# Introduction to CTN Carbon Chain Trusted Network

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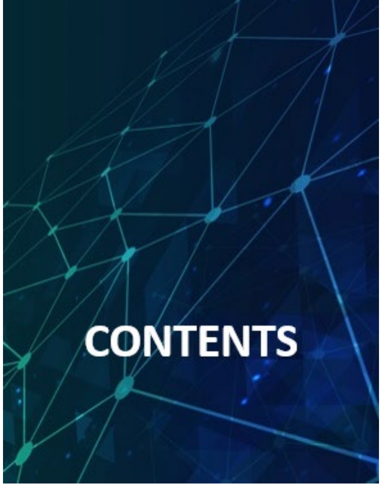
Industrial Value Chain Initiative




## Executive Summary

Carbon neutrality (CN) is an important issue to be addressed at the individual, corporate and societal levels. Trusted carbon chain networks make their own CO2 reduction efforts sustainable by interlinking them with each other. The calculation of the carbon footprint (CFP), which becomes important here, is complicated by the need to allocate the CO2 emissions of each business unit to each product unit. This white paper explains, using concrete numerical examples, a model that enables even small and medium-sized enterprises (SMEs) to calculate the CFP easily. The calculation model aggregates the CFP of the materials that make up the product and obtains the CO2 emissions resulting from production at the business via the equipment emissions factor corresponding to the energy use by the equipment. By increasing the granularity and reliability of the data step by step, the model is expected to be used by enterprises at various management levels.

For CFPs to be routinely exchanged along with products and services between enterprises, primary data such as equipment operating data needs to be exchanged on a trusted data federation infrastructure. This white paper shows that four types of services enabled by the Connected Industry Open Framework (CIOF) are essential building blocks for the realization of CN. The emissions intensity factor service calculates and provides emissions intensity, which is the basis for calculating CO2 emissions, using statistical methods. The CFP calculation support service provides a mechanism to enable small and medium-sized manufacturing companies to calculate CFP in an accumulative manner. Furthermore, the CFP certification service mediates CFP between companies and certifies as a third party that the value has been correctly calculated. The traceability search service discloses the data on the basis of CFP to consumers and manufacturers when they want to know the data on the basis of CFP, without any disadvantage to the provider.

In order for all countries and regions to start working towards the realization of CN on a global scale, and for CFP-based carbon chain visualization to make a significant contribution to the realization of CN, it is necessary to ensure correct ownership of the data presented outside the enterprises, define a database dictionary that allows for diverse values, provide an incentive mechanism to disclose the correct CFP, and a mechanism for tracing the entire data set in a distributed environment based on data linkages. Standardization and rule-making activities to realize these open ideas and ensure their wide recognition are also crucial.

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# 1. Introduction

In 2020, Japanese Government declared carbon neutral (CN) by 2050 by then Prime Minister Yoshihide Kan. In 2021, at the 26th Conference of the Parties (COP26) to the UN Framework Convention on Climate Change (UNFCCC), the current Prime Minister Fumio Kishida, explained the specific targets to the world, and in 2022, the decarbonization became one of the most important issues regarding Green Transformation (GX). To promote this in the public and private sectors, it is estimated that over 150 trillion yen of investment will be required over the next 10 years.

The main breakdown of CN investment is the de-energization of energy supply (60 trillion yen) at the top of the list, followed by the structural transformation of industry (50 trillion yen). Capital investment and research and development need to be encouraged, but with such large amounts, there are limits to what can be done through subsidies and tax incentives. Transition finance and other related means is based on the assumption of future growth, and ultimately the manufacturing sector in particular will be strongly required to bear the cost of CO2 emissions through carbon pricing.

Carbon pricing can be divided into a price approach and a quantity approach, with the former embodied in a carbon tax and the latter in a carbon emissions trading scheme. As of December 2022, Japan's carbon tax is 289 yen per ton of CO2 emissions, while the EU-ETS (European Emissions Trading Scheme) is 90 euros (12,600 yen: converted to 140 yen) in terms of emissions trading. There are also examples of emissions trading in Japan with J-credits for more than 10,000 yen. In FY2023, at the initiative of Prime Minister Kishida, the GX League will be established and growth-oriented carbon pricing under Japan's version of the GX-ETS will be launched.

Such policy initiatives for GX are commendable in that they embed the decarbonization trend into the market mechanisms rather than subsidies. On the other hand, these schemes and initiatives are more geared towards companies upstream in the supply chain, such as in the energy and materials industries, and large, high-profile companies. They are not sufficient as a mechanism to encourage the small and medium-sized manufacturing industry, which makes up the majority of the manufacturing sector, and society as a whole, including end consumers, to bear the cost burden. For large companies, a simple structure in which the burden for GX increases as the company's performance improves could also stifle economic growth.

Considering this, this paper proposes an approach based on carbon footprinting (CFP), using a framework for data linkage between companies, as an initiative to promote the transformation of industrial structures towards carbon neutrality (CN) in 2050. CFP is an approach whereby each product, from its materials to all processes in the supply chain , to calculate CO2 emissions from a Life Cycle Assessment (LCA) perspective.

In promoting decarbonization and low-carbon initiatives through CFP, even in the most fundamental processing and assembly-type manufacturing industries, common calculation methods and rules have not yet been established. In addition to the issue of calculation methods, there are many issues to be solved, such as the cost burden on the information system to calculate CFP on a daily basis, and the issue of guaranteeing the validity of the CFP calculation basis when CFP is linked to the selection of suppliers and transaction prices by the manufacturer.

The Carbon Chain Trust Network (CTN) proposed in this paper is expected to be an effective tool to address these issues. The CTN is positioned as a mechanism for society as a whole to tackle CN as an ecosystem that includes these SMEs and small businesses.

In section 2 below, the necessary data and calculation methods for CFP are presented with specific examples, using a general processing and assembly manufacturing industry as an example; in section 3, four services for utilizing CFP and the data between enterprises are presented. Furthermore, in section 4, a practical approach using a framework for data distribution between enterprises (CIOF) is described. And in 5, the CTN framework is proposed again as an initiative to realize CN.

# 2. Primary Data and Computational Model for CFP

The calculation of $CO_2$ emissions can be divided into two types: emissions calculations based on business units and emissions calculations based on product-by-product approach.

The former method of calculating emissions per business unit is shown on the website of the Japanese Ministry of the Environment and is used by companies to prepare SBTs and CSR reports that show their own $CO_2$ reduction targets. This is a global standard in accordance with ISO 14064/14065 and the calculation method corresponding to the GHG Protocol established under the initiative of the WBCSD is widely used.

On the other hand, CFP, which is important for the CTN presented in this paper, is based on the latter product-by-product approach. The calculation of $CO_2$ emissions per product clarifies the environmental impact of products and services as a Life Cycle Assessment (LCA) in accordance with ISO 14040/14044. CFP is specified in ISO 14067 as a method of LCA and is Scope 3 Category 1 (purchased and acquired products and services) in the GHG Protocol.

As the main purpose of the GHG Protocol is to calculate $CO_2$ emissions per business unit, emission for purchased and acquired products and services is secondary data, i.e. statistically processed data obtained from external databases such as IDEA provided by the Sustainable Management Promotion Organization (SuMPO). In many cases, this data is used. However, as the CFP requires businesses to calculate $CO_2$ emissions corresponding to the products and services they sell and provide to their customers, it is necessary to use primary data actually obtained from factory production lines, especially in the case of manufacturing industries.

$CO_2$ emissions in the production line of a product correspond to Scope 1 (direct emissions) and Scope 2 (indirect emissions) of the GHG Protocol. Therefore, it can be said that for companies that calculate $CO_2$ emissions on a business-by-business basis according to the GHG Protocol, the $CO_2$ emissions resulting from the production process in the factory can be calculated based on primary data. The calculation formula is as follows.

$$CO_2 \text{ emissions} = \text{activity} \times \text{emissions intensity} \qquad (1)$$

Here, in the calculation of direct emissions corresponding to Scope 1, the activity is a unit of consumption, such as the weight or volume of fuel, with a corresponding emissions intensity (coefficient). For example, the emission intensity of petrol is 2.322 $tCO_2$/kl and that of distributed gas is 2.234 $tCO_2$/thousand $Nm^3$. In the case of indirect emissions calculations corresponding to Scope 2, the amount of electricity consumed is used as the amount of activity, and the emissions intensity is based on figures provided by the respective power companies. For example, the $CO_2$ emissions intensity of TEPCO in FY2021 is 0.452 kg-$CO_2$/kWh.

In order to calculate $CO_2$ emissions using the stacking method, it is necessary to obtain the required granularity of activity as primary data. Here, the granularity as a period of time and the granularity as a range of coverage are problematic. For example, in the case of electricity, the figures may not be annual totals, but monthly, date and time, and in some cases, half-hourly figures may be required. In addition, the scope of coverage should not be the entire business, but figures measured on a site-by-site basis (e.g. factories), production line-by-line basis, or, more specifically, on a facility-by-facility basis.

Even today, when it is relatively easy to acquire data from the field through IoT, it is rare for companies to be able to acquire such data correctly. This is especially true for sSMEs. The CTN therefore obtains the minimum required granularity values for CFP calculation from the coarse-grained primary data actually obtained, by means of a sufficiently convincing allocation calculation.

On the other hand, there are two types of data that need to be obtained from suppliers as emission intensity, as shown in Table 2. If the relevant data is not available from the supplier, it may be obtained from an external database as secondary data.

The CFP to be calculated here is the emissions intensity per unit corresponding to the products sold by the business to its customers. To distinguish this from emissions intensity by material, it is calculated as emissions intensity by product, using formulae (2) to (4).

Table 1 Primary data for CFP calculation

| name | granularity | Description. |
|---|---|---|
| Consumption by energy | By energy, by day | Total amount of energy consumed during the period. |
| facility operating hours | By equipment, by day | Total hours equipment operated and contributed to production during the period. |

Table 2 Secondary data for CFP calculation

| name | granularity | Description. |
|---|---|---|
| Emissions intensity by energy | By Energy | Intensity units regularly disclosed by energy providers. |
| Emissions intensity by material | By Material | Intensity obtained from suppliers or from third-party DBs. |

Emissions intensity by product

= emission intensity by product_process_min.

+ emission intensity by product_materials (2)

Emission intensity by product_process_min.

= Σ (emission intensity by facility

x standard hours) (3)

Emissions intensity by product_materials

= Σ (emission intensity by material

x quantity required) (4)

The calculation of product-specific emissions intensity (CFP) is obtained by dividing the emissions into material and process fractions and added together. The material content is calculated using the amount of material required per unit of product obtained from the Bill of Materials (BOM). For the process portion, the standard time for each process in the Bill of Processes (BOP) is used.

In the case of lot or batch production, the standard time of the process unit is divided in advance by the lot or batch size. The required quantity, standard time and lot size are set in advance for each product by the operator, but in the case of individual orders or when requested by the customer, actual values obtained from the equipment can be used on a case-by-case basis.

The CTN further defines facility-specific emission intensity. This value needs to be calculated for each CFP calculation. The emissions intensity by facility is a value corresponding to the amount of CO2 emissions for operating one unit of equipment (usually minutes). Therefore, the process-specific emissions intensity by product can be calculated by multiplying the operating time of the equipment. The following formulae (5) to (8) are used in the calculation of emission intensity by equipment.

Energy-specific emissions

= energy-specific consumption

x energy-specific emission intensity (5)

Energy-specific equipment allocation basis

= equipment energy performance

x Σ equipment operating hours (6)

Energy-specific equipment allocation factor

= Energy-specific weighted factor (energy-specific facility allocation basis) (7)

Emissions intensity by facility

= ( Σ (energy-specific emissions)

× (energy-specific equipment allocation ))

/ Σ Equipment operating hours (8)

Here, facility equipment energy performance, as well as energy-specific equipment allocation basis and energy-specific allocation factor, are defined for each individual business unit as a Bill of Energy Consumptions in Table 4. The facility equipment energy performance is the pre-existing energy performance of the facility and sets the relative quantifiable energy consumption level per hour for the same energy item. For example, for electricity, the unit is the power consumption value (kW).

The energy-specific equipment allocation basis in equation (6) and the energy-specific facility allocation factor in equation (7) are the reference values and factors for allocating the daily sum of energy-specific emissions calculated in equation (5) to the facilities using the energy in question. The energy-specific weighted factor is a function for normalizing the reference value as a weight that sums to one.

In Tables 3 to 10 below, specific examples of the calculation of product-specific emissions intensity (CFP) are given based on simple numerical examples. First, in Table 3, assuming that the energy consumption for a specific period of time (e.g. the previous day) is available, the CO2 emissions are calculated based on the emission intensity obtained in advance.

Table 4 uses the values previously registered as energy tables, plus the total operating hours, which is the sum of the effective operating hours of each piece of equipment corresponding to the period in question. Based on these values, the equipment allocation criteria and equipment allocation factors in Table 5 are calculated.

Table 3 CO2 emissions intensity by energy

| Energy items | Amount of consumption | Emission intensity | CO2 emissions |
|---|---|---|---|
| Electricity | 120.0 kWh/day | 0.452 kg-CO2/kWh | 54.24 kg-CO2 |
| Distributed gas | 5.00 thousand Nm3 | 2.234 t-CO2/thousand Nm3 | 11.17 kg-CO2 |

Table 4 Facility energy performance (energy table: Bill of Energy Consumption)

| Energy items | Heating furnace | NC processing machine | Assembly line |
|---|---|---|---|
| Electricity | 30 kW | 10 kW | 0.5 kW |
| Distributed gas | 10 m3/min | - | - |
| Total hours worked | 180 minutes. | 300 minutes. | 420 minutes. |

Table 5: Equipment allocation criteria (equipment allocation factors)

| Energy items | Heating furnace | NC processing machine | Assembly line |
|---|---|---|---|
| Electricity | 5400 (0.627) | 3000 (0.348) | 210 (0.025) |
| Distributed gas | 1800 (1.000) | - (0.000) | - (0.000) |

As shown in Table 6, the emissions intensity by facility is first calculated for each facility based on the facility allocation factor and the CO2 emissions by energy type for the facility in question. The total emissions of all energy items are then divided by the operating hours to give the facility-specific emissions intensity in Table 6. The operating hours are the sum of the operating hours of each facility, but to calculate the emissions intensity by product as CFP, the operating hours by product or lot are required. The total operating hours in Table 6 correspond to the total operating hours by product in Table 7.

As shown in Equation (2), the final product-specific emissions intensity (CFP) to be determined is the sum of the process component shown in Table 8 and the material component shown in Table 9. The process part of the product-specific emissions intensity is an example corresponding to equation (3) and the material part to equation (4). Table 10 shows an example of the result of calculating the product-specific emissions intensity (CFP) by summing them.

Table 6 Emission intensity by facility

| Energy items | Heating furnace | NC processing machine | assembly line |
|---|---|---|---|
| Electricity | 34.008 kg-CO2 | 18.876 kg-CO2 | 1.356 kg-CO2 |
| Distributed gas | 11.17 kg-CO2 | 0 kg-CO2 | 0 kg-CO2 |
| Total emissions | 45.178 kg-CO2 | 18.876 kg-CO2 | 1.356 kg-CO2 |
| Total hours worked | 180 minutes. | 300 minutes. | 420 minutes. |
| Emissions intensity by facility | 0.251 kg-CO2/min. | 0.063 kg-CO2/min | 0.002 kg-CO2/min |

Table 7: Equipment-based standard times by product

| Product | | Heating furnace | NC processing machine | assembly line |
|---|---|---|---|---|
| Product A | production output | 20 pcs | 10 pcs | 12 pcs |
| | number of hours worked | 120 min | 200 min | 220 min |
| | standard time | 6 min | 20 min | 18.3 min |
| Product B | production output | 10 pcs | 8 pcs | 10 pcs |
| | number of hours worked | 60 min | 100 min | 200 min |
| | standard time | 6 min | 12.5 min | 20 min |

Table 8 Emission intensity by product (for processes)

| Equipment | Emissions intensity by facility | Product A | | Product B | |
|---|---|---|---|---|---|
| | | standard time | emission | standard time | emission |
| Heating furnace | 0.251 | 6.0 | 1.506 | 6.0 | 1.506 |
| NC processing machine | 0.063 | 20.0 | 1.260 | 12.5 | 0.788 |
| Assembly line | 0.002 | 18.3 | 0.037 | 20.0 | 0.040 |
| Emission intensity by product_process | | 2.803 g-CO2 | | 2.334 g-CO2 | |

Table 9 Emissions intensity by product (for materials)

| Material | Emissions intensity by material | Product A. | | Product B. | |
|---|---|---|---|---|---|
| | | amount required | emission | amount required | emission |
| Iron (S45C) | 0.393 | 28g | 11.015 | 13g | 5.109 |
| Resin (ABS) | 0.254 | 12g | 3.047 | 7g | 1.777 |
| ... | | | 4.026 | | 8.205 |
| Emissions intensity by product_material | | 18.088 g-CO2 | | 15.091 g-CO2 | |

Table 10 Aggregate emissions intensity by product

| item of expenditure | Product A | | Product B. | |
|---|---|---|---|---|
| Emission intensity by product_process | 2.803 | g-CO2 | 2.334 | g-CO2 |
| Emission intensity by product_materials | 18.088 | g-CO2 | 15.091 | g-CO2 |
| Emission intensity by product (CFP) | 20.891 | g-CO2 | 17.425 | g-CO2 |

For SMEs that have not yet made the transition to digitalization and IoT, primary data on a daily basis may also be used on a weekly or even monthly basis, in order to achieve this at minimum cost when requested to calculate CFPs by their clients. However, as a minimum data requirement, standard hours by product by equipment corresponding to Table 7 should be prepared.

The CTN has made it possible to dramatically increase the coverage rate of companies involved in CN by providing flexibility in the level of implementation. The CTN has made it possible to dramatically increase the coverage rate of companies involved in CN.

# 3. Four Mechanisms for Realizing CN

The biggest challenges to realizing CN are shared awareness of the issue among all stakeholders and cost-bearing mechanisms. Instead, it is more natural to see it as a new burden.

However, this is not an unfeasible mechanism if, like plastic bags in supermarkets, the burden is spread widely and thinly in a fair and equitable mechanism. The definition of the CFP calculation method and the establishment of rules are necessary for this.

If the CFP is a communication tool to promote decarbonization throughout society, mechanisms are needed to make it work within society. In particular, SMEs, which account for more than 90% of the manufacturing sector, must play a central role in this network, otherwise the carbon chain will not be connected from materials to the final consumer.

For CFPs to be distributed throughout society and to function towards the realization of CN, at least the following four types of service mechanisms are needed. The key to the realization of CN is that these services are provided by third-party organizations at the lowest possible cost.

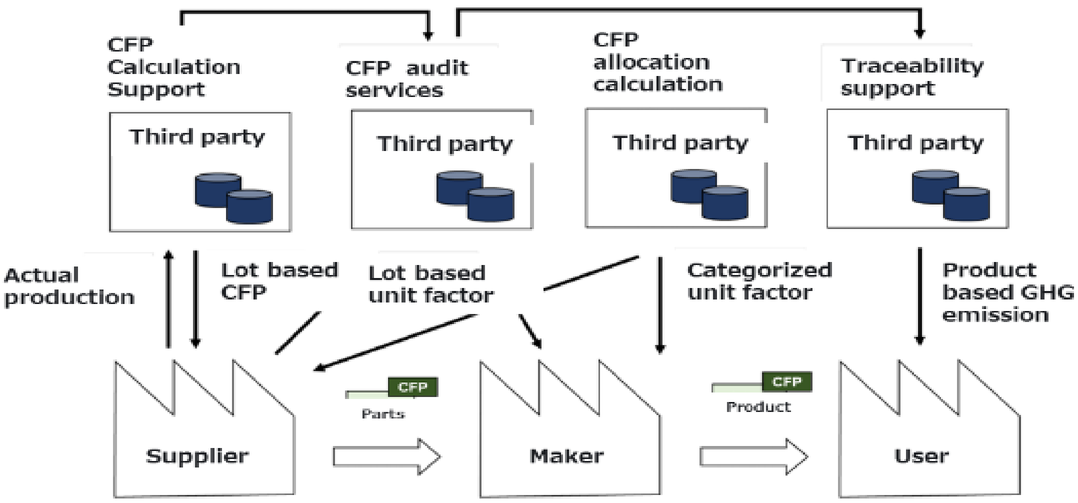


Figure 1 Four types of services for CN realization

## 2.1. CFP Calculation Support Service

Eventually in 2050 all businesses may provide CFPs to their products and services, during the transitional period only a few key products may be provided with CFP. Specially for SMEs, they should only be possible to provide CFP for products to few specific suppliers.

In case of such partial adoption, it is not economically feasible or cost-effective to rebuild the in-house information system. In such phases, external resources should be used effectively. This is particularly the case for SMEs, which lack sufficient financial and human resources and therefore make use of SaaS-type services.

The problem here, however, is to ensure consistency with already existing business systems. Even in SMEs, most of them have in-house purchasing and production management systems, and these systems operate on a daily basis; it is difficult to force double data entry for CFP, so data integration with existing systems is key to its implementation.

Another problem is information security. Most manufacturing companies are basically extremely reluctant to let data out of their premises. In principle, it is forbidden to take data outside the company, not only data relating to intellectual property such as design information and recipes, but also relatively non-confidential information such as production capacity and operating status of equipment. Even for the purpose of calculating CFP, there may be resistance to registering bill of materials (BOM) and process chart (BOP) information in an external cloud.

As explained in the next chapter, the CTN can solve these challenges through the Connected- Industry Open Framework (CIOF). For SMEs that cannot build their own systems, there are also solutions using templates for CN support applications using no-code development tool Contextor. In particular, as explained in the next chapter, CIOF is a data collaboration infrastructure between companies, where data transaction agreements are set up on a case-by-case basis, making it possible for the factory side, as the data provider, to place restrictions on how the data is used and also to monitor whether there is any unauthorized use.

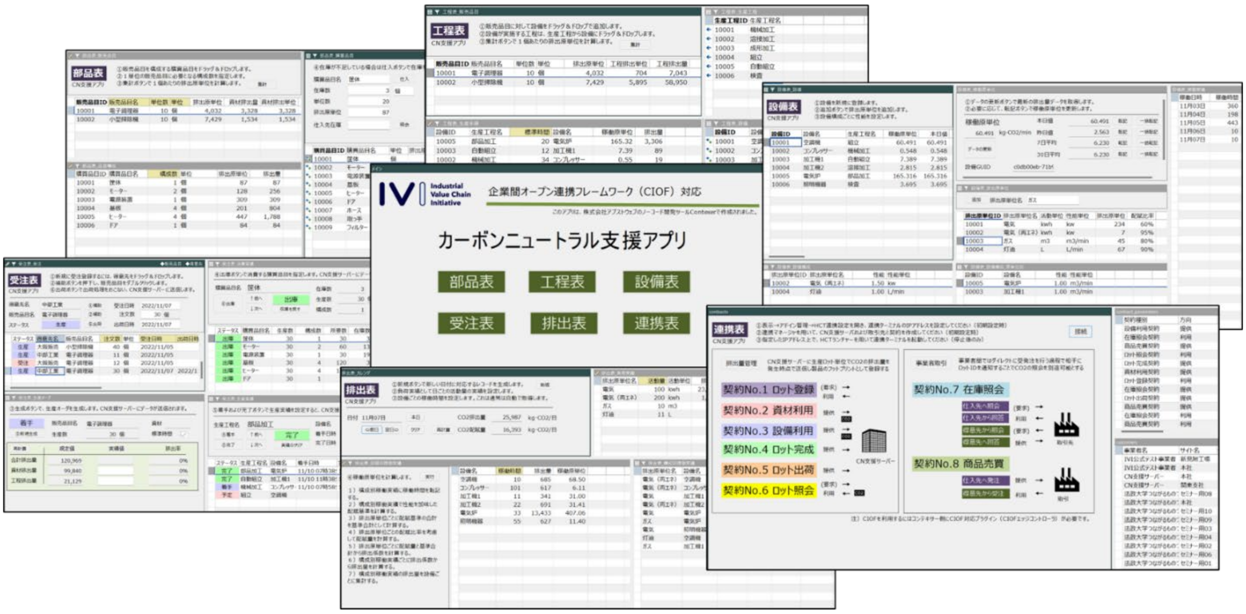


Figure 2 Carbon neutral support app (available free of charge to IVI members).

## 2.2. CFP Audit Service

The second function required for the social implementation of CFP is the brokering and certification of CFP, which is passed from suppliers to manufacturers and from manufacturers to customers in the flow of supply and engineering chains of products and services, and will be added to the list of required information as part of the traditional delivery note or invoice. Some customers may require a separate LCA document, e.g., for hazardous substance regulations such as RoHS or REACH.

Such documents on CFP are digitized and circulated between suppliers, but when this is done between two parties, a mechanism is required to guarantee the legitimacy of the content. This is because, while the purchaser of a product or service would like to select a product or service with the lowest possible CFP value, there is a lot of ambiguity in the CFP calculation rules and the data on which the CFP is based, which leaves a lot of room for the provider to be more lenient.

Especially if carbon pricing takes off, the value of CFP will have a direct impact on a company's earnings and will eventually be recorded as a figure in the company's financial profit and loss account. CFP has no future unless it can prevent fraud and ensure a fair-trading environment as a system.

Perhaps, for the time being, CN-related consulting and certification support services could cover these needs for large companies, using mechanisms such as SBT (science-based targets) and the GX League. However, SMEs downstream in the supply chain, for example, would be supported by tax accountants and accountants as part of their services. Alternatively, SME diagnosticians may provide accompanying support.

The challenge in this context is the mechanisms and methodologies to ensure a credible CFP. Regular audits are necessary, but digital technology should dramatically reduce the cost of such audits and make it impossible to commit fraud in the first place. In the manufacturing industry, the issue of falsification of quality data is a regular topic of discussion, and it is natural to expect that, in addition to such falsification, the CFP will be lowered by not providing the data itself. It is particularly difficult to ensure such comprehensiveness.

This problem also exists in the calculation of CO2 emissions per business unit according to the GHG Protocol: calculations according to the GHG Protocol use methods such as setting cut-off criteria for each product category defined in the PCR (Product Type Standard), but this does not provide a scientific basis. However, objective values should be available as primary data held by each business, at least for the total value within the period covered by Scope 1 and Scope 2 on a business-by-business basis.

The CTN therefore constitutes a carbon chain network, with each business as a unit that can regularly present its CO2 emissions in Scope 1 and Scope 2 of the GHG Protocol. Each business is a node, and the inflow and outflow of CO2 emissions as products and services, as well as emissions carried over from one period to the next, are converted as flows. The difference value in each period as a business is the net emissions of the business. Therefore, if the CO2 emissions of the products provided to suppliers are under-reported, the CO2 emissions as a business will increase by the amount of the under-reporting.

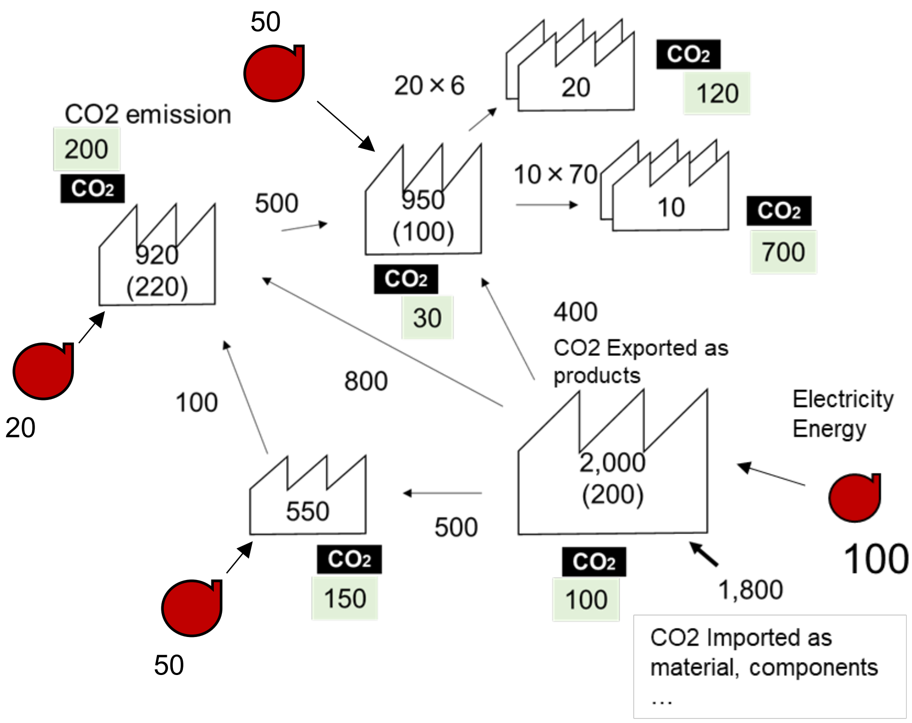


Figure 3 Network model of carbon flows

In addition, the CTN also ensures that the CFPs of products and services traded between businesses are correctly communicated. For example, suppose that a material purchased from a supplier is 160 kg-CO2 when it is 200 kg-CO2 in the PCR-compliant database. Two possible cases of fraud could be considered: either the supplier falsely declares that the material is actually 200 kg-CO2, or the supplier declares 200 kg-CO2 but the purchaser declares it to be 160 kg-CO2.

In the first case, the problem can be solved by making the data on which the 160 kg-CO2 is based available to third parties, such as tax accountants and accountants, if necessary. It is almost impossible to falsify such time-series data.

With regard to the second case of CFPs not being correctly communicated between businesses, the CTN responds by adding a unique ID to every production lot and disclosing the value at the request of the business partner. By notifying their clients of the ID together with the CFP values of the products and services they provide, businesses can obtain third-party assurance on the CO2 emissions of their products and services.

## 2.3. Emission Intensity Provisioning Service

As indicated in the previous chapter, the calculation of CFPs partly requires data to be obtained from external databases. For the main energy commodities, emission intensities per unit are already available from external third-party organizations and these will be used; for categories 1 and 2 of the GHG Protocol, such data will be necessary for the calculation of the basic CO2 emissions. In the future, these data will automatically respond to accesses from individual business software by means of APIs (application interfaces), without human intervention.

On the other hand, there are still many issues to be addressed with regard to databases of emission intensity corresponding to CFPs for the materials to be purchased. In many cases, these values are based on statistical processes based on input-output tables, which means that the values vary from country to country and region to region, as well as between third-party providers. The frequency of updates also varies, and some databases are not adequately maintained. Ultimately, the user has to choose between these databases and bear the costs of using them as well.

An even more serious problem is when the emission intensity corresponding to the purchased product or service does not exist in the database as a category in the first place. Currently, SuMPO's IDEA, a domestic LCI database, has a dataset of about 4,800 products. Overseas, the Life-Cycle Inventory Database in the USA has approximately 5,700 products, while the Ecoinvent Database, which is widely used in Europe and the USA, has approximately 18,000 products.

At first glance, the database seems to be meticulous, but these are mainly raw materials and materials corresponding to the upstream of the supply chain. Businesses in the midstream and downstream of the supply chain are not registered, especially for processing and assembly-type products such as automobiles and electrical products. In the case of automobiles, a single vehicle model requires tens of thousands of components, and there are also many variations in the finished product from manufacturer to manufacturer and model to model.

In practice, strongly affiliated groups of companies would establish their own standard emissions intensity database and share data with their affiliates, including Tier 2 and Tier 3 companies. However, such an approach may not guarantee mutual compatibility across affiliations.

Under ISO 14025, a Product Category Rule (PCR : Product Category Rule) can be established for each industry, and IDs can be standardized to identify products and services subject to CFP. However, to do so, it is necessary to reach a consensus with stakeholders, and the process and effort involved are significant. In cases where an industry is at a budding stage or does not have an industry association, such as SMEs, there is no body to formulate such rules. Moreover, even if an industry-wide agreement were to be reached, its scope would have to be limited. It could probably take six or twelve months or more, from the time a new category of product is created to the time the data becomes available, if it has to go through expert assessment. From the perspective of the business community, such speed is also an important factor.

The CTN takes a 'loose standards' approach, which is also the basic concept of the IVI to which the author belongs. In the loose standards approach, common terms and their usage are not defined unilaterally, but are defined in a way that acknowledges the specificity of each, and then the common parts are increased after the fact and in stages. The common dictionaries defined as common parts are used only in a limited community, so each operator belongs to several communities and uses several common dictionaries.

If a 'loose standard' is followed, experts are no longer needed for PCR-compliant assessments, and the system can be operational immediately on an application basis. If a new category is to be added, at least a minimal community can be established by agreement between the supplier and the parties concerned. The system then undergoes a process of autonomous evolution, either by increasing the number of operators using it or by merging with other dictionaries, in order to become a standard in both name and substance and to be used in common by many parties. Some will become de facto standards, most will remain in use as loose standards, or will eventually fall out of use and be eliminated. This is an ecosystem of standards themselves.

Currently, IVI provides the PSLX (Product and Service Lifecycle Transportation) Common Dictionary as a loose standard dictionary; the number of data (number of product and service categories) in the 2022 edition is approximately 2,700, which is updated and added every year. The CTN will use the PSLX Common Dictionary to first set up product categories for CFP in a relatively free manner, and then gradually map them to external standard databases and standardize them within the CTN.

Loose standards use a bottom-up, inductive procedure to converge common categories. In this process, statistical methods enable comparisons to be made between products and services in similar categories. Such data could also be used as a business model to enable data-driven value-added services, such as ranking between businesses and consulting services by benchmarking against other companies in the same industry, with the result that the decarbonization trend will be further accelerated.

## 2.4. Traceability Support Service

The fourth function is a search service for traceability in CFP enquiries. This is a function that traces the carbon chain corresponding to a product or service, from the material or raw material to the final consumer or the stage where the business is located. This makes it possible to trace the supply chain back to its source and get a bird's-eye view of how much $CO_2$ emissions have been generated at any given point in time. This information can also be used for BCP (Business Continuity Planning) in the event of a disaster.

However, while the data that forms the basis of such information can be obtained from subsidiaries and affiliates over which the company has control, it may be questionable whether it is possible to go beyond that and visualise all the links from the end of the supply chain in the first place. For companies, information on their purchasers and suppliers is also trade secret information. Even if a neutral third-party organization were to provide such data to the outside world, the hurdle would be quite high.

The CTN addresses this challenge with two basic ideas. The first idea is the anonymization of information, which in the CTN is achieved through a mechanism whereby all the data required to trace the carbon chain and the contents of individual CFPs are managed using a hashed 128-bit ID, with no names or attributes stored on the server. The name and attributes are not stored on the server.

For example, the product name and lot number of a product shipped to a client will be notified of the lot ID, without informing the third-party server. In addition, the amount of activity and intensity related to materials and equipment, which are the basis for selecting the CFP for that product, will all be hashed IDs; the actual product and equipment names corresponding to the IDs will be disclosed to the company or its clients individually under the CIOF's data transaction agreement through a different route than this, and will be corresponding to.

This would lower the mental hurdle to disclosure on the part of the business providing the data, as the content of the data would be a series of numbers and letters, both in display and in substance. Even if data is leaked, for example due to a cyber-attack, the damage can be minimized.

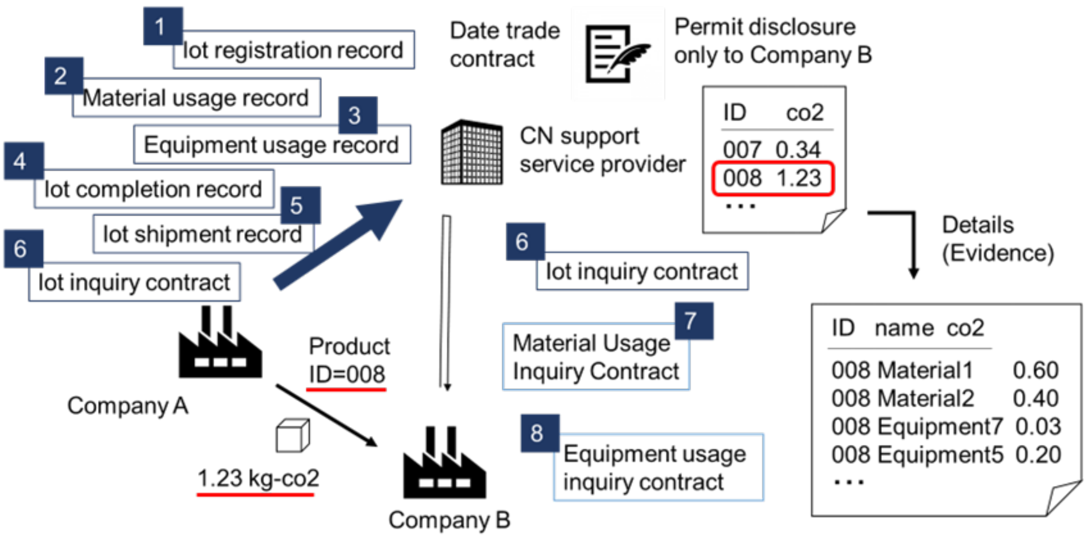


Figure 4 Mechanism for anonymizing CFP information

A second idea for CTNs is the decentralization of information. Here, the decentralization of information is strongly related to the system architecture when building a CTN. Typical supply chain visualization assumes that data is available from all operators in the supply chain, from upstream to downstream. However, it is difficult to obtain the information needed to trace the movement of goods in and out of an actual factory in a timely manner, rather than simulating it on a model, except for influential business partners or companies with capital ties.

Conversely, information may be disclosed as required if requested by a client. Therefore, the CTN does not consolidate all information in a single database, but uses a method of clarifying the carbon chain by tracing it sequentially from downstream to upstream. Specifically, a disclosure request is made to the target manufacturer to find out the breakdown of the components of a certain product. Then, the supplier of the component parts is requested to disclose the breakdown of the materials and components. Of course, it is not necessary to disclose all the lot IDs that make up the product, but it may be possible, for example, to disclose only those items that are registered as product type standards (PCR).

Of course, the assumption is that such enquiries and queries are handled automatically by computers via APIs provided by the respective servers. If necessary, such as RPA may also be used in combination. However, as a precondition for this, the scope of disclosure of their data needs to be registered in advance by each business as a contract for disclosure rules. Such data transact automation ion agreements are managed by the CIOF.

Even more important for a distributed architecture is the fact that the servers providing such services can be interconnected, even if they are provided by multiple providers as different mechanisms. In order for the CTN to function in such a decentralized and diverse environment, it is necessary to define in advance for each provider, in an international agreement, how to manage CFPs and how to share data. The following are some of the key issues that need to be addressed.

The security challenge is further solved by keeping a history as a distributed ledger using blockchain technology to ensure that each participating federated server is able to properly manage and share data.

Currently, data distribution infrastructures such as GAIA-X are being developed in Europe. The CIOF, on which the CTN is based, is already in operation as a data federation infrastructure with a particular focus on the manufacturing industry, and new developments, including its use in the CTN, can be expected in the future. New developments can be expected.

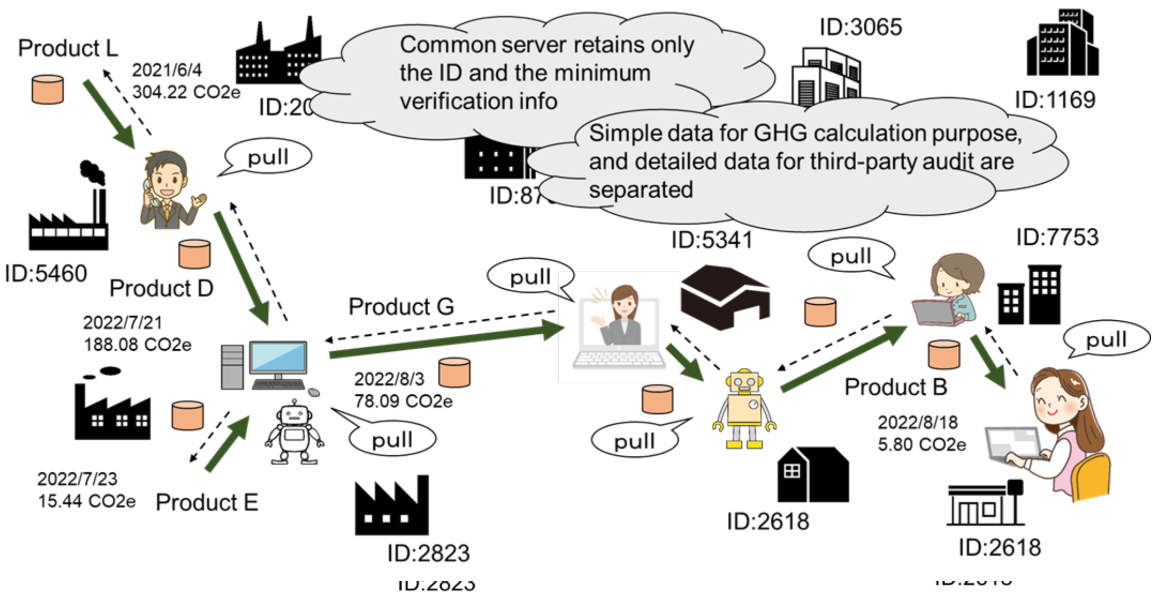


Figure 5 PULL-type carbon chain network

# 3. Framework for Business-to-Business Data Distribution

The Connected Industry Open Framework (CIOF), which forms the basis of the CTN, was developed by the Industrial Value Chain Initiative (IVI) as a subsidized project launched by the New Energy and Industrial Technology Development Organization (NEDO) Japan in FY 2019, with demonstration tests starting in FY 2022. The CTN uses this data linkage infrastructure to enable the four services described in the previous chapter. This chapter describes specific methods for carbon chain linkages based on data transaction agreements.

CIOFs can be characterized by; providing and using of data based on contract, defining data content beforehand by dictionaries, and authenticating to guarantee that the data has been handled correctly. It is particularly important to guarantee the rights of the data provider to increase the reliability of data transfer between companies. To this end, CIOF includes functions to monitor the use of the provided data and to request the deletion of provided data and to confirm the implementation of such a request.

These functions are expected to replace the conventional mail and file delivering activities used to exchange data between companies. The following section looks at the contracts required for CTN.

## ■ Data transactions to support CFP calculations

First, in the CFP calculation support service, the contract between the target business and the CN support provider is setting up units of the data composition model (in terms of tables in a normal database). Table 11 describes the use of the contracts for providing (PUSH) or using (PULL) of data from the business unit, together with the parameters that constitute them. In terms of a normal information system, these are similar to the definitions of the APIs that a server has; CIOF defines each of these as a contract for the transmission or reception of data and can clarify the rights and obligations attached to that action.

## ■ **Ensuring credibility in CFPs between operators**

The above 11 types of contracts are used in the CFP calculation support service and at the same time function as a CFP intermediary and certification service. For example, manufacturers who receive materials from suppliers can inquire about the $CO_2$ emissions of the relevant materials by receiving lot ID at the time of delivery.

If the manufacturer calculates CFP in the same way as the supplier, the material lot ID obtained from the CFP calculation is used to set the necessary parameters for the use of materials in its own production. With the supplier's permission, it is also possible to view a detailed breakdown of $CO_2$ emissions by using the Equipment Usage Inquiry and Material Usage Inquiry functions.

## ■ How to expand emissions intensity database.

The CFP intermediary certification service enables the enquiry of $CO_2$ emissions for a specific lot obtained from a specific supplier. On the other hand, there may be many cases where suppliers who have purchased materials do not use the CFP calculation service. In such cases, the emission intensity provision service presents a standard CFP from the database registered for the category according to the commodity type standard (PCR), etc. In the CTN, the source of this information is a statistical processing of the content disclosed by the CFP enquiry service.

Until now, building and maintaining such emission intensity databases required significant costs and specialist knowledge. With the CTN method, on the other hand, data is accumulated semi-automatically by simply obtaining product profiles for the target production lot with prior permission for use. The number of categories will be expanded autonomously, forming a network effect where the existence of more data attracts more users bringing in more data.

## ■ **Visualization of the entire supply chain.**

CTN is still at the proof-of-concept stage, but by the increase in the number of businesses that support CTN concept, and the lots produced by each business will be linked through material use contracts, creating a carbon chain network in the CTN. Initially, the chain will have to be fragmented, but as usage progresses, it is expected that by 2030 it will be extended throughout the supply chain for almost all products and services with a consumption point

in Japan. As a result, any product in the chain will be able to trace its carbon chain and $CO_2$ emissions back to the source.

| Contract Name | Parameter | Direction | Description. |
|---|---|---|---|
| Lot Registration | ID | PULL | Lot ID is obtained for the final product to be shipped at the start of its production. Thereafter, the CO2 emissions are accumulated for this lot ID. |
| Material Use | Lot ID, material lot ID, consumption | PUSH | Specify the lot ID and the amount consumed as a component, such as material, for the lot to be produced. The CO2 of the corresponding material lot is accumulated. |
| Equipment Use | Lot ID, equipment ID, activity volume | PUSH | Set the ID of the equipment used to produce the target lot and the operating hours as activity. The CO2 is accumulated according to the intensity of the equipment. |
| Lot Completed. | Lot ID, number completed, number of defects | PUSH | The number of completed lots and the number of defects are set when the production of the subject lot is completed. This operation determines the lot's CO2 emissions and calculates the CFP per good. |
| Lot Shipment | Lot ID, ID of the business to which the shipment is made, number of shipments | PUSH | The quantity of a completed lot is set when the lot is shipped to a specific trading partner. Thereafter, the trading partner to whom the lot is shipped becomes the owner and information on the lot can be queried. |
| Lot Enquiry | Lot ID, CO2. | PULL | The lot ID is used to query its CO2 emissions. Basically, anyone who knows the lot ID can obtain the CO2 emissions. |
| Material Use Enquiry | Lot ID, material lot ID, consumption, CO2, date | PULL | Queries the material lot ID corresponding to the lot ID and relevant data such as the amount discharged and the date and time of production. Only authorized persons have access. |
| Facility Usage Enquiry | Lot ID, equipment ID, activity, CO2, date | PULL | It queries the ID of the equipment used in correspondence with the lot ID, as well as the date, time and duration of use, and data such as the amount of emissions. Only authorized persons have access. |
| Equipment Registration | Equipment ID, units and equipment intensity | PULL | Prior to the production of a lot, the company registers its equipment to be used in production and obtains a corresponding equipment ID. |
| Equipment Intensity Registration | Equipment ID, equipment intensity | PUSH | The emission intensity corresponding to the facility operation is set using the facility ID. The registered emission intensity is reflected in the calculation of CO2 emissions in the subsequent use of the equipment. |
| Equipment Enquiry | Equipment ID, equipment intensity, units | PULL | Inquire about the current list of equipment intensity for equipment that has been registered so far by the own business. |

Table 11 Data trading agreements for CTNs

However, it can be argued that this trend cannot be achieved by the manufacturing sector alone - a strong desire to decarbonize among end-consumers is essential if the 2050 CN target is to be met. By using CTN Traceability Services, CFP figures individual businesses claim becomes accurate and justified.

# 4. Summary and Recommendations

The new corona-virus infection that shook the world in 2020 quickly spread globally, plunging humanity into a pandemic. Amidst unfathomable fear, the world came together as one to confront a single enemy. The same thing is now looming without a footstep as a new crisis due to global warming. Because of the slow pace at which the situation is progressing, a sense of crisis in a physical sense has not yet been recognized easily. Science-based simulations and social and policy discussions have finally moved to the feasible step of how to solve this difficult problem and implement the target reduction of 1.5 degrees Celsius.

However, this challenge does place certain constraints on the growth and development of individual enterprises and individuals. The same structures that were used to curtail free economic activity through behavioral restrictions during pandemics are included in the efforts for carbon neutrality. The problem is even more serious than the corona disaster in that it calls for endless behavioral restrictions.

The Carbon Chain Trusted Network (CTN) for carbon footprint (CFP), described in this paper, is a social mechanism to solve this challenge beyond the efforts of individual companies and individuals. To fairly distribute the burden to society from an impartial standpoint, this must go beyond government measures and NGO initiatives, and must be integrated into and function within the industrial structure as an ecosystem. As the nervous system of society, a social information system is required that can share the pain and deal with the necessary responses in an autonomous, symbiotic, and decentralized manner.

CFP is the key word that links such global task with a more concrete and realistic measures at hand, and CTN is the means to realize it. It is a key factor for a sustainable and neutral ecosystem. With the CTN, we can take a steady first step towards this grand goal.

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