DIAS

SMART ADAPTIVE
REMOTE DIAGNOSTIC
ANTITAMPERING
SYSTEMS

Tampering of Emission Controls and Countermeasures

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LAT

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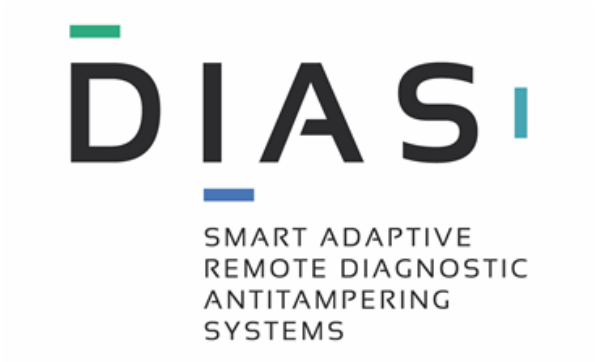
Contributions from DIAS project

Many thanks to the Work Package leaders:

- Ann Delahaye (TNO)
- Miao Zhang (FEV)
- Andreas Hastall (Bosch)

and all other DIAS colleagues



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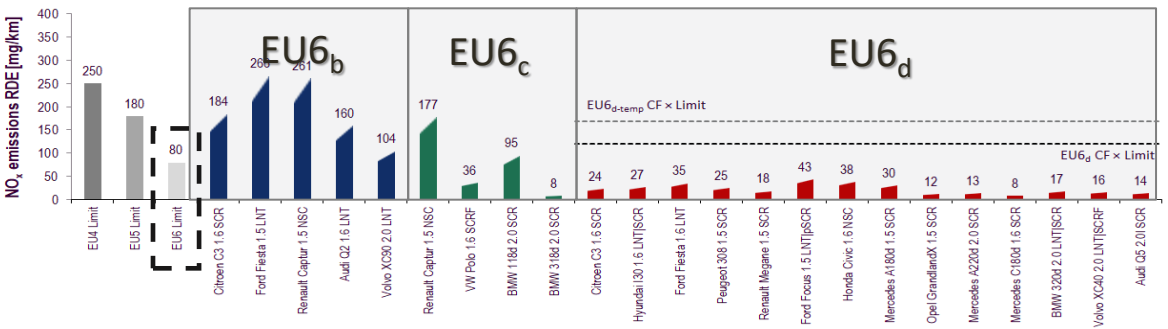
Introduction-The DIAS consortium

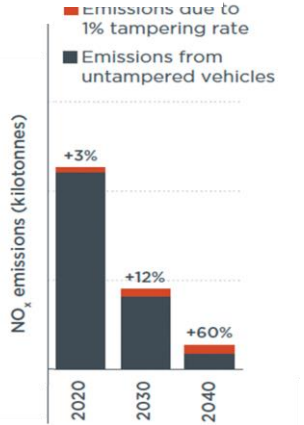
- Smart Adaptive Remote **Di**agnostic **A**ntitampering **S**ystems
- 11 partners with various competencies
- Part of H2020 European programme (smart, green and integrated transport sector)
- International co-operation
- Budget: €4.99M
- Duration: 38 months (Sept. 2019 – Oct. 2022)

Introduction-Problem statement

- NOx emissions (diesel):
  - EU6d fleet average: 20-30 mg/km thanks to the development of effective Environmental Protection Systems (EPS)
  - Tampered vehicle: More than x10 higher emissions



Tampered Vehicles



ICCT, 2021

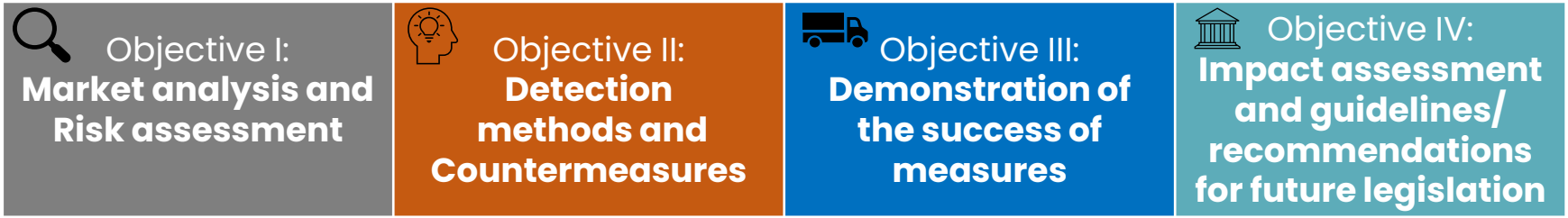
- Even a small percentage of tampered vehicles (1%) can lead to a huge increase in fleet emissions in the future (+60% for 2040)
- **Up to 10% of EU5/V and EU6/VI vehicles** in the EU are estimated to have **tampered** with environmental protection systems

Objectives of DIAS

1. **Detect tampering** using On-Board Diagnostics and Monitoring (OBD/OBM)
2. **Prevent tampering** via hardened in-vehicle communication and component security
3. **Report** tampering events and relevant data to appropriate authorities

Target: Make tampering **economically unattractive and reduce emissions**

Our methodology:



Objective I: Market Analysis

Overview of tampered systems and motives

Tampered Systems and Motives

SCR tampering (NOx emissions)

- Eliminate/reduce urea cost (>**€2K/truck/year**) and cost of replacing malfunctioned SCR components

DPF (GPF) tampering (PM emissions)

- Avoid the high cost of DPF replacement (>**€1.5K**), eliminate regeneration fuel penalty

EGR tampering (NOx emissions)

- Avoid the high cost of EGR-components replacement (*Note: Reduced motivation in EU6*)

TWC tampering

- *Negligible/zero for EU5/6 (Note: it was an issue for EU4)*

Tampering Methods

ECU reprogramming

- Manipulation of calibration values in the ECU memory
- Complex method with high cost **(from 200€)**
- Used by experienced tamperers

Emulators and "DTC clear" devices

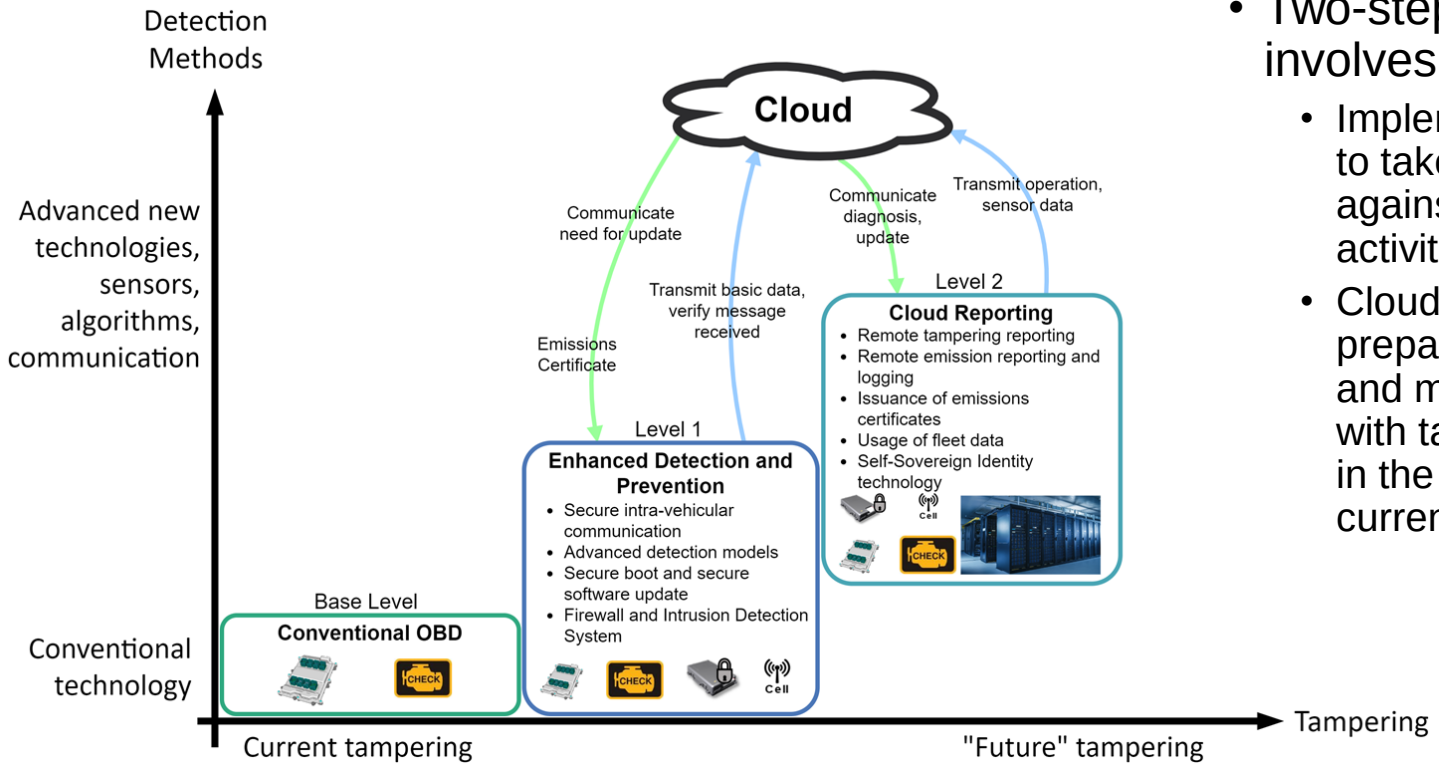
- Provide manipulated signals and "Diagnosti Code Clear" commands to the ECU
- Low cost **(from 20 €)**
- Easy to install but with operational/reliability issues
- Applicability continuously decreasing
- Prone to visual inspection checks
- More common in HD instead of LD vehicles

Modifiers

- Simpler emulators e.g. mechanical spacers, se extensions, mini catalysts, resistors

Test programme: 42 commercial tampering devices/services, 5 "homemade" tampering devices

Objective II: Detection methods and countermeasures - Overview

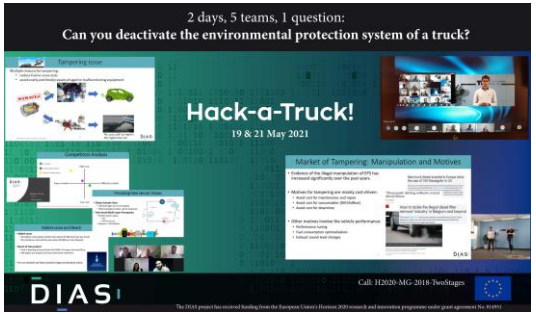


- Two-step approach that involves:
  - Implementing measures to take early actions against tampering activities.
  - Cloud-based step that prepares methodologies and means for dealing with tampering attempts in the future that are currently unknown.

Objective III: Demonstration of the success of measures

- Installation of anti-tampering systems on demonstrators:
  - Demonstrator vehicle provided by partner Ford OTOSAN
  - Stand-alone lab demonstrators

- Evaluation of anti-tampering systems via:
  - **Internal** verification and validation of the system *(on-going)*
  - **External** hacking events:
    - Analysis of vehicle hardware and software by IT security experts and hackers
    - Hackathon #1 organized in May 2021
    - Hackathon #2 organized in March 2022



→ Received feedback led to adjustments on DIAS solutions and further considerations

Objective IV: Impact assessment and guidelines/recommendations on future legislation – Impact assessment

- Environmental, Health and Societal

  - Address societal **needs to understand the tampering phenomenon** and generate considerable **climate** and **public health co-benefits**

Note: *A detailed Impact Assessment is currently finalizing, results will be available very soon*

- Regulatory

  - **Influence** on European and the global economy by **assessing** manipulated vehicles and **providing solutions** for **reducing** their negative **impact**
    - DIAS technical solutions are leveraged to **recommend regulatory provisions:**
      - **For vehicle manufacturers:**
        - For Type Approval of new vehicles
        - After the Type Approval for future vehicles in-service
      - **For many other end-users**

Input data for DIAS Impact Assessment

- Needed inputs to quantify tampering:
  - **Tampering emission rates [-]:** ratio of tampered vehicle emissions to non-tampered vehicle emissions
    - → Calculated based on tailpipe emissions from tampered vehicles in chassis dyno or on the road (remote sensing, plume chasing, PEMS, SEMS) compared with non-tampered data from the same vehicle
  - **Tampering vehicle shares [%]:** ratio of tampered to non-tampered vehicles
    - → Calculated based on a 2-step approach:
      - Step 1: **High emitters** are identified via remote sensing, plume chasing, etc.
      - Step 2: **Tampered high emitters** are identified via visual inspection and other tampering-related checks
      - Tampering share [%] = (high emitters share [%]) × (tampered high emitters share [%])

Tampering vehicle shares [%]

Country	Vehicle type	Vehicle registration	Euro V			Euro VI			Total (Euro V + Euro VI)			EPS affected
			High emitters	Tampered high emitters	Tampered share *(high emitters * tampered high emitters)*	High emitters	Tampered high emitters	Tampered share *(high emitters * tampered high emitters)*	High emitters	Tampered high emitters	Tampered share *(high emitters * tampered high emitters)*	
Austria	Trucks	All countries	-	-	-	-	-	-	10%	**15%**	1.5%	SCR (NOx)
Austria	Trucks	Mostly East/South EU	**35%**	50%	17.5%	**25%**	50%	12.5%	-	-	-	SCR (NOx)
Sweden	Trucks	All countries	-	-	-	**2%**	50%	1%	-	-	-	SCR (NOx)
Germany	Trucks	Germany	-	-	-	**6.9%**	50%	~3.5%	-	-	-	SCR (NOx)
Germany	Trucks	Eastern Europe	**~26%**	50%	~13%	**18.9%**	50%	9.5%	-	-	-	SCR (NOx)
Spain	Trucks	All countries	**20%**	**47%**	**9.4%**	-	-	-	-	-	-	SCR (NOx)
Denmark	Trucks	All countries	**6.2%**	**20%**	**~1.2%**	**2.2%**	**27%**	**~0.6%**	**3.4%**	**24%**	**~0.8%**	SCR (NOx)
Switzerland	Trucks	All countries	-	-	-	-	-	-	-	-	**~1%**	SCR (NOx)
UK	Trucks	All countries	-	-	-	-	-	-	-	-	**~4%**	SCR (NOx)
UK	Lorries	UK	-	-	-	-	-	-	-	-	**8%**	DPF, SCR, EGR (PM/PN, NOx)
Germany	Taxis	Germany	-	-	-	-	-	-	-	-	**10%**	DPF (PM/PN)
Germany	PC	Germany	-	-	-	-	-	-	**10%**	50%	5%	DPF, EGR (PM/PN, NOx)
Netherlands	PC	Netherlands	**12.5%**	50%	~6%	**5%**	50%	2.5%	**6%**	50%	3%	DPF (PM/PN)
EU fleet	PC	All countries	-	-	-	-	-	-	-	-	**4%**	DPF (PM/PN)
max	**HD**	All countries	-	-	~10%	-	-	*1% (1 source)*	-	-	-	
		East/South Eu.			~18%			~13%				
max	**LD**	All countries	-	-	-	-	-	-	-	-	10%	

Tampering rates and shares (intermediate scenario)

Tampering emission rates [-]: **Ratio** of tampered to non-tampered **emissions**

Vehicle Type	NOx			PM		
	Euro 5/V	Euro 6/VI	Euro 7	Euro 5/V	Euro 6/VI	Euro 7
LDVs gasoline	1	1	1	1	5	25
LDVs diesel	4	10	20	10	20	50
HDVs	4	10	20	4	20	50

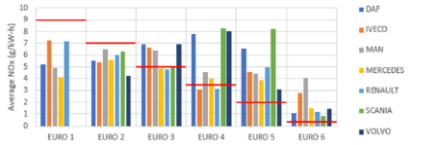
Tampering vehicle shares [%]: **Ratio** of tampered to non-tampered **vehicles**

Vehicle Type	NOx			PM		
	Euro 5/V	Euro 6/VI	Euro 7	Euro 5/V	Euro 6/VI	Euro 7
LDVs gasoline	0	0	0	0	2.5	1.3
LDVs diesel	2.5	5	2.5	5	5	2.5
HDVs	8.5	6	3	8.5	6	3

- Data availability for shares of tampered vehicles of the current fleet is limited thus, **assumptions/scenarios were needed**
- Assumptions are also needed regarding future rates/shares for EU7 tampered vehicles based on how the problem will evolve

Modelling the environmental and health impacts of tampering

Country	Vehicle type	Vehicle registration	Euro V			Euro VI			Total (Euro V + Euro VI)			Ref.
			High emitters	Tampered high emitters	Tampered share (high emitters * tampered high emitters)	High emitters	Tampered high emitters	Tampered share (high emitters * tampered high emitters)	High emitters	Tampered high emitters	Tampered share (high emitters * tampered high emitters)	
Austria	Trucks	All countries	-	-	-	-	-	-	10%	15%	1.5%	Austria
Austria	Trucks	Mostly East/South Europe	35%	50%	17.5%	25%	50%	12.5%	-	-	-	Austria
Sweden	Trucks	All countries	-	-	-	2%	50%	1%	-	-	-	Sweden
Germany	Trucks	Germany	-	-	-	6.8%	50%	~3.5%	-	-	-	Germany
Germany	Trucks	Eastern Europe	~26%	50%	~13%	18.9%	50%	9.5%	-	-	-	Germany
Spain	Trucks	All countries	10%	47%	4.7%	-	-	-	-	-	-	Spain
Denmark	Trucks	All countries	6.2%	20%	~1.2%	2.2%	27%	~0.6%	3.4%	24%	~0.8%	Denmark
Switzerland	Trucks	All countries	-	-	-	-	-	-	-	-	~3%	Switzerland
UK	Lorries	UK	-	-	-	-	-	-	-	-	8%	UK
Germany	Taxis	Germany	-	-	-	-	-	-	-	-	10%	Germany
Germany	Passenger cars (TUV)	Germany	-	-	-	-	-	-	10%	50%	5%	Germany
Netherlands	Passenger cars	Netherlands	12.5%	50%	~0%	5%	50%	2.5%	6%	50%	3%	Netherlands
EU fleet	Passenger cars	All countries	-	-	-	-	-	-	-	-	4%	Netherlands
max	HD	All countries	-	-	4.5 %	-	-	1%	-	-	-	
		East/South Eu.			17.5%			12.5%				
max	LD	All countries	-	-	-	-	-	-	-	-	10%	



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LDVs gasoline	1	1	1	1	5	25
LDVs diesel	4	10	20	10	10	20
HDVs	4	10	20	4	10	20

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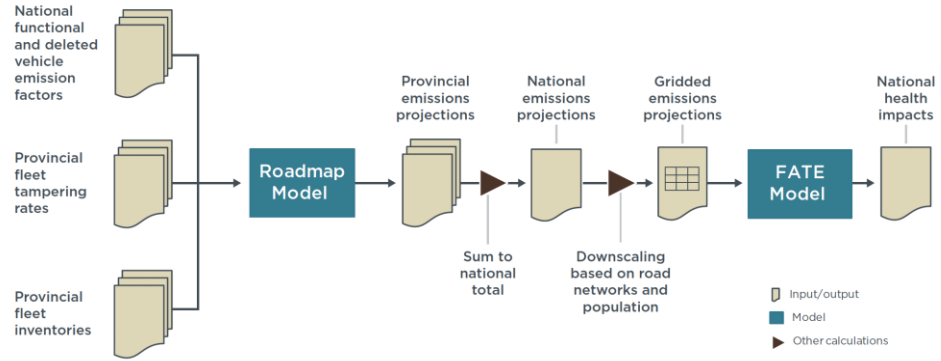

Summary

- Even a small number of tampered vehicles can lead to a remarkable increase in fleet emissions *(note: actual number of tampered vehicles may be underestimated today)*
- Developed solutions are in 3 directions: diagnostics, security and reporting
- Successful anti-tampering should engage several end-users; DIAS focuses on guidelines for vehicle manufacturers and covers many other end-users
- Legislative framework should:
  - Cover both the Type Approval of vehicles and vehicles in-service
  - Combine information and actions for all involved end-users
- The tampering emission rates and vehicle shares for an intermediate scenario indicate that:
  - For a tampered EU6 LDV the NOx emissions can be ×10 higher compared to a non-tampered vehicle
  - More than 6% of the EU6 LDVs have been tampered with their environmental protection system
- These number are at least double for the worst-case scenario

Thank you

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Register for the DIAS final dissemination event on the 25th of October 2022 (remotely)

Register here (remote participation)