# An Experiment on Precise and Secure Calculation on GHG Emissions

Takashi Michikata

Associate Professor

Interfaculty Initiative in Information Studies

The University of Tokyo

# Content

- Three whys on calculation of GHG emissions
  - Why do you need to calculate GHG emissions?
  - Why do you need to calculate GHG emissions accurately?
  - Why do you need to calculate GHG emissions securely?
- How do you calculate GHG emissions accurately and securely?
- Experiment Using Self-Driving Electric Vehicle

# Why do you need to calculate Greenhouse Gas (GHG) emissions?

# Global Trends in Greenhouse Gas Reduction

- The Paris Agreement in 2015
  - to hold “the increase in the global average temperature to well below 2° C above pre-industrial levels”
- The European Union aims to be climate-neutral by 2050.
- Japan aims to achieve carbon neutrality by 2050.
- China aims to archive carbon neutrality before 2060.

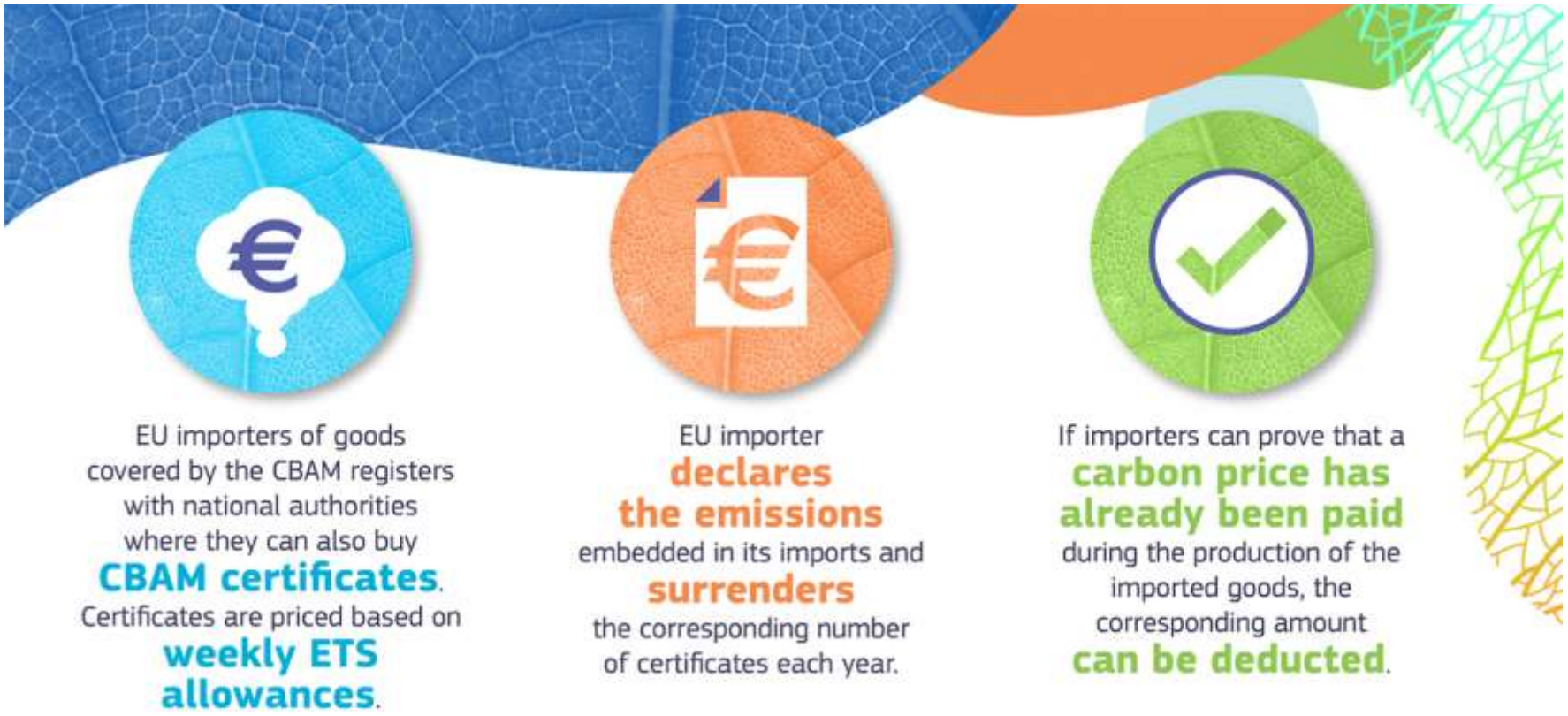
**It’s 2023,**

**and you may feel 2050 is a distant future.**

**But things have already started!**

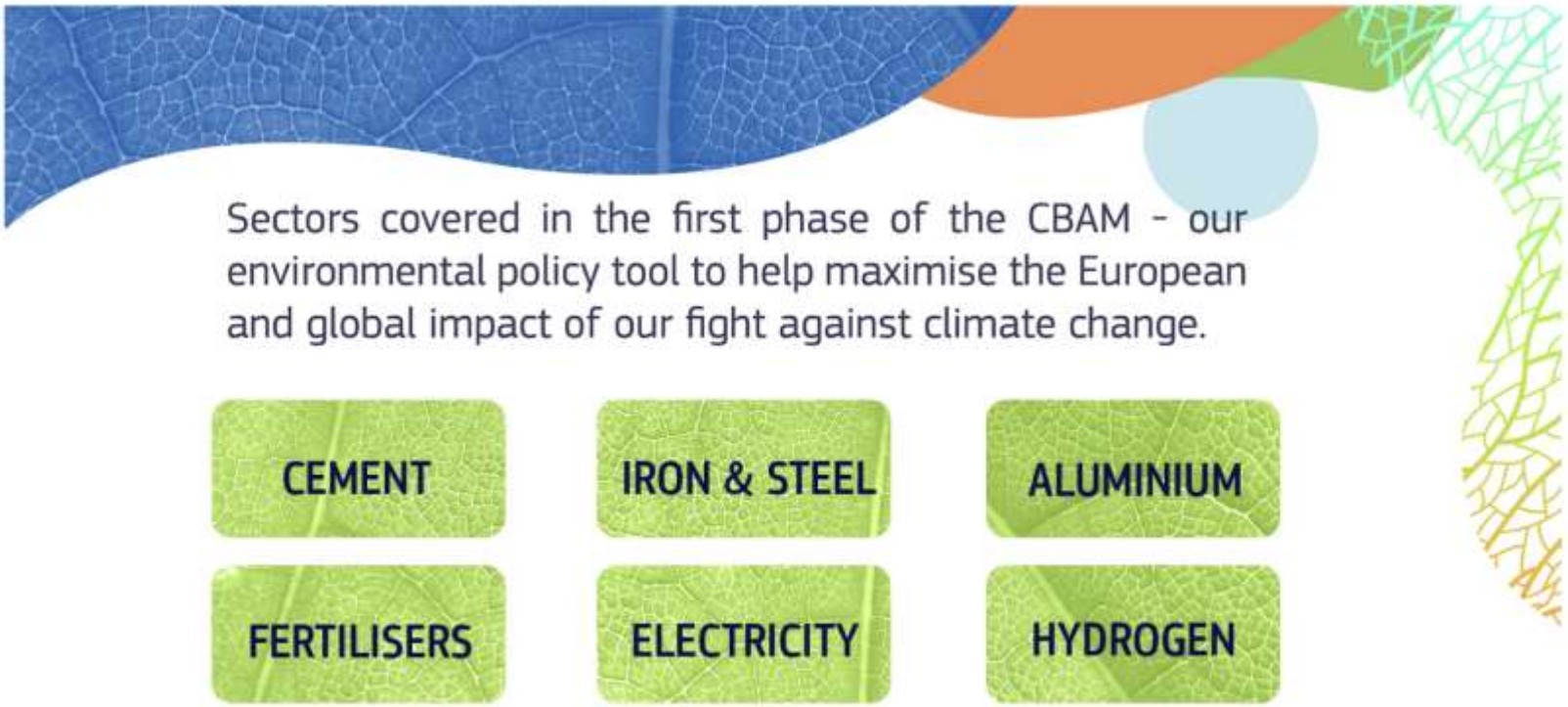
# The Carbon Border Adjustment Mechanism(CBAM) by EU

- The CBAM is a type of carbon tax on imported goods toward EU.
- The objective is to avoid ‘carbon leakage’.



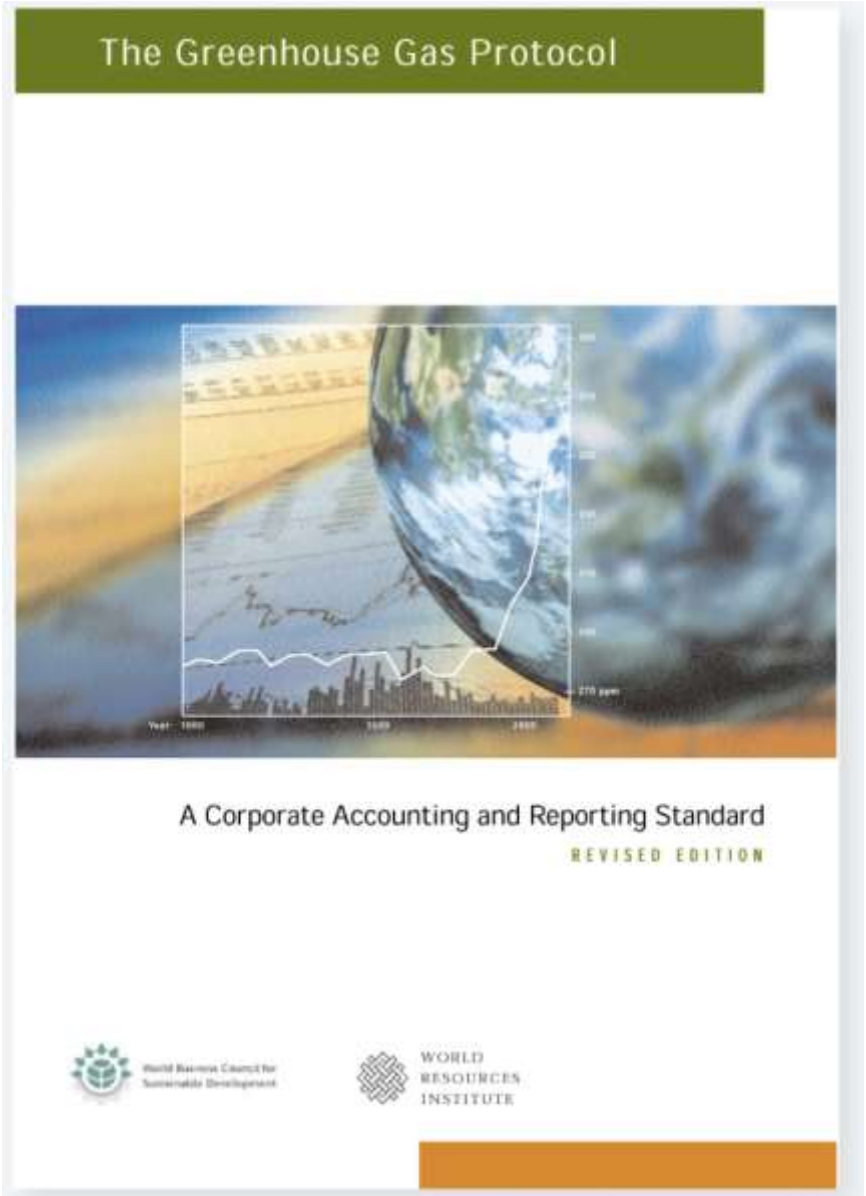
# The Carbon Border Adjustment Mechanism(CBAM) by EU (cont.)

- The CBAM just entered in its transitional phase on October 1st 2023.
- In the transitional phase, importers of the carbon intensive goods have to report the embedded carbon emissions generated in the production.
- The CBAM eventually will become a carbon import tax and affect global industries.



# Why do you need to calculate GHG accurately?

# The GHG Protocol: Global standard to calculate GHG emissions for industries



# Basic Calculation of GHG Emissions

**Activity Data X Emission Factor = GHG Emissions**

**It looks very simple,**
**but it could get very complicated!**

# Examples of activity data and emission factors for automobiles

- Activity Data
  - **Fuel Consumption (e.g., 50 liters)**
  - Electricity Consumption (100kWh)
  - Distance traveled (e.g., 320 kilometers)
- Emission Factors
  - **Gasoline (e.g., 2.3 kg $CO_2$ per litter)**
  - Electricity (e.g., 0.5 kg $CO_2$/kWh)
  - Emission factors per distance (for gasoline)(e.g., 0.2kg $CO_2$ per kilometer)

**For example, a GHG emission can be calculated like this.**

**50 liters X 2.3 kg $CO_2$ per litter = 115 kg $CO_2$**

**The “emission factors” are general data, which are taken from some stats.**

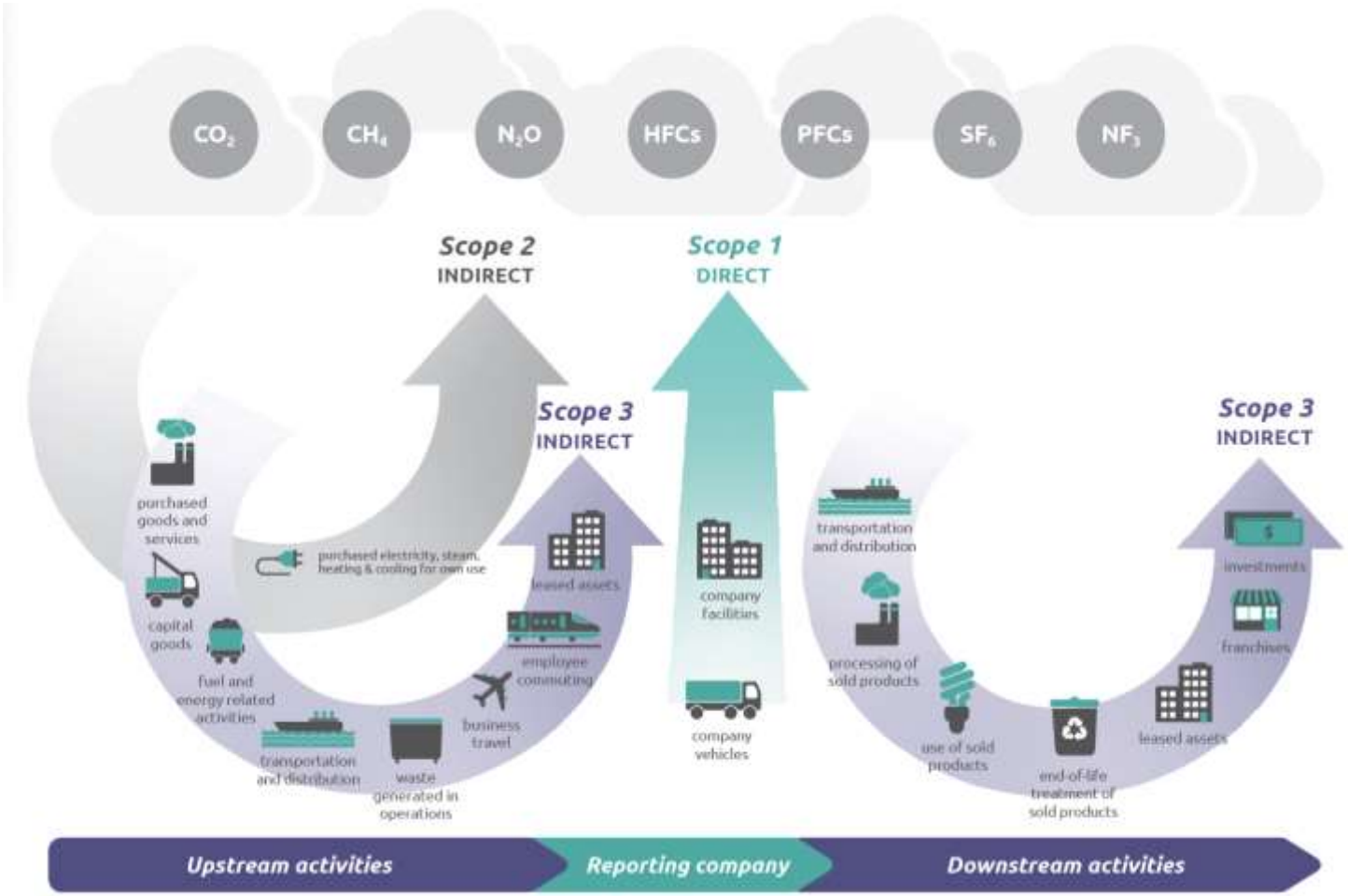
**But what if you are driving an energy-efficient car.**

**You want to bring specific data and calculate CO2 emissions accurately to report lower CO2 emissions.**

# Why do you need to calculate GHG emissions securely?

# Scope3 Emission in the GHG Protocol

- The GHG Protocol defines direct emissions as Scope1, indirect emissions from energy purchases as Scope 2 and **other indirect emission as Scope3.**



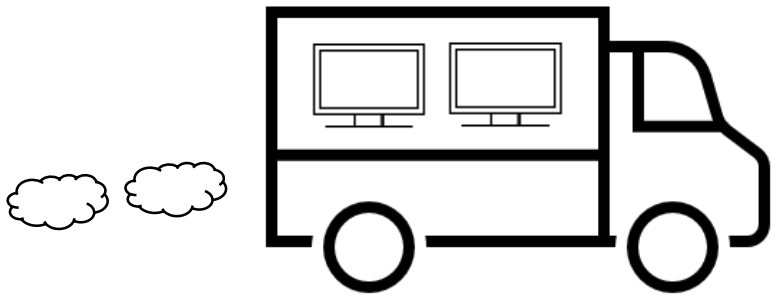

(Source: https://ghgprotocol.org/scope-3-calculation-guidance-2)

# What is an indirect emission?

**If you are a manufacturer,**
**you need to ask a logistics company to bring your product to deliver.**

**The logistic company drives a truck and it emits GHG.**

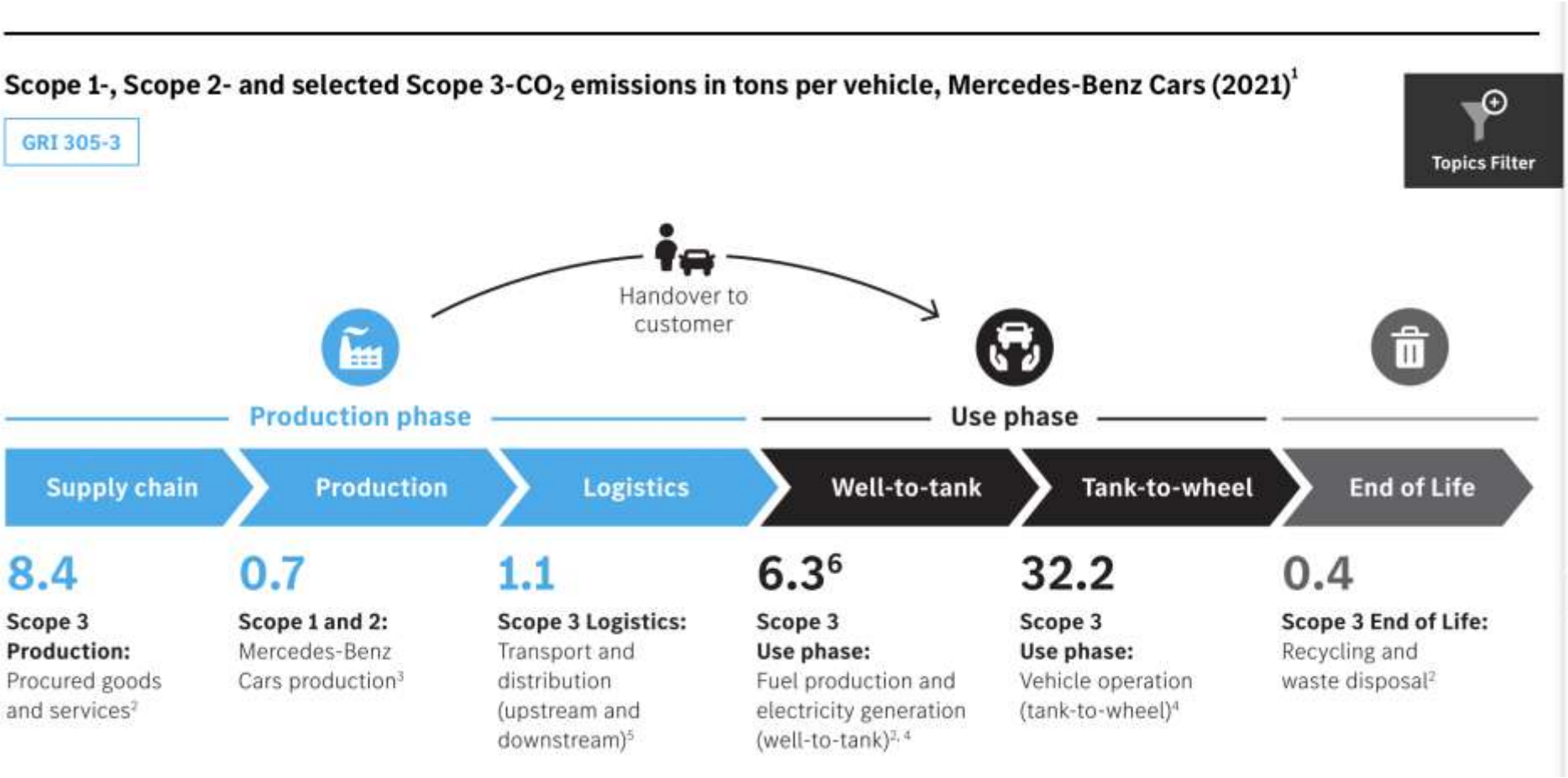
**That is an indirect emission (Scope 3 emission).**



**You need other parties' data to calculate indirect GHG emissions.**

# Example of Calculation of GHG Scope 3 Emissions (Mercedes-Benz)

- The large part (80%) of GHG Emissions for cars comes from their use phase (Scope 3 emissions).




(Source: https://ghgprotocol.org/scope-3-calculation-guidance-2)

# Example of Calculation of GHG Emissions (Mercedes-Benz) (Cont.)

- Excerpt form Mercedes-Benz Website
  - We determine the $CO_2$ emissions of our vehicles in the use phase on the basis of our worldwide sales figures and the fleet's average normalised $CO_2$ emissions figure. For this calculation, we assume that **each vehicle travels 20,000 kilometres per year**. We also assume that **each car is used for a period of ten years**. The average total mileage thus amounts to **200,000 kilometres per vehicle**.

**What if cars are energy efficient ones such as hybrid cars or electric cars?**

**To report lower CO2 emissions, they need more data from their users.**

**However,**

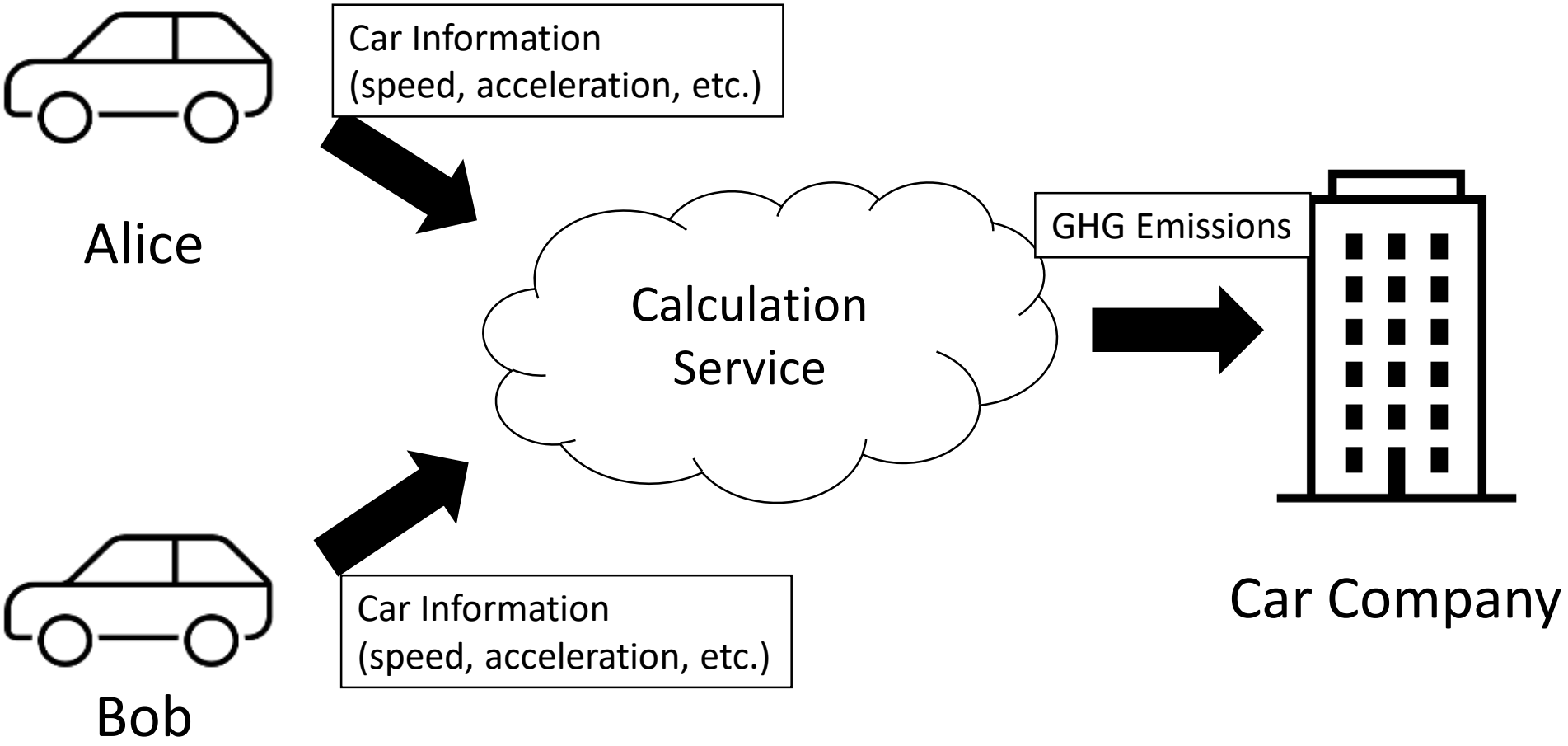
**the data contains private information (e.g., locations and speeds of the cars).**

**You need a system for privacy-preserving secure calculation!**

# How do you calculate GHG emissions accurately and securely?

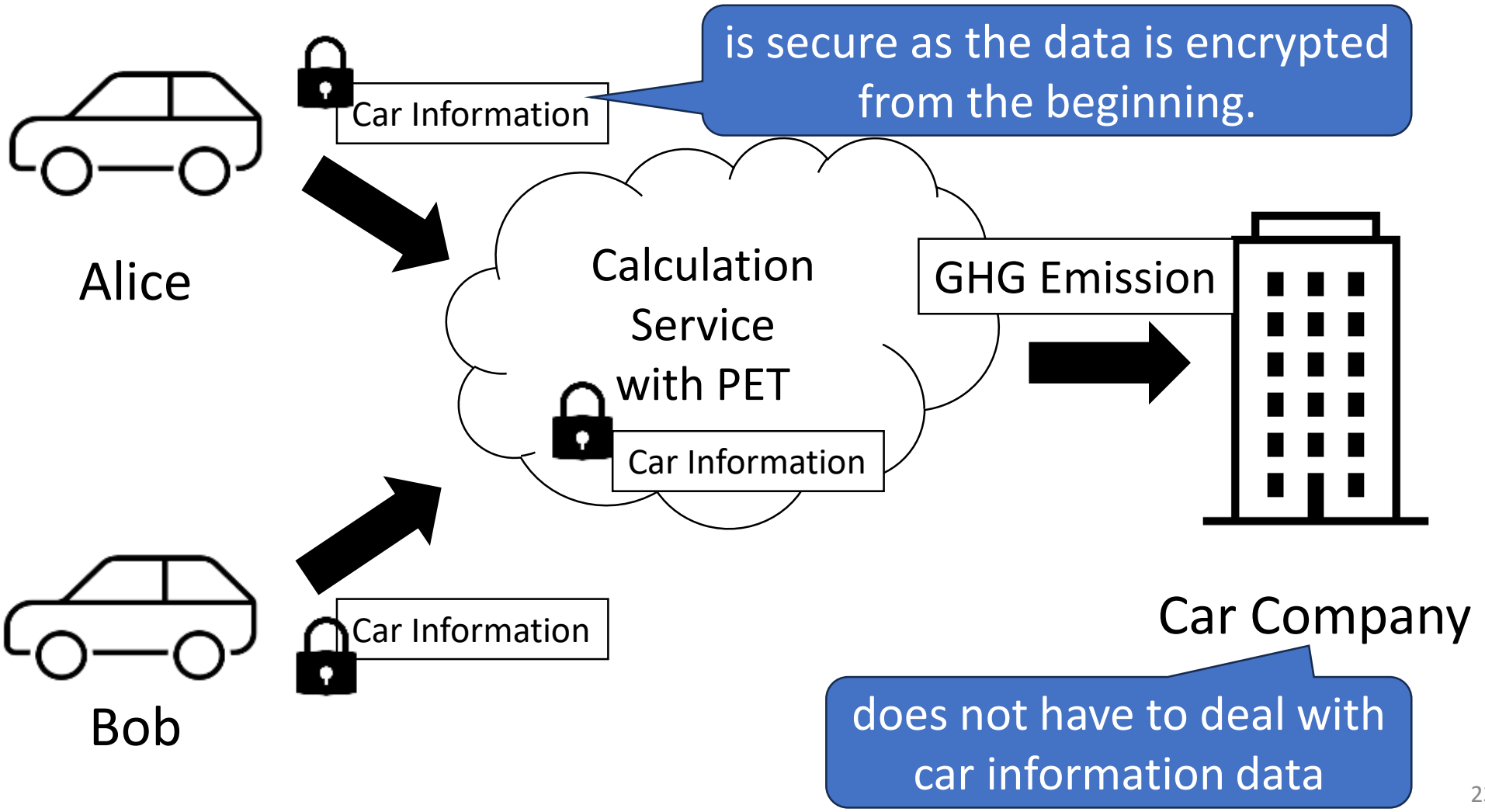
# Hypothetical Scenario

The Car Company wants to calculate GHG emissions of Alice and Bob without knowing their car information.



# Privacy Enhancing Technology(PET) (Homomorphic Encryption)

With a PET, Alice and Bob's information remains encrypted, and the Car Company can still get the total GHG emissions.



# Some Drawbacks of the PET

## Performance Overhead

Computations on encrypted data take a lot of time.

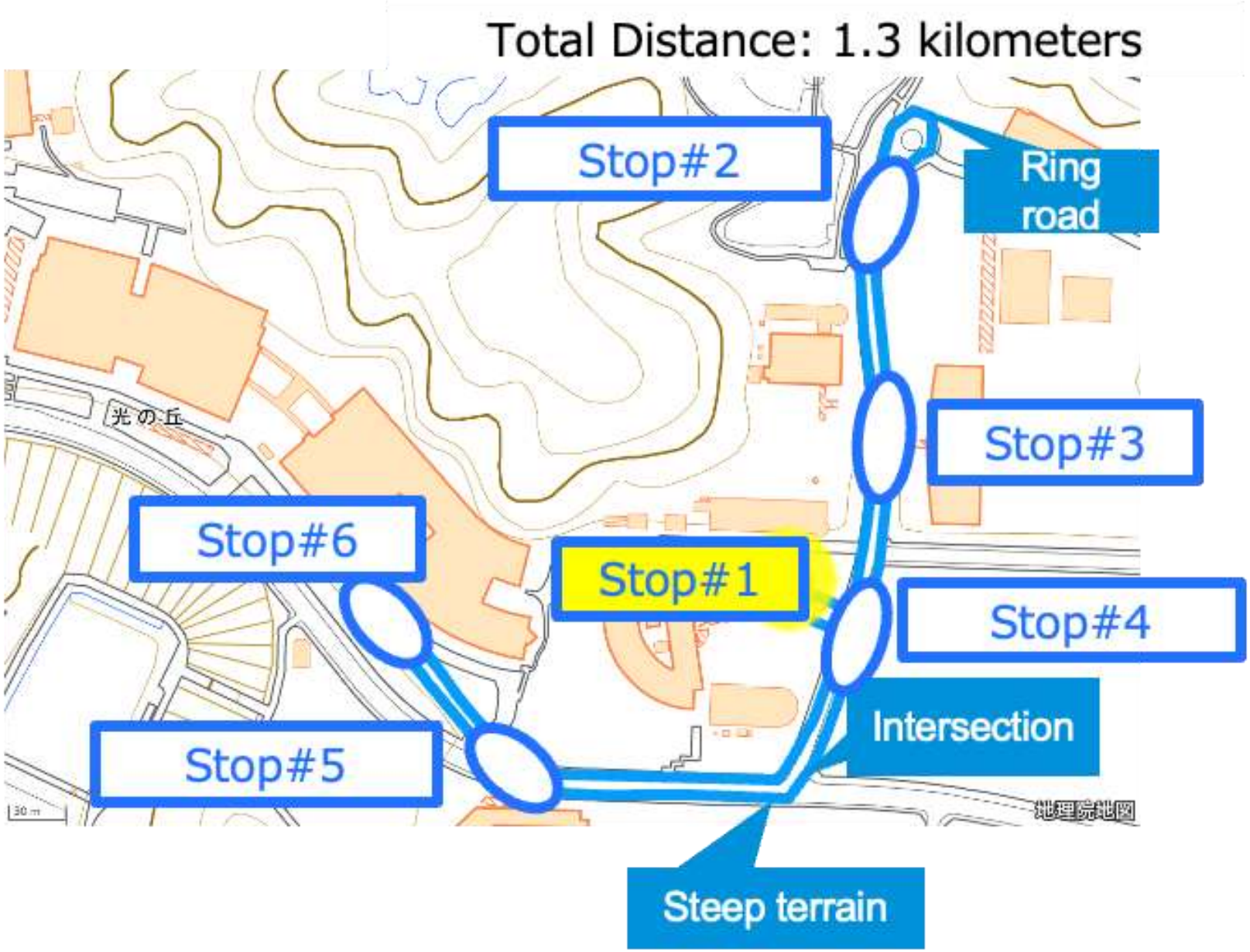
Encrypted data are much bigger than plain data.

## Key Management

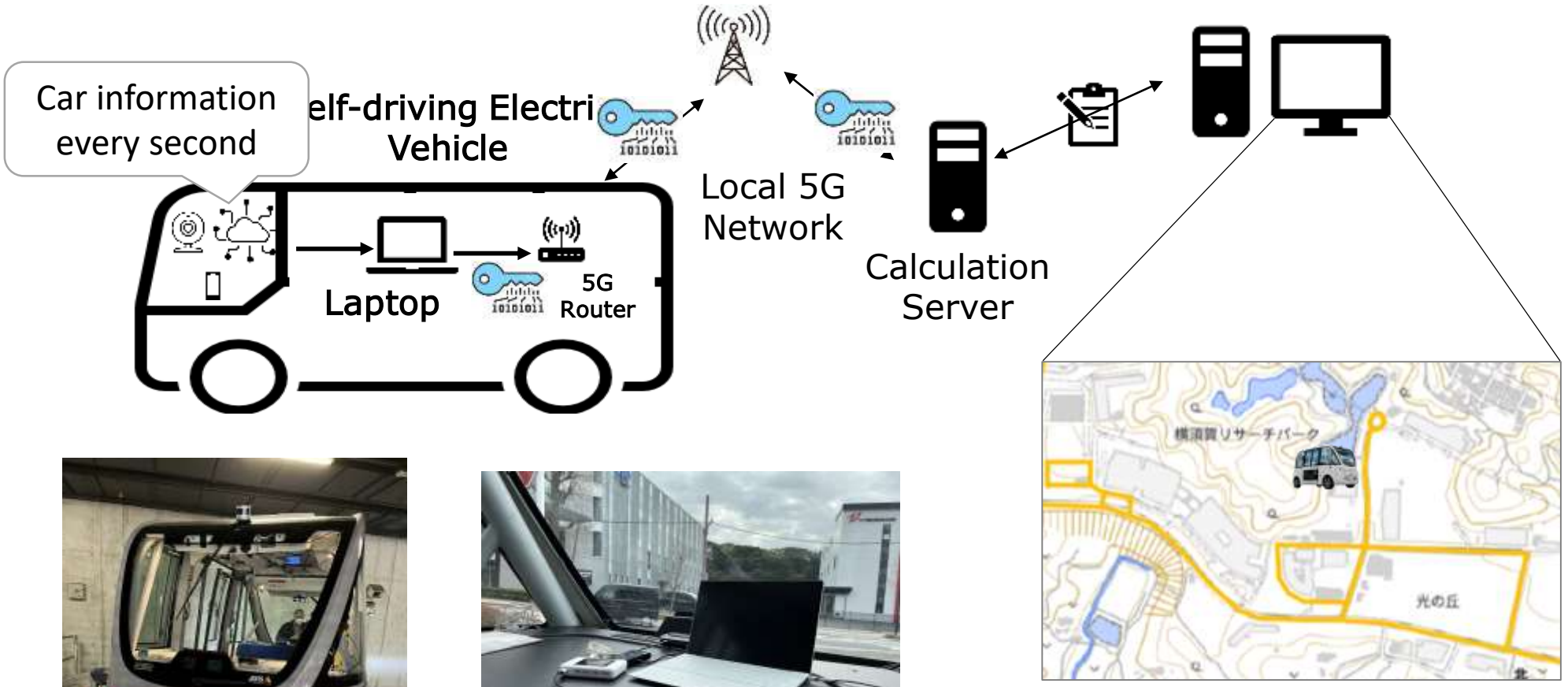
A private key to encrypt data must be kept under strict control.

# Experiment on Self-Driving Electric Car to Evaluate Performance Overhead

# The Experiment Course at Yokosuka Research Park



# The Experiment Setting




# The Experiment Result

Vehicle speed: 9.3km/h Energy Consumption: 24532.1Wh CO2 Emission:11.1kg-CO2/h

Time spent (1)Total: 3687ms (2)Encrytion: 21ms (3)Data transfer: 3477ms (4)Secure computation: 186ms (5)Decryption: 3ms

# Evaluation of the Performance Overhead (Computation and Data Transfer)

- Table of average time spent for computations and data transfer

| Transfer Interval[s] | Total[ms] | Encryption [ms] | Data Transfer[ms] | Computation [ms] | Decryption [ms] |
|---|---|---|---|---|---|
| 5 | 4,495.0 | 21.6 | 4,302.4 | 189.4 | 3.2 |

- Data Transfer is very costly even with 5G high-speed network.
- Need to work on how to develop and how to apply this technology.

# Conclusion

- There are global trends in GHG reduction, and the EU has enforced the CBAM regulation.
- To comply with the regulation, an accurate GHG emission calculation is necessary, and it may require to deal with some private information.
- Secure and precise GHG emission calculations are required.
- Our experiment shows some possibility of applying a privacy enhancing technology to the calculations.


# Thank you!

takashi.michikata@koshizuka-lab.org

Acknowledgement: Part of this study is supported by Ministry of Internal Affairs and Communications (MIC), the Government of Japan, within their “Wide Local 5G Technical Experiment.”