An Experiment on Precise and Secure Calculation on GHG Emissions

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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’.

EU importers of goods covered by the CBAM registers with national authorities where they can also buy **CBAM certificates**. Certificates are priced based on **weekly ETS allowances**.

EU importer **declares the emissions** embedded in its imports and **surrenders** the corresponding number of certificates each year.

If importers can prove that a **carbon price has already been paid** during the production of the imported goods, the corresponding amount **can be deducted**.

#EUGreenDeal
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 $\times$ 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 (100 kWh)
  - 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., 0.2 kg CO$_2$ per kilometer)

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

\[
50 \text{ liters} \times 2.3 \text{ kg CO}_2 \text{ per litter} = 115 \text{ kg CO}_2
\]
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?
The GHG Protocol defines direct emissions as Scope 1, indirect emissions from energy purchases as Scope 2 and **other indirect emission as Scope 3.**

(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)
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.

Car Information (speed, acceleration, etc.)

Calculation Service

GHG Emissions

Car Company
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.

Car Company

is secure as the data is encrypted from the beginning.

Calculation Service with PET

Car Information

Car Information

Car Information

does not have to deal with car information data
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

Total Distance: 1.3 kilometers

- Stop #2
- Stop #3
- Stop #4
- Stop #1
- Stop #6
- Stop #5
- Ring road
- Intersection
- Steep terrain
The Experiment Setting

Car information every second

self-driving Electric Vehicle

Laptop

5G Router

Local 5G Network

Calculation Server

Visualizing System

Visualizing System

Car information every second

self-driving Electric Vehicle

Laptop

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The Experiment Result

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

Time spent (1)Total: 3687ms (2)Encryption: 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

<table>
<thead>
<tr>
<th>Transfer Interval[s]</th>
<th>Total[ms]</th>
<th>Encryption [ms]</th>
<th>Data Transfer[ms]</th>
<th>Computation [ms]</th>
<th>Decryption [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4,495.0</td>
<td>21.6</td>
<td>4,302.4</td>
<td>189.4</td>
<td>3.2</td>
</tr>
</tbody>
</table>

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!

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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.”