Passenger Car and Heavy Duty Emission Model (PHEM) PHEM模型

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- **Introduction in PHEM model structure PHME模型结构介绍**
  - Vehicle longitudinal dynamics simulation 车辆纵向动力学模拟
  - PHEM engine emission maps PHEM发动机排放图
  - Models for exhaust aftertreatment 尾气后处理模型
- **Examples for model application模型应用案例**
  - Emission factors for the HBEFA / CRTEM HBEFA/CRTEM排放因子
  - Link to micro-scale traffic models 关联微观交通模型
- **Summary 总结**

PHEM – Overview model features (1/2)

- **PHEM development started at TUG in late 90'ies to simulate emission factors [g/km] for the "Handbook Emission Factors for Road Transport" (HBEFA)** 模型自90年代末开始开发，为HBEFA提供排放因子
- **Main model output: fuel consumption, CO2 and most relevant pollutant emissions**模型主要输出：油耗，二氧化碳及重要污染物排放
- **Vehicle longitudinal dynamics simulation using a "backward" approach.**纵向模拟
- **Engine emission behaviour characterised by "emission maps" via engine speed and and engine power** 通过发动机速度和功率建立的排放地图表现发动机行为特征
- **Additional model elements for exhaust aftertreatment simulation (e.g. SCR, NSC), electrified power trains (HEV, PHEV, EV) and emission behaviour in transient conditions** 排放后处理模拟模块，电动化，和瞬态排放行为
- **Time resolution: 1Hz** 时间分辨率

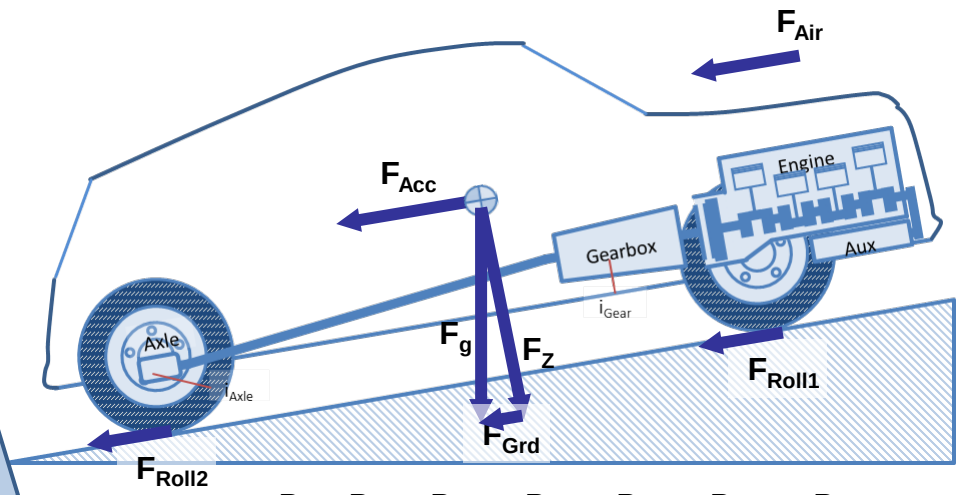
PHEM – Overview model features (2/2)

- **Features a data base on HBEFA “average-vehicles” which is parameterised based on ERMES data collection. 基于ERMES数据较定的HBEFA平均车辆参数建立数据库**
- **Features an interface to micro-scale traffic models (e.g. VISSIM, Aimsun) 建立与微观交通模型的关联**
- **PHEM is the “parent model” of VECTO (Vehicle Energy consumption Calculation Tool) which will be used from 2018 in the European HDV CO2 certification PHME是VECTO的原型**

Vehicle longitudinal dynamics simulation
车辆纵向动力学模拟

Vehicle parameters车辆参数

Chassis底盘	C_d x A, mass, rot. Inertias
Tires 轮胎	r_{dyn}, RRC
Gearbox + axle 变速器	loss maps i_{Gears}, i_{Axle}
Engine 发动机	P_{rated} full load curve 满载曲线 Emission map排放图 Transient parameters
Auxiliaries 附属物	Avg. Power demand per auxiliary 平均功率需求
After treatment 后处理	Thermal capacities热容量 Functions for conversion efficencies转换效率



$$P_e = P_{Air} + P_{Roll} + P_{Acc} + P_{Grd} + P_{Loss} + P_{Aux}$$

Backward model approach

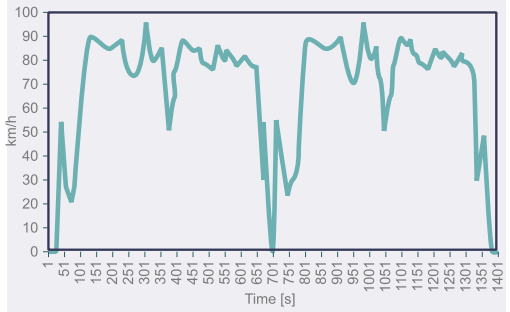
Calculation in each 1 Hz time step:每Hz的计算步骤

- Given: v, a from driving cycle输入驾驶工况速度
- Result: power at engine 输出发动机功率

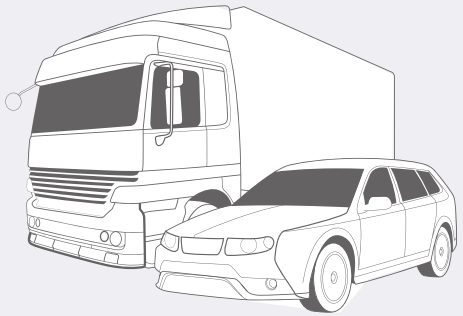
+ additional driver model elements和其他参数 (acceleration behaviour, gear shift strategy, etc.)
加速状况，换挡状况等

PHEM Passenger car and Heavy duty Emission Model

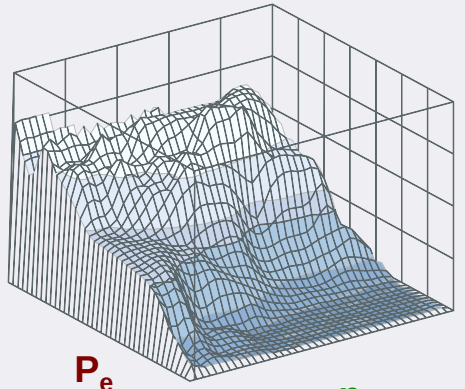
Driving Cycle in 1Hz



Vehicle data车辆数据



Emission-Maps 排放地图



E_m

Velocity 速度

Gradient 坡度

Driving resistances
Losses in drivetrain
动力损失

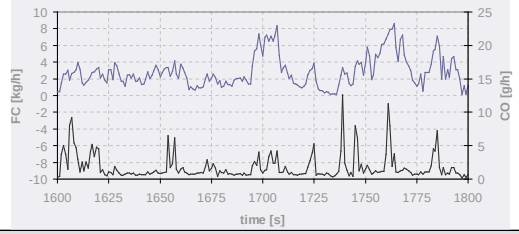
Optional:
HEV
Routines

***Gear optional*档位选择**

Transmission ratios传动比

Gear shift model换挡方式

Emissions排放
Fuel consumption油耗



Transient correction 瞬态修正

Thermal behaviour of catalysts 热催化

Cold start 冷启动

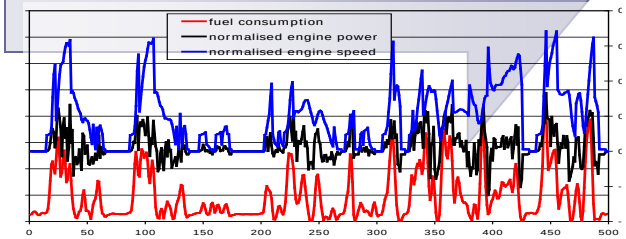
SCR

Generation of PHEM engine maps

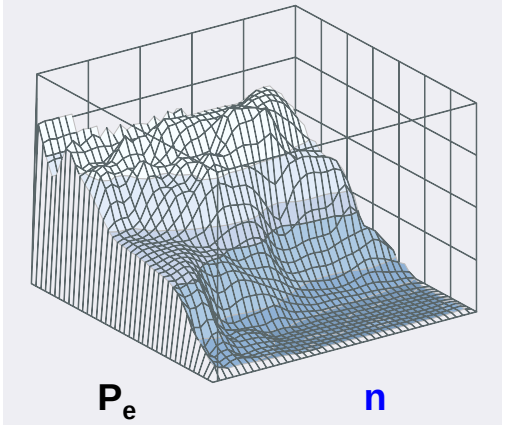
***Engine power*发动机功率**

***Engine speed*发动机转速**

***Emissions*排放**



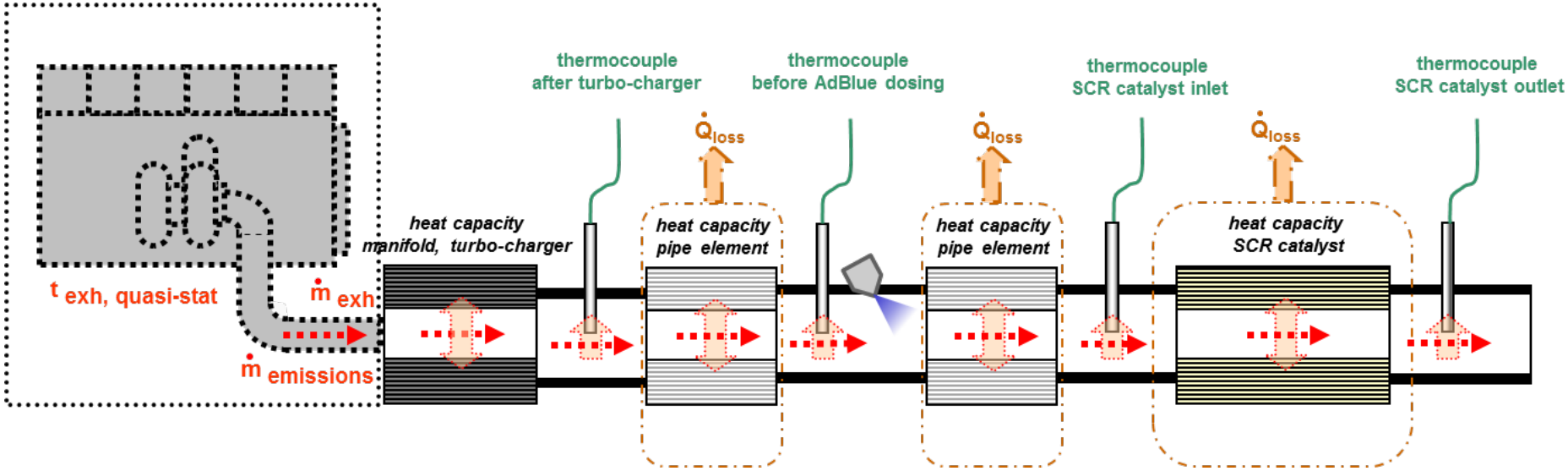
Emission-maps



E_m

- **Options to parameterise engine maps发动机图参数化**
  - **steady state tests (engine dyno)稳态测试**
  - **transient measurements (chassis dyno, PEMS)瞬态测试**
- **From in-use testing typically chassis dyno or PEMS data are available 目前在用的典型数据来自台架测试和PEMS测试**
  Requirements: 1) High coverage of engine map 发动机图高覆盖
  2) Precise correction for variable transport time of exhaust gas and analysers response time 精确修正
- **Algorithms to parameterise PHEM from PEMS measurements w/o power signal available 基于PMES测试功率信号的PHEM参数算法**

PHEM Thermal model for exhaust system
尾气的热力学模型



Model structure:模型结构

- 0-dimensional heat capacities 0维的热容量
- Heat transfer between exhaust gas and heat capacities: convection (turb / lam) 热量在尾气和热容间对流转化
- Heat transfer between heat capacities and environment: convection, radiation 热量在热容和环境间对流/辐射转化
- Catalysts: heat input from exothermic reactions (conversion rate = f(temp, mass flow))催化剂：热量来自放热反应
- Thermal behaviour of thermocouples included (essential for comparison of model results with measurement data) 热电偶的热力学行为
- Model structure optimised for simple parameterisation (ERMES in-use testing) 最优化模型结构获取简单参数化

PHEM – "HBEFA" SCR DeNO$_x$ model

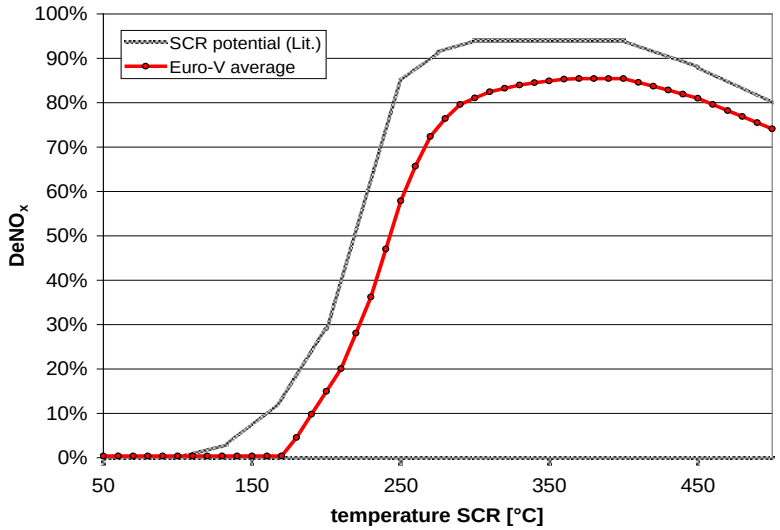
$$\dot{m}_{NO_x,tailpipe} = \dot{m}_{NO_x,engine\ out} \cdot (1 - DeNO_x)$$

$$DeNO_x = f_{DeNOx}(t_{SCR}) + f_{corr}$$

Dosing strategy & NH$_3$-storage

定量政策，氨储量

1) Baseline NOx conversion rate over catalyst temperature
催化温度上氮氧化物的基础转换率



Space velocity

空速

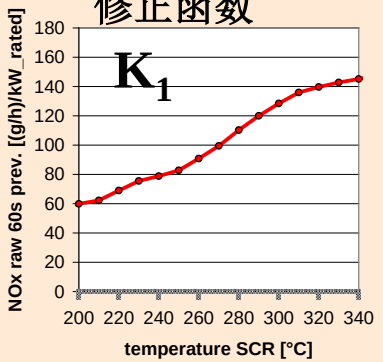
Catalyst temp gradient

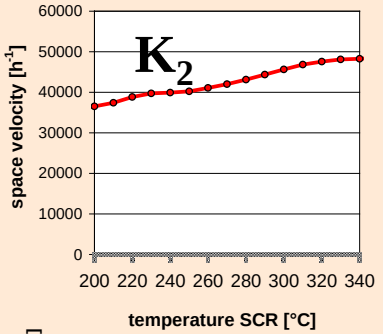
催化温度曲线

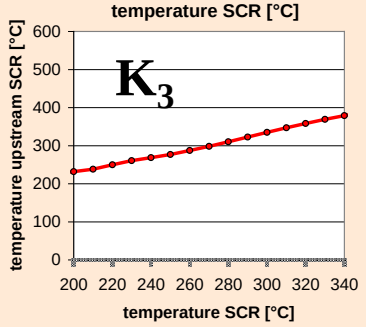
2) Correction functions for additional influences 其他影响修正

$$f_{corr} = \sum_{i=1}^{3} a_i \cdot [K_i - f_{Ki}(t_{SCR})]$$

Correction functions
修正函数



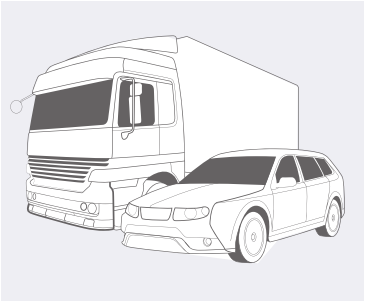




PHEM – Typical model applications
典型应用

- **Used for elaboration of HBEFA emission factors for passenger cars, light commercial vehicles and heavy duty vehicles. HBEFA的小型客车，轻型商务车和重型车排放因子的精确计算**
  Implementation of two-wheelers in progress for HBEFA4. HBEFA4中两轮车上应用
- **Using HBEFA "average vehicles" for generation of emission factors for special local conditions (user defined data on driving cycles, road gradient, ambient conditions, special fleet mix …) HBEFA中特定环境下的"平均车辆"排放因子**
  Example: Comparison emissions speed limit 30km/h vs. 50km/h 30km/h和50km/h排放比较
- **Research and engineering tool 研究工具**
  Example: simulation of thermal conditions in the exhaust system for layout of heat recovery systems 为热回收系统模拟排放系统中的热力学情景
- **Link with micro-scale traffic models (e.g. VISSIM, Aimsun) 与微观交通模型关联**
  Examples: Traffic light optimisation, high resolution air quality modelling 优化红绿灯控制，高分辨率空气质量模型
- **Academic use (teaching)学术应用**
- **…**

Database of “average vehicles” for Handbook Emission Factors (HBEFA)
HBEFA排放因子的“平均车辆”数据库



Vehicle category 车辆类别	Propulsion technology 动力技术	Weight category 车重类别	Emission-Standard 排放标准	Emission control 排放控制
Pass car	Gasoline	LCV N1 I	Pre EURO 1	DPF
LCV	Diesel	LCV N1 II	EURO 1	SCR
Rigid truck	HEV*	LCV N1 III	EURO 2	EGR
Tractor & trailer	EV*	HDV ≤ 7.5t	EURO 3	
Coach		HDV 7.5t - 12t	EURO 4	
Bus		HDV 12t - 14t	EURO 5	
Two-Wheelers*		...	EURO 6	

* PHEM models available but so far not used for HBEFA

Data included in PHEM HBEFA3.2 emission maps
PHEM HBEFA3.2 排放图中包含的数据

Number of measured vehicles (engines) per EURO class:
各排放标准中测试的车辆(发动机)数量

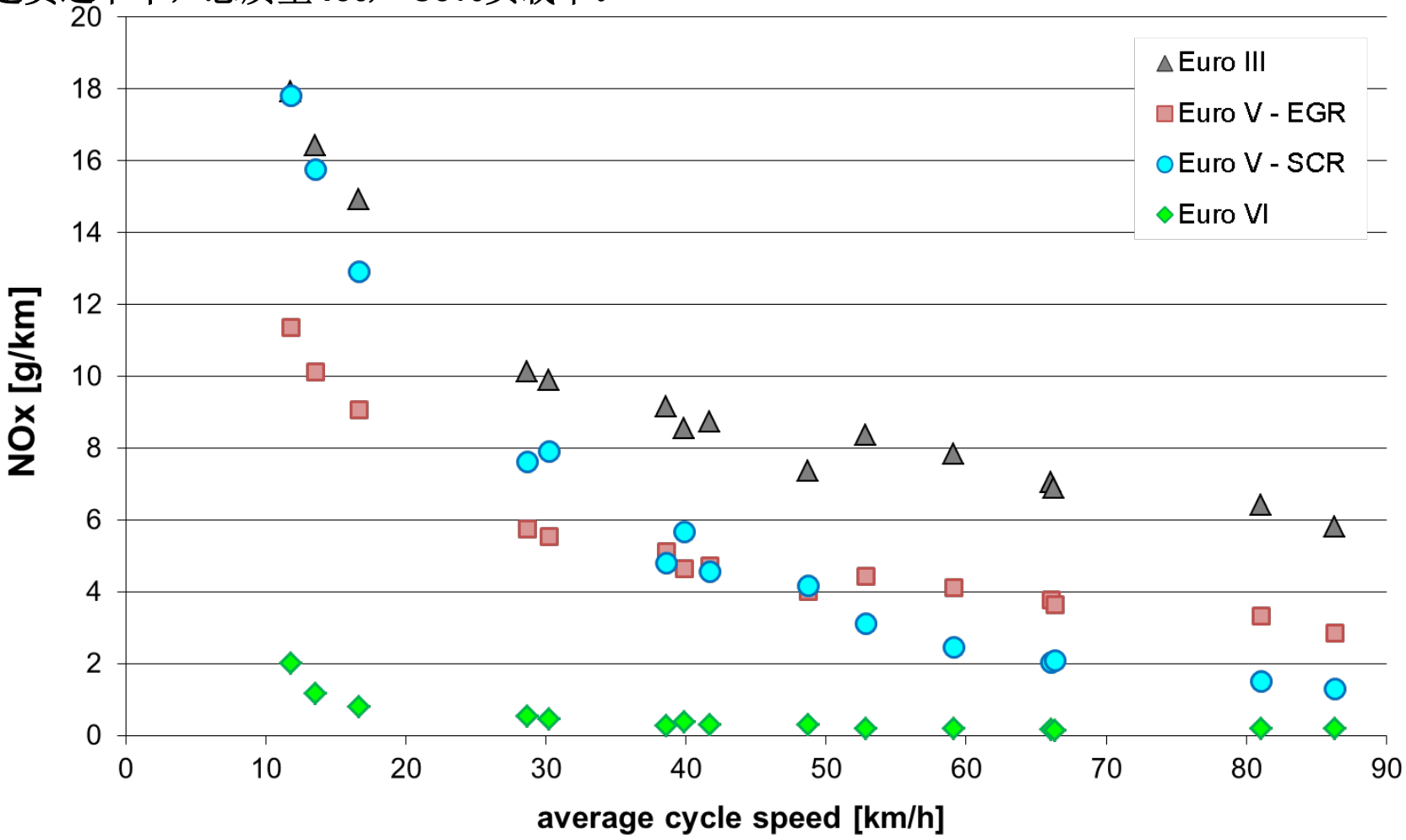
		pre EURO	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	EURO 6c
PC	Gasoline	**2** (878)	**3** (1191)	**4** (164)	**9** (156)	**23** (208)	**18** (31)	**1** (1)	n.a.
	Diesel	**0** (207)	**0** (48)	**4** (54)	**8** (135)	**24** (99)	**27** (50)	**5** (19)	n.a.
LCV	Gasoline	**0** (19)	**0** (14)	**0** (5)	**0** (0)	**0** (0)	**0** (0)	n.a.	n.a.
	Diesel	**0** (7)	**0** (7)	**0** (9)	**0** (2)	**2** (15)	**3** (3)	n.a.	n.a.
HDV	Diesel	**2** (40)	**2** (13)	**10** (21)	**13** (27)	**8** (8)	**11** (11)	**7** (7)	

Numbers bold:
加粗数字：
(Numbers in brackets):
(括号中数字)：

Instantaneous data for detailed analysis available
可用于详细分析的瞬态数据
Results for total cycles available for calibration of overall emission level
可用于整体排放水平标定的总工况测试结果数

Example for PHEM emission factors for HBEFA3.2
HBEFA3.2中的PHEM排放因子

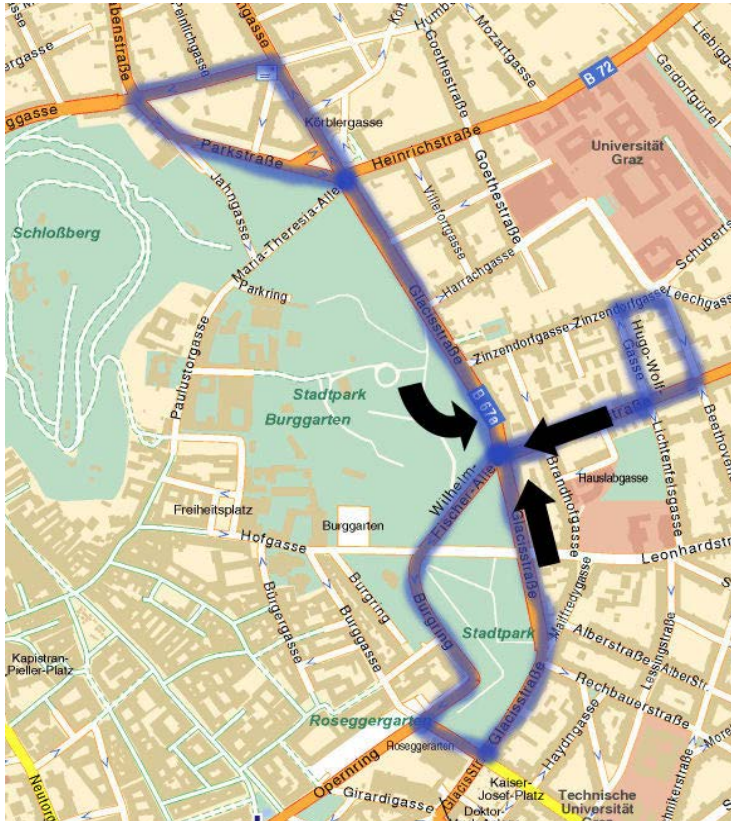
Vehicle segment车辆类别: Long haul truck 40t GVW, 50% loading 长途货运卡车，总质量40t， 50%负载率。



PHEM model link with micro-scale traffic model
PHEM模型与微观交通模型关联

Project „Graz Adaptive Traffic Light Control“ 格拉茨交通信号灯控制项目

Investigations on emission reduction potential of alternative traffic light control strategies
对不同信号灯控制政策的减排潜力研究



- Investigation area: 研究范围
  Arterial road in Graz city center 格拉茨市中心干路
  10 coordinated traffic lights 10个协调信号灯
  2 pedestrian traffic lights 2个人行道信号灯
- Instantaneous traffic flow (1Hz) simulated in PTV VISSIM for baseline and different „alternative“ traffic light control strategies 基础情景和不同控制政策下的瞬态交通流模拟
- Emissions per road section simulated by PHEM for each strategy PHEM计算不同政策下各路段排放
- Best “alternative” strategy was implemented in application area 最佳的控制政策实施
- Model validation performed via recording of GPS data in investigation area 使用研究区域GPS数据对模型进行验证

PHEM model link with micro-scale traffic model
PHEM模型与微观交通模型关联

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Investigations on emission reduction potential of alternative traffic light control strategies

Results结果:

	CO_2 [g/km]	NO_x [g/km]	PM [g/km]
Baseline strategy 基础方案	255	0.827	0.058
Optimised strategy 优化方案	220	0.666	0.048
	-14%	-19%	-17%

Summary总结

- **PHEM (Passenger car and Heavy duty Emission Model) is a tool for simulation of fuel consumption and emissions for all types of road transport vehicles PHEM是可以模拟全部道路交通车辆油耗和排放的工具**
- **Main model elements:模型主要模块**
  - Vehicle longitudinal dynamics simulation 车辆纵向动力学模拟
  - PHEM engine emission maps PHEM发动机排放图
  - Models for exhaust aftertreatment 尾气后处理模型
- **Required model input: Driving cycle in ≥ 1Hz 至少1Hz的工况数据输入**
- **PHEM is tailor-made for emission modelling on fleet level PHEM是特别针对车队水平的排放模型**
- **Most prominent model application is calculation of emission factors for the Handbook Emission Factors for Road Transport (HBEFA) HBEFA排放因子计算是最佳的模型应用案例**
- **Default database for "average vehicles" according to HBEFA can be obtained with the model 能够获得HBEFA的"平均车辆"数据库**

Thank you for your attention!

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