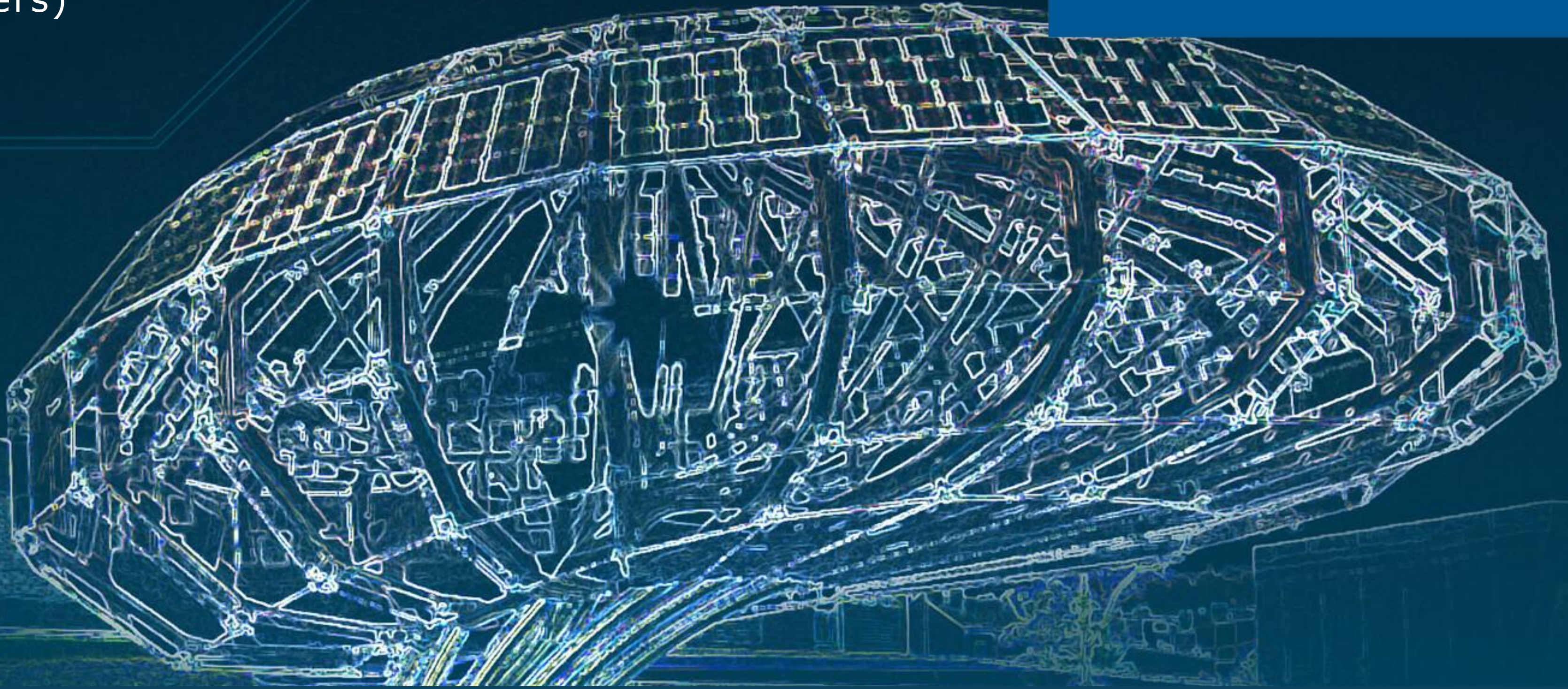
AVL List GmbH (Headquarters)



Highly Efficient EAS for Future Diesel Application

10. International Exhaust Gas and Particulate Emissions Forum

Wancura, Hadl, Wieser, Weißbäck, Krapf, Mitterecker

Public

Content

- Project Motivation
- Aftertreatment Layout
- Challenge to achieve lowest Emissions
- Development Results Vehicle
- Summary and Next steps

Content

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- **Aftertreatment Layout**
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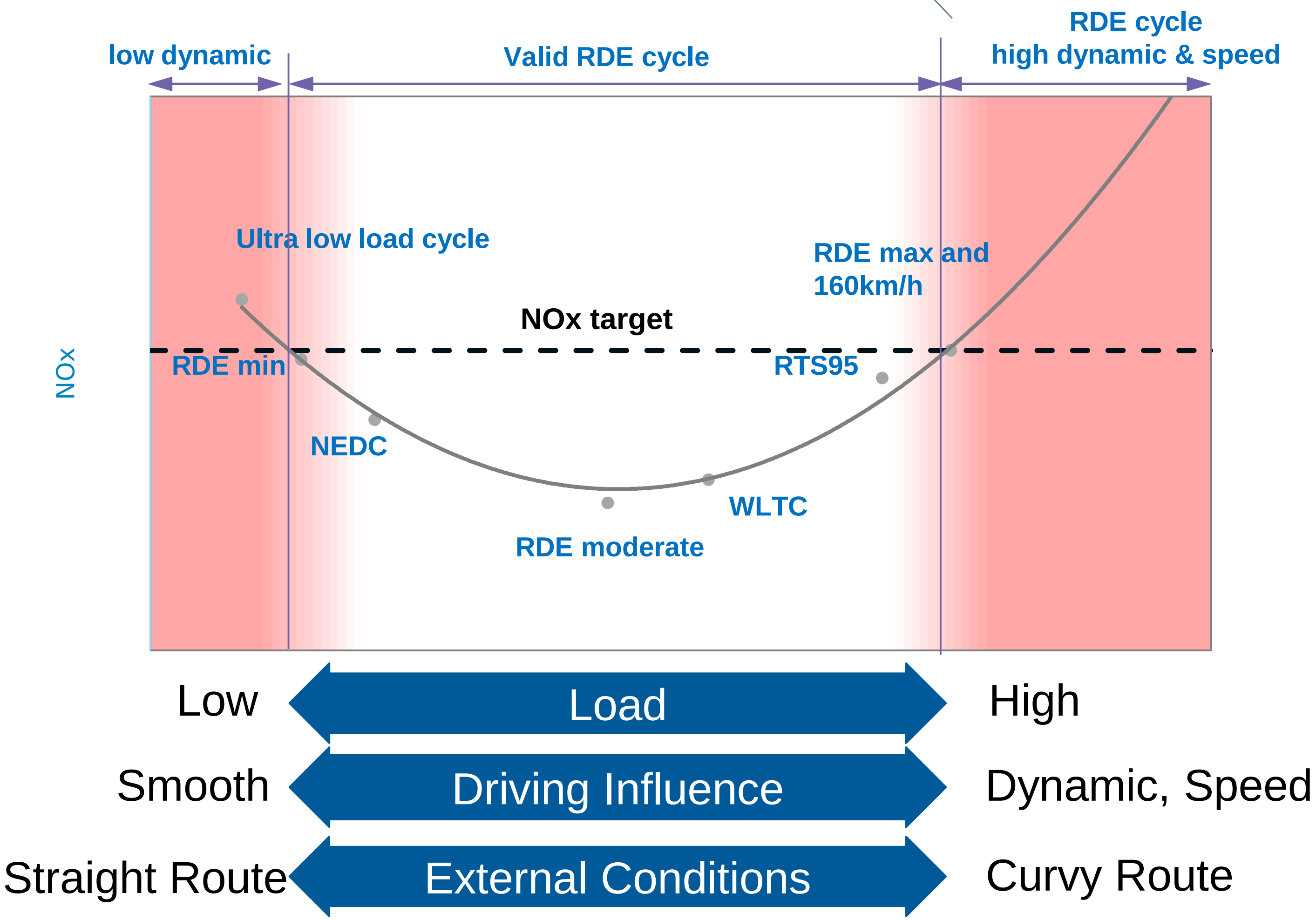
Project Motivation



Challenges

- ❑ Temperaturemanagement in low load city operations
- ❑ Aggressive driving style
- ❑ Too high temperature and space velocity for aftertreatement due to
  - ➢ Heavy weight, small engine
  - ➢ Long time high speed driving e.g. German Highway

➔ Borderline areas to be focused on

Project Motivation

GEN1

GEN2

GEN1
❑ Optimization for SULEV30
❑ Closed coupled SDPF
❑ ECAT as heating measure and LNT support

GEN2
❑ Base is GEN1
❑ EAS and engine adapted to RDE boundaries
❑ Additional 2nd Urea dosing for high load operation

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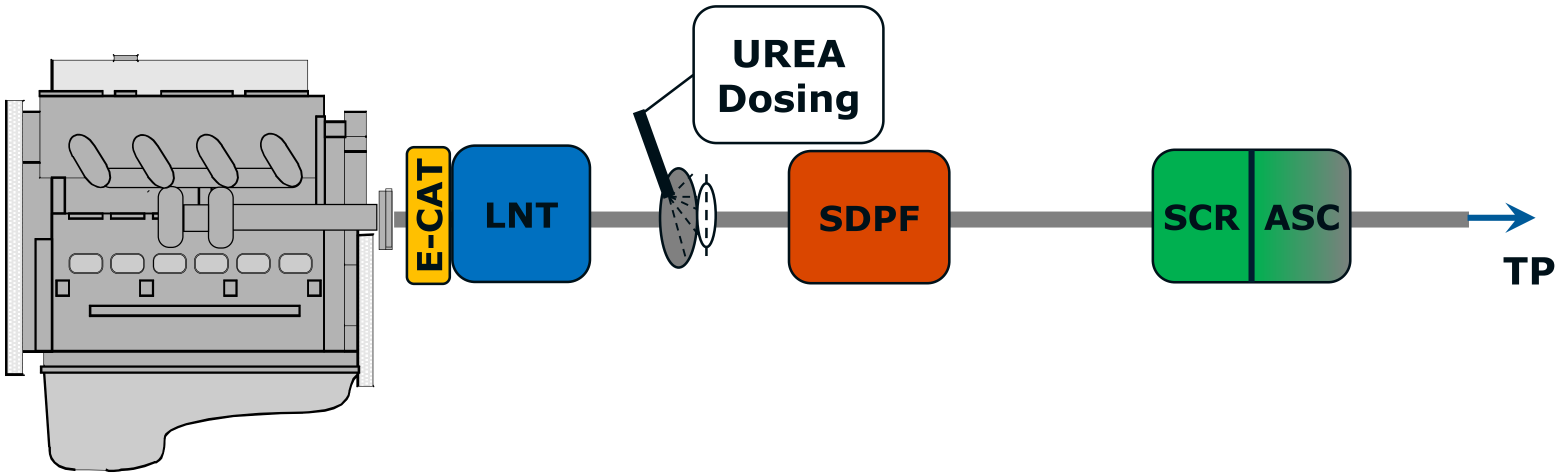
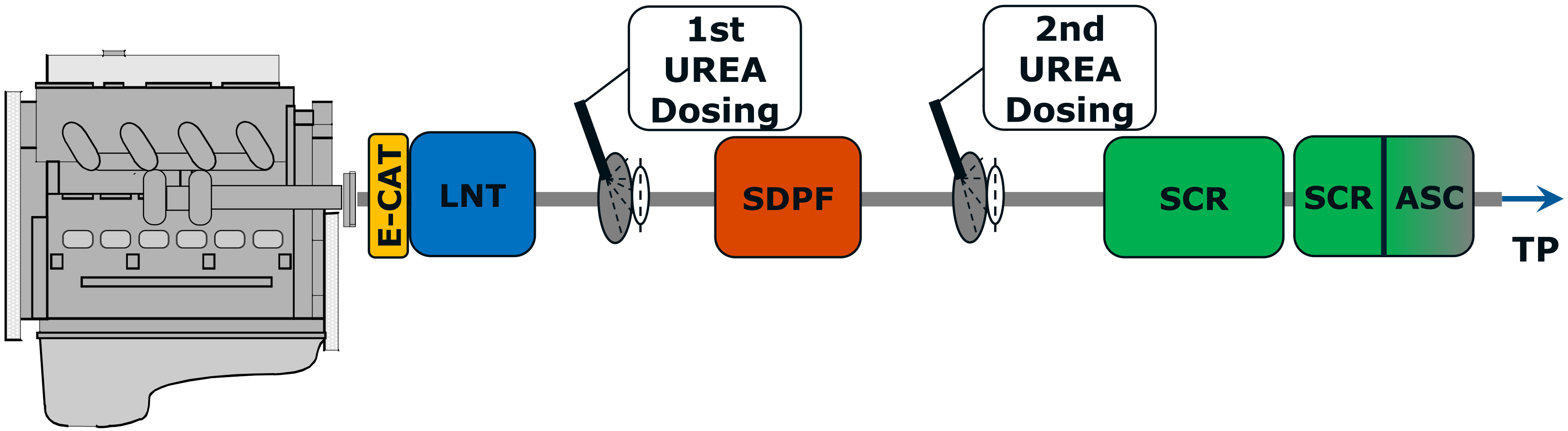
Aftertreatment Layout

Aftertreatment layout SULEV30 – GEN1

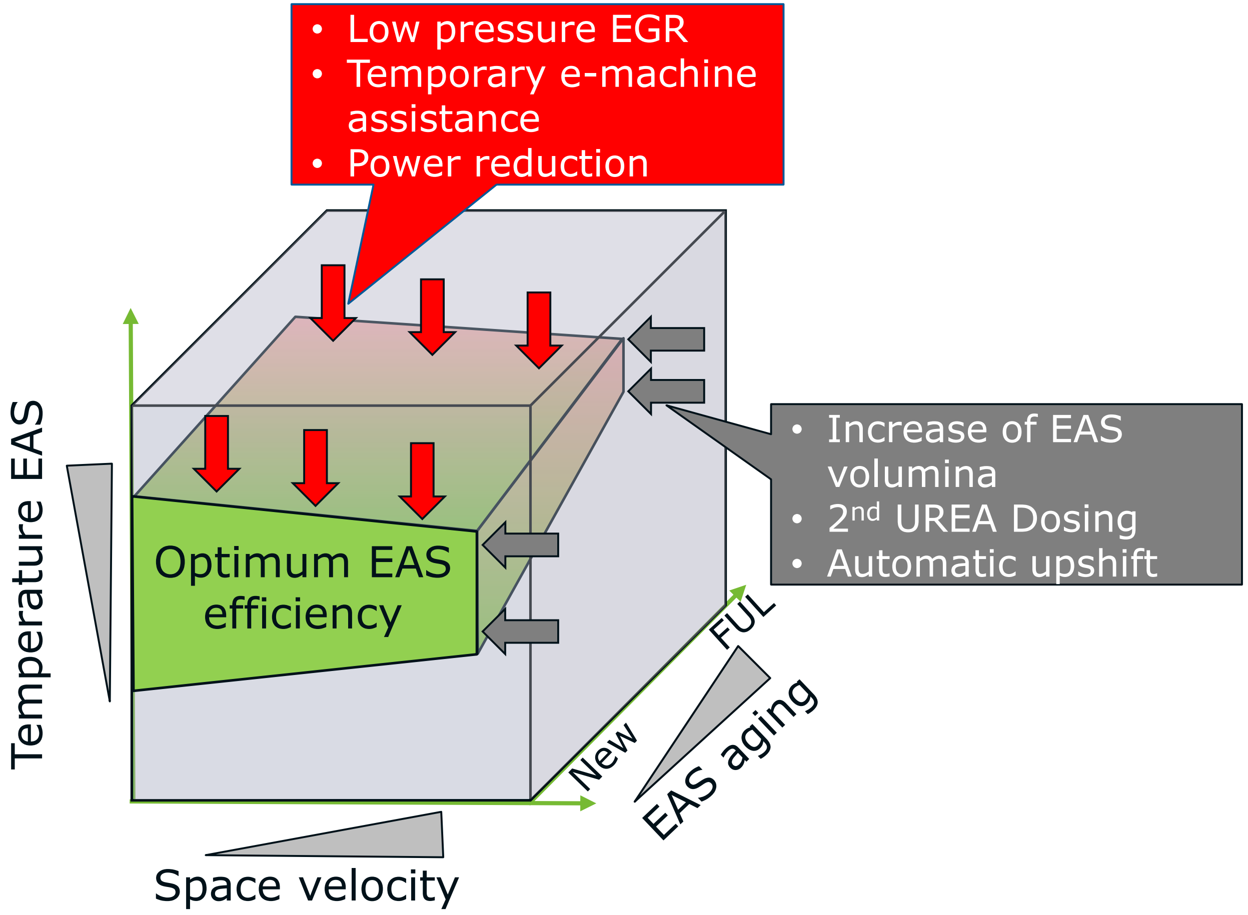


Aftertreatment layout with Dual Urea dosing – GEN2



Content

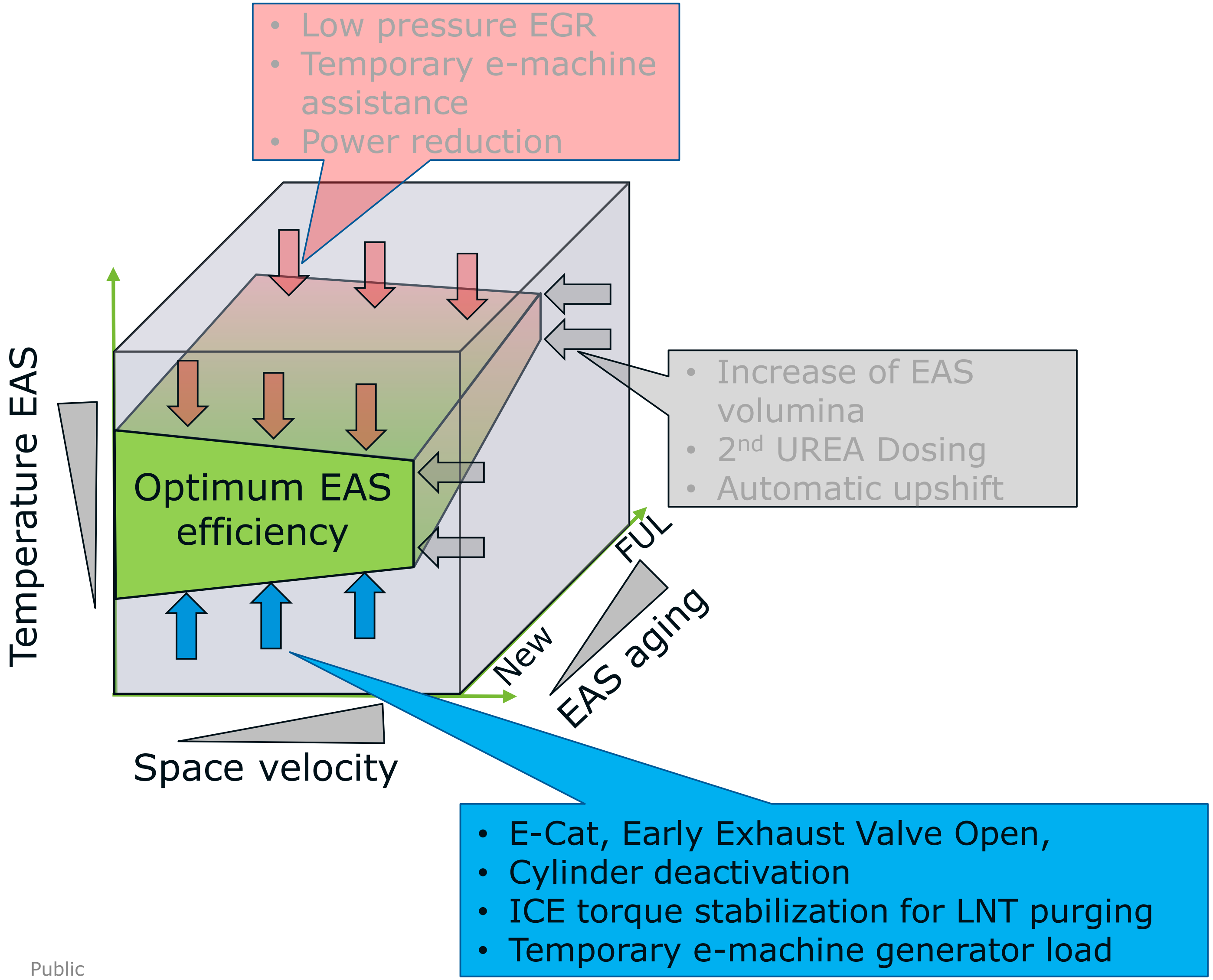
Challenge to achieve lowest Emissions



Major challenges:

- **High power and high mass flow**

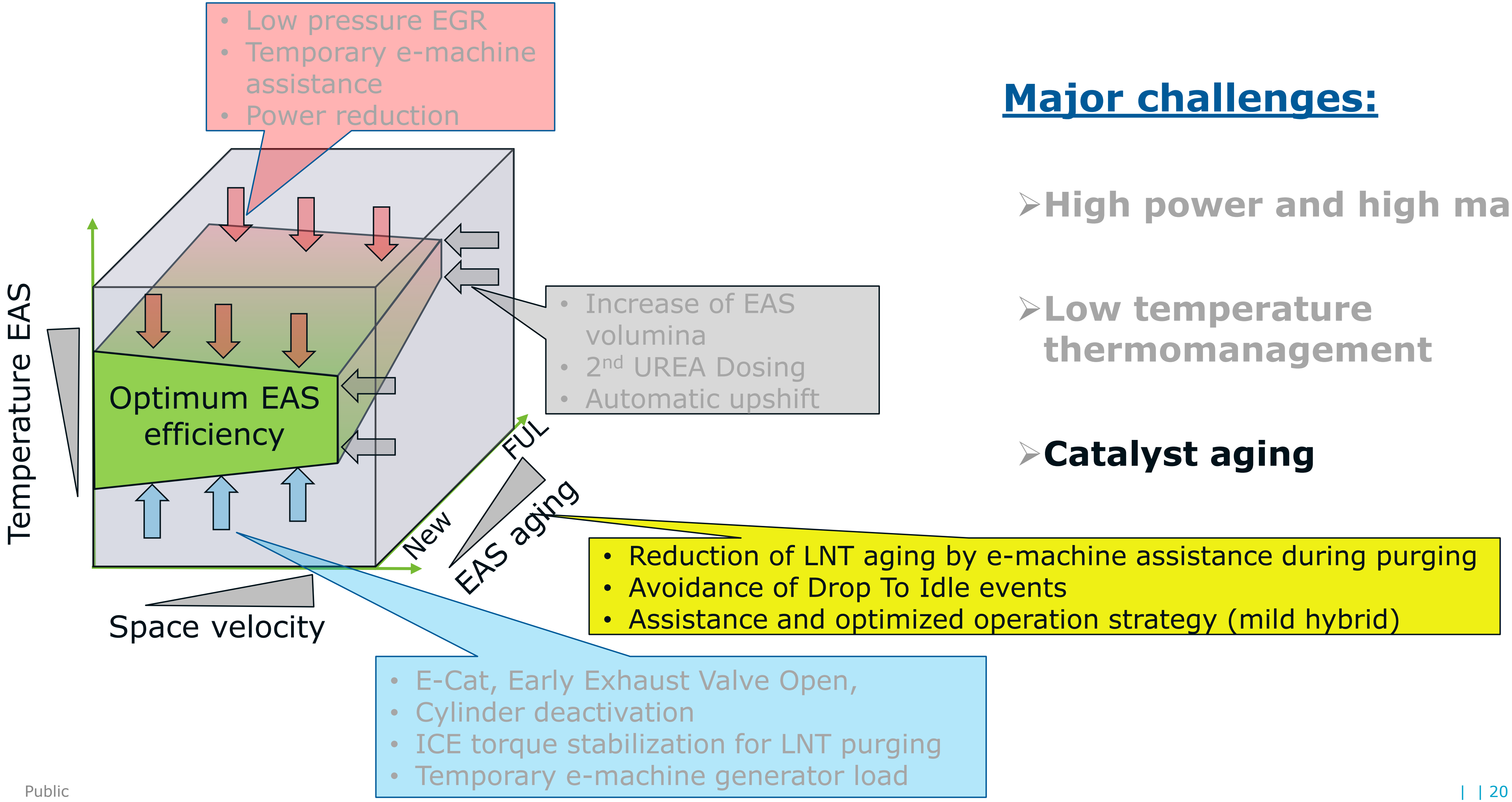
Challenge to achieve lowest Emissions



Major challenges:

- High power and high mass flow
- **Low temperature thermomanagement**

Challenge to achieve lowest Emissions

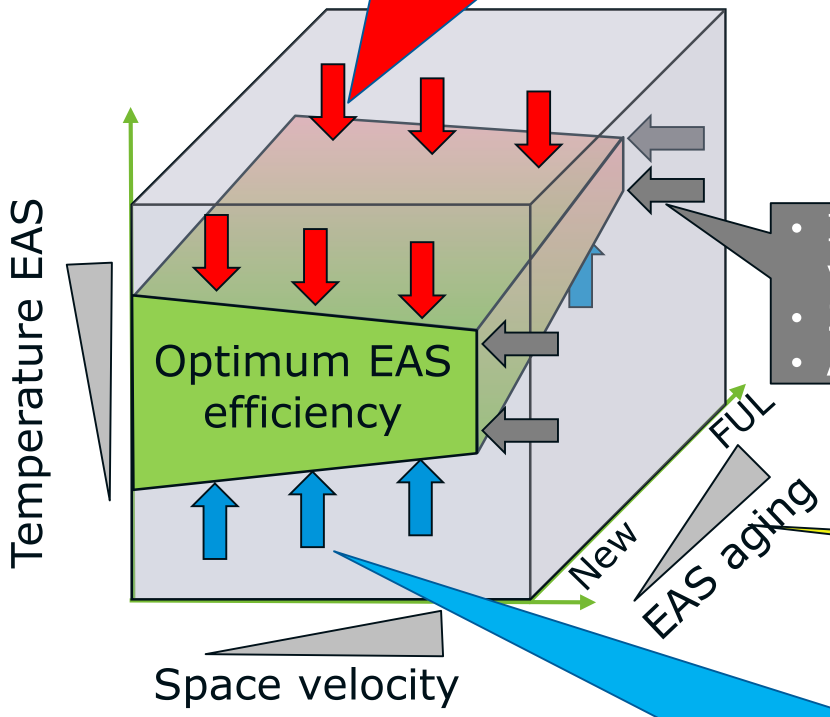


Major challenges:

- High power and high mass flow
- Low temperature thermomanagement
- **Catalyst aging**

Challenge to achieve lowest Emissions

- Low pressure EGR
- Temporary e-machine assistance
- Power reduction



- Increase of EAS volumina
- 2nd UREA Dosing
- Automatic upshift

- Reduction of LNT aging by e-machine assistance during purging
- Avoidance of Drop To Idle events
- Assistance and optimized operation strategy (mild hybrid)

- E-Cat, Early Exhaust Valve Open,
- Cylinder deactivation
- ICE torque stabilization for LNT purging
- Temporary e-machine generator load

Major challenges:

- **High power and high mass flow**
- **Low temperature thermomanagement**
- **Catalyst aging**

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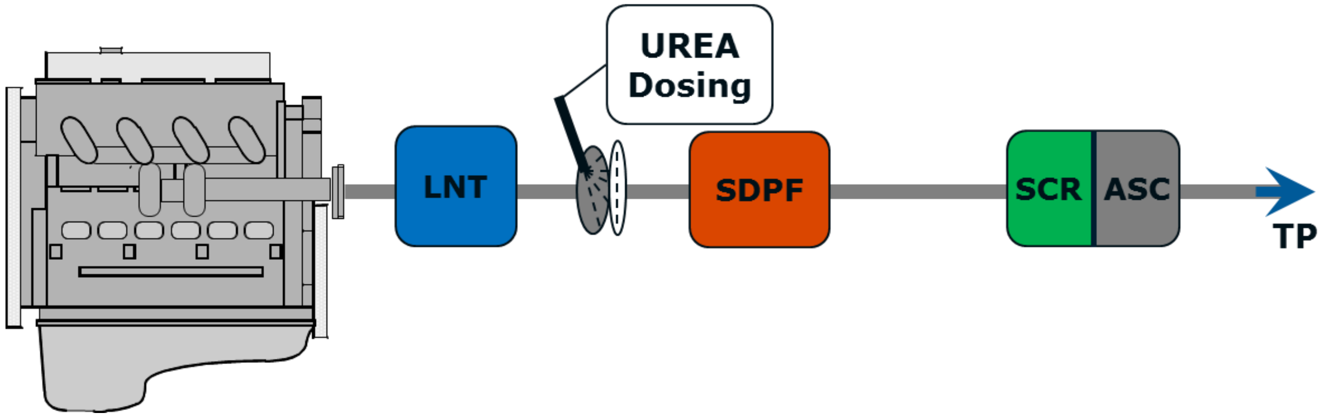
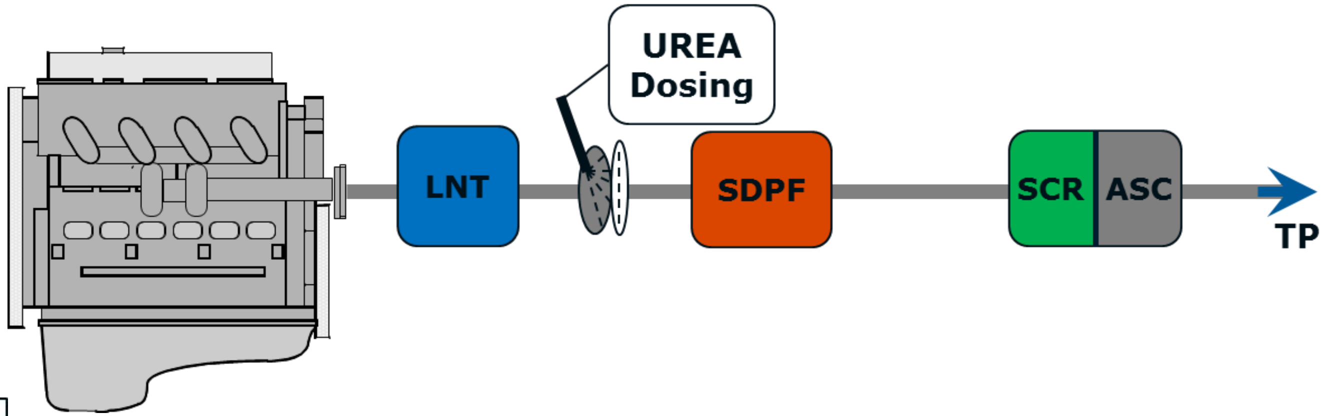
Development Results Vehicle

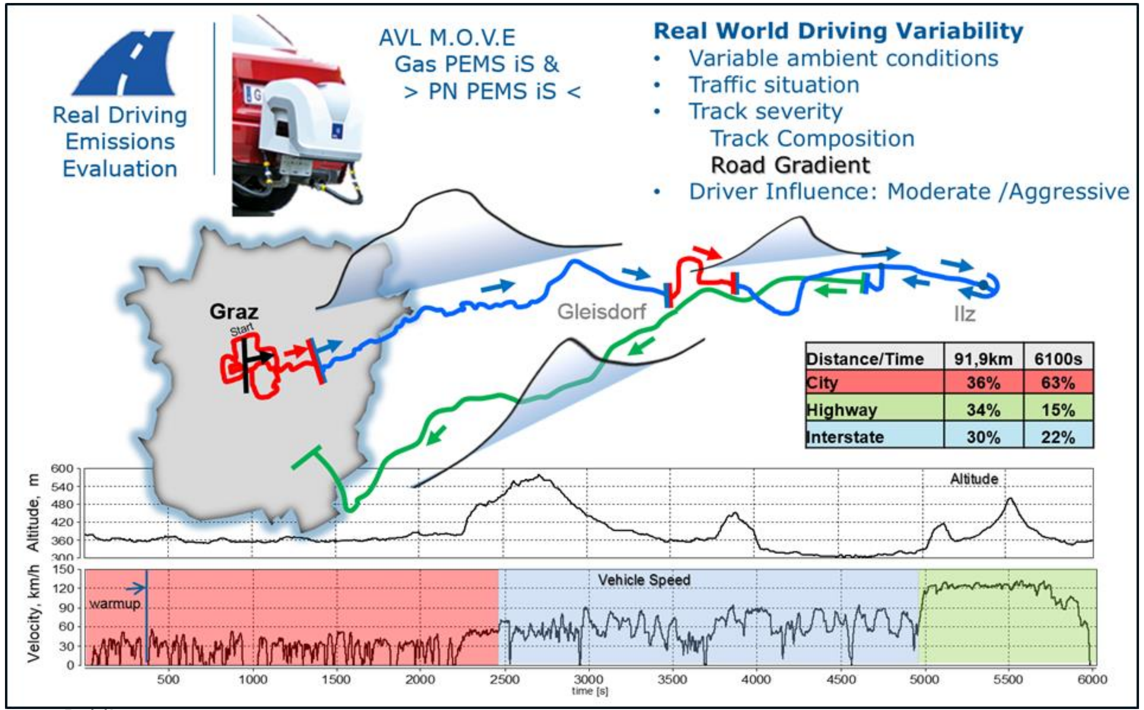


Single SCR Dosing without ECAT

Development Results Vehicle
Single SCR Dosing without ECAT

- Cycle boundaries
  - Moderate driven, v*a+ = 15.8m²/s³
  - Without ECAT
  - Single UREA dosing
  - Aged aftertreatment



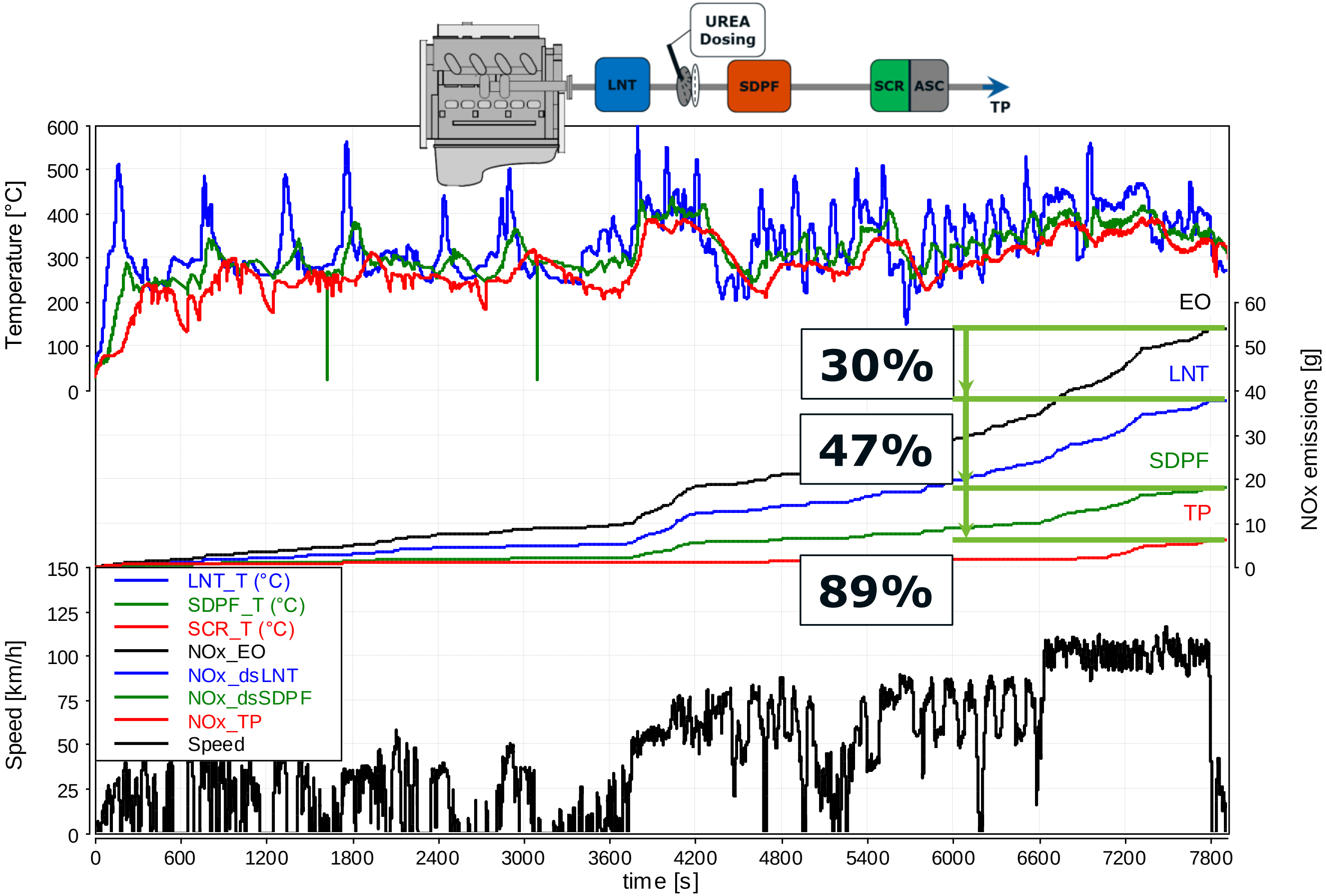


Distance/Time	91,9km	6100s
City	36%	63%
Highway	34%	15%
Interstate	30%	22%

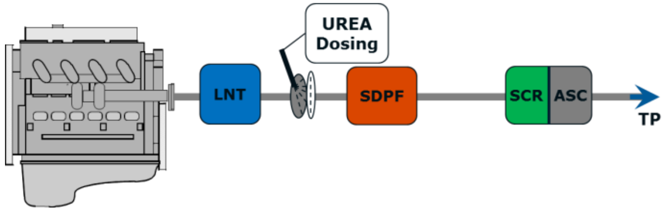
Development Results Vehicle
Single SCR Dosing without ECAT

- Cycle boundaries
  - Moderate driven, v*a+ = 15.8m²/s³
  - Without ECAT
  - Single UREA dosing
  - Aged aftertreatment

- Results:
  - The LNT can convert 30% of the total NOx, with the main focus in the city part
  - The SDPF is reaching a NOx conversion of 47%
  - The passive underfloor SCR/ASC can support the system to a total NOx conversion of 89%

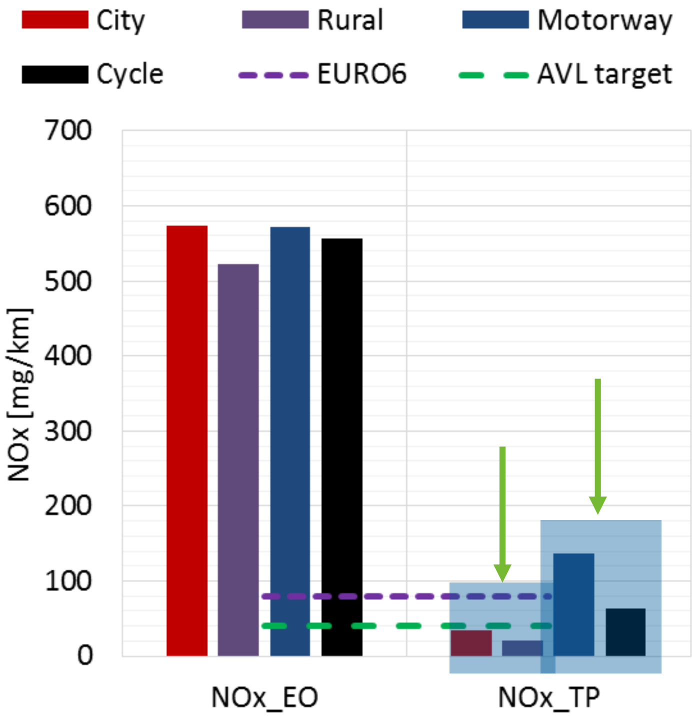


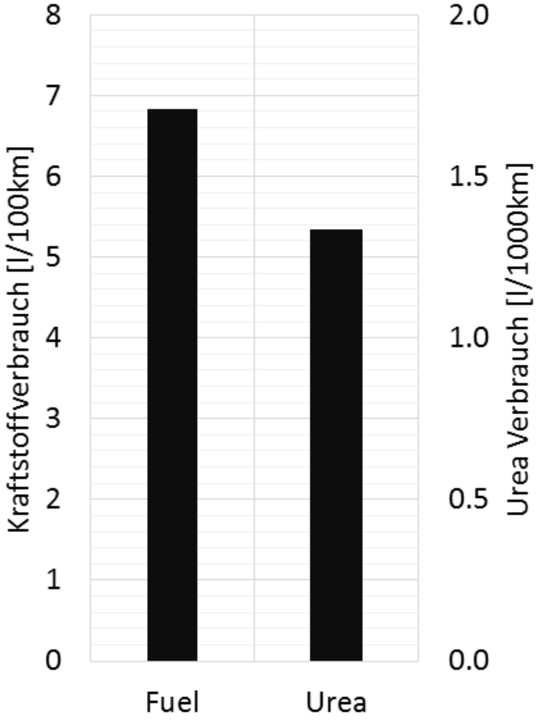
Development Results Vehicle
Single SCR Dosing without ECAT



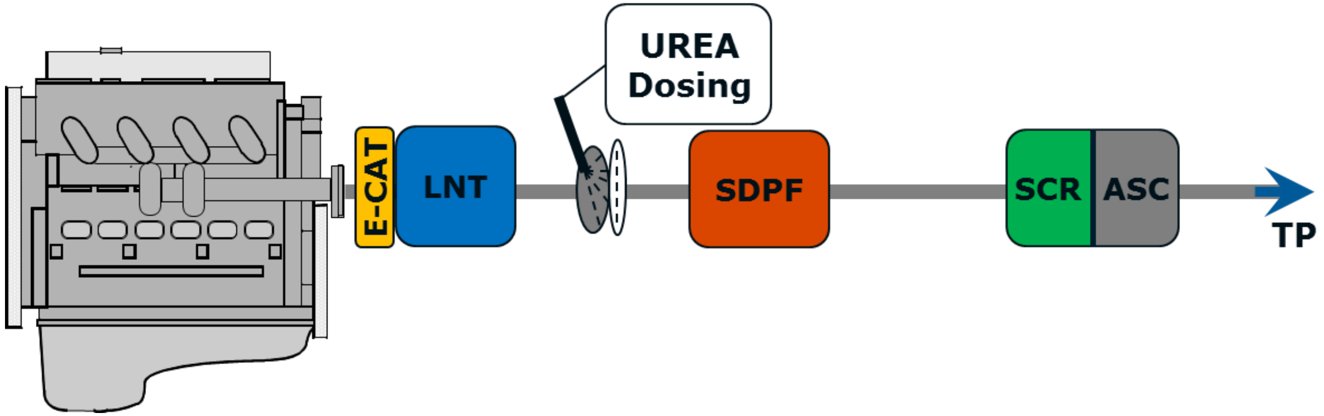
- Cycle boundaries
  - Moderate driven, v*a+ = 15.8m²/s³
  - Without ECAT
  - Single UREA dosing
  - Aged aftertreatment

- Results:
  - Without the usage of the ECAT in the city and rural part it is possible to reach a CF of 0.4
  - Due to the high temperature at the SDPF in the motorway part the CF is above 1.5
  - Fuel consumption 6.8 $^{l}/_{100km}$
  - Urea consumption 1.33 $^{l}/_{1000km}$





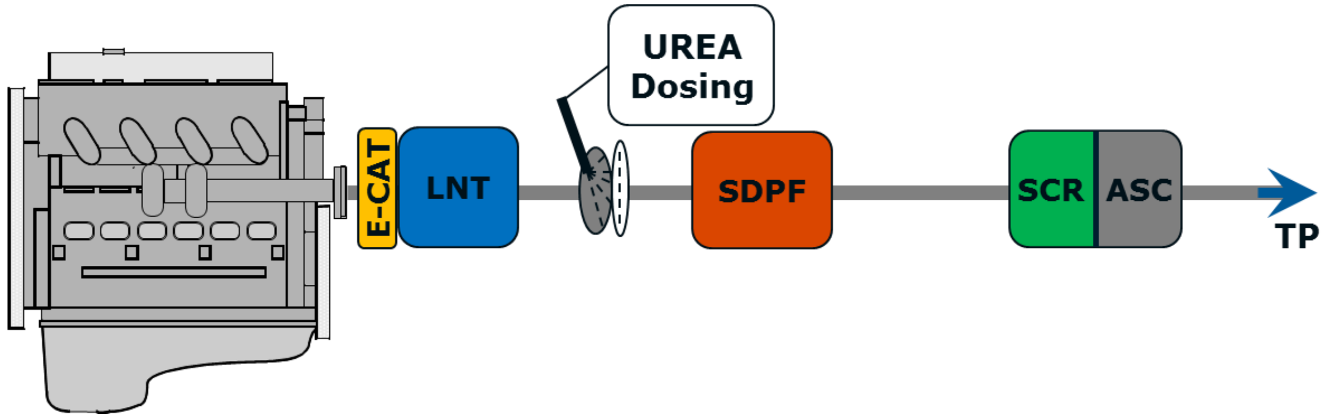
Development Results Vehicle



Single SCR Dosing with ECAT

Development Results Vehicle
Single SCR Dosing with ECAT

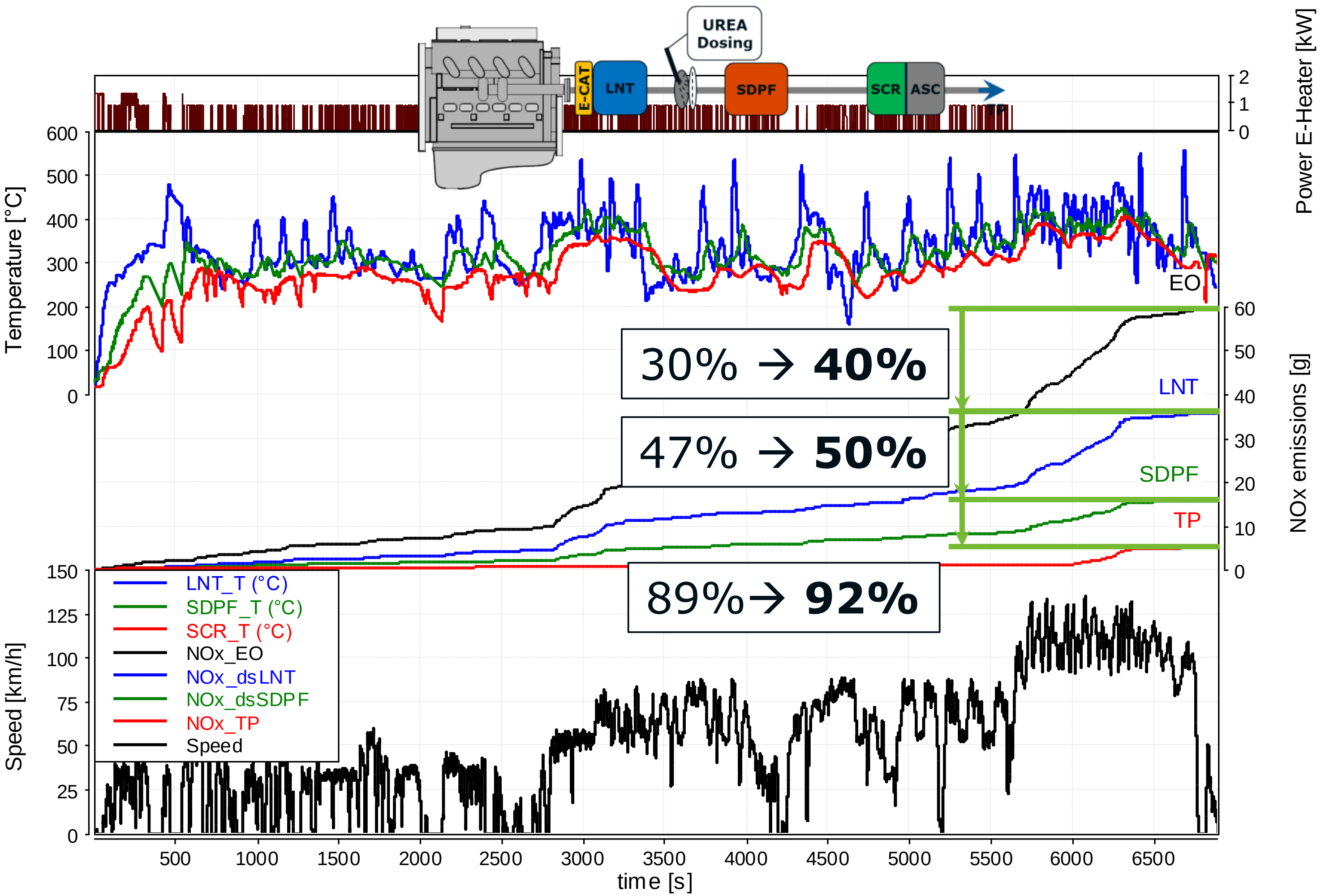
- Cycle boundaries
  - Moderate driven, v*a+ = 16.0m²/s³
  - **With** ECAT
  - Single UREA dosing
  - Aged aftertreatment



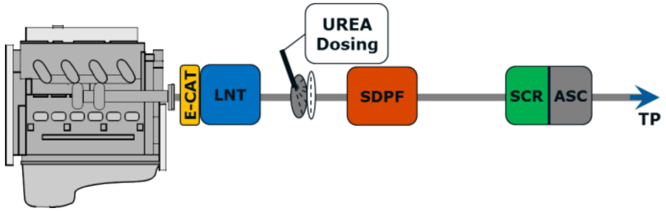
Development Results Vehicle
Single SCR Dosing with ECAT

- Cycle boundaries
  - Moderate driven, v*a+ = 16.0m²/s³
  - **With** ECAT
  - Single UREA dosing
  - Aged aftertreatment

- Results:
  - With the support of the ECAT the LNT can convert 40% of the total NOx, with the main focus in the city part
  - The SDPF is reaching a NOx conversion of 50%
  - The passive underfloor SCR/ASC can support the system to a total NOx conversion of 92%

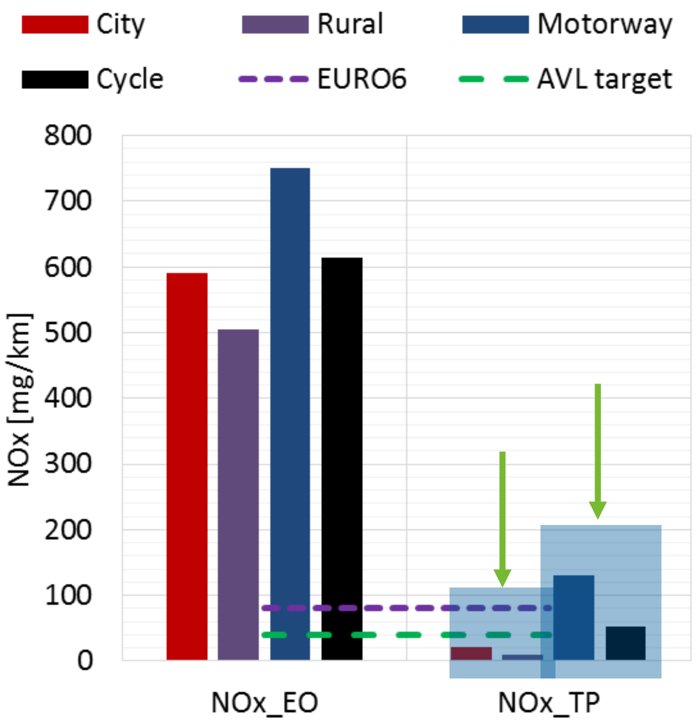


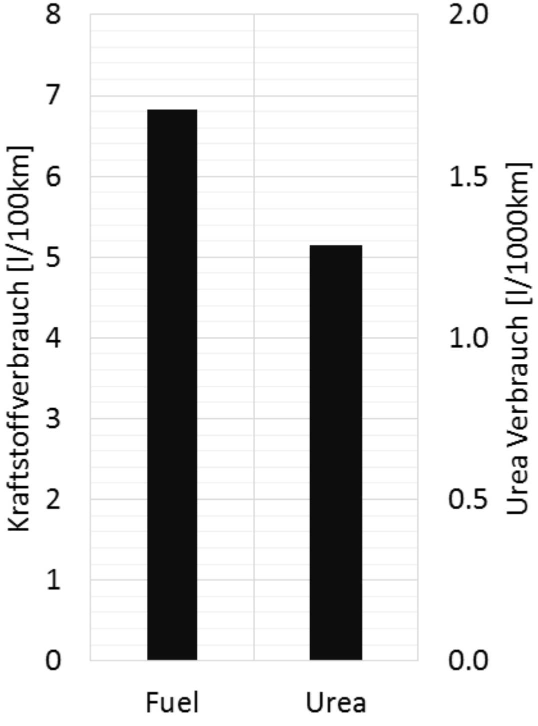
Development Results Vehicle
Single SCR Dosing with ECAT



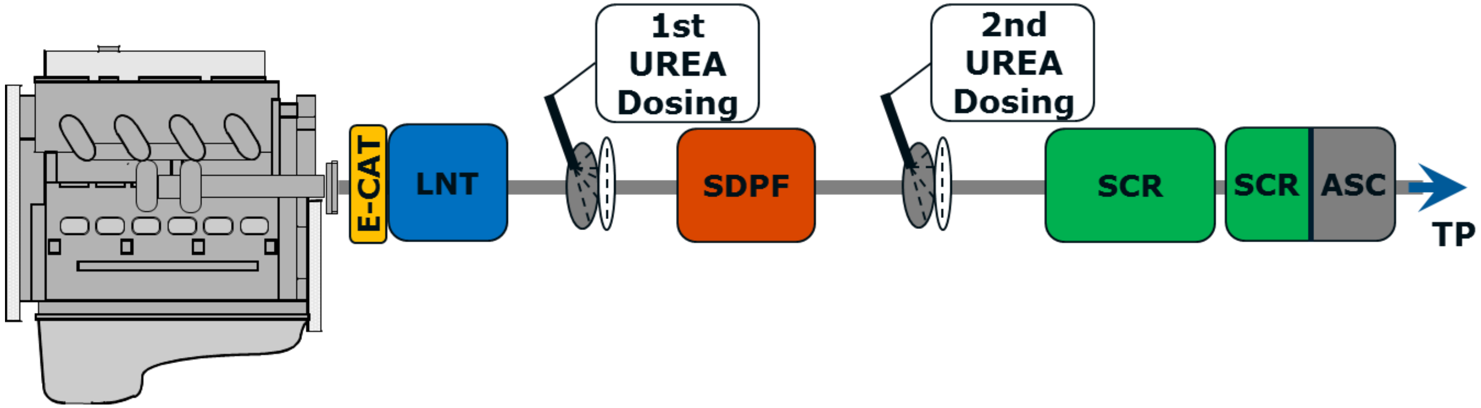
- Cycle boundaries
  - Moderate driven, v*a+ = 16.0m²/s³
  - **With** ECAT
  - Single UREA dosing
  - Aged aftertreatment

- Results:
  - The ECAT is improving the total NOx conversion in the city and in the rural part CF below 0.3
  - The ECAT is not able to change the behavior in the motorway part → CF is still above 1.5
  - Fuel consumption 6.6 $^{l}/_{100km}$
  - Urea consumption 1.29 $^{l}/_{1000km}$





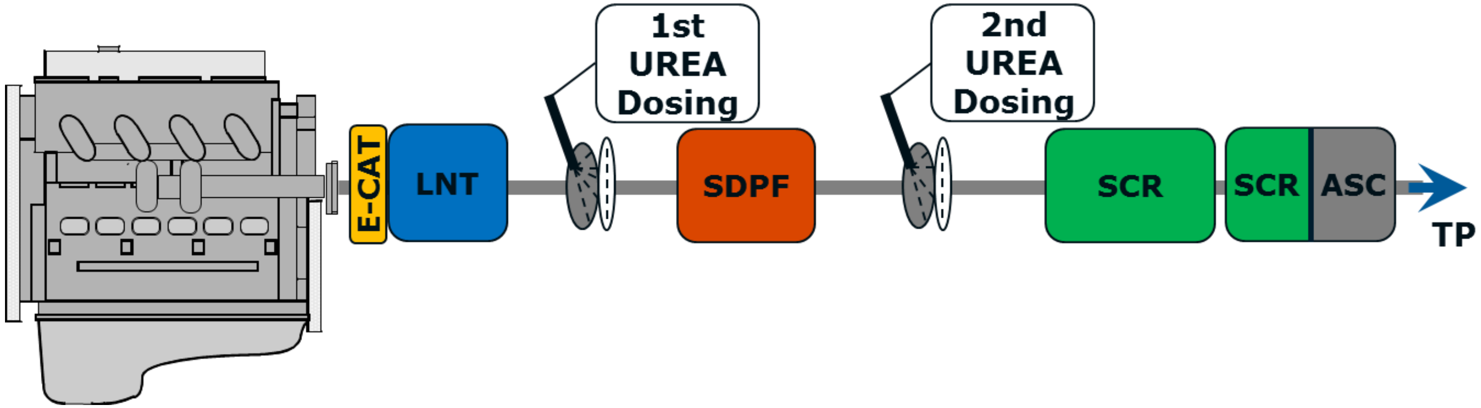
Development Results Vehicle



Dual UREA Dosing with ECAT

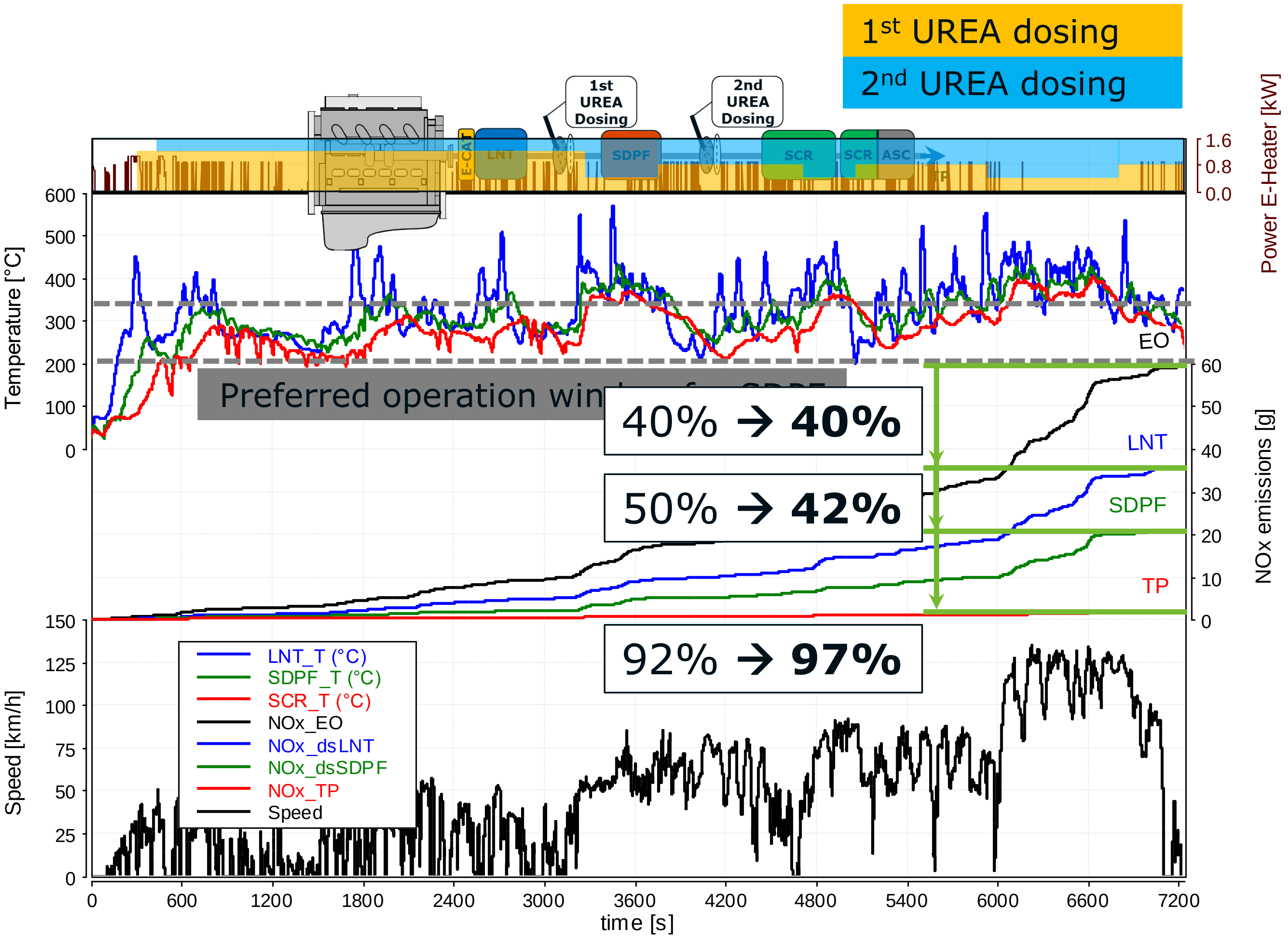
Development Results Vehicle
Dual UREA Dosing with ECAT

- Cycle boundaries
  - Moderate driven, v*a+ = 15.0m²/s³
  - **With** ECAT
  - **Dual** UREA dosing
  - Aged aftertreatment

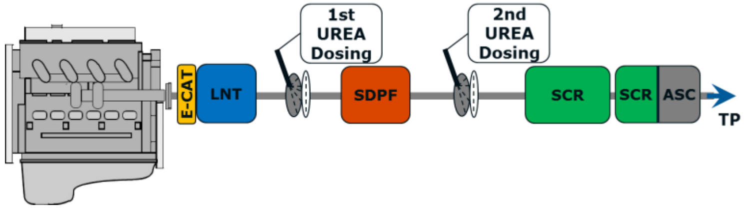


Development Results Vehicle
Dual UREA Dosing with ECAT

- Cycle boundaries
  - Moderate driven, v*a+ = 15.0m²/s³
  - **With** ECAT
  - **Dual** UREA dosing
  - Aged aftertreatment
- Results:
  - The LNT performance is unchanged by using the 2nd urea dosing → 40%
  - In the rural part the SDPF dosing is reduced and by that the conversion is reduced to 42%
  - By improving the NOx conversion in the motorway part the overall NOx conversion is 97%

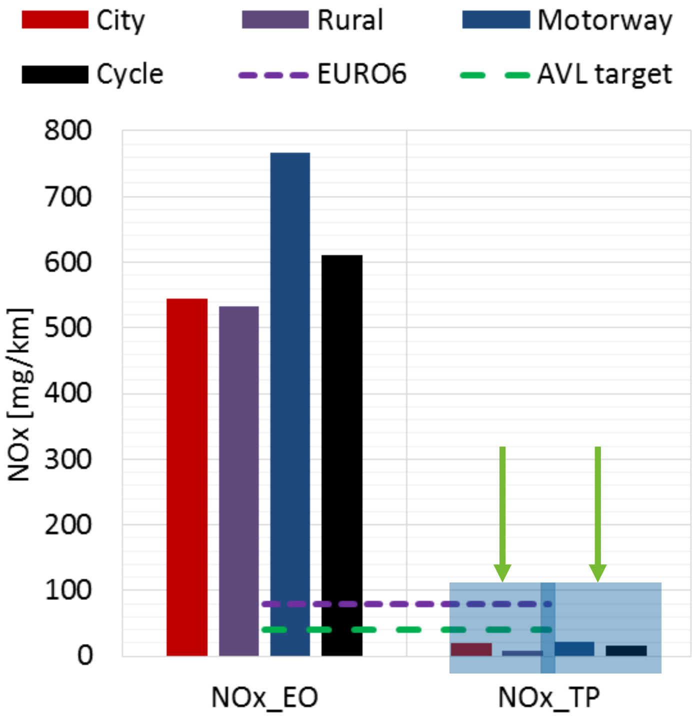


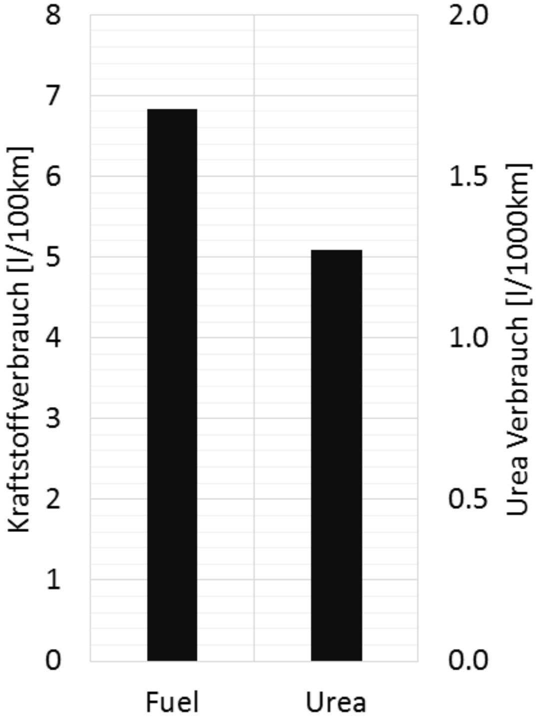
Development Results Vehicle
Dual UREA Dosing with ECAT



- Cycle boundaries
  - Moderate driven, v*a+ = 15.0m²/s³
  - **With** ECAT
  - **Dual** UREA dosing
  - Aged aftertreatment

- Results:
  - The NOx conversion in the city and rural part is not effected by the second dosing unite → CF still below 0.3
  - With the second dosing unite in the underfloor a CF below 0.3 is possible
  - Fuel consumption 6.6 $^{l}/_{100km}$
  - Urea consumption 1.27 $^{l}/_{1000km}$





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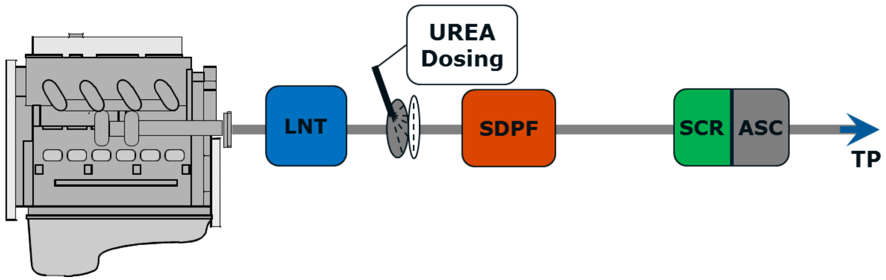
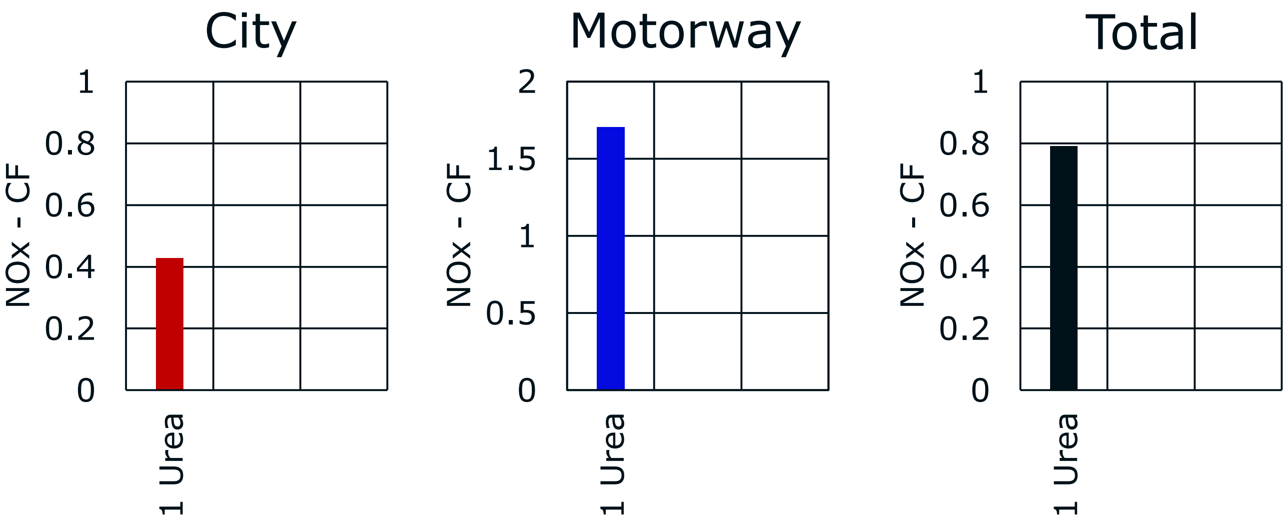
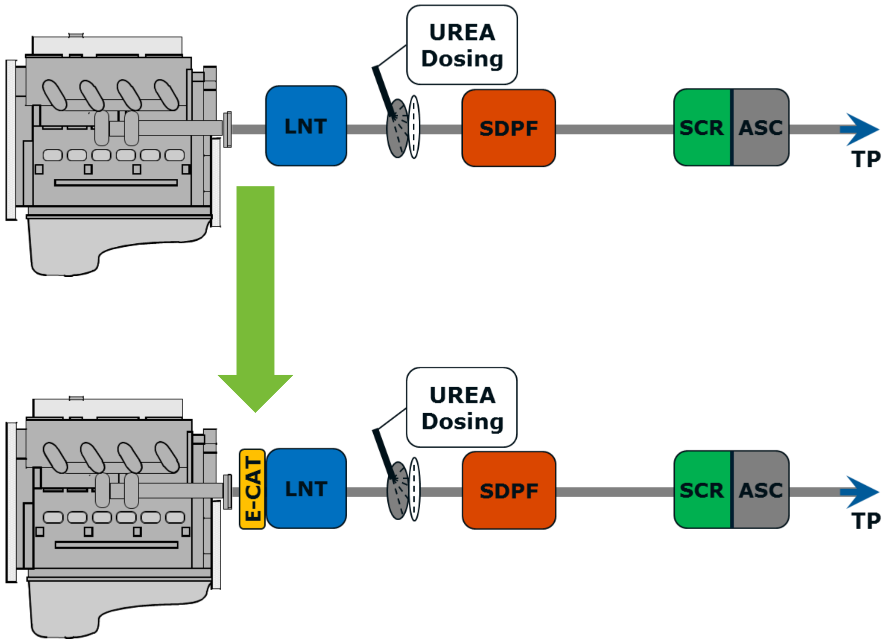
Summary
Development Results

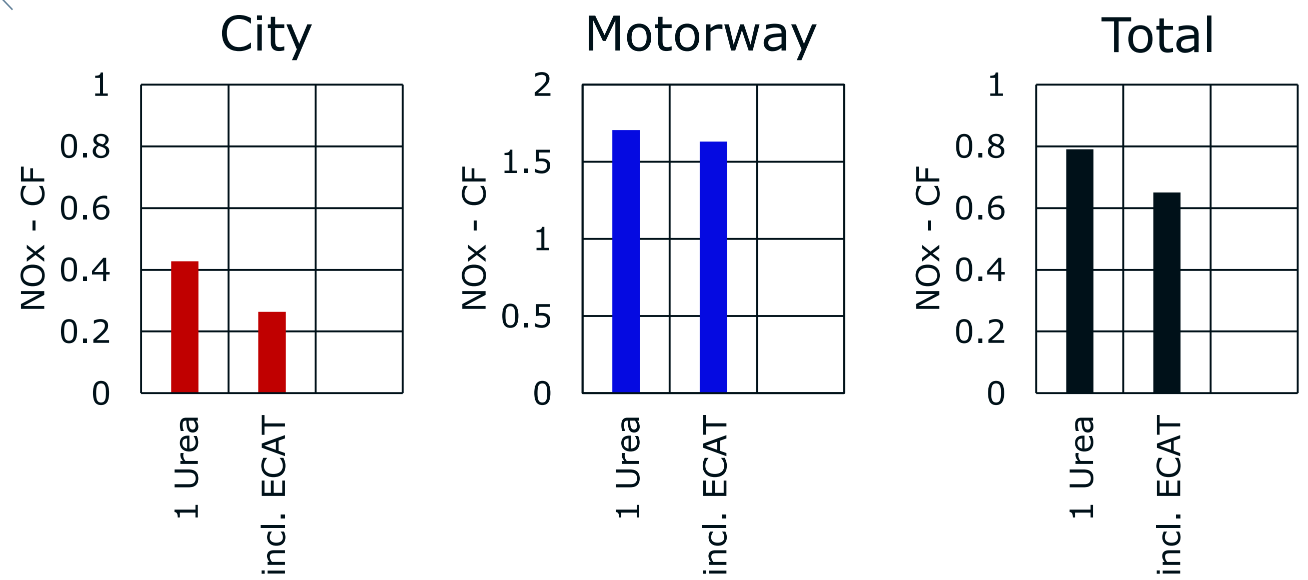




- **Without the ECAT → CF 0.8**

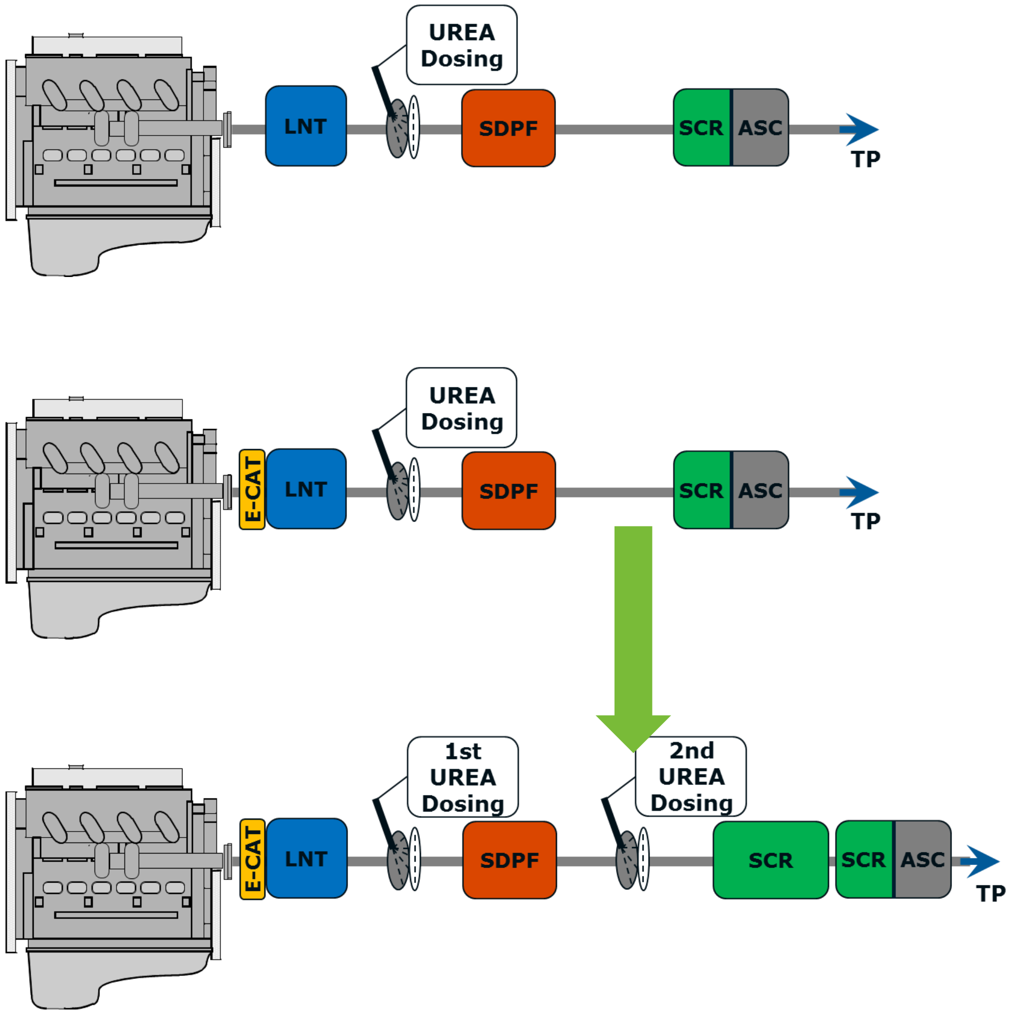
Summary
Development Results

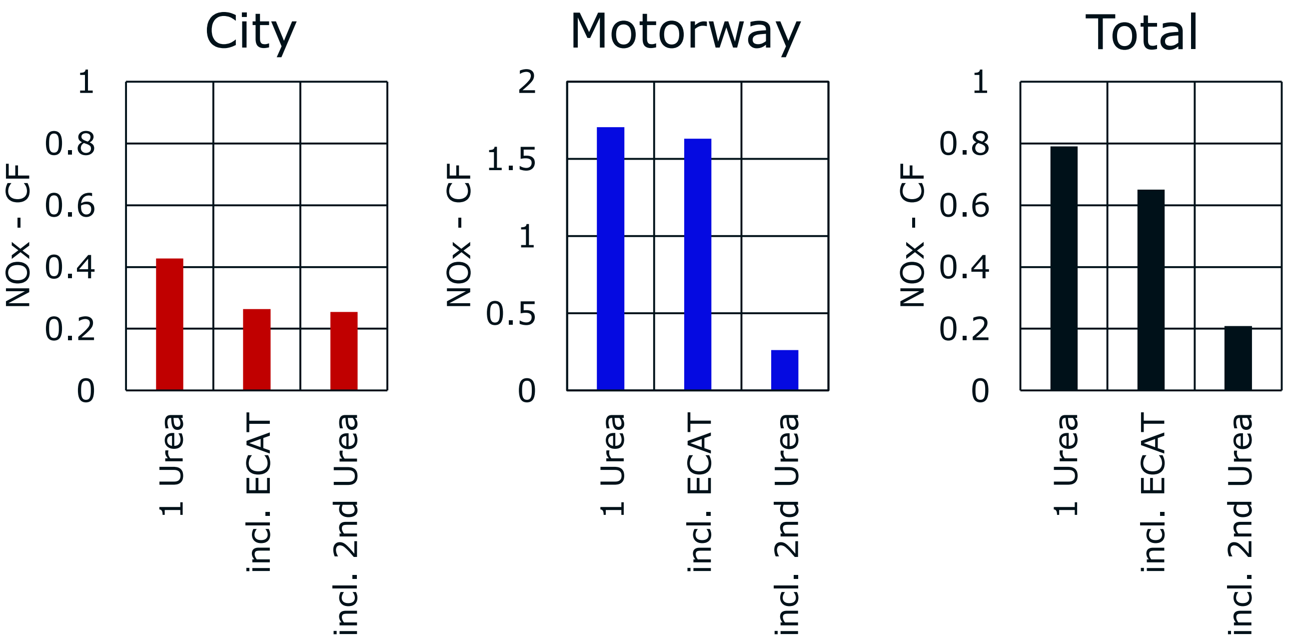




- **Without the ECAT → CF 0.8**
- **Including the ECAT → CF 0.7**

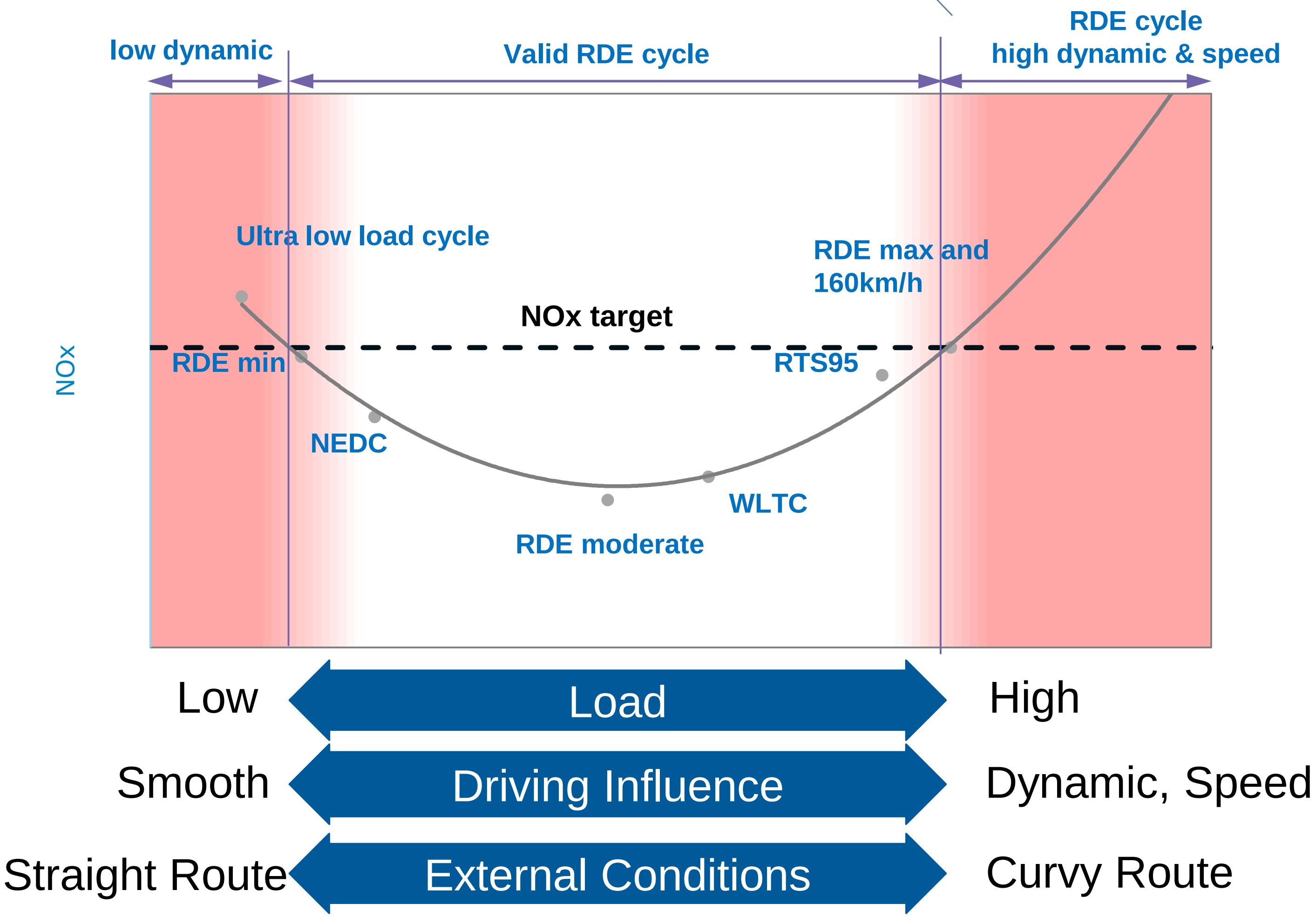
Summary
Development Results





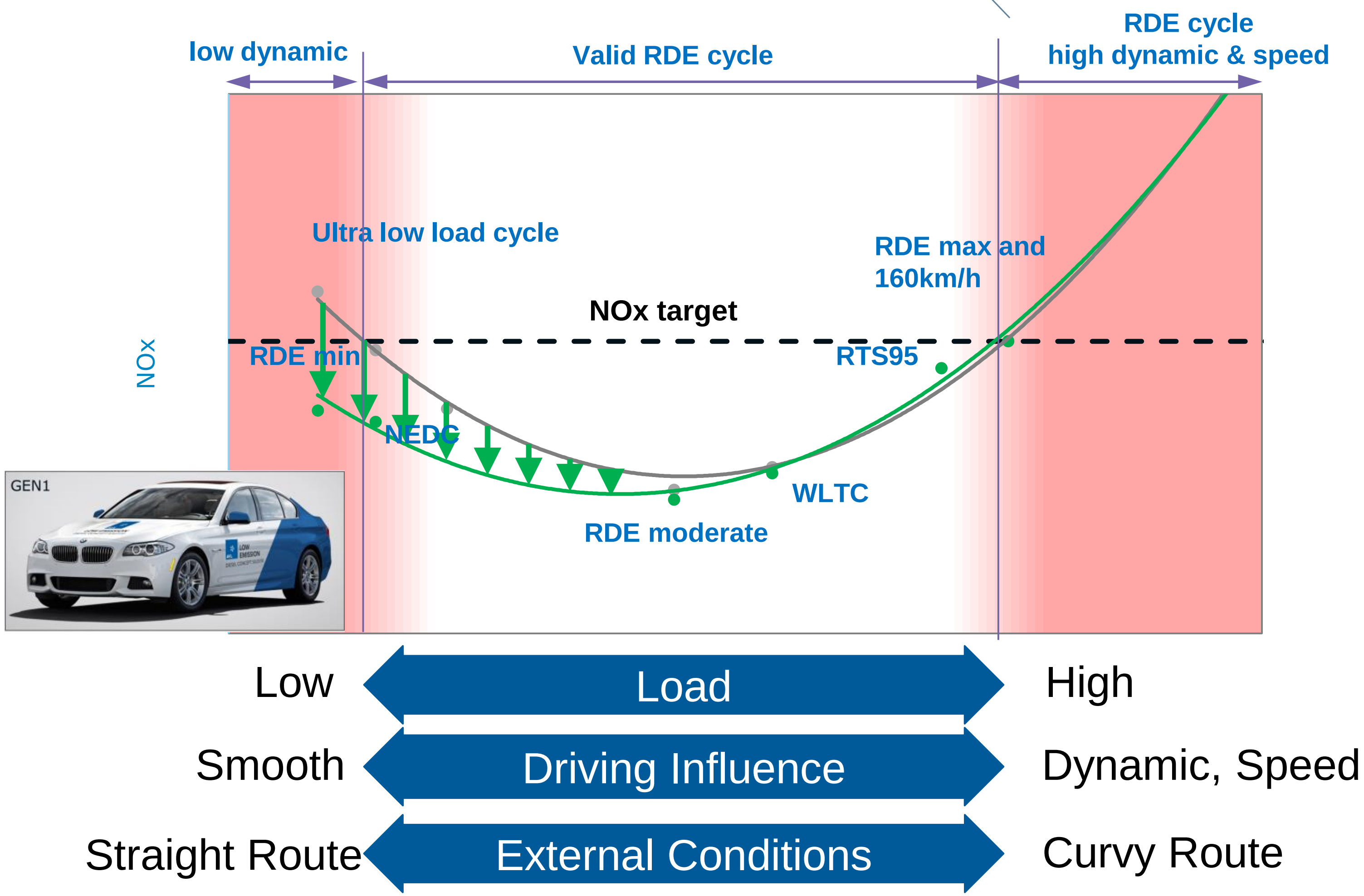
- **Without the ECAT → CF 0.8**
- **Including the ECAT → CF 0.7**
- **Using a 2nd Urea dosing → CF 0.2**

Summary



low dynamic
Valid RDE cycle
RDE cycle
high dynamic & speed
NOx
Ultra low load cycle
RDE max and
160km/h
NOx target
RDE min
RTS95
NEDC
WLTC
RDE moderate
Low
Load
High
Smooth
Driving Influence
Dynamic, Speed
Straight Route
External Conditions
Curvy Route

Summary

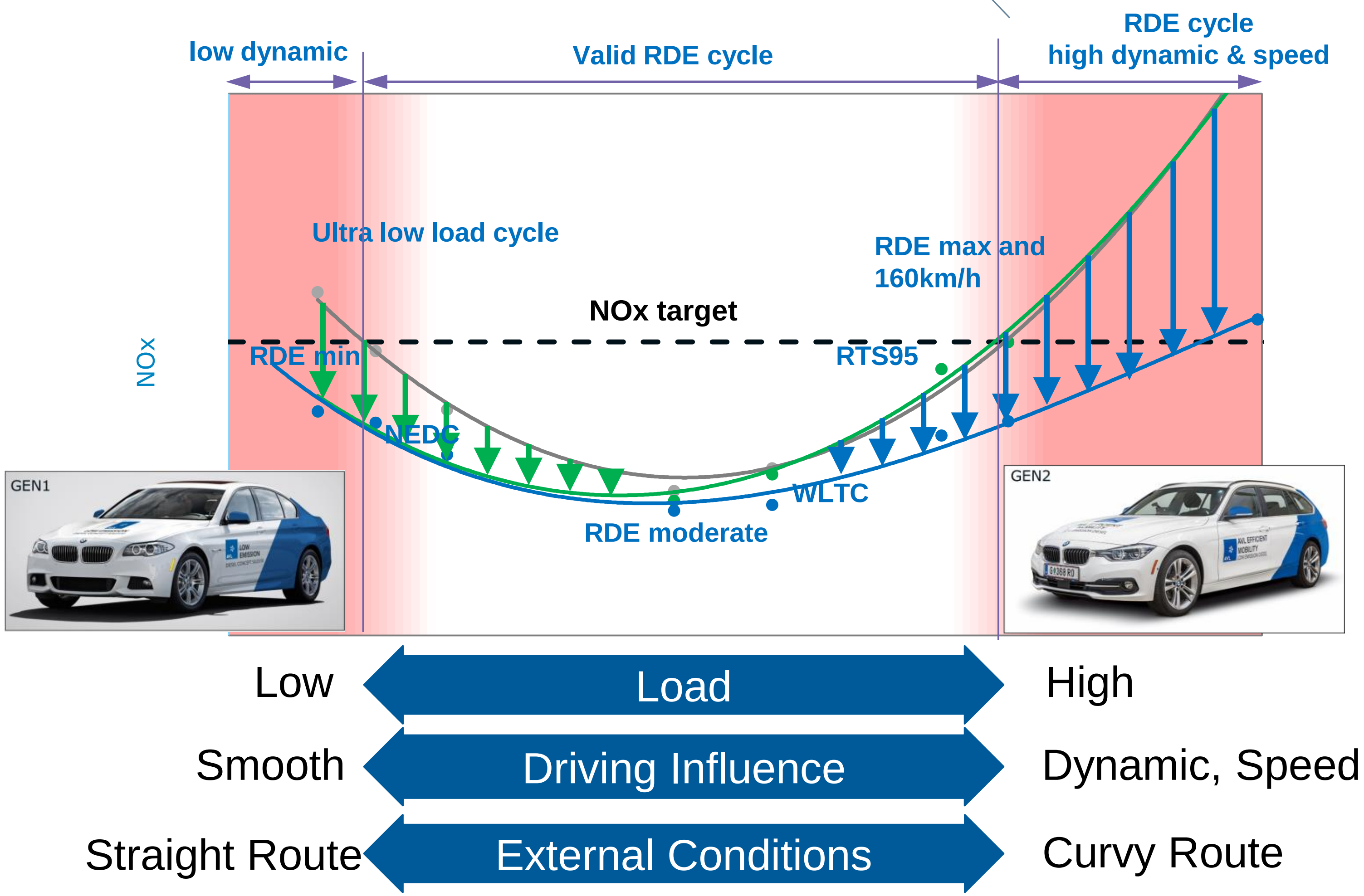


Results

- GEN1
  ECAT improves the NOx reduction in the low load operation

→ Improved Emission robustness in low load

Summary

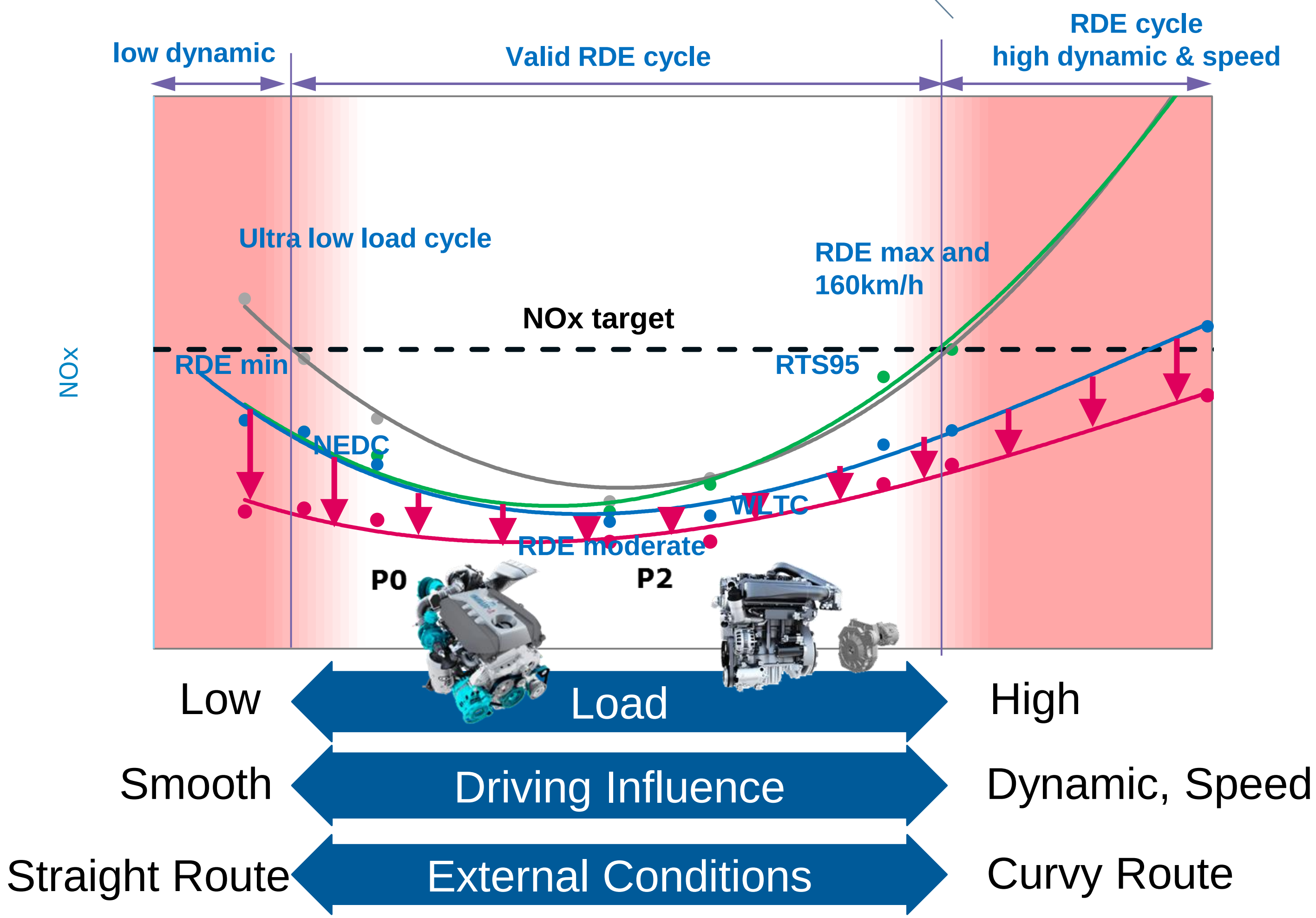


Results

- **GEN1**
  ECAT improves the NOx reduction in the low load operation
- **GEN2**
  Dual Urea dosing improves the NOx reduction in high load operation / high temperature

→ Improved Emission robustness in high load

NEXT steps



Results

- **GEN1**
  ECAT improves the NOx reduction in the low load operation
- **GEN2**
  Dual Urea dosing improves the NOx reduction in high load operation / high temperature
- **GEN3**
  Hybridization with P0/P2

→ Improved NOx and CO2 emissions

Thank You

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