AUTO-ID LABS

The Potential of the EPC Network to Monitor and Manage the Carbon Footprint of Products

Part 1: Carbon Accounting

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Abstract

Greenhouse gas accounting has, until now, been an overhead process that is performed at enterprise- or plant-level for annual reporting or emission trading purposes. Companies are requiring more integration of greenhouse gas accounting and optimization into their transactional tools & systems, just as in financial accounting and quality management. Also, when companies extend greenhouse gas accounting beyond their four walls, they have to collaborate with their suppliers and treat carbon as an additional supply chain indicator to be optimized, such as time, quality, and total cost. These internal requirements, in addition to consumer pressure and national legislation, are leading to the emergence of the *product carbon footprint* as a supply-chain-wide environmental indicator.

Several methodologies are being specified to account for this environmental indicator, either by extending the enterprise-wide carbon accounting standards or by building on available lifecycle assessment methodologies. However, the process of determining the carbon footprint of a product is still considered a major challenge since companies face a number of hurdles concerning methodology, standardization, and data collection. This paper provides an elaborate review of the carbon accounting activities both on the enterprise- and the product-levels and outlines the challenges that need to be addressed before product carbon footprinting can be adopted on a wider scale.

One major challenge is the variation in lifecycle emissions due to changes, e.g. in logistics and suppliers. Supply chain fluctuations result in variable carbon footprints over time, in different selling locations, and among different instances of the same product. If these variations are tracked and integrated in the enterprise decision support systems, businesses will have more opportunities to cut environmental impact and monetary costs. Also, ecology-minded consumers may be interested to compare the carbon footprints of the products they buy with the product average. In this paper we describe scenarios where the EPC Network can be used for tracking and communicating differences in carbon footprints among instances of the same product. Finally, we give an outlook to further research in the field of product-level greenhouse gas accounting that will considerably benefit from the adoption of the EPC Network infrastructure.

1 Introduction

Companies measure and report their impact on the environment for legal, social, political, and monetary reasons [18, 12]. Parameters that are often measured include the amount of materials and energy used and the emissions released. In order to facilitate these environmental accounting activities, companies rely on specific accounting standards and IT tools to handle the complex monitoring process efficiently. Recently, special political and public attention was devoted to greenhouse gas (GHG) emissions and their effect on global warming. The current standards and tools can also account for the GHG emissions caused by a company on a process, site, or enterprise level. Furthermore, several companies plan to provide information with higher-granularity, namely by calculating the GHG emissions over all the lifecycle stages of their products [21, 2]. These companies aim to make the so-called carbon footprint of their products available to the consumer, often in form of a label on the products or in marketing / consumer information campaigns [16]. Since the calculation involves several stakeholders, the standards and tools should be prepared to enable this inter-company calculation. In fact, different instances of the same product could have different footprints, depending on factors such as process efficiency of the logistics activities or duration of refrigeration. Calculating a dynamic footprint on the increasing granularity level of batches, pallets, cases, or even instances poses a challenge to the current enterprise information systems.

We review in this paper the most important greenhouse accounting standards and methodologies both on various levels of reporting granularity. We also illustrate how the EPC Network can be used to meet the challenges of dynamic carbon footprints on the product level. Chapter 2 deals with greenhouse gas accounting on the enterprise level, providing an analysis of the most prominent standard used. Chapter 3 shifts to a product-lifecycle view of greenhouse gas accounting, reviewing the current efforts and challenges in this domain. Chapter 4 illustrates how the EPC Network can tackle an important challenge, namely that of emissions that are highly variable among different product instances. We provide a summary and an outlook to future work in chapter 5.

2 Enterprise-Level Greenhouse Gas Accounting

Companies measure the released greenhouse gas emissions to comply with regulations, to assess their performance in an energy-constrained economy, and to participate in a growing carbon market [12]. Several national and international instruments exist as platforms for companies managing their greenhouse gas emissions. These include greenhouse gas reduction programs, emission trading schemes, and greenhouse gas accounting standards. Companies rely on the accounting standards to guide them in the complex monitoring process and to enable comparisons with previous year and with other companies. We give in section 2.1 an overview of two important instruments that rely on greenhouse gas accounting, namely GHG reduction programs and emission trading schemes. Because greenhouse gas accounting is a necessary step for these tools, we provide in section 2.2 a summary of the key parts of the most prominent greenhouse gas accounting standard – the Greenhouse Gas Protocol.

2.1 Greenhouse Gas Reduction Programs and Emission Trading Schemes

Numerous greenhouse gas programs exist that companies can participate in to reduce their enterprise-wide emissions. The programs are voluntary instruments offered by national authorities, regional bodies, and non-profit-organizations. Typically, a known carbon accounting standard is used to quantify the greenhouse gas emissions caused by a participating company or such a standard is built upon and adapted for the program's purposes. After setting up a company-specific greenhouse gas inventory, a plan is specified to reduce emissions to targets measured in comparison with base-year values. The target year can be any year in the future, and the base-year is typically 1990. A selection of greenhouse gas reduction programs is shown in Table 1 along with the standard they use for estimating emissions and the geographic area where they are most widely used. The table shows that the Greenhouse Gas Protocol [15] is the most widely used international standard.

Greenhouse gas reduction program	Accounting standard built on	Regional area
World Wildlife Fund (WWF) Climate Savers	Not Specified	International
US EPA Climate Leaders	Greenhouse gas protocol	United States
US DoE 1605b Voluntary Reporting Program	DoE Program Guidance	United States
American Carbon Registry (ACR)	IPCC Guidelines for National GHG Inventories, ISO 14064, Voluntary Carbon Standard (VCS), etc.	United States
California Climate Action Registry (CCAR)	Greenhouse gas protocol	California
Wisconsin Voluntary Emission Reduction Registry	Greenhouse gas protocol, DoE program guidance, & IPCC Guidelines for National GHG Inventories	Wisconsin
New Hampshire Voluntary GHG Reductions Registry	DoE Program Guidance	New Hampshire
Australian Greenhouse Office (AGO) Greenhouse Challenge	Greenhouse gas protocol, ISO 14064, & IPCC Guidelines for National GHG	Australia

Plus (GCP)	Inventories	
Carbon Reduction Institute	Greenhouse gas protocol	Australia
Canadian Standards Assoc. (CSA) GHG Registries	ISO 14064	Canada
Carbon Trust Standard	Greenhouse gas protocol & ISO 14064	UK
Business Leaders Initiative on Climate Change (BLICC)	Greenhouse gas protocol	Sweden

Table 1. Selection of greenhouse gas reduction programs

Another instrument to decrease greenhouse gases is emission trading schemes, also referred to as cap-and-trade. The main objective behind emission trading schemes is to create market-driven economic incentives for companies to cut their emissions. This is achieved via a central authority that provides emission allowances for emitting organizations to use during a specific period. The allowances represent a permission to emit a limited amount of gases referred to as the "cap". Companies that exceed their limit at the end of the specified period should buy allowances from others who have emitted less than their permitted amount. The consequence is that companies who can reduce their emissions the cheapest will do so and the others will buy additional allowances. In theory, the price to achieve the emission reductions is equal to the price of the allowances as determined by the emission trading market [14].

The EU Emissions Trading Scheme (ETS), in operation since January 2005, is the largest greenhouse gas platform of its kind [9, 14]. The ETS is one of many instruments that the European Union is employing to reach its greenhouse gas emission targets as specified in the Kyoto protocol. The ETS includes installations that together contribute 40% of the total greenhouse gas emissions of the EU [11]. The 25 European countries participating in the scheme determine, subject to approval by the European Commission, how they allocate the emission allowances among their affected installations, thus contributing to their national reduction targets. The EU provided guidelines to the concerned installations that explain how the monitoring and reporting of greenhouse gas emissions should be undertaken [10]. According to these guidelines, three other carbon accounting standards were taken into consideration, namely the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, the ISO 14064 standard, and The Greenhouse Gas Protocol. In the next section, we will explain in more detail the different parts of the latter as it is broadly used for setting up greenhouse gas inventories – both for the reduction and trading of emissions.

2.2 The Greenhouse Gas Protocol

The Greenhouse Gas Protocol: Corporate Standard [15] (referred to as the Protocol from here on) is the de facto guideline for enterprises that are estimating their greenhouse gas emissions. We review in this section the different parts of the standard, paying close attention to the implications on product-level carbon accounting.

The Protocol follows five guiding principles that determine, in general terms, which emissions should be included in a greenhouse gas inventory. These are:

- Relevance: Inventory serves the decision-making needs
- Completeness: Report everything & justify exclusions
- Consistency: For meaningful comparisons over time
- Transparency: Include assumptions, references, methodologies, etc
- Accuracy: Reduce uncertainties

These principles can also be extrapolated when considering product-level carbon accounting across the supply chain. For example, product lifecycle emissions should be included when they contribute to the carbon footprint accuracy and comparability, especially when they affect the decision-making process.

The Protocol also describes the reasons why companies report their greenhouse gas emissions, and these comprise the following drivers:

- Managing GHG risks associated with future constraints
- Identifying reduction opportunities
- Reporting to voluntary GHG programs
- Eco-labelling and certification
- Participating in mandatory reporting programs
- Participating in GHG trading programs
- Recognition for early voluntary action

Several of these drivers can apply to product-level carbon accounting. The current most obvious reason for companies participating in such efforts fall under the category of eco-labelling, where legislation also promises to play an important role, e.g. “Le Grenelle de l’Environment” in France that requires carbon labels in the consumer products sectors by 2011. However, in the future, several complementary actions can provide further drivers for product-level reporting, such as participating in emission-trading programs on a micro level.

The standard then guides companies to determine the proportion of emissions from affiliated organizations that should be included in the mother company’s inventory. Two approaches are proposed, namely the equity share approach and the control approach. In the former, emissions of a daughter company that are attributed to the mother company are proportional to the percentage owned. In the latter, the emissions are assigned to the entity that has financial or operational control, irrespective of the equity share distribution. These guidelines for setting organizational boundaries will not be relevant for product carbon accounting because the frame of reference is the produced unit, thus the inclusion of emissions from various organizations is commonplace.

The next part of the standard, *setting the operational boundaries,* is the one that specifies what emissions should be reported. The standard differentiates between three types of emissions that are called *scopes.* The first type of emissions is direct emissions released from company-owned assets and the other two comprise indirect emissions due to the company's needs and activities but emitted elsewhere.

- Scope 1: Direct emissions released from company-owned assets; must be reported.
- Scope 2: Indirect emissions due to the use of electricity, heat, or steam; must be reported.
- Scope 3: All other indirect emissions; subject to voluntary reporting.

Scope 3 emissions typically include lifecycle discharges that are outside the direct control or ownership of the company, e.g. those caused to extract and produce assets purchased by the company, transport of customers to retail stores, etc. Since the standard leaves the decision for companies to include or exclude these emissions, different organizations adopt different choices. The definition of which scope 3 emissions should be included in a product-level carbon footprint becomes of crucial importance, because these contribute, in many cases, the majority of lifecycle discharges (as compared with production-only emissions).

The protocol also guides companies interested in tracking their emissions over time. First they should select a base year whose emissions are used as a benchmark. This is typically 1990 to be consistent with the Kyoto protocol, or an average of several years to smooth out fluctuations. The standard points out that a recalculation of base year emissions is necessary in the case of:

- Structural changes affecting the organization, e.g. mergers, acquisitions, etc,
- Changes in methodology or data accuracy improvements, or
- Discovery of significant errors.

It is still not clear how product-level carbon accounting will be exploited to achieve continuous reductions and thus if benchmark emissions at a certain point in time will be needed. If so, then structural changes should not induce a recalculation of the base-year emissions because the unit of reference would be the product and not the organization. However, a recalculation would be needed in the remaining two cases.

The protocol then maps out a five-step approach for companies to identify and calculate their greenhouse gas emissions:

1. Identify emission source. The emissions to be included should be grouped by scope.
2. Select the calculation approach. The more common option that companies opt for is a stoichiometric calculation, achieved by multiplying activity data (e.g. amount of fuel

used) by an accepted emission factor. The less common approach is based on direct measurement, e.g. with the help of a sensor that measures the emission flow rate.

3. Collect activity data and choose emission factors. This is the process of collecting the required primary data from the company sources and the secondary data from external source.
4. Apply calculation tools. These are typically spreadsheet tools or more sophisticated enterprise software.
5. Roll-up data to the corporate level. The standard differentiates here between a centralized and decentralized approach.

The first four steps will also be used to find emissions on the product level, although the emissions considered will cover a wider range of sources. The fifth step will not be relevant because a different unit of reference is used than the corporation.

The next part of the standard deals with managing the greenhouse gas inventory quality, e.g. through developing the appropriate organizational procedures. The given guidelines can be applied to carbon accounting in general, including on the product level. A chapter is also dedicated to deal with emission reductions, both in the company and through external projects & offsets. Corporate emission reduction should be reflected in the greenhouse gas inventory where as project-based ones should be quantified with another standard and reported separately.

The protocol then discusses what information companies are expected to report and how they should report it. Organizations should provide required information such as a description of their organizational and operational boundaries, which base year they chose, the quantity of emissions split in scope and greenhouse gas, etc. Then there is optional information such as scope 3 emissions, offsets, and greenhouse gases not covered in the Kyoto protocol. Also within the optional inclusions are *ratio performance indicators.* In contrast to absolute emission numbers, these are normalized numbers that aim at better efficiency comparability between companies of different sizes. Example ratio indicators include:

- Productivity or efficiency ratios (e.g. sales per GHG)
- Intensity ratios: GHG impact per unit of economic output
    - Product emission intensity
    - Service emission intensity
    - Sales emission intensity
- Percentages (e.g. current emissions as % of baseline)

The product intensity indicator is the closest idea to a product carbon footprint, except that it includes only the product-related emissions caused by the producing company, without taking a lifecycle approach.

Finally, the standard outlines guidelines for the verification of GHG emissions and for selecting a target, both of which are less relevant for product carbon accounting and will thus not be summarized here.

Our analysis of the greenhouse gas protocol showed that many of the ideas can be extrapolated to product carbon accounting and reused in that context. Some other concepts should be adapted, for example, setting the operational boundaries has to be properly tackled by specifying which scope 3 emissions should be included. Determining the emissions to be included in the carbon inventory of a product is important for an EPC-enabled tracking of the emissions. The next chapter will deal with product carbon accounting in the light of recent pilots and standardization efforts.

3 Product-Level Greenhouse Gas Accounting

The total enterprise greenhouse gas emissions discussed above cannot be used to determine the carbon footprint of individual products since (1) all company emissions are lumped together and the share of different products is not allocated accordingly and (2) the emissions due to activities of other supply chain partners are not considered. Therefore, a few pilot projects recently started to apply newly developed lifecycle-based methodologies to quantify the carbon footprint of sample products.

In this chapter, we first provide an overview of some prominent pilot carbon footprint projects. The goal is to give a clear map of the ongoing efforts in terms of methodology development and standardization. Next we will analyze the most important challenges facing reliable, efficient, and precise carbon accounting on the product level that allows comparability. We will focus on the prominent Publicly Available Specification (PAS) 2050 as an exemplary carbon accounting methodology. Also, specific references from the standard draft will be highlighted because they point to areas where variations in greenhouse gas emissions among different instances of the same product are significant. These are areas where an infrastructure like the EPC network can facilitate variable emission calculations.

3.1 Drivers & Goals of Carbon Footprinting

Chapter 2 gave an overview of greenhouse gas accounting and reduction tools on the enterprise or plant level. However, current greenhouse gas accounting practices have two shortcomings. First, they are limited to the plant or enterprise level, even though recent works emphasized the importance of looking beyond a company's four walls to achieve environmental excellence; the same way companies collaborate with partners to improve their supply chains with respect to time, quality, and total cost [52, 24, 51]. Second, current GHG accounting is rather an overhead process which is not integrated into daily business decisions. Companies are requiring more integration of greenhouse gas accounting and optimization into usual transactional tools & systems, just as in financial accounting and quality management.

In addition to the internal requirements, businesses are being faced with external pressure to take a product-level approach to GHG accounting. Example external drivers of supply chaib carbon footprinting include:

- **Authorities**: For example, there is legislation proposed by the French government[1] that all products sold to consumers in France should have a carbon footprint label by beginning of 2011. The label should indicate the greenhouse gases caused across the product's lifecycle.
- **Consumers**: Several research studies [13, 20] indicate that a growing number of consumers would want to know the carbon footprints of the products they buy, and some are even willing to pay a little more for ecologically friendly products.
- **Focal supply chain partners**: In certain supply chains, one partner has enough leverage to ask its suppliers for certain environmental information. For example, Wal-mart is assessing energy information from a group of its suppliers and will encourage them to reduce their greenhouse gas emissions [17]. This in turn will translate into a reduction of Wal-mart's total carbon footprint (via reducing the scope 3 emissions).

The above-mentioned requirements are translating into concrete pilots to account for and communicate the lifecycle environmental impact of products, most prominently the greenhouse gas emissions they cause. The business goals of companies participating in these supply-chain-wide carbon footprinting activities directly map to satisfying the requirements above:

- To comply with *legislation* or to be prepared for anticipated legislation
- To differentiate from competitors by providing carbon footprint information to *customers* and *end consumers*.
- To find and implement GHG reduction opportunities across their *supply chain*
- To better *internally allocate* GHG impacts, thus reaching better decisions

3.2 Overview of Current Carbon Footprint & Labelling Pilots

The Carbon Trust developed the PAS2050 and is applying it in pilot projects with several companies in the UK. Some of the companies working with the Carbon Trust include Coca-Cola, Cadbury Schweppes, Kimberly-Clark, and Tesco [16, 3]. The PAS2050 suggests using a five-step approach to products carbon footprints. First, the product lifecycle data should be analyzed, including the source of the product's ingredients or components, the production and logistics processes, and finally the usage and disposal phases. The process map is then built and the boundary conditions defined. The next step is to collect the required data and finally the greenhouse gas emissions are calculated and added up. The Carbon Trust offers a

[1] http://www.legrenelle-environnement.fr/

carbon *reduction* label with a carbon footprint value displayed as a mass of CO2-eq, along with tips for consumers to help them reduce emissions in the use-phase. An example such label is shown in Figure 1. Companies that work with them have to commit to reductions and if after 2 years they don't reduce their carbon footprint, they lose the label.

Figure 1. Carbon label as provided by the Carbon Trust

Thema1 in Germany is leading a project where lifecycle assessment (LCA, standardized under ISO14064) is being carried out by organizations such as *ökoinstitut* to quantify the greenhouse gas emissions of several pilot products from consumer goods companies and retailers [19]. The participating companies include a number of important players such as *Tchibo, Henkel, FRoSTA,* and *Rewe*. The German pilot didn't have labels at all, and some partners are against communicating the information with consumers anyway. The reasons are that (1) consumers don't understand what a carbon footprint is, (2) any communicated value will be uncertain so one shouldn't base purchase decisions on it, and (3) carbon footprinting should be a tool only for supply chain optimization and decision support.

Legislation is providing a strong driver for carbon labeling in France where companies are requested to label products with a carbon indicator. For example, *Groupe Casino*, the French retailer, is working with *ADEME* (French Environment and Energy Management Agency) to put a carbon label on 3000 of the products it sells [1]. Casino in France shows on the products a carbon footprint scale with ~7 slots and places the footprint value of the labeled product in the respective slot, thus clustering *all* products by carbon footprint value. They backed this approached by their consumer insight: consumers need to know if it's serious/scientific (thus the value) and if it's good or bad (thus the scale).

Another project is going on in Switzerland where *climatop*, a joint initiative of *myclimate* and *ökozentrum*, is using a custom-developed methodology to find and label the least carbon intensive products out of sample product groups at *Migros*, the Swiss retailer [5]. The climatop labeling approach is to offer a label *without* a footprint value on only the least carbon-intensive product(s) in a particular category – the "Carbon Champion". Products that are within 20% emissions of the best product would also receive the label. Finally, Svenskt Sigill in Sweden issues a label *without* a carbon footprint value for products that achieve demanded improvements.

3.3 Overview of Carbon Footprint Standardization Efforts

Lifecycle assessment (LCA) is already a well-established field and an international standard exists in the ISO14040-14044 series. Pilots in the domain of product-level environmental footprints either use the ISO series or follow a product-specific methodology based on these international standards. However, because of the particular interest in carbon footprints in the context of global warming, more specific methodologies are needed. The current interest is spawning several methodologies which are sometimes incompatible. This leads to the lack of comparability between product carbon footprints derived through different methodologies. Such a situation is very counterproductive: citizens should be able to compare products from different manufacturers with confidence in the methodologies they follow – the same is true of enterprise sourcing decisions. The importance of standardization in this field is giving way to three major efforts, in addition to smaller country-specific initiatives. We summarize these below.

- **BSI & Carbon Trust: PAS2050**: The British Standards Institute (BSI) & the Carbon Trust, an organization created by the U.K. government, have been working on a carbon footprint methodology in 2007 & 2008. In October 2008 they published this under the Publicly Available Specification 2050 [4]. The PAS2050 is available for companies to use and is currently the most advanced carbon footprint methodology. It bases the emission calculations on a process lifecycle approach. Comments received by companies using PAS2050 will be incorporated into a revised edition expected in 2010.
- **WRI/WBCSD: Product and supply chain greenhouse gas protocol**. The World Resource Institute (WRI) and the World Business Counsel for Sustainable Development (WBCSD) have previously authored the most widely used standard for *enterprise-wide* greenhouse gas accounting, the Enterprise greenhouse gas protocol. In late 2008, the named organizations decided to start the consultations on a new product-level protocol. The work is now being pursued in several working groups, each focusing on a technical issue. One group is considering which of three methods to use for carbon footprint calculation: process LCA (bottom-up), input/output (top-down), or hybrid. The two-year initiative should result in a final guideline in late 2010.
- **ISO 14067: TC207/SC7 working groups.** The international standards organization has recently initiated a process to create another ISO LCA standard but specific to greenhouse gas product emissions. It is expected that it will take under 2011 for a standard to be in place.

- **Country specific initiatives**, e.g. in France: RBP X30-323. There is legislation proposed by the French government that all products sold to consumers in France should have a carbon footprint label by beginning of 2011. The label should indicate the greenhouse gases caused across the product's lifecycle. The legislation still has to be endorsed by parliament. Also, carbon footprint guidelines were published in Japan.

3.4 Carbon Footprint Challenges

To exploit its full business and environmental value, product carbon footprinting will need to leverage information technologies that enable efficient, dynamic emission monitoring and decision support. Without the supporting systems, carbon footprints will still require a relatively high-effort to calculate, thus limiting them to occasional efforts on a limited number of products. Without IT solutions that streamline the product carbon accounting efforts, their results will not be exploited to improve the business or the environment. In this section we will elaborate on some open issues in the carbon footprint methodology that should be resolved by a common standard, in addition to shortcomings that could be addressed by information systems.

3.4.1 Methodological Challenges

Two of the most important questions that the carbon footprinting methodologies aim to answer are (1) how to determine the emission shares of co-products sharing the same process and (2) which lifecycle emissions to include and which to exclude.

In many cases it is relatively straightforward to allocate the emissions that a product is responsible for, especially when the corresponding activity is exclusively responsible for one product. Otherwise, two approaches exist for emission sharing in LCA literature: allocation and substitution. The former requires that emissions are allocated in proportion to a relevant attribute, e.g. price, mass, volume, etc. The latter adopts an elaborate economic method of substituting the co-products with equivalent products to estimate the displaced emissions of each co-product separately. The PAS2050 assumes by default allocation based on economic value but allows for other approaches too.

All emissions included in a carbon footprint study should be within what is referred to as the system boundary. This includes all direct emissions that a product is responsible for, e.g. due to energy use of production machines or fuel use of transport fleets. These are the scope 1 emissions according to the Greenhouse gas protocol. Also included are the indirect emissions due to the use of electricity – scope 2 emissions. Moreover there are many sources of indirect emissions that are arguably part of a product's lifecycle emissions. These are the scope 3 emissions, e.g. emissions from employee travel for product marketing, emissions due to the production of machines that manufacture the products, emissions due to customer travel to buy the products, etc. The PAS2050 gives guidelines into which emissions should be included in a product's carbon inventory.

Additional issues should be adequately addressed by a standardized methodology in order to achieve comparable carbon footprints among different products. For example, it is still not clear which greenhouse gases to include and whether the product use phase emissions should be included. Because such questions are better answered by LCA experts and standardization organizations, they will remain outside the scope of IT leverage and thus of the EPC Network. Never-the-less, an IT solution for monitoring carbon footprints should be able to simultaneously support different alternatives and thus different standards.

3.4.2 Scalability Challenges

Since the focus of the current pilot projects is on applying a methodology and reaching a standard, it is not clear if and when such efforts will be repeated. As such, the pilots are one-time audits whose next revision is not in scope. Furthermore – understandably so due to their focus – the projects are not leveraging enterprise information systems to gather and present much of the needed data. Regular carbon footprint monitoring and decision support will open up new saving opportunities for businesses and the environment but will only be possible with adequate information technology support. Otherwise the efforts will still require lots of resources and their savings will not match the allocated effort.

Also, early pilots showed how complex lifecycle-based environmental footprint studies can be. The difficulty lies in mapping all the relevant lifecycle processes and collecting data – typically from different supply chain partners – about each process. Such a study takes much time & effort, and is currently not scalable to account for a wide portfolio of products. The business challenge is to find a scalable, yet methodologically sound way to calculate environmental parameters of hundreds and thousands of products.

3.4.3 Average vs. Dynamic Emissions

PAS2050 points out to several product lifecycle stages where carbon emissions vary considerably among instances of the same product [4]. The example areas named are:

- Seasonal fruits whose associated emissions vary depending on the season
- Highly variable supply chains, where suppliers are frequently replaced
- The degree of using reused or recycled components in products
- The downstream distribution of products to different locations
- The mode of usage of the product

The PAS2050 draft mentions that working groups will investigate the open issues above, but for the time being, average numbers are used when highly variable values are encountered.

Continuing this approach of masking significant emission differences will make it less possible for companies to take better decisions based on the variations.

We differentiate between three approaches:

- *Static product-level carbon footprint*: This is the current approach of using the same *average* emission numbers for all instances of a product to come up with one value that is not changed often enough to reflect real business changes. In certain situations, using average emission numbers will be sufficient because the variation is not high or frequent enough to affect the decisions based on the carbon footprint
- *Instance-level carbon footprint*: A very fine granular approach where each product instance has a different carbon footprint depending on its lifecycle history. While this approach may better reflect reality, it will not help consumers at the shop floor who would be overwhelmed by the information they have to process.
- *Dynamic product-level carbon footprint*. This is a hybrid approach where the consumer interacts with one carbon footprint value per product (similar to the interactions with other product parameters) but the actual value is dynamic – reflecting business changes – and is based on product *and* item-level data.

3.4.4 Conclusion

This section showed three challenges facing carbon footprint efforts, the first should be addressed by a common standard, and the other two are suitable for IT support. Namely, real-world process data can be collected from enterprise systems and track & trace infrastructures to make product-level carbon accounting more dynamic, accurate, and scalable to cover many products. In the next chapter we provide an illustrative description of how the EPC Network can help in the latter, namely in dynamically tracking greenhouse gas emissions of different product instances.

4 EPC Network Support for Dynamic Product Carbon Footprints

We outlined in the previous section how enterprises can quantify the average amount of emissions due to a particular product. This averaged-out number does not take the dynamic nature of the carbon footprint into consideration. Namely, when different suppliers have different footprints, or when there are temporal or spatial variances between different instances of a product, the use of average numbers leads to inaccurate results [6]. For example, fruits bought in different seasons of the year will require different periods of chilled storage, resulting in carbon footprints that vary over the year. Also, different instances of products may be shipped over longer distances or subject to production processes of varying efficiency, also resulting in different carbon footprints.

Providing increased granularity in the GHG calculation process, such as finding the footprints of individual batches, cases, or even items, will have three important effects:

1. Providing more visibility for enterprises into their processes, thus enabling them to understand and mitigate the cause of potential variations in their products' footprints.
2. Enabling real-time decision-making that has an immediate effect on decreasing monetary and environmental operation costs
3. Differentiating an enterprise from its competitors by providing the consumer with more information, and thus decision empowerment. The consumer could then purchase the less carbon-intensive variants of a product and by this exert his or her market power.

Calculating the carbon footprint information with an increased level of granularity poses some additional challenges on enterprise information systems. Namely, companies need to identify each unit whose emissions should be quantified and track those emissions across the lifecycle of the unit.

4.1 The EPC Network

Several technologies are available that can identify products, logistic units, individual items, etc., and each technology uses one or more coding schemes. The Electronic Product Code (EPC) [8] has been developed for the purpose of identifying heterogeneous types of units, e.g. products, cases, and pallets, in addition to uniquely identifying individual product instances. EPC Information Services (EPC IS) provide the services required for querying and capturing EPC event data about the tagged products and the repositories needed to store this data. EPC Discovery Services (EPC DS) locate the EPC IS instances that have information about a particular EPC. Together, the EPC IS and EPC DS, in addition to the readers and middleware underneath, constitute the EPC network infrastructure [7]. We propose in the following using the EPC network for tracking environmental information, e.g. GHG emissions, on the identified units. The goal is to enable the dynamic calculation and communication of GHG emissions on different levels of granularity, such as batch, pallet, case, and item.

4.2 The EPC Network for Carbon Footprint Differentiation

In this section, we will provide an example of how the EPC network can be used to track GHG emissions dynamically and in varying levels of granularity across the supply chain. Consider the exemplary supply chain shown in figure 1.

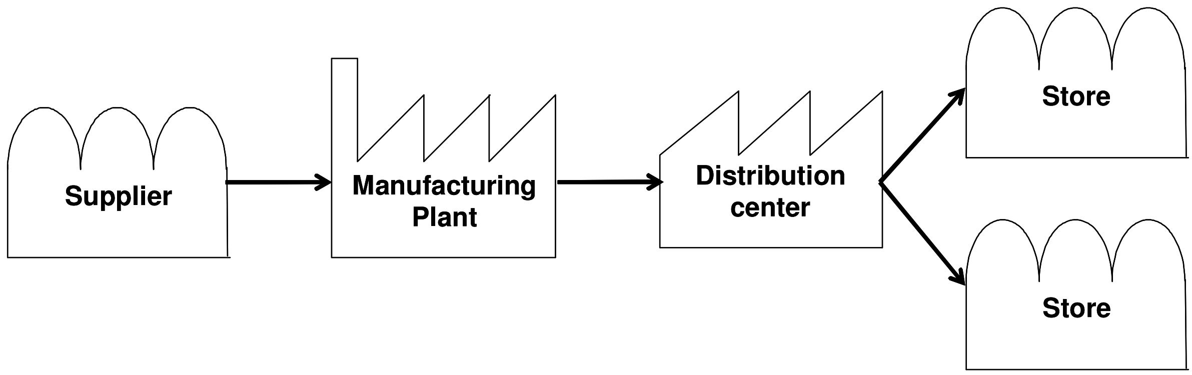

Figure 2: Sample Supply Chain

The manufacturer receives EPC-tagged components from its supplier; with the carbon footprints of the components already calculated using the supplier's environmental management information systems (EMIS) and stored in the respective EPC IS. The manufacturer accounts for the GHG emissions of its internal production processes using its EMIS. In addition, the manufacturer publishes an EPC aggregation event, specifying the parent-child relationship between the produced item and its components. A user can query for the carbon footprint of a particular item right after production using its EPC number, and the unique item is identified along with its components and the cumulative GHG emissions. Items with components from different suppliers will already have different carbon footprint at this stage.

After producing the items, the manufacturer aggregates them into cases and aggregates the cases into pallets. These aggregations are stored as EPC events with the parent-child relationships accounted for. The manufacturer then ships the pallets to the distribution center and publishes an EPC event that includes the pallet EPC and the time of shipment.

An EPC event is generated when the items reach the distribution center. We assume that the relevant environmental information, such as the type of transportation used and its corresponding emissions, is integrated in the shipping notices. Using the time difference between the two EPC events (leaving the manufacturer and arriving at the distribution center), and given the emission factor of the transportation fuel used, we can calculate the emissions caused by the shipment of goods to the distribution center.

When the goods leave the distribution center we can similarly calculate the storage time. If the storage included chilling the goods, we can calculate the emissions caused over that period of time and attribute the corresponding amount of emissions to those goods.

Before leaving the distribution center, the goods get disaggregated into cases and those cases get shipped to different retailers. The cases may have differing footprints from this point because, for example, of the different transportation distances and the different cooling time. These different footprints can be accounted for separately because the cases are uniquely identified with EPC numbers.

With all the supply chain processes accounted for, and all aggregation and disaggregation events recorded, we can deduce the footprint on different levels of granularity, e.g. the whole shipment, a pallet, case, or an individual item.

4.3 The EPC Network for Carbon Footprint Communication

The previous section showed that the EPC Network can be used to collect item-level events that will differentiate product instances in terms of their carbon footprints. This can be used to establish better estimates of the product carbon footprint or provide basis for supply chain optimization. On the other end of the value chain, consumers want to know more about lifecycle ecological implications of the products. However, communicating different carbon footprint values of the same product might confuse the ordinary consumers. We therefore envision a scenario where consumers could retrieve the *dynamic product-level carbon footprints* of the goods they purchase and, typically, not the instance level footprints.

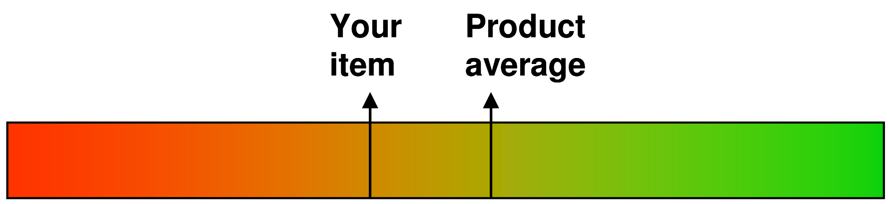

Figure 3. Carbon footprint of a particular instance in comparison to a product average

What some consumers may still be interested to know, though, is how the particular item they bought or are about to buy fares in comparison to its product-class average. An example result is shown in Figure 3. This is a scenario where an item-tracking infrastructure such as the EPC Network can help. Namely, when a consumer queries about the carbon footprint of a specific product instance, the item's unique serial number is sent to the EPC Discovery Service which retrieves the specific object trace, along with relevant data that contributes to carbon footprint variations (e.g. transport vehicles, storage time, etc). The emission variations between the product instance and average due to each step in the supply chain are then calculated and summed to present a certain deviation. This is finally displayed to the consumer, say on his/her mobile device.

This paper serves as a starting point for further research in the domain of dynamic carbon accounting. The next section outlines the planned research that focuses on (1) finding the processes most suitable for an EPC-based approach and (2) defining the respective solution concepts. The future work will be detailed in the next whitepapers according to the project proposal "The EPC Network for energy efficient and low emission supply chains – EPC green strategy".

5 Outlook

We presented in this paper a spectrum of approaches for companies who wish to monitor and communicate their GHG emissions. We first reviewed the commonly practiced enterprise-wide reporting activities and supporting tools. We then described the current goal of several companies to quantify the emissions with respect to particular products across their lifecycle. Finally, we proposed how enterprises can go a step further to account for their GHG emissions on an increased level of granularity, such as that of cases or single instances. We gave a conceptual example involving the EPC network that could support such dynamic, fine granular information gathering and communication.

As noted in section 3.4.3, carbon footprint variations can be significant or marginal and tracking them is only sometimes possible with cheap information technologies. Yet, the degree of emission variability of different lifecycle stages is still not clear, and neither is their relative importance. Our next challenge is to take a supply-chain-wide view and analyze different sources of emission variability in order to find out which should be dynamically tracked. The work must analyze which processes cause emissions that can be controlled by the responsible company, because otherwise tracking them wouldn't bring any value. Then, the analysis should compare the sources of carbon footprint variability, focusing on the degree of and frequency of the fluctuations. The result is an analysis of supply chain processes and decisions specifying the significance of their carbon footprint variability and the need to dynamically track it.

Even when we understand the processes and the emissions that should be dynamically monitored, the required systems that allow companies to track them in an efficient, reliable, and precise way are still not available. To go one step further that current pilots and track the highly variable emissions, companies should adopt more efficient – thus cheaper – methods. This paper motivated the value of the EPC Network as an infrastructure for dynamic emission monitoring. A proof-of-concept that demonstrates the monitoring of variable emissions remains to be implemented with the EPC Network.

References

[1] ADEME. Un nouvel étiquetage des produits de grande consommation! Online, August 2007.

[2] CARBON TRUST. Carbon Footprints in the Supply Chain: The Next Step for Businesses, 2006.

[3] CARBON TRUST. Tesco and Carbon Trust join forces to drive forward carbon labelling. Online, 2008.

[4] CARBON TRUST, AND DEFRA. Pas 2050:2008 - specification for the assessment of the life cycle greenhouse gas emissions of goods and services. PUBLICLY AVAILABLE SPECIFICATION, 2008.

[5] CLIMATOP, AND MIGROS. Climatop zeichnet klimaschonendste Produkte mit CO2-Label aus. Online, 2008.

[6] DADA, A., STAAKE, T., AND FLEISCH, E. The potential of UbiComp technologies to determine the carbon footprints of products. In *Workshop on Pervasive Persuasive Technology and Environmental Sustainability, Pervasive 2008* (2008), A. Zaslavsky and K. Truong, Eds., pp. 50–53.

[7] EPCGLOBAL. The EPCglobal Architecture Framework, 2005.

[8] EPCGLOBAL. Electronic Product Code (EPC): An Overview, 2007.

[9] EUROPEAN COMMISSION. EU action against climate change: EU emissions trading, September 2005.

[10] EUROPEAN COMMISSION. COMMISSION DECISION of 18 July 2007 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, 2007.

[11] EUROPEAN ENVIRONMENT AGENCY. Greenhouse gas emission trends and projections in Europe 2008. EEA Report No 5/2008, 2008.

[12] GRAY, R., OWEN, D., AND ADAMS, C. *Accounting and Accountability*. Prentice Hall, London, 1996.

[13] GROUPE CASINO. The casino carbon footprint, the 1st complete environmental labelling scheme in france. Online: https://portal.health.fgov.be, 2008.

[14] KRUGER, J., AND PIZER, W. A. The EU Emissions Trading Directive: Opportunities and Potential Pitfalls. RFF DP 04-24, April 2004.

[15] RANGANATHAN, J., CORBIER, L., BHATIA, P., SCHMITZ, S., GAGE, P., AND OREN, K. The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard. WBCSD and WRI, 2004.

[16] RECYCLINGSUPERMARKET.COM. Leading firms sign up for carbon rating. Online, 2007.

[17] REUTERS. Wal-mart to look at suppliers' energy efficiency. Online: http://www.reuters.com/article/environmentNews/idUSN2426684420070925, September 2007.

[18] SOLOMON, A., AND LEWIS, L. Incentives and Disincentives for Corporate Environmental Disclosure. *Business Strategy and the Environment 11* (2002), 154–169.

[19] THEMA1. PCF Pilot Project Germany presents three new corporate partners from the wholesale, retail and chemicals sectors. Online, July 2008.

[20] WHEATLAND, J. The L.E.K. Consulting Carbon Footprint Report 2007. L.E.K. Research Insights, 2007.

[21] WIEDMANN, T., AND MINX, J. A Definition of 'Carbon Footprint'. ISA Research Report 07-01, 2007.