge the CO₂ gap?

EC transport 2050 target: -60% CO₂ compared to 1990

Tank-to-wheel CO₂ reduction

No single, silver bullet

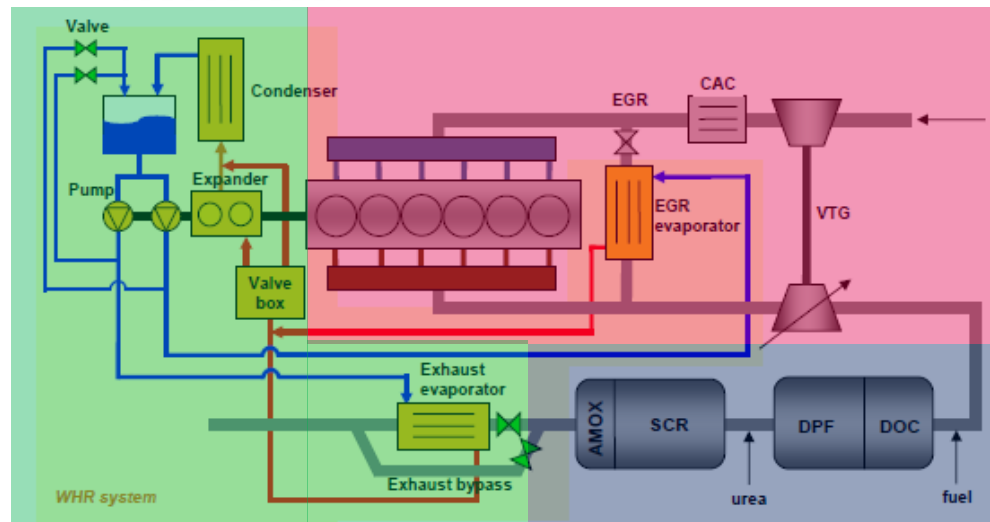


Tank-to-wheel CO₂ reduction

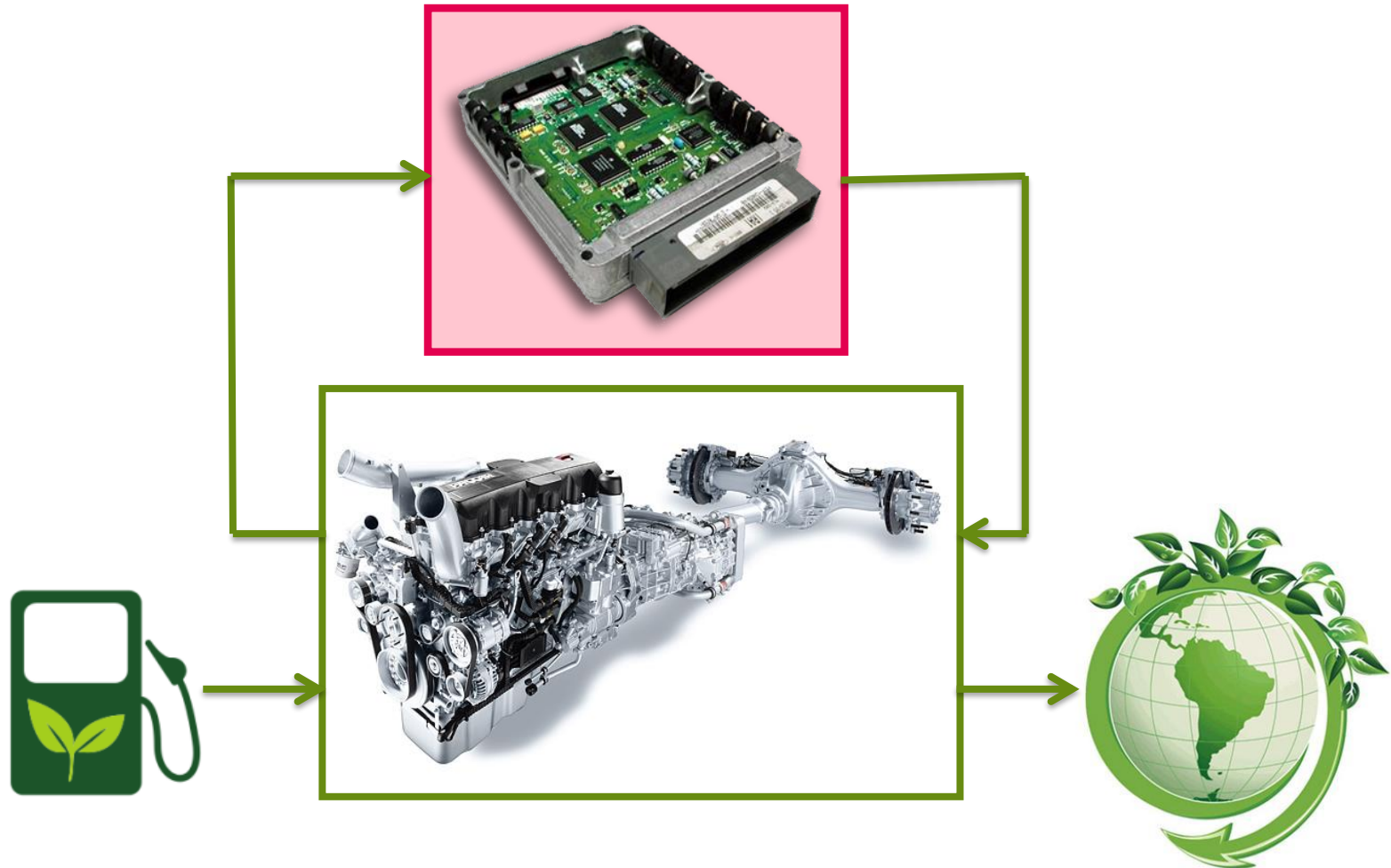
Growing complexity

$$gCO_2 = \underbrace{\frac{gCO_2}{MJ} \times \frac{MJ}{v.km}}_{\text{CO}_2 \text{ intensity of transport}} \times \underbrace{\frac{v.km}{ton.km} \times \frac{ton.km}{ton}}_{\text{transport demand}} \times \frac{ton}{product} \times \#products$$

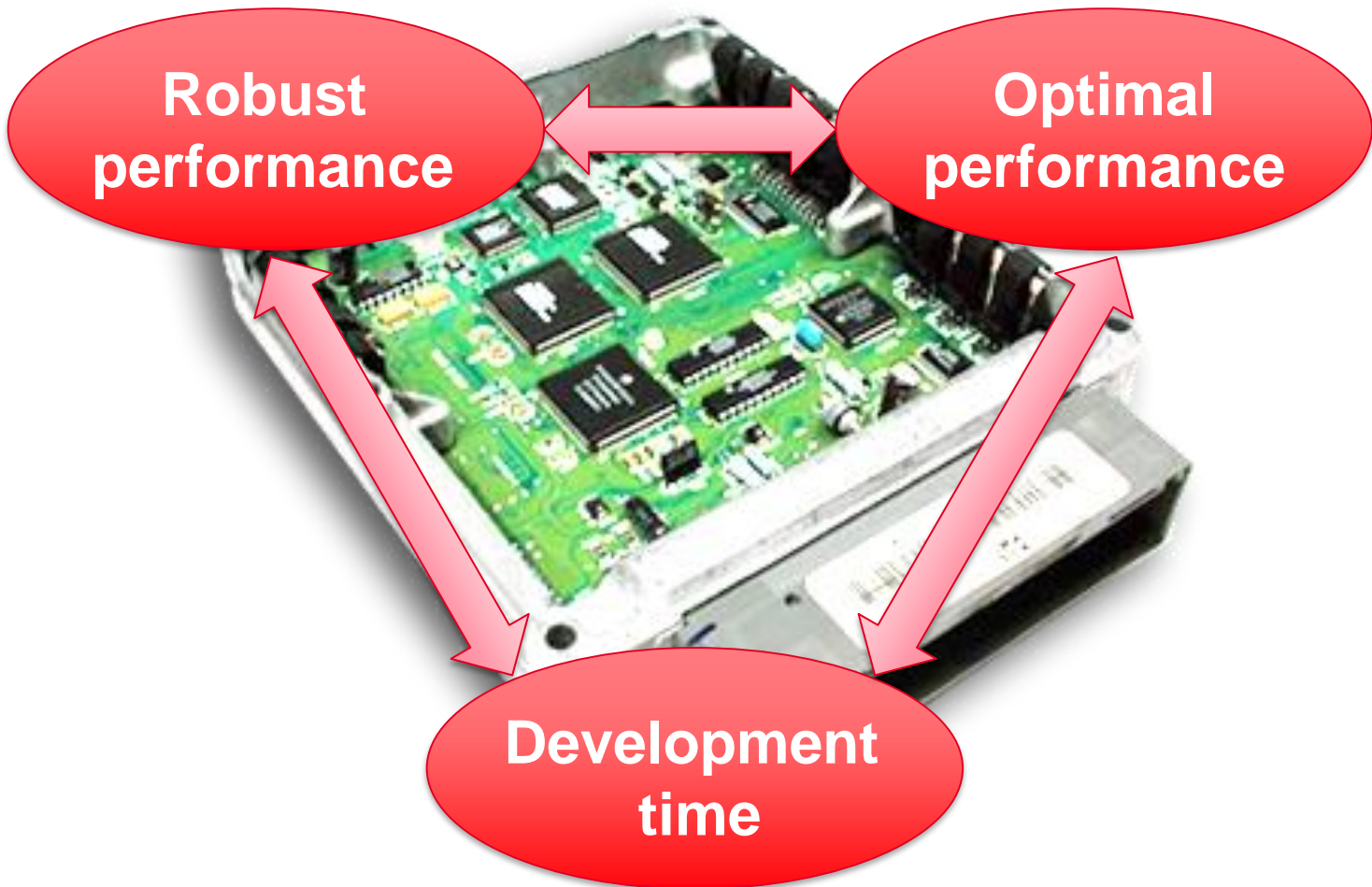
FUEL
VEHICLE
LOGISTICS & SUPPLY CHAIN
PRODUCTION SYSTEM



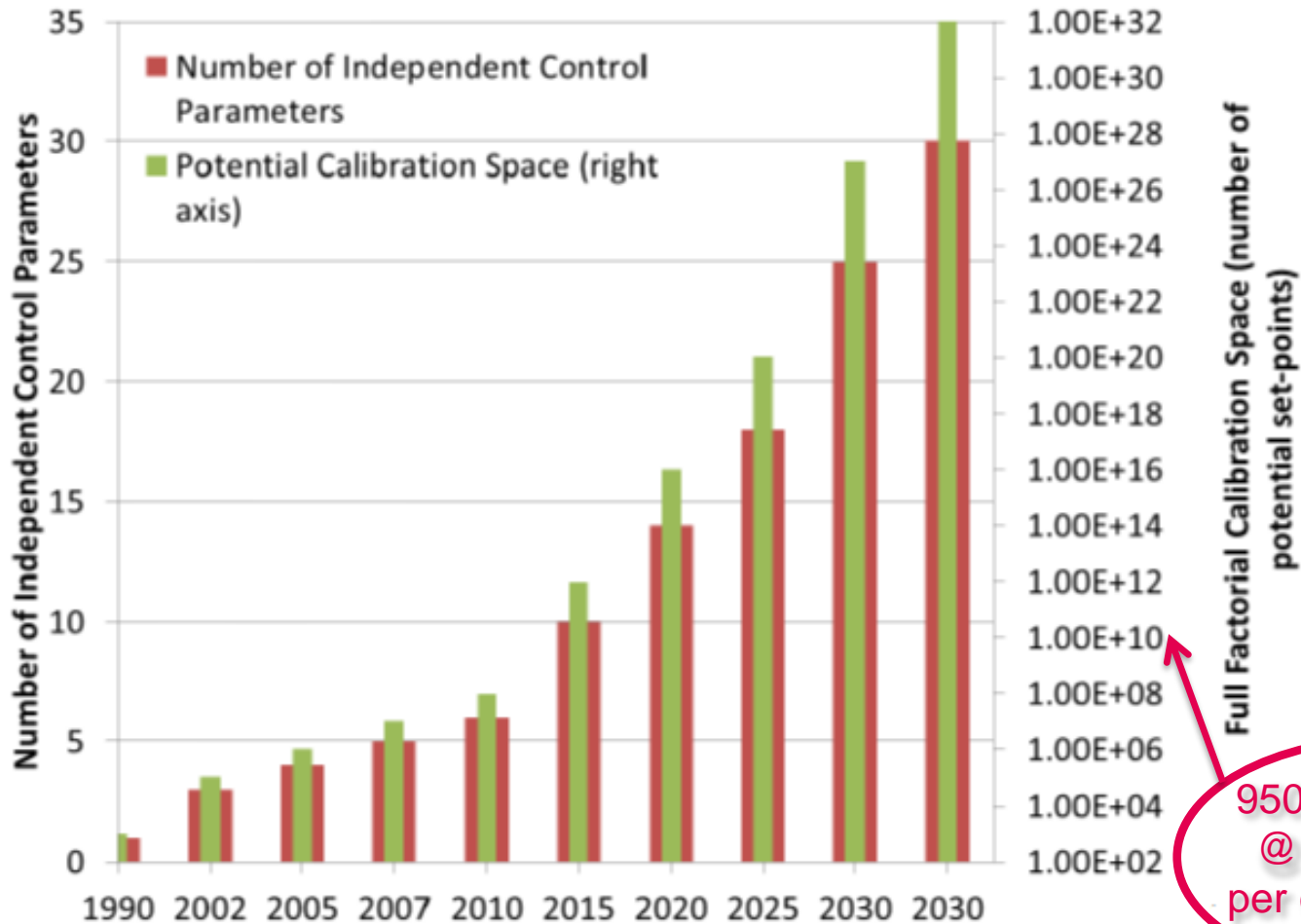
Growing importance of powertrain control



Growing importance of powertrain control

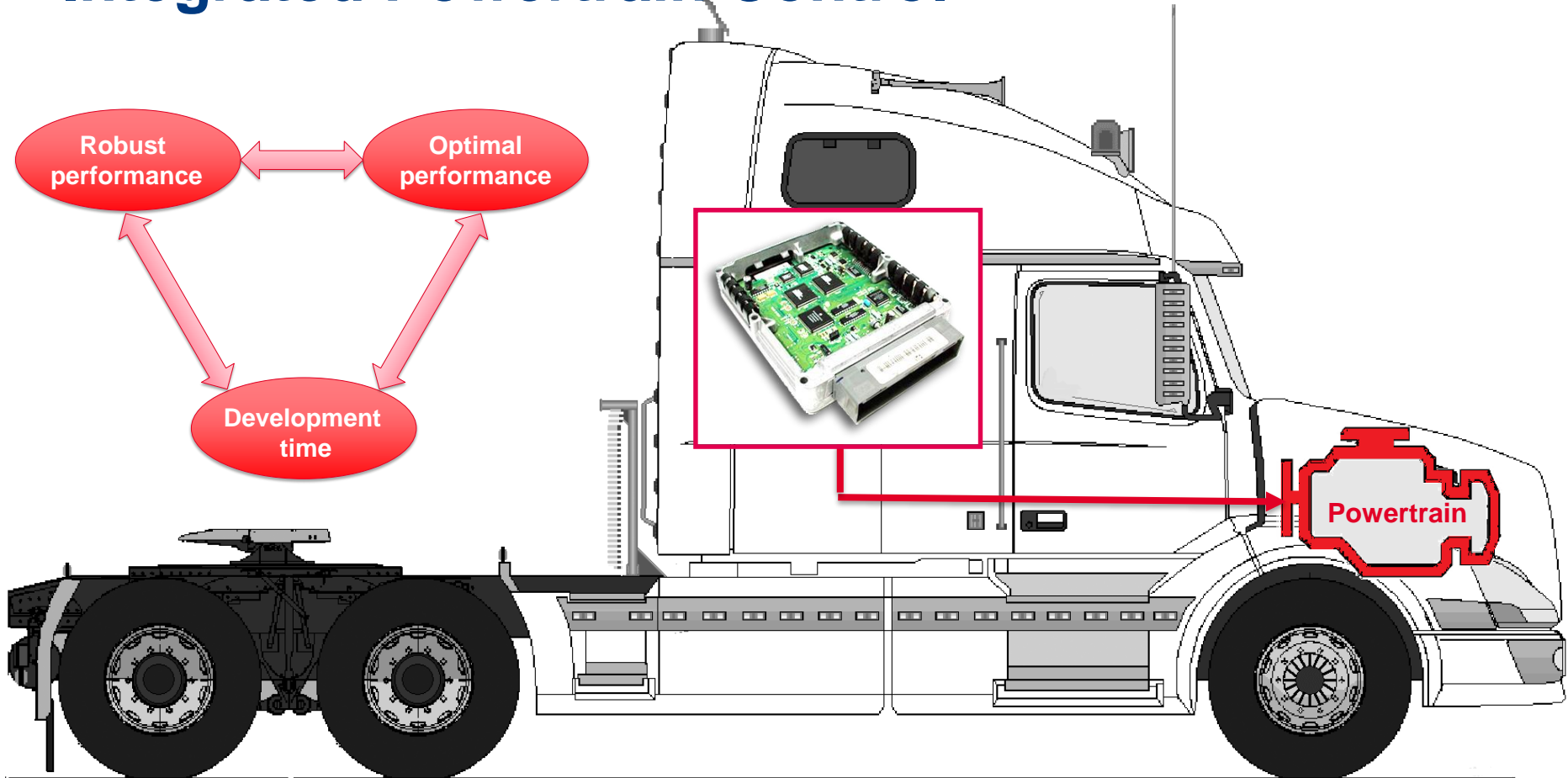


Map-based control is facing turning point

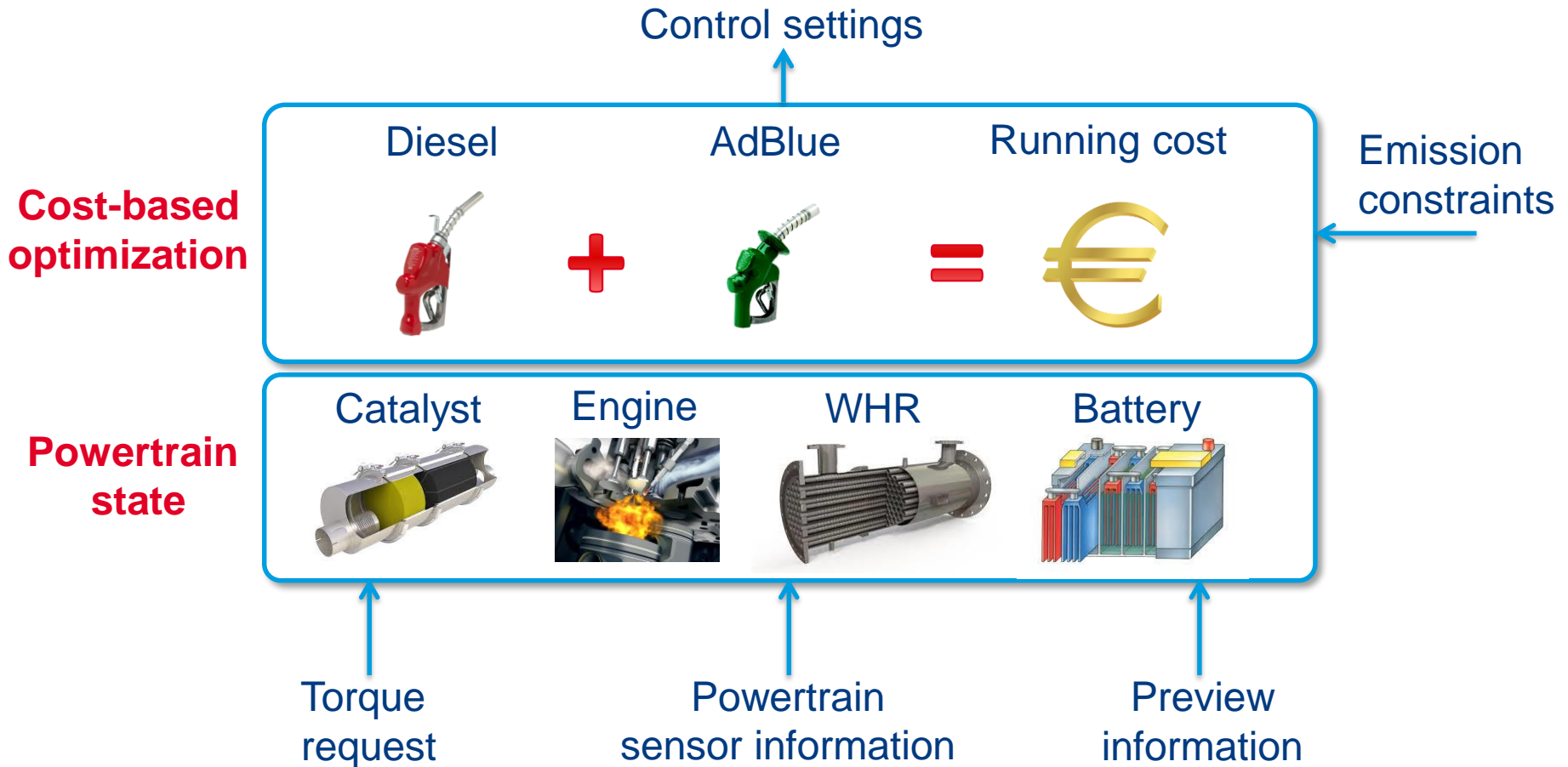


95000 dyno years @ 5 min testing per operating point

Integrated Powertrain Control

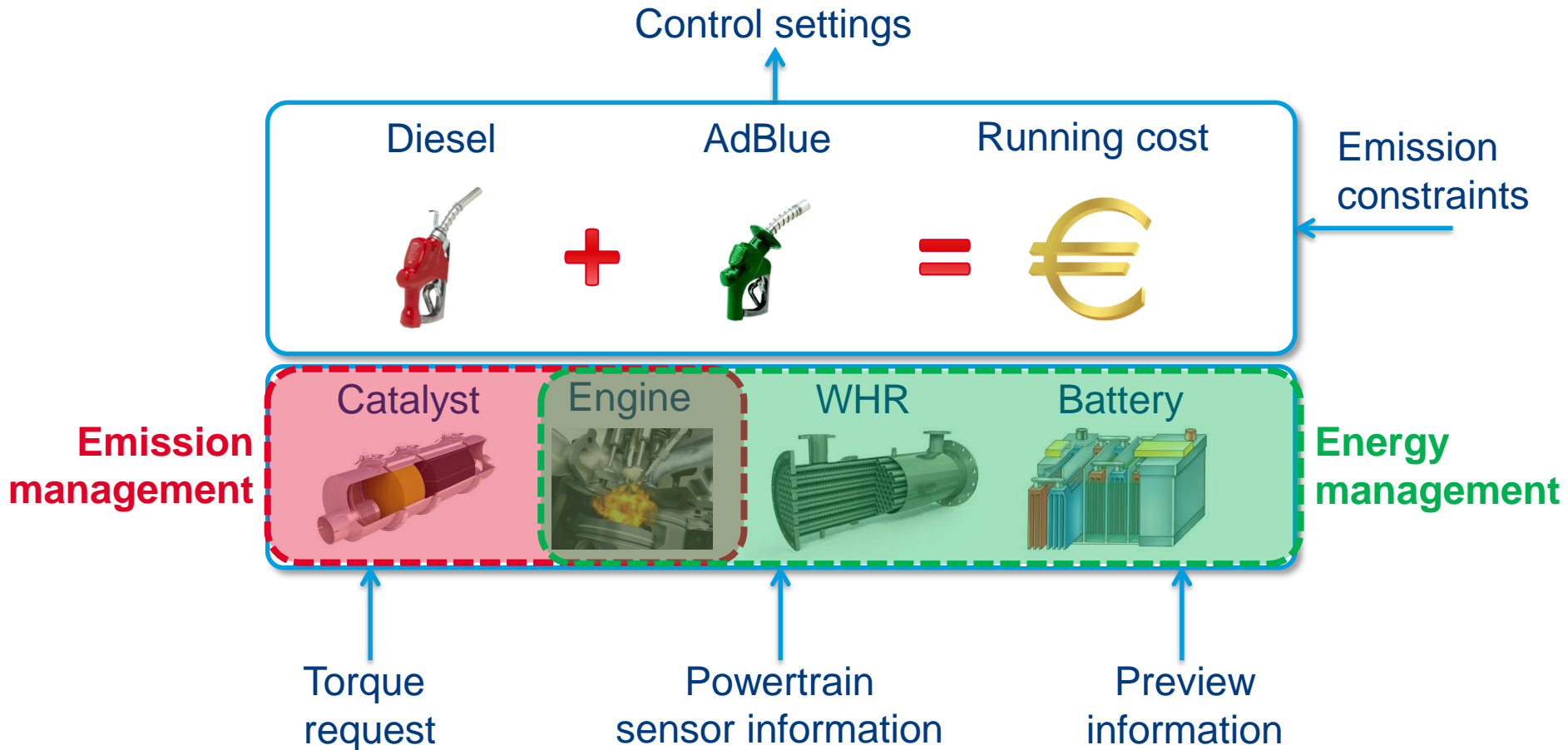


Integrated Powertrain Control

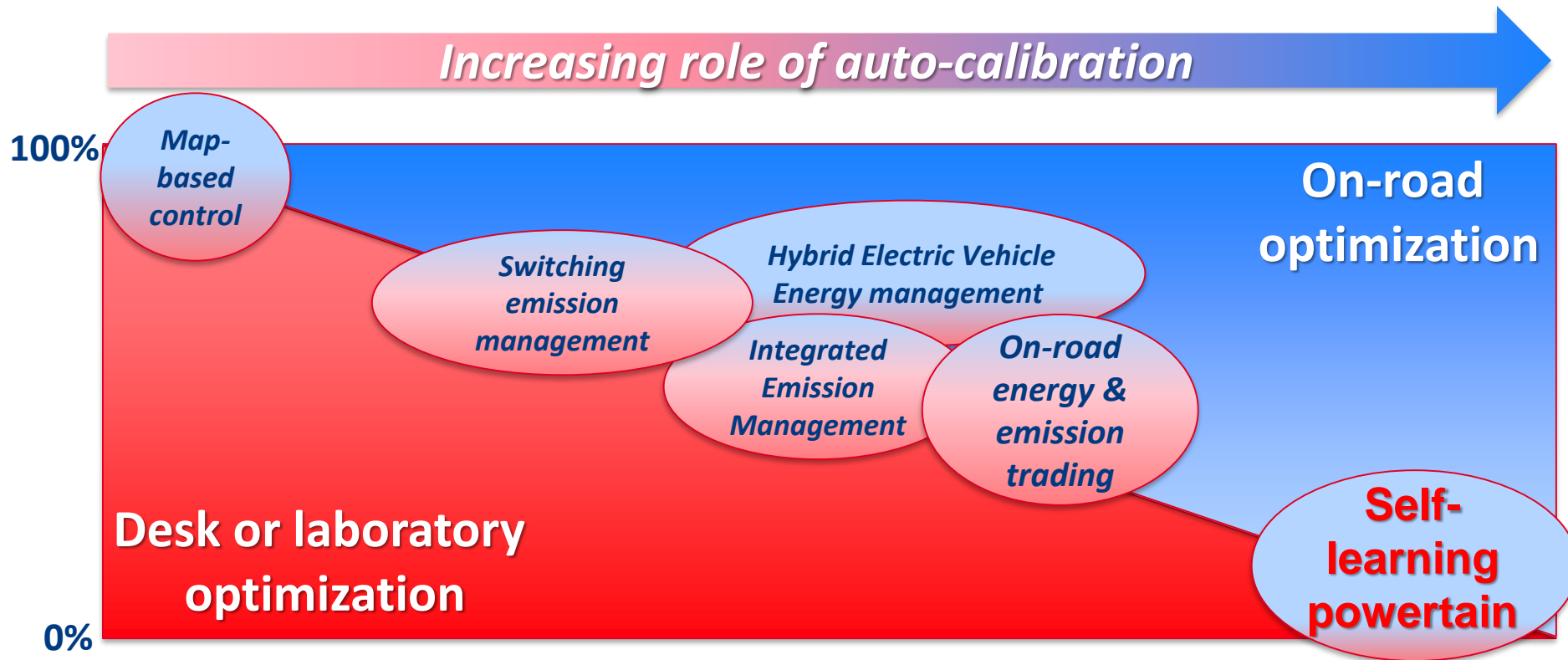


Integrated Powertrain Control

On-road energy and emission trading



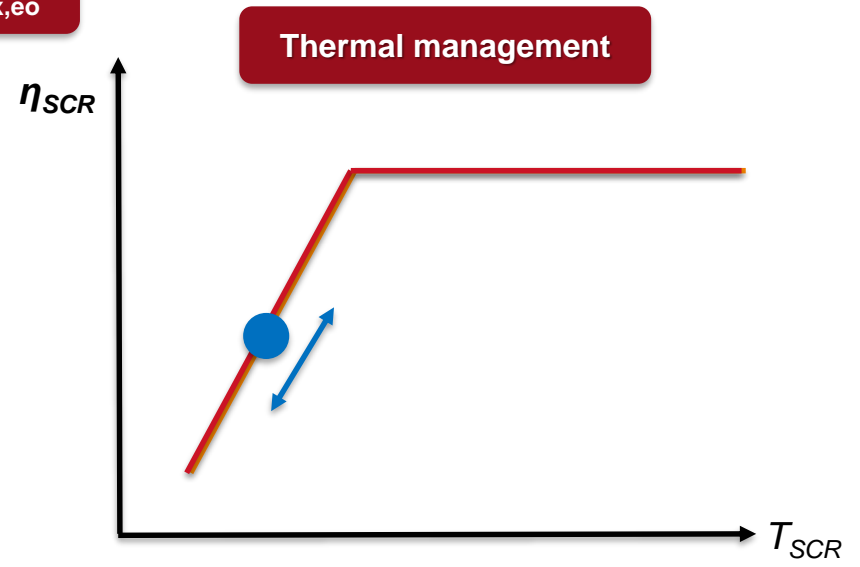
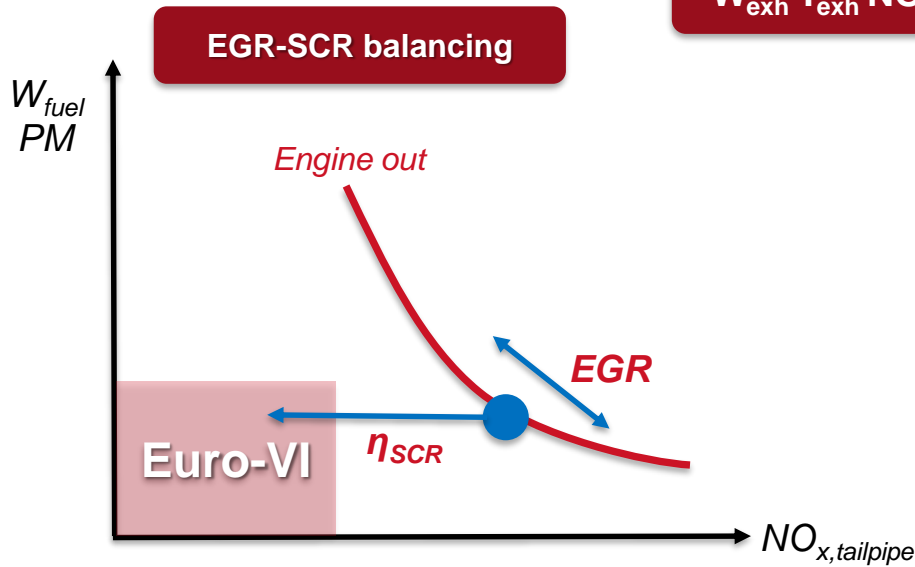
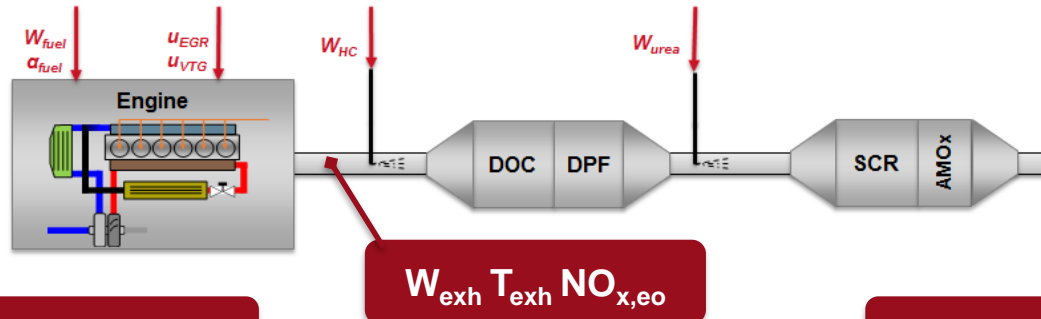
Towards Self-Learning Powertrains



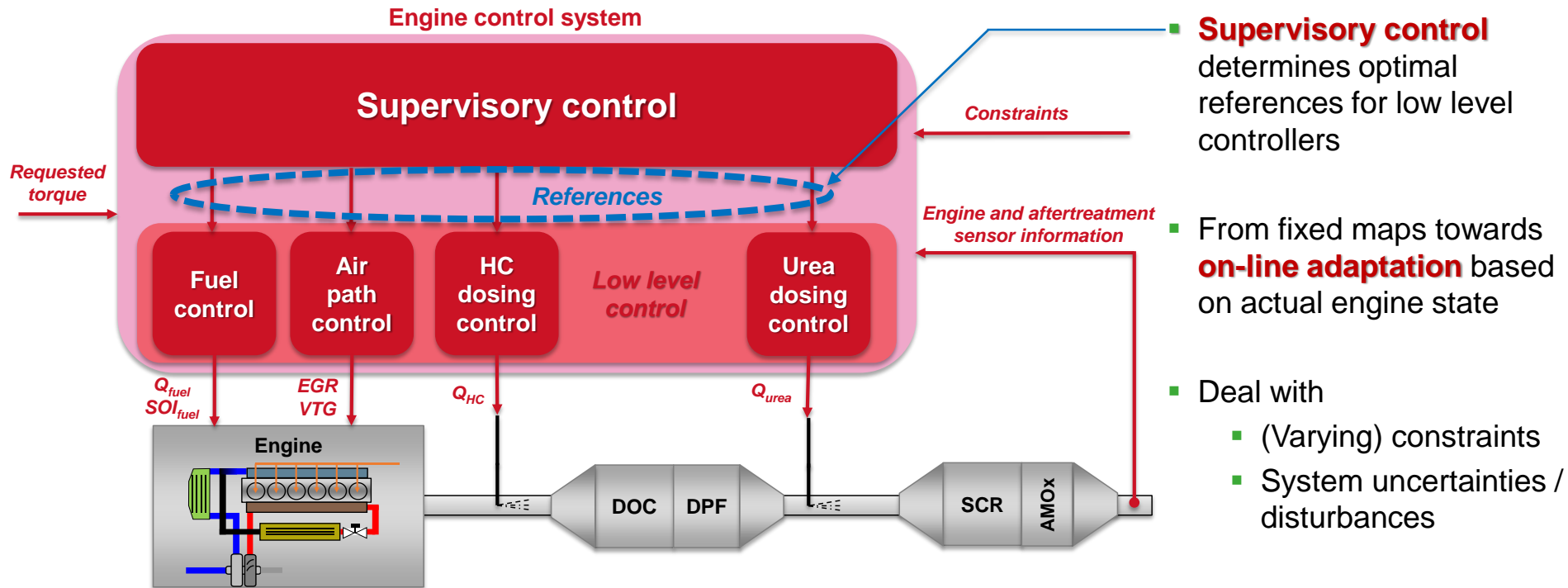
Emission management

Case study

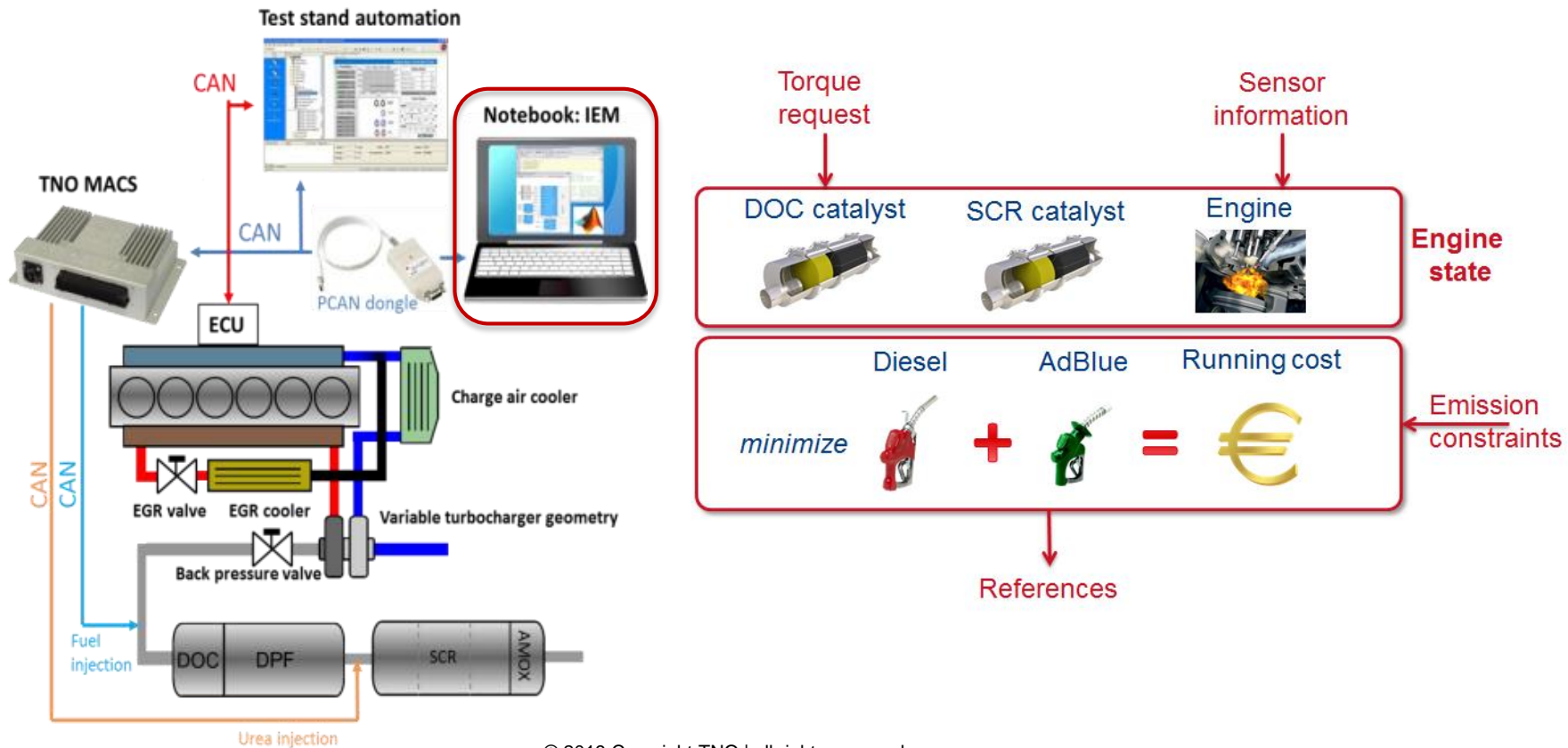
WHAT IS EMISSION MANAGEMENT?



INTEGRATED EMISSION MANAGEMENT

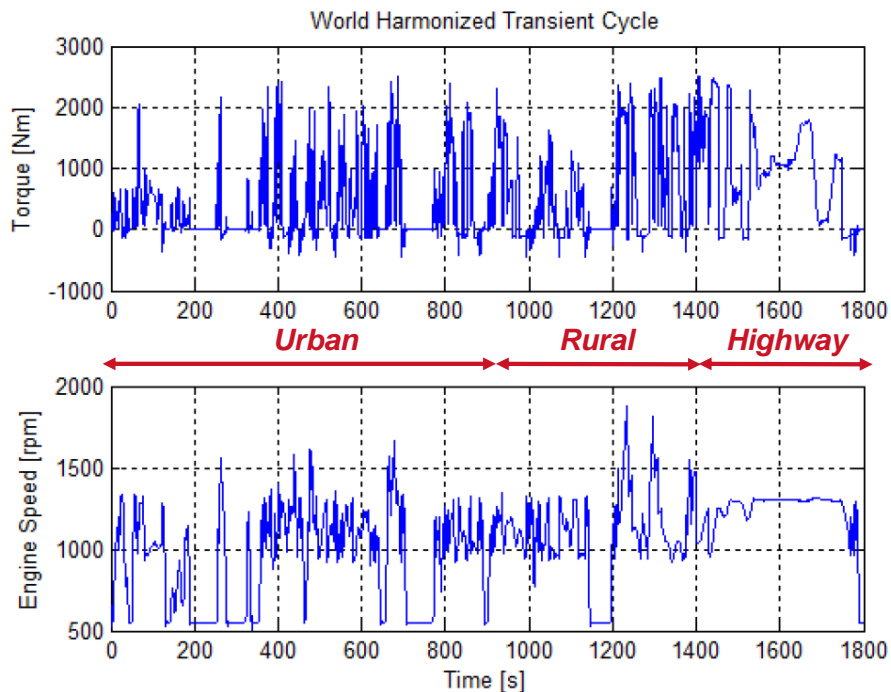


INTEGRATED EMISSION MANAGEMENT ON-LINE COST-BASED OPTIMIZATION



EXPERIMENTAL DEMONSTRATION

WORLD HARMONIZED TRANSIENT CYCLE (WHTC)



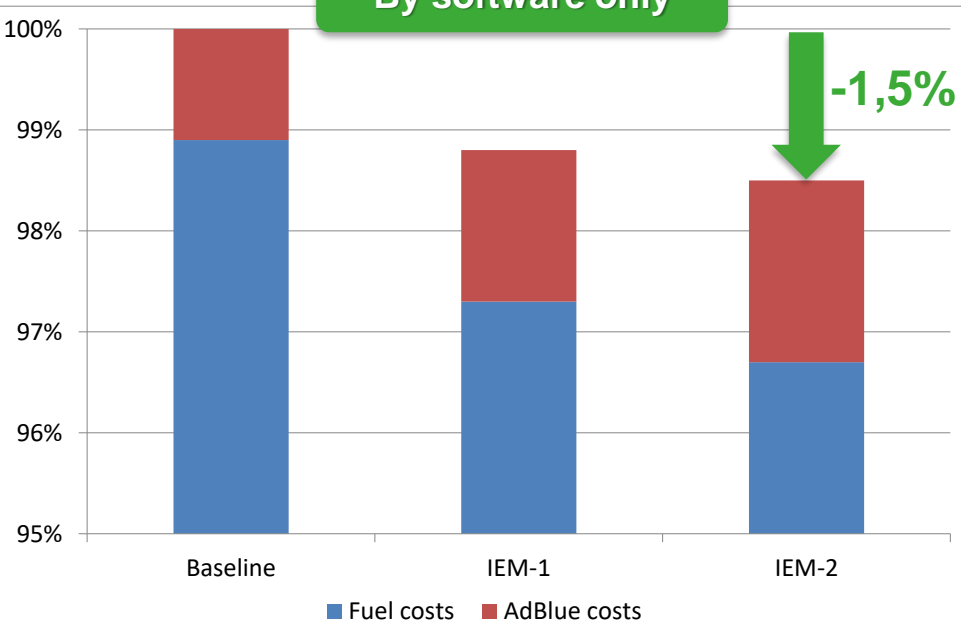
Comparison of:

- Production Euro-VI baseline strategy
- Two IEM strategies (**different λ_3 calibrations**)
 - IEM-1: NO_x EURO-VI compliant
 - IEM-2: low BSFC

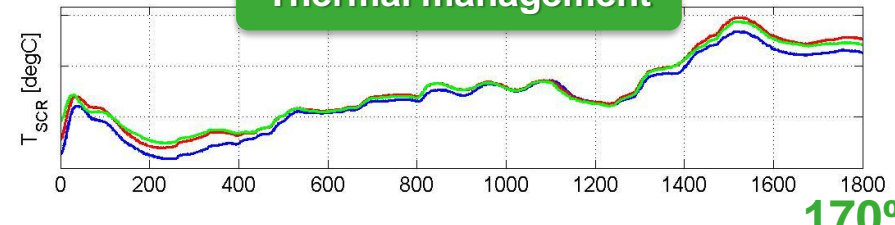
Focus on hot start WHTC

INTEGRATED EMISSION MANAGEMENT EXPERIMENTAL RESULTS

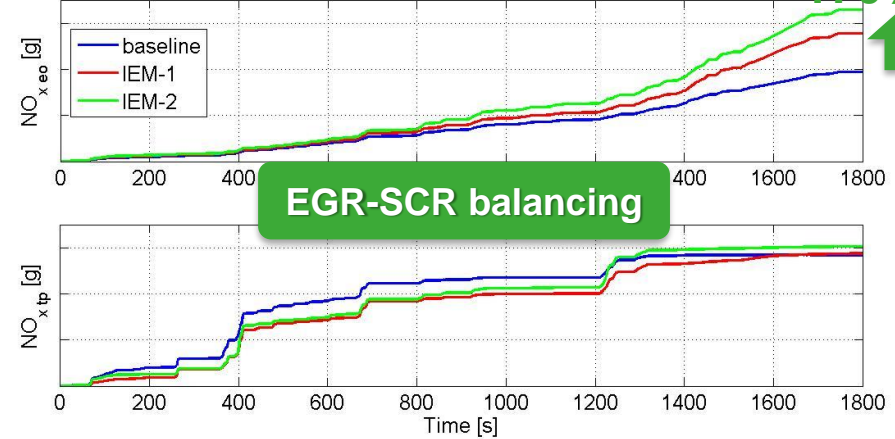
By software only



Thermal management



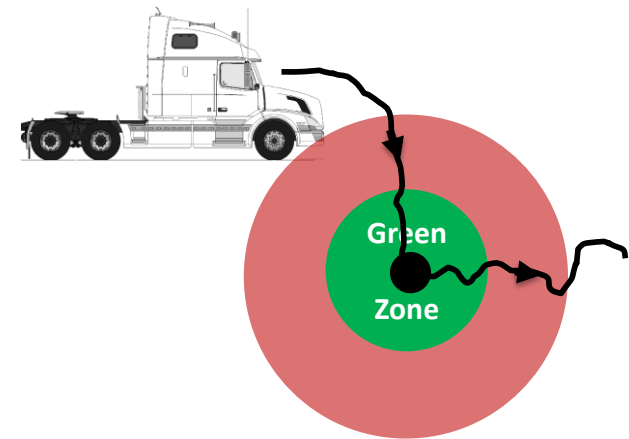
EGR-SCR balancing



OUTLOOK

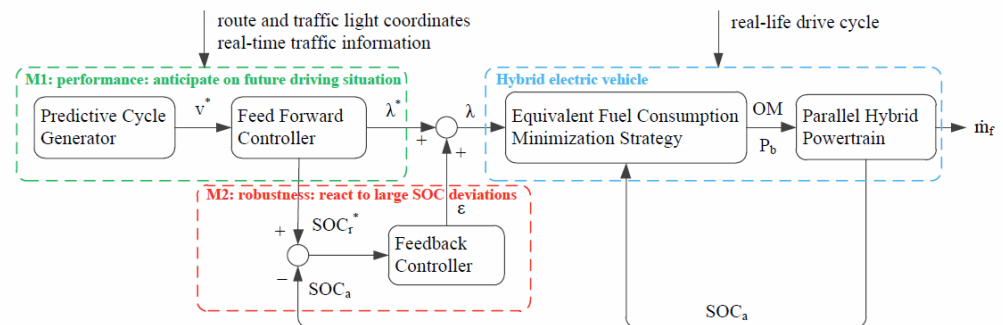
Challenges for hybrid-electric vehicles: **integrated energy & emission management**

- Frequent engine on/off
- Low temperature operating conditions for SCR system
- IEM approach can easily be extended:
 - Hybrid Electric Vehicles (HEV)
 - Waste Heat Recovery (WHR)

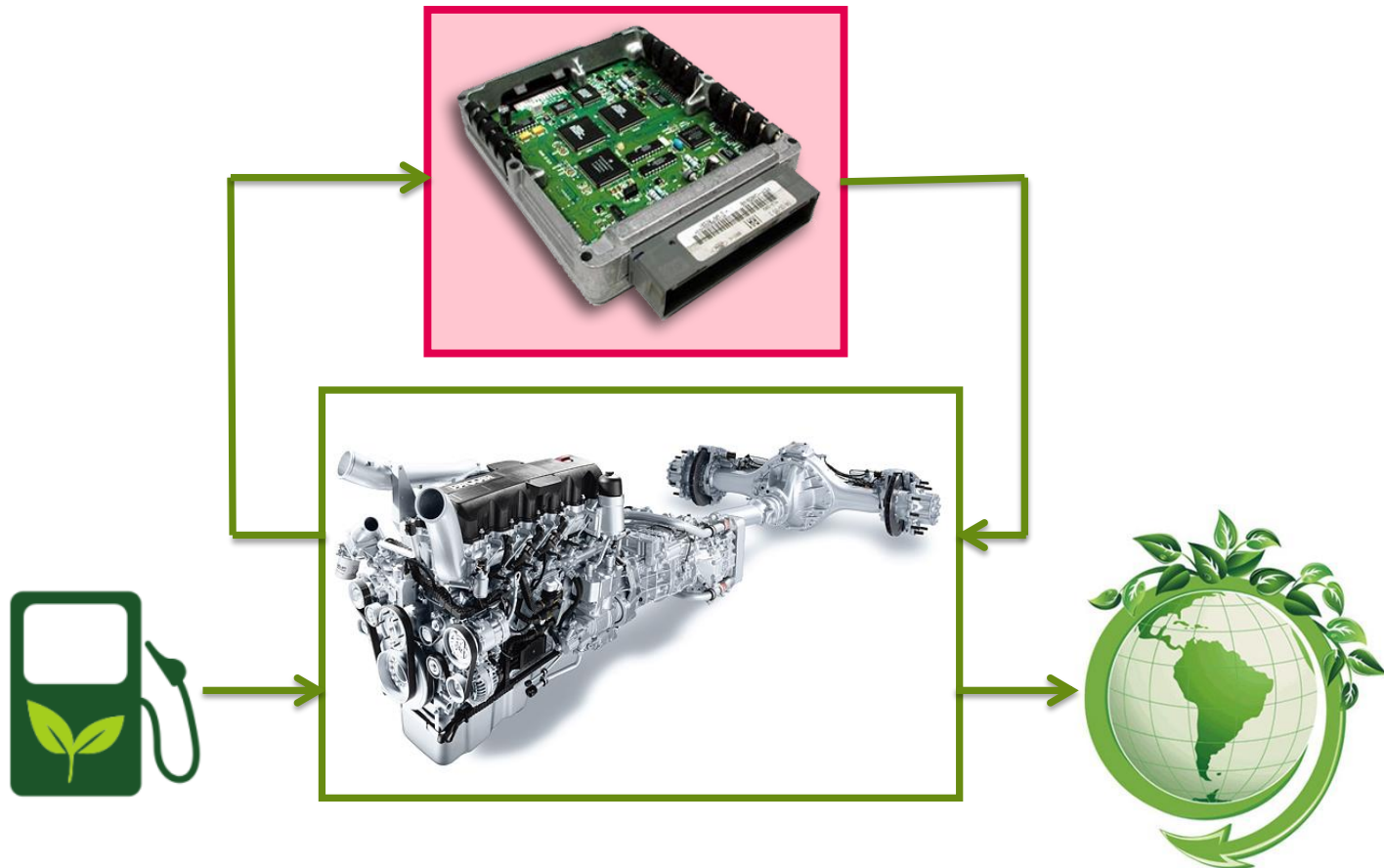


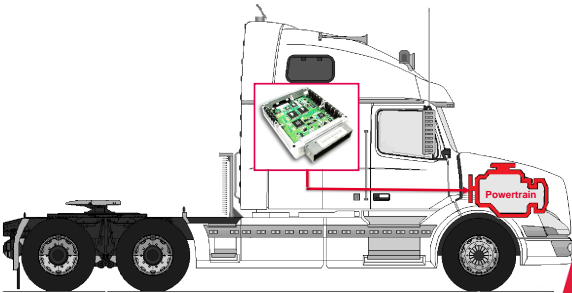
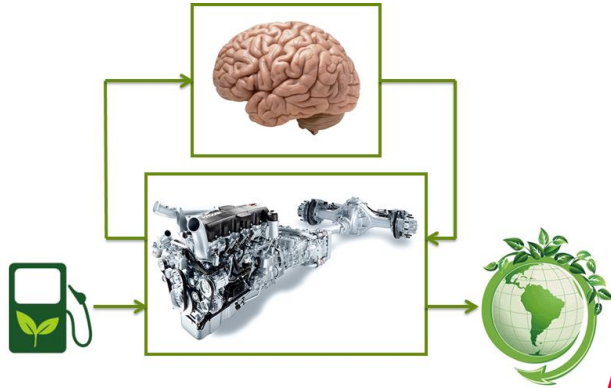
Opportunities for autonomous vehicles

- How to benefit from route, traffic, weather info?
 - Predictive control
 - Self-learning powertrain



New, exciting chapter for powertrain control





Thank you for your attention

Prof. Frank Willems

Visiting professor

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