



# **IO1: Methodologies for carbon footprints**

## **Bibliography report on carbon emissions**

What are they ? How to measure them ?

Focus on transport-related emissions in Europe

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# What are carbon emissions ?

**Greenhouse Gas (GHG)** = gas in the atmosphere that absorbs and re-emits infrared radiation coming from Earth's surface. Contributes to the greenhouse effect.

**The Kyoto Protocol defines 7 GHGs to be reported:**

- $CO_2$  – carbon dioxide
  - $CH_4$  – methane
  - $N_2O$  – nitrous oxide
  - $HFCs$
  - $PFCs$
  - $SF_6$
  - $NF_3$
- fluorinated gases  
(f-gases)



**Precursor gas** = not a GHG, but their emission creates GHG by reaction in the atmosphere. Only encouraged to be reported.

- $CO$  (carbon monoxide)
- $NMVOCs$  (non-methane volatile organic compounds)
- $NO_x$  (nitrogen oxides)

# How to measure carbon emissions ?

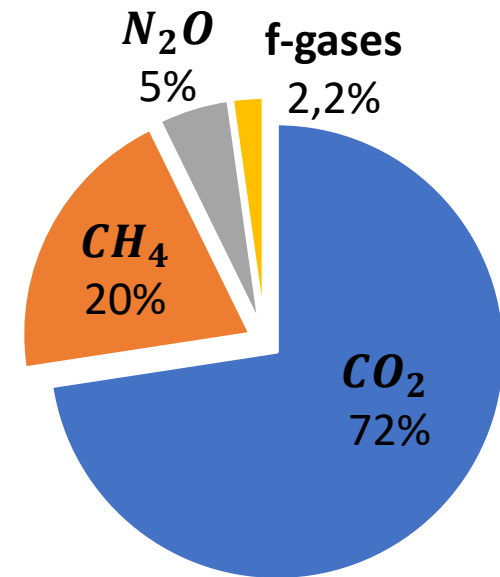
① **GHG inventory** = details sources of carbon emissions and carbon sinks from human activity.

② **Carbon footprint** = sum of GHG emissions in equivalent  $CO_2$  emissions ( $CO_{2eq}$ ).  
Obtained with the 100-year Global Warming Potential (GWP) value.

↳ **GWP** = quantifies the climate impact from the emission of a GHG compared to  $CO_2$

Examples:  $GWP_{CH_4} = 28 \rightarrow 1g \text{ of } CH_4 = 28g \text{ of } CO_{2eq}$   
 $GWP_{SF_6} = 23\,500 \rightarrow 1g \text{ of } SF_6 = 23\,500g \text{ of } CO_{2eq}$

$$\text{Total emissions } (CO_{2eq}) = \sum_{GHG} \text{Emissions}_{GHG} \times GWP_{GHG}$$



Total GHG emissions **in  $CO_{2eq}$**  worldwide in 2010

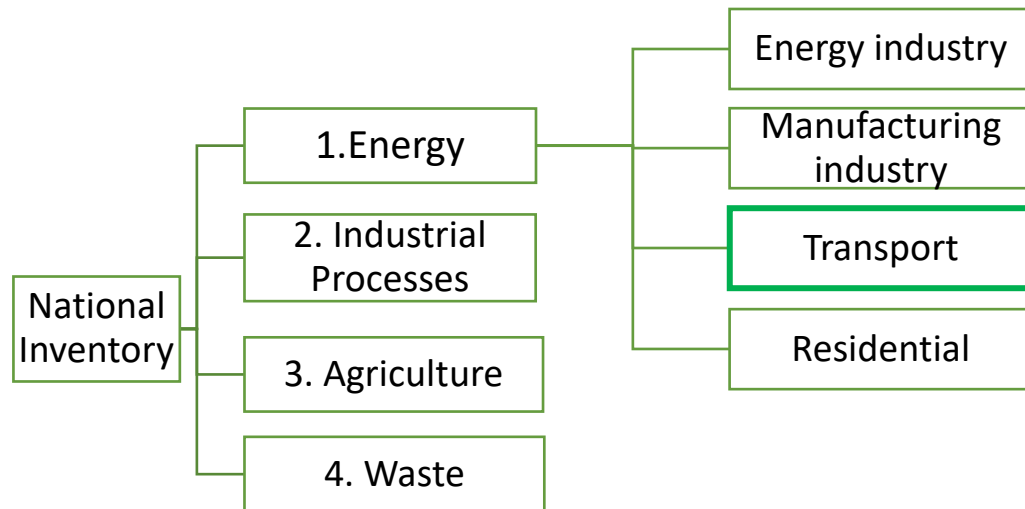
# GHG inventory international methodologies

## Nations

All EU countries report national GHG inventories to the **UNFCCC** (United Nations Framework Convention on Climate Change)

→ **2006 IPCC Guidelines for National GHG Inventories**

### Sectorial approach



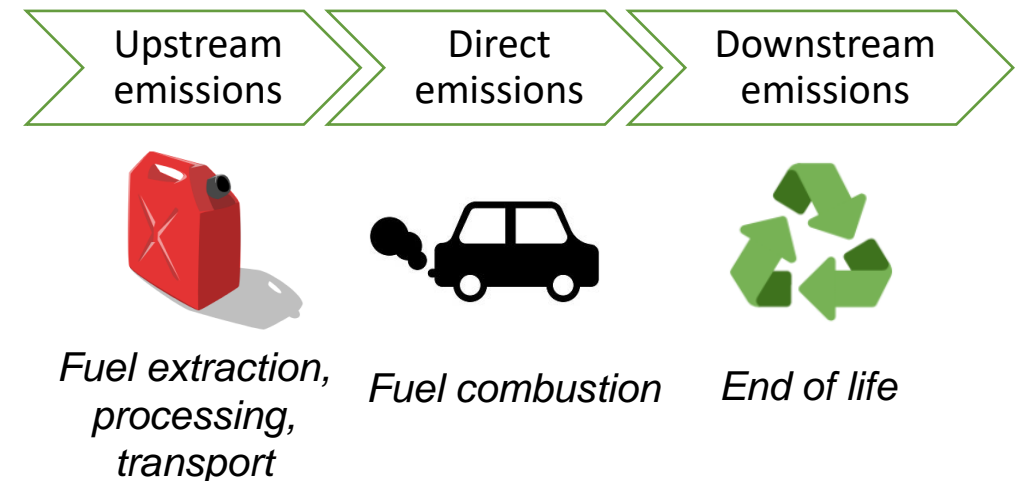
- ⊕ detailed methodologies for each sector
- ⊖ no indirect emissions

## Organizations

Depends on national and international legislation, often based on

- **GHG Protocol 'Corporate Standard'**
- **ISO 14064-1**

### Direct / indirect emissions approach



- ⊕ indirect emissions and passenger responsibility
- ⊖ less detailed methodologies

# What is the general methodology ?

## 6 steps for a GHG inventory:

- 1- Perimeter definition
- 2- Choice of methodology

Most usual method:

$$\text{Emissions} = \text{Activity Data (AD)} \times \text{Emission Factor (EF)}$$

*Examples for transport: AD = km traveled → EF = CO<sub>2</sub> emitted per km*

*AD = fuel consumed (liters) → EF = CO<sub>2</sub> emitted per liter*

- 3- Collecting the data

**Primary data** = data from direct measurement OR **Secondary data** = data from literature or other database (national averages, sector statistics, ...)

- 4- Estimating emissions
- 5- Uncertainty evaluation
- 6- Quality assessment and Reporting

# Methodology specific to transport – Road transport

Combustion emissions:

$CO_2$

only depend on fuel type

$CH_4, N_2O,$   
precursors and others

depend on fuel type, vehicle technology and operation

Different level of detail (tiers):

- **Tier 1 – fuel-based**

$$\text{Emissions} = \sum_{\text{Fuel}} \text{Fuel consumption} \times \text{EF}$$

—————→ for  $CO_2$

- **Tier 2 – fuel-based by vehicle type**

$$\text{Emissions} = \sum_{\text{Vehicle type}} \sum_{\text{Fuel}} \text{Fuel consumption} \times \text{EF}$$

—————→ for  $CH_4, N_2O$

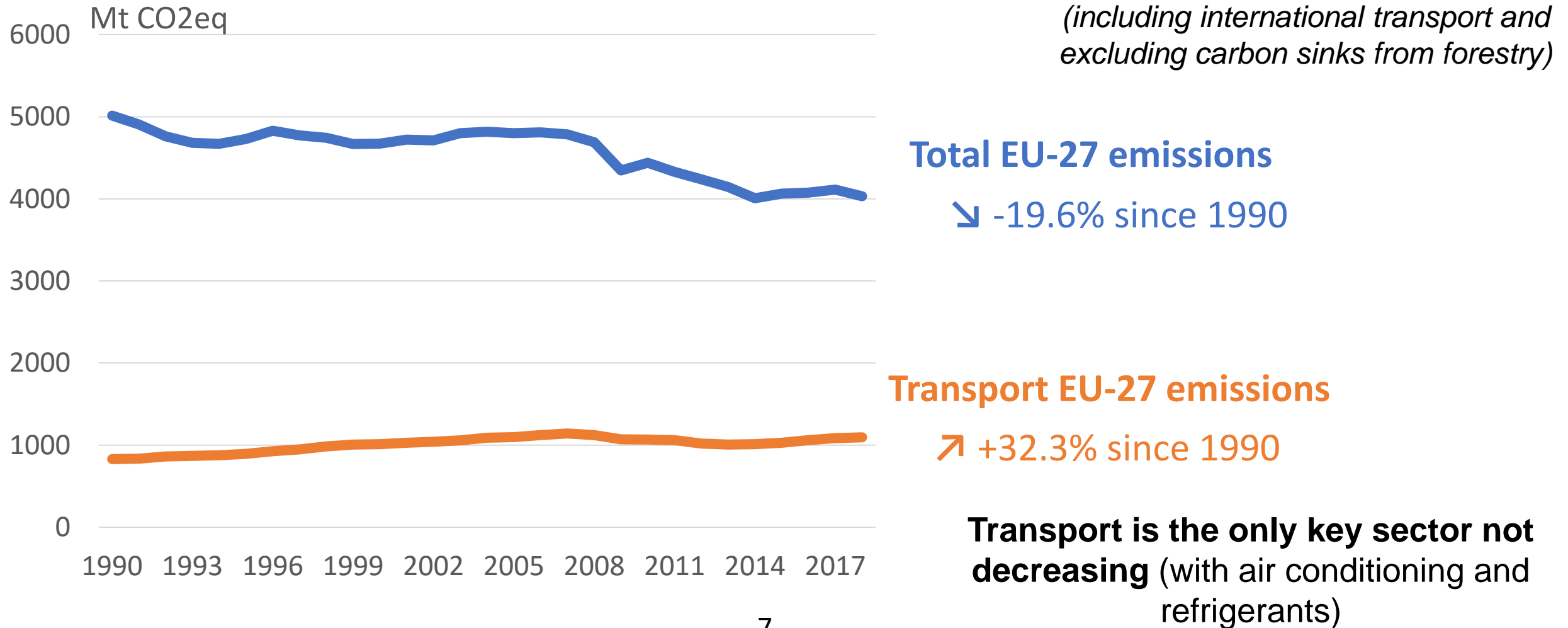
- **Tier 3 – distance-based models**

- COPERT model from EEA (European Energy Agency)
- MOVES or MOBILE models from USEPA (US Environmental Protection Agency)

—————→ for  $CH_4, N_2O$

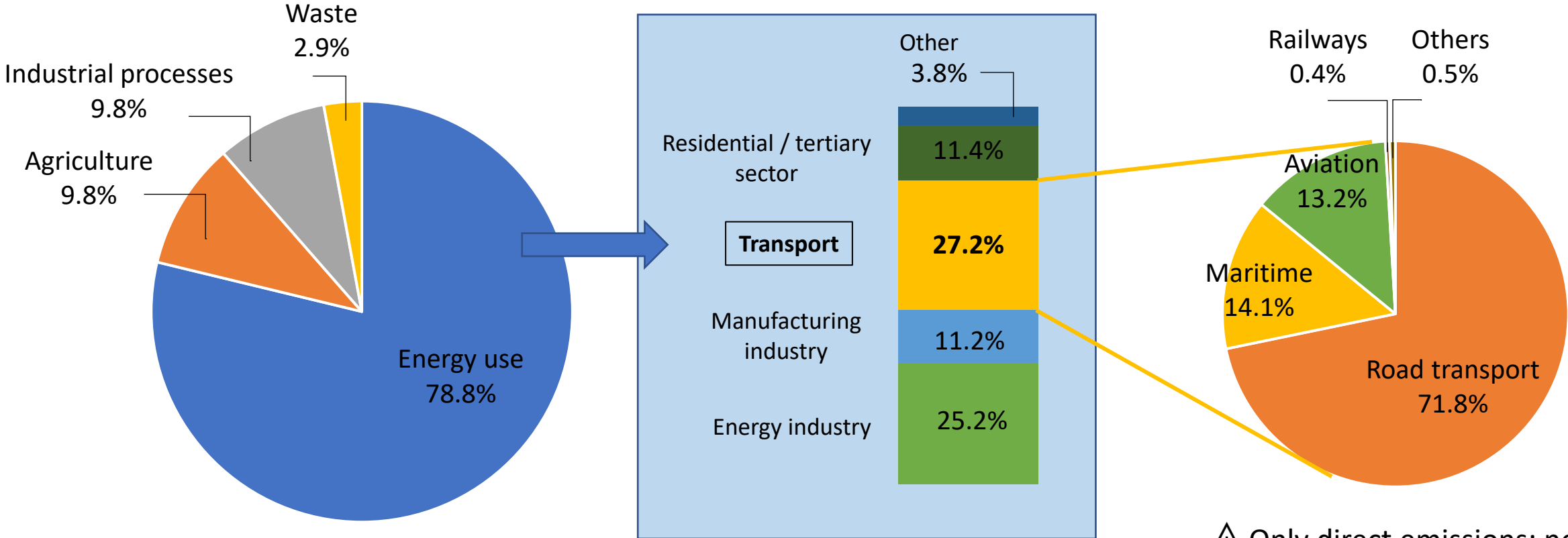
# Evolution of carbon emissions in Europe

Data from the annual EU report to the UNFCCC, available on the EEA website



# Repartition of carbon emissions in Europe

Data from the annual EU report to the UNFCCC, available on the EEA website



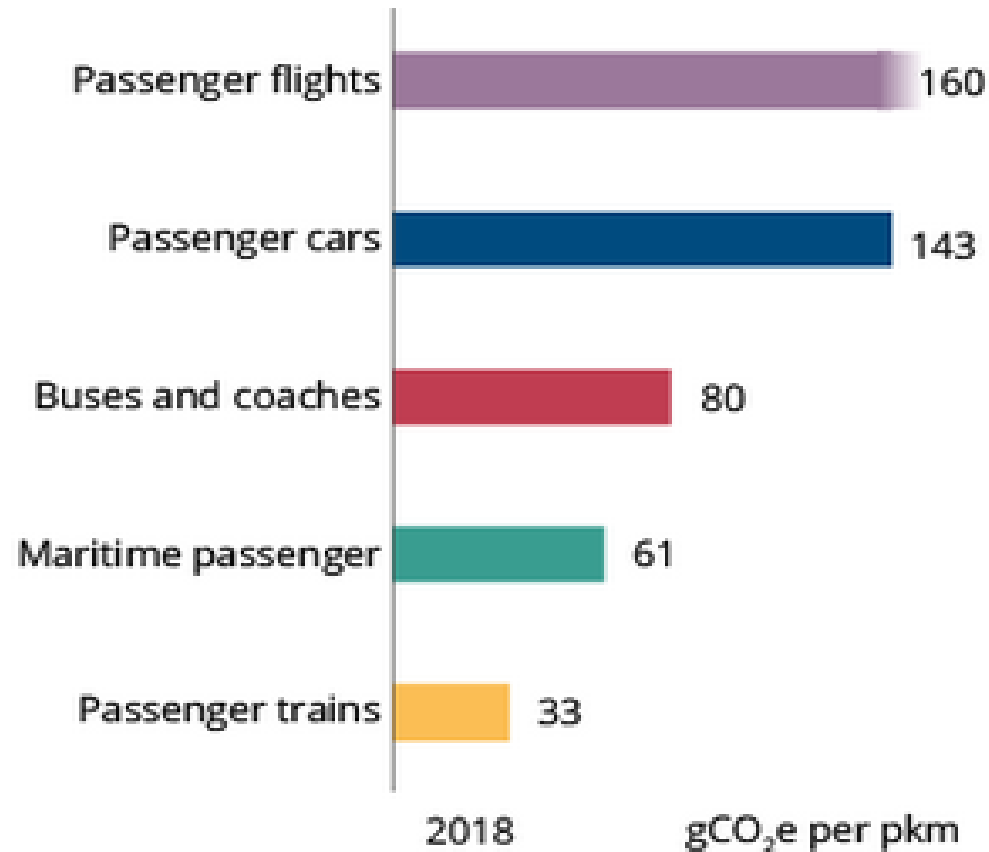
Total EU-27 GHG emissions in CO<sub>2</sub>eq in 2018

⚠ Only direct emissions: no emissions from electricity generation for electric vehicles



# Comparison of modes of transport in the EU-27

Including fuel life cycle indirect emissions (Well-to-Wheel emissions)



pkm = passenger kilometer  
(moving one passenger  
over one km)

**Airplanes and cars emits the most.  
Trains emits the less (realies heavily on electricity)**



**Thank you for your  
attention !**

# Methodology specific to transport - Aviation

Combustion emissions from aircraft: ~70% CO<sub>2</sub>      ~30% H<sub>2</sub>O      <1% other (NO<sub>x</sub>, CO, ... )

2 phases of operation: Landing / Take-Off (LTO) – below 914m  
Cruise operations – above 914m

- **Tier 1 – fuel-based**

$$\text{Emissions} = \text{Fuel consumption} \times \text{EF}$$

- **Tier 2 – fuel-based with separation of LTO and Cruise operations**

$$\text{Emissions} = \text{Emissions}_{\text{LTO}} + \text{Emissions}_{\text{Cruise}} = (\text{Fuel}_{\text{LTO}} \times \text{EF}_{\text{LTO}}) + (\text{Fuel}_{\text{Cruise}} \times \text{EF}_{\text{Cruise}})$$

- **Tier 3A – distance-based models with origin and destination**

$$\text{Emissions} = \text{Distance} \times \text{EF}_{\text{Distance}}$$

but EF differ according to the distance  
(short, middle, long-haul flights)

- **Tier 3B – computer models using full flight data**

- AERO2K from European Commission
- SAGE (System for assessing Aviation's Global Emissions) from US Federal Aviation Administration

# Carbon emissions from transport in Europe

Data from the annual EU report to the UNFCCC, available on the EEA website

