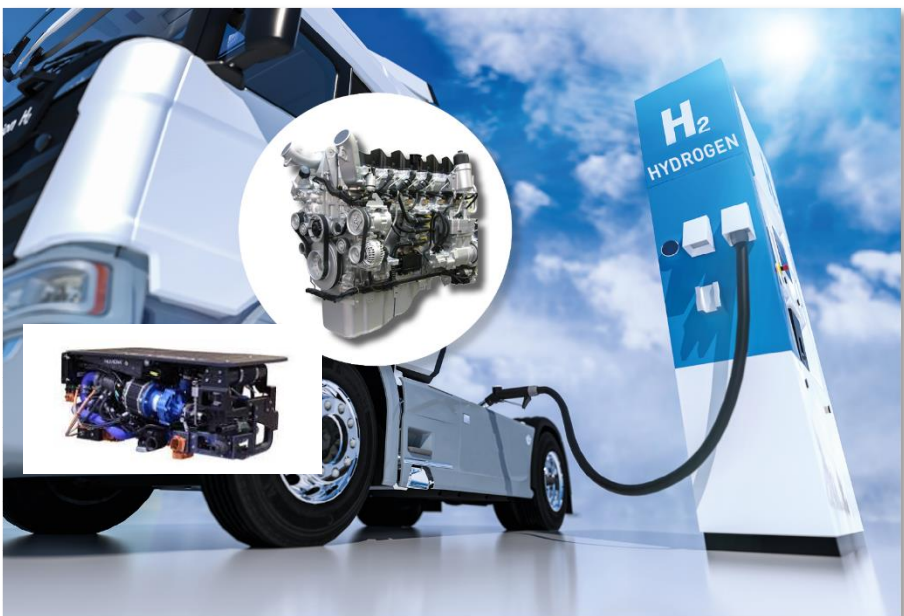


## 15th Concaawe Symposium

**Session2:  
Opportunities, how to  
make the low carbon  
transition successful?**

**LCA as a method and a tool  
(passenger cars and HDV)**

**Joris Melgar**



# ABOUT US

A public sector  
**R&I** body

A **training**  
center

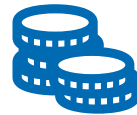
An industrial  
**group**

An international scope in the fields of energy, transport  
and the environment



**1,635**  
people

**€120.5m**  
budget allocation  
In 2020

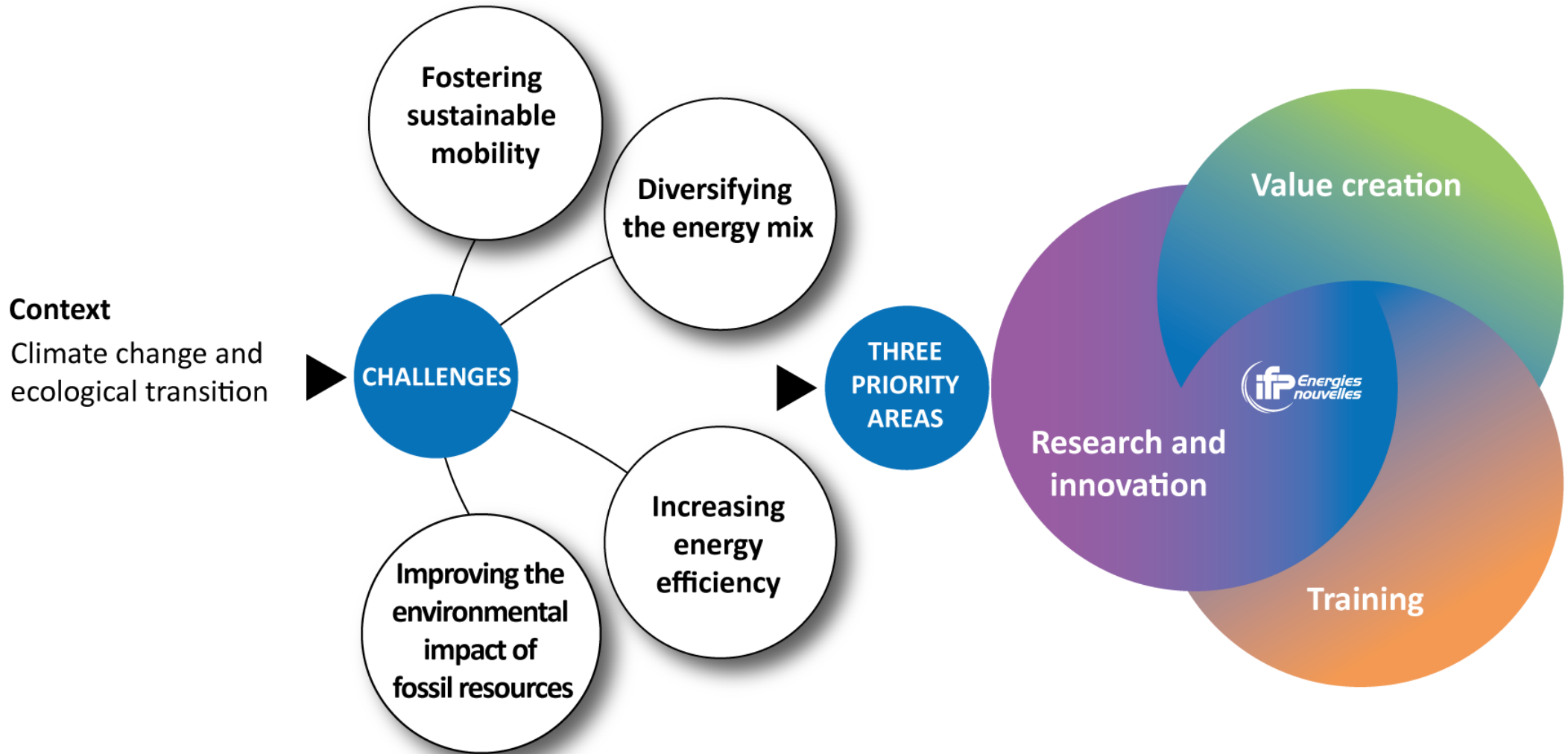


**1,190** engineers and  
technicians dedicated  
to research

**€146.5m**  
own resources  
In 2020



# OUR MISSION



# OUR R&I FOCUS AREAS

Sustainable  
mobility

- Developing vehicle electrification
- Offering solutions for connected mobility
- Improving IC powertrains
- Optimizing the use of alternative fuels

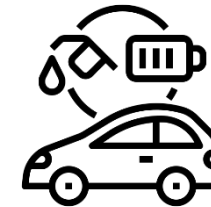


## ● Introduction to Life Cycle Assessment (LCA)



## ● Concawe's light passenger vehicle CO<sub>2</sub> emissions comparator

- Purpose : Evaluation of PHEVs in real-world conditions
- Methodology : experimental data and simulation results



## ● Concawe's heavy duty vehicle CO<sub>2</sub> emissions comparator

- Purpose : Comparison of CO<sub>2</sub>eq emissions over HDVs applications
- Methodology : Simulation calibration and extrapolation

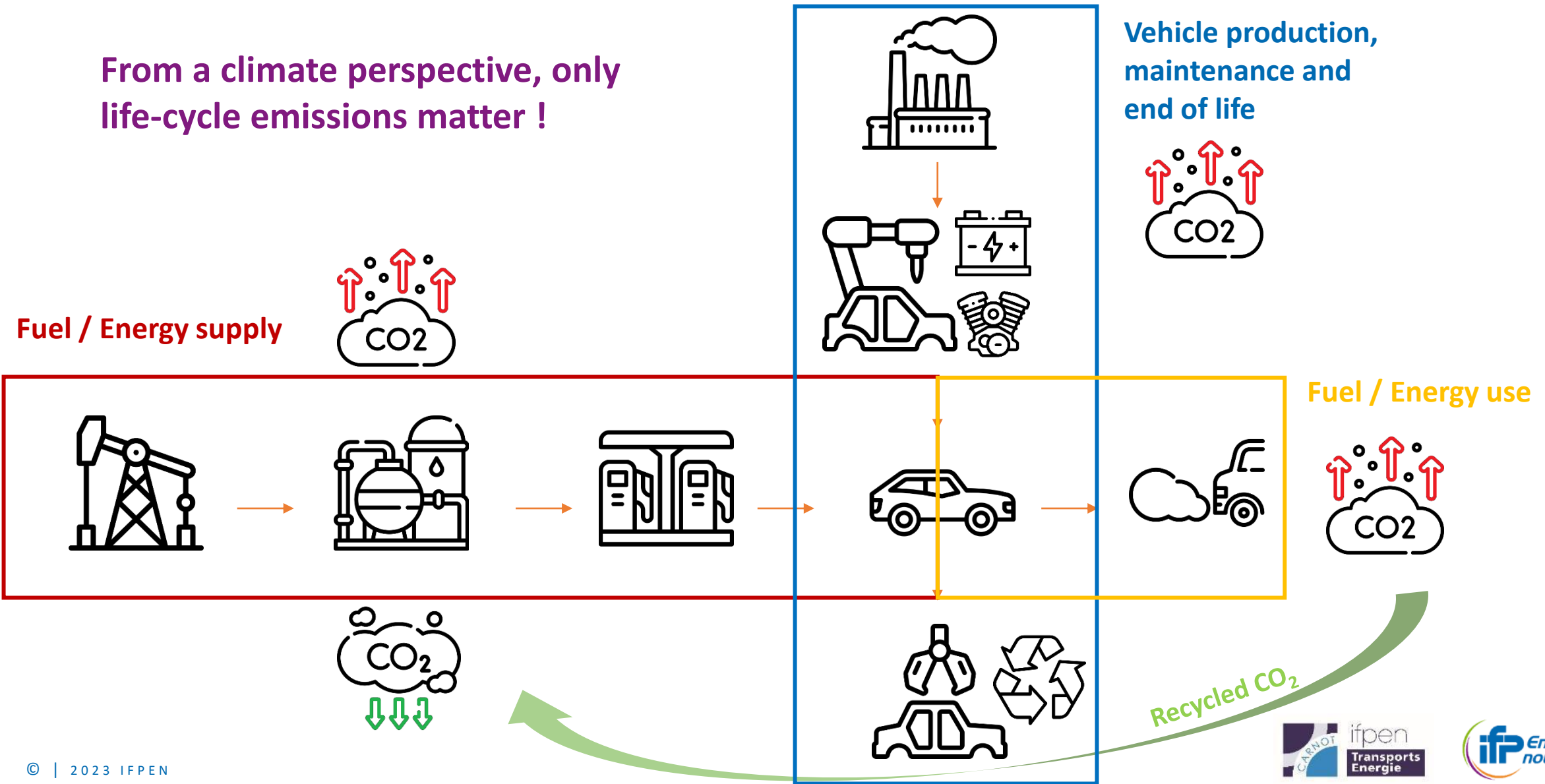


## ● Limits and perspectives



# INTRODUCTION TO LIFE CYCLE ASSESSMENT (LCA)

From a climate perspective, only life-cycle emissions matter !

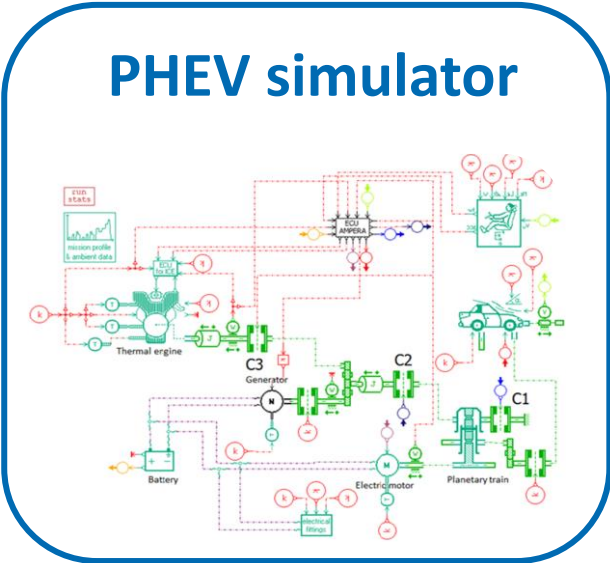


*2020-2022 Concawe/IFPEN collaboration : "Evaluation of Plug-in Hybrid Electric Vehicles in real-world conditions"*

- **Experimental** campaign on 2 tested PHEVs :
  - In-lab and on-road
  - Between -2°C and +35°C
  - Gasoline, Diesel and renewable fuels
  - Recharged and uncharged conditions
  - Various driving profiles
- Calibration of a **simulation platform** for vehicle energy assessment
- Integration of **CO2 emission factors** linked to use and manufacture
- Development of an emissions **comparison tool**

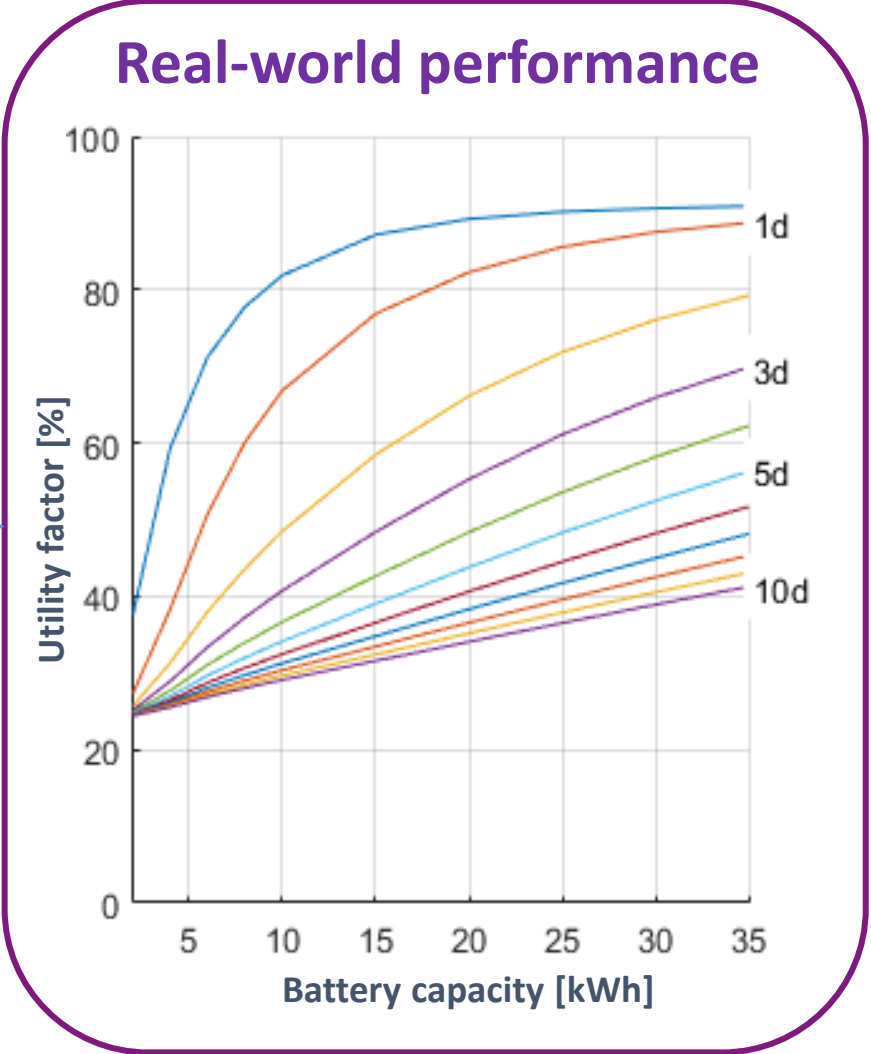
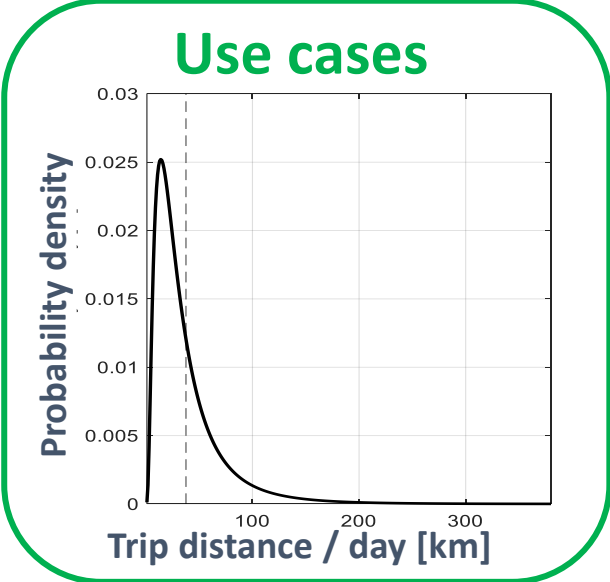


# CONCAWE'S LIGHT PASSENGER VEHICLE CO2 EMISSIONS COMPARATOR



Calibrated on experimental data  
**+50'000 simulations!**

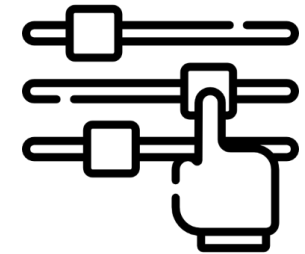
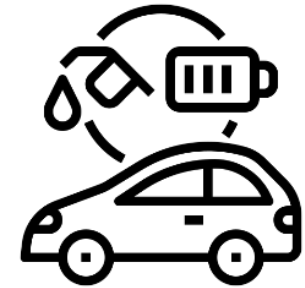
**Statistical model**





**An interactive tool, with guided scenarios,** allowing to compare life-cycle CO2 emissions from passenger cars, function of your own use case and own sensitivities according to parameters :


- **Configuration and design of the vehicles**
  - Hybrids, Plug-in hybrids and Electric cars
  - Battery capacity and emission related to its manufacture
  - Lifetime mileage
- **Usage of the vehicles**
  - Recharge frequency for the plug-in hybrids
  - Typical trip profiles
  - Climate conditions
- **Energy carriers**
  - Carbon intensity of electricity used
  - Fuels, with fossil and renewable options



# CONCAWE'S LIGHT PASSENGER VEHICLE CO2 EMISSIONS COMPARATOR

Sustainable mobility

Tests, modeling & design by



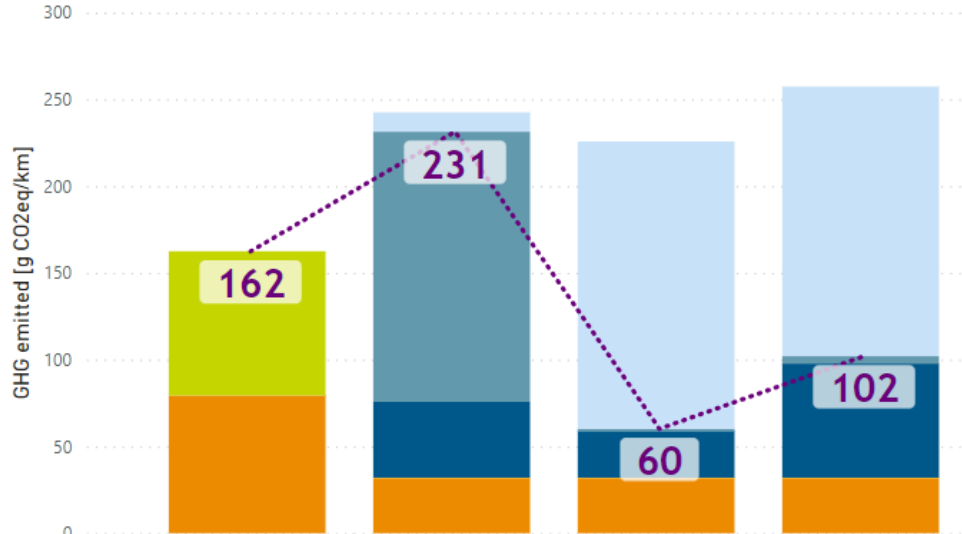
## Life cycle assessment (LCA) of greenhouse gas emissions from passenger cars in real-world conditions

A function of electrification level, end-user behavior, fuel, industrial and energy sector key parameters

*Please click on the information buttons to get further explanations for each parameter*

*To reset to default parameters, please use the page refresh button of your browser*

● Manufacture 
 ● Electricity 
 ● Fuel WTT 
 ● Fuel TTW minus Recycled CO2 
 ● Recycled CO2 
 ⋯ Total LCA GHG



Scenario	Vehicle Type	GHG emitted [g CO2eq/km]
(Blank)	BEV	162
E10	HEV	231
e-gasoline	HEV	60
HVO	BEV	102

As powertrains diversify in their electrification levels – Hybrids (HEV), Plug-in Hybrids (PHEV) and Battery Electric Vehicles (BEV) – along with the fuel production pathways – fossil and renewable routes – the carbon footprint over their life cycle heavily depends on their use cases (e.g. driving profile) and context of use (e.g. carbon intensity of electricity). This interactive tool allows to design several scenarios combining these parameters and to compare their environmental performance.

### Vehicles

Electrification level: HEV PHEV BEV

Battery capacity [kWh]: 2 4 6 8 10 15 20 30

Battery production [kgCO2eq/kWh]: 120

Total lifetime mileage [km]: 125000 150000 187500 250000

### Usages

Recharge interval (RI) for PHEVs [days]: 0.5 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Daily vehicle mileage scenarios: Short Average Long Certification

Climate: Cold Temperate Hot

### Energies

Electricity carbon intensity gCO2eq/kWh: 335

Mostly fossil, available today:


- B7 - fossil diesel blended with 7% renewable biodiesel
- E10 - fossil gasoline blended with 10% renewable ethanol

100% renewable Diesel, available today:

- HVO, made from renewable vegetable oil and waste cooking oil

100% renewable, future fuel:

- e-Diesel, made from renewable electricity and captured CO2
- e-gasoline, made from renewable electricity and captured CO2



<https://www.carsco2comparator.eu/>

# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

## *2023 Concawe/IFPEN collaboration “A life-cycle assessment tool for heavy-duty vehicles”*

- Calibration of a **simulation platform** for vehicle energy assessment
- Integration of **CO<sub>2</sub> emission factors** linked to use and manufacture
- Development of an emissions **comparison tool**

### Welcome to the HDV CO<sub>2</sub> comparator

This tool shows the life-cycle assessment of greenhouse gas emissions from heavy duty vehicles in real-world conditions.

As powertrains diversify in their electrification levels – hybrids, plug-in hybrids, battery electric vehicles and fuel cell electric vehicles – along with the fuel production pathways – fossil and renewable routes – the carbon footprint over their life-cycle heavily depends on their use cases (e.g. driving profile) and context of use (e.g. carbon intensity of electricity). This interactive tool developed by IFPEN and commissioned by Concawe allows to design several scenarios combining these parameters and to compare their environmental performance.

TRY IT OUT NOW!

<https://hdvco2comparator.eu/>

# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

## Simcenter Amesim simulation platform

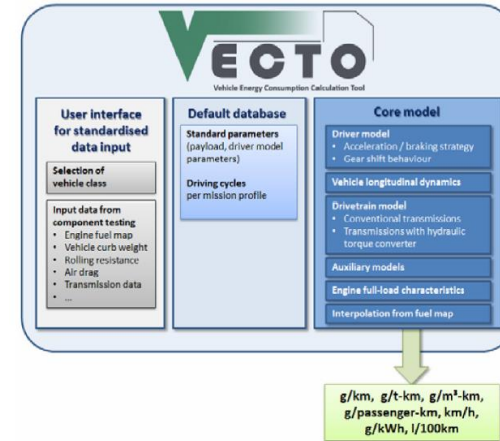
→ Calibration of ICEVs models on VECTO tool and data (developed on behalf of European Commission-JRC by TU-Graz)

VECTO : Expert tool to simulates CO<sub>2</sub> emissions and fuel consumption based on vehicle longitudinal dynamics. It is developed on behalf of European Commission-JRC by TU-Graz

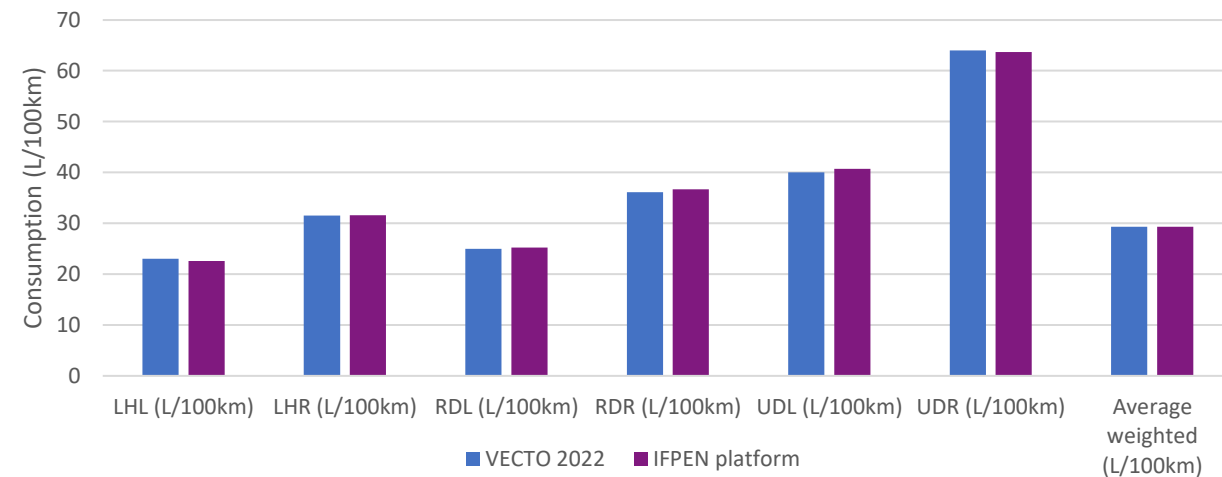
Used for :

- CO<sub>2</sub> certification of HDV in the EU
- CO<sub>2</sub> emissions definition of the European heavy duty vehicle fleet

Electrified powertrains not covered by current version !



Consumption comparison - Class 5 Trailer truck 4x2



# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

## Simcenter Amesim simulation platform

- Literature review to define powertrains sizing

- Creation of dedicated Simcenter Amesim sketches for each powertrain architecture (ICEV, HEV, BEV and FCEV)

Powertrain	Energy carrier	Class 5 Long haul	Class 2 delivery	City bus 12m	Coach	Refuse truck
ICE	Diesel	12.8L / 400kW /2700Nm / 12gears	7.1L / 225kW /1130Nm / 12gears	7.1L / 225kW /2700Nm / 6 gears	7.7L / 250kW / 1400Nm / 6 gears	7.1L / 225kW /2700Nm / 6 gears
	CNG	12.9L / 340kW/ 2000Nm / 12gears	9L / 225kW/ 1150Nm / 12gears	9L / 225kW/ 1150Nm / 6 gears	9L / 225kW/ 1150Nm / 6 gears	9L / 225kW/ 1150Nm / 6 gears
	H2	15.2L / 410kW/ 1950Nm / 12gears	9.3L / 220kW /1100Nm / 12gears	9.3L / 220kW/ 1100Nm / 6 gears	9.3L / 220kW/ 1100Nm / 6 gears	9.3L / 220kW/ 1100Nm / 6 gears
HEV	Diesel	12.8L / 400kW /2700Nm / batt 20kWh/ e-motor 150kW / 12gears	7.1L / 225kW /1130Nm / batt 30kWh/ e-motor 100kW / 12gears	7.1L / 225kW /1130Nm / batt 10kWh/ e-motor 35kW -250Nm / 6 gears	7.7L / 250kW /1400Nm / batt 10kWh/ e-motor 35kW - 250Nm / 6 gears	7.1L / 225kW /1130Nm / batt 10kWh/ e-motor 35kW - 250Nm / 6 gears
PHEV	Diesel / Electricity	12.8L / 400kW /2700Nm / batt 130kWh/ e-motor 250kW -1100Nm / 12gears	7.1L / 225kW /1130Nm / batt 100kWh/ e-motor 250kW -1100Nm / 12gears	7.1L / 225kW /1130Nm / batt 100kWh/ e-motor 160kW-400Nm / 6gears	7.1L / 225kW /1130Nm / batt 35kWh/ e-motor 160kW-400Nm / 6gears	7.1L / 225kW /1130Nm / batt 35kWh/ e-motor 160kW - 400Nm / 6gears
BEV	Electricity	batt 400kWh / e-motor 350kW-2000Nm-5krpm / 2gears	batt 300kWh / e-motor 250kW-1100Nm / 2gears	batt 400kWh / e-motor 250kW-1100Nm / 2gears	batt 500kWh / e-motor 300kW -1500Nm / 2gears	batt 300kWh / e-motor 250kW-1100Nm / 2gears
FCEV	H2	FC 225kW / H2 50kg / batt 100kWh / e-motor 350kW-2000Nm-5krpm / 2gears	#1 :FC 225kW / H2 30kg / batt 20kWh / e-motor 250kW-1100Nm / 2gears #2 :FC 75kW / H2 15kg / batt 100kWh / e-motor 250kW-1100Nm / 2gears	FC 75kW / H2 35kg / batt 75kWh / e-motor 250kW-1100Nm / 2gears	FC 75kW / H2 35kg / batt 75kWh / e-motor 300kW - 1500Nm / 2gears	FC 75kW / H2 25kg / batt 75kWh / e-motor 250kW - 1100Nm / 2gears

→ IFPEN Simcenter Amesim platform allows for **extending energy comparisons** (other than conventional diesel)

→ A **vehicle / powertrain sizing matrix** is proposed for consumption and LCA analysis

# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

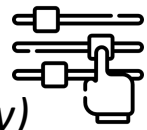


## Total vehicle CO<sub>2</sub>eq emissions

**Energy supply (WtT) :** data related to fuels and electricity carbon intensity

### Variable WtT emission factors :

- Electric carbon intensity
- H<sub>2</sub> production (blue/green/grey)
- Fuel (biofuel, e-fuel, renewable gas etc..)

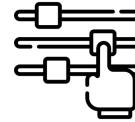


## Vehicle life cycle :

Performed using SimaPro® version 9.2.0.2 + Ecoinvent v.3.7.1 LCA database + Environmental Footprint reference packages 3.0 (European commission)

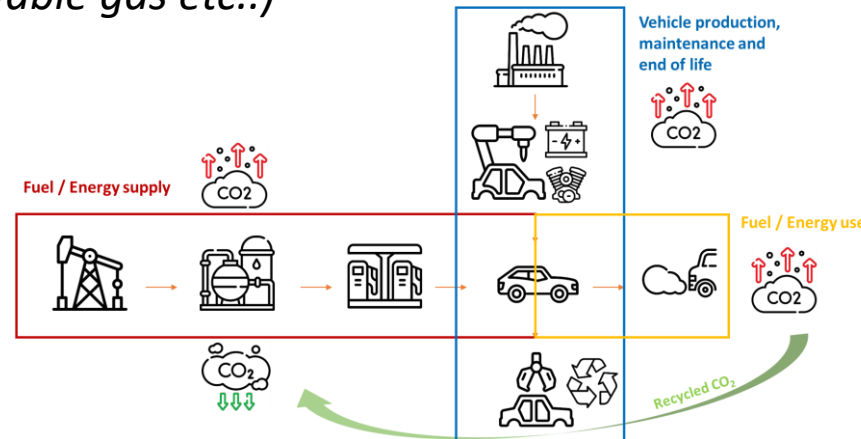
### Variable production emission factors :

- Battery
- Fuel cell
- H<sub>2</sub> tank



### Sources :

- JEC v5 2020
- ConcaWE 17/22 report
- JRC Scarlet 2022 report

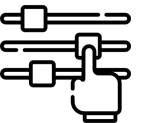


## Energy use (TtW) :

Energy and fuel consumptions from simulations

### Variable parameters for vehicle energy consumptions :

- Powertrain sizing and efficiency
- Usage



# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

An interactive tool, with guided scenarios, allowing to compare life-cycle CO<sub>2</sub> emissions from heavy-duty applications (trucks and buses) :

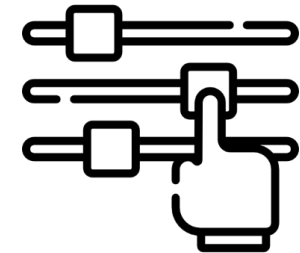
- **Configuration and design of the vehicles**

- ICEVs, HEVs, PHEVs, Electric and Fuel Cell vehicles
- Battery capacity and emission related to its manufacture
- H<sub>2</sub> capacity and emission related to carbon fiber tank manufacture
- Powertrain efficiencies



- **Usage of the vehicles**

- Payloads
- Typical trip profiles



- **Energy carriers**

- Carbon intensity of electricity used
- Diesel-like, Gas and H<sub>2</sub> with fossil and renewable options

# CONCAWE'S HEAVY DUTY VEHICLE CO<sub>2</sub> EMISSIONS COMPARATOR

Sustainable mobility

## Life Cycle Assessment (LCA) of greenhouse gas emissions from Heavy Duty Vehicles

september 2023 version

As powertrains diversify in their electrification levels along with the fuel production pathways – fossil and renewable routes – the carbon footprint over their life cycle heavily depends on their use cases (e.g. driving profile) and energy carrier specifics (e.g. carbon intensity of electricity). This interactive tool allows to design several scenarios combining these parameters and to compare their environmental performance over heavy-duty applications.

Select application to see the LCA comparison of propulsion solutions by clicking on vehicle pictures:

- Tool user guide
- Further explanation regarding the methodology



Long haul - Class 5



Delivery truck - Class 2



City bus



Inter regional coach



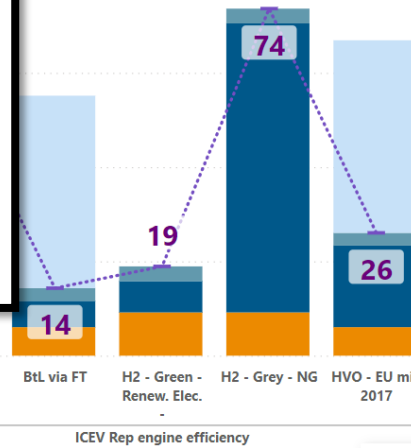
Refuse truck

This dashboard uses visual resources from Elaticon.com

### LCA of greenhouse gas emissions from Heavy Duty Vehicles

Class 5

minus Recycled CO<sub>2</sub> ● Recycled CO<sub>2</sub> ● Total LCA GHG



Mouse over each bar for more information about selected vehicles such as fuel consumption and estimated range (Check the consistency of ranges between vehicles when comparing GHG emissions)

Return to the selection of the application

Vehicles *To reset to default parameters, please use the page refresh button of your browser*

Powertrains: ICEV, HEV, PHEV, FCEV, BEV, CEV

Engine efficiency levels: Low, Rep, Max

Fuel cell efficiency levels: Low, Rep, Max

Battery capacity for BEV [kWh]: 400, 600, 900

Battery packs in the lifetime: 2

Battery production [kgCO<sub>2</sub>eq/kWh]: 86

H2 capacity [kg]: 70

Fuel cell production [kgCO<sub>2</sub>eq/kW]: 40

H2 tank production [kgCO<sub>2</sub>/kg]: 25

Usages

Cycle: Long haul VECTO, Regional VECTO, Urban delivery VECTO

Payload: Low, Rep, Max

Daily mileage [km] for PHEV usage: 600

Energies

Electricity carbon intensity [gCO<sub>2</sub>eq/kWh]

H2 production carbon intensity: H2 - Blue - NG CCS, H2 - Green - Renew. Elec., H2 - Grey - NG

Open fuel panel

<https://hdvco2comparator.eu/>

→ live demo !



→ The tools created by Concaawe and IFPEN utilize **energetic simulation results and emission factors derived from LCA** to assess and contrast the **CO<sub>2</sub>eq emissions of various propulsion options for both passenger cars and heavy-duty vehicles**

→ These tools are designed to guide the public and decision-makers in **identifying solutions for decarbonising the road transport sector**

→ The tools do a lot but do not answer all questions :

The environmental analysis only focuses on **CO<sub>2</sub>eq emissions**

Other environmental impacts such as consumption of water and raw materials and emissions of local pollutants should not be overlooked

Economic considerations would be relevant to complete the comparison of technologies

Periodic updates are essential to incorporate the ongoing energy and technological advancements within the transport sector

A peer-reviewed scientific paper outlining the first study's methodology



Transportation Research Part D: Transport and Environment  
Volume 119, June 2023, 103721



Evaluation of plug-in hybrid vehicles in real-world conditions by simulation