Physical Internet and its impact on the emission calculation standardization of transport chains – are we there yet?

Verena Charlotte Ehrler [1]

1. DLR Institute of Transport Research, Rutherfordstr. 2, 12489 Berlin, Germany

Corresponding author: verena.ehrler@dlr.de

Abstract: *Expectations are high that the Physical Internet (PI) will contribute substantially to the improvement of transport chains' efficiency and therefore to a swift reduction of freight transport related emissions. However, the PI's ecological superiority still needs to be proven in reality. Moreover, in a synchro modal hyper-network, where routing management is decentralized, mechanisms need to be implemented that support emission minimization, both for individual flows as well as on a systems level. A standardized emission calculation tool for measuring emissions of freight transport chains ex-ante as well as ex-post is therefore necessary. Over the past decade, various approaches toward such a standard have been developed. This paper analyzes whether the currently existing approaches of emission calculation standardization are able to provide the necessary evaluations and whether they are equally able to support a successful steering of transport within the PI, so that lower emissions of freight transport can be realized compared to today's freight transport system. Based on an overview of the basic principles of the PI and on a summary of the status of transport chain emission standardization approaches, the paper analyzes how far these two developments are fully compatible already and which major gaps still need to be closed.*

Keywords: *Physical Internet, global logistics, transport, emission calculation, international standardization, sustainability, transport chains, greenhouse gas emissions*

1 Motivation and objective

The need to reduce emissions related to transport chains is pressing: annual global greenhouse gas (GHG) emissions have to peak by 2020 and then have to be reduced by 40% by 2040 (UNEP 2016; WRI 2017; IPCC 2014) (see Figure 1: Historical GHG emissions and projections until 2050) to ensure that we remain within the climate target of a maximum global warming of 2˚C. Therefore, the European Union (EU) aims for a reduction of greenhouse gas emissions of 20% by 2020 and of 40% by 2030 compared with 1990 levels (EU 2014), and the reduction of transport emissions plays an important role, as it is estimated that transport contributes with about 25% to CO_2 emissions, on a worldwide scale as well as on a European level. In 2004 roughly 21% of these transport related emissions derived from the domestic freight transport in the UK, which corresponds to 6% of total CO_2 emissions from all sectors (McKinnon 2010). Data for France indicates a 14% share of freight transport in greenhouse gas emissions (Duong, Savy 2008) and for Germany around 20% of all CO_2 emissions are related to road transport (Shell, DLR 2016).

As freight transport is expected to further increase over the coming years (e.g., for Germany an increase of freight transport of around 50% by 2040 is expected (Shell, DLR 2016)) and as global freight transport is currently based by a minimum of 95% on energy from fossil fuels, it is important, if not vital, to ensure that its greenhouse gas emissions remain within the climate goal target (IPCC 2014).

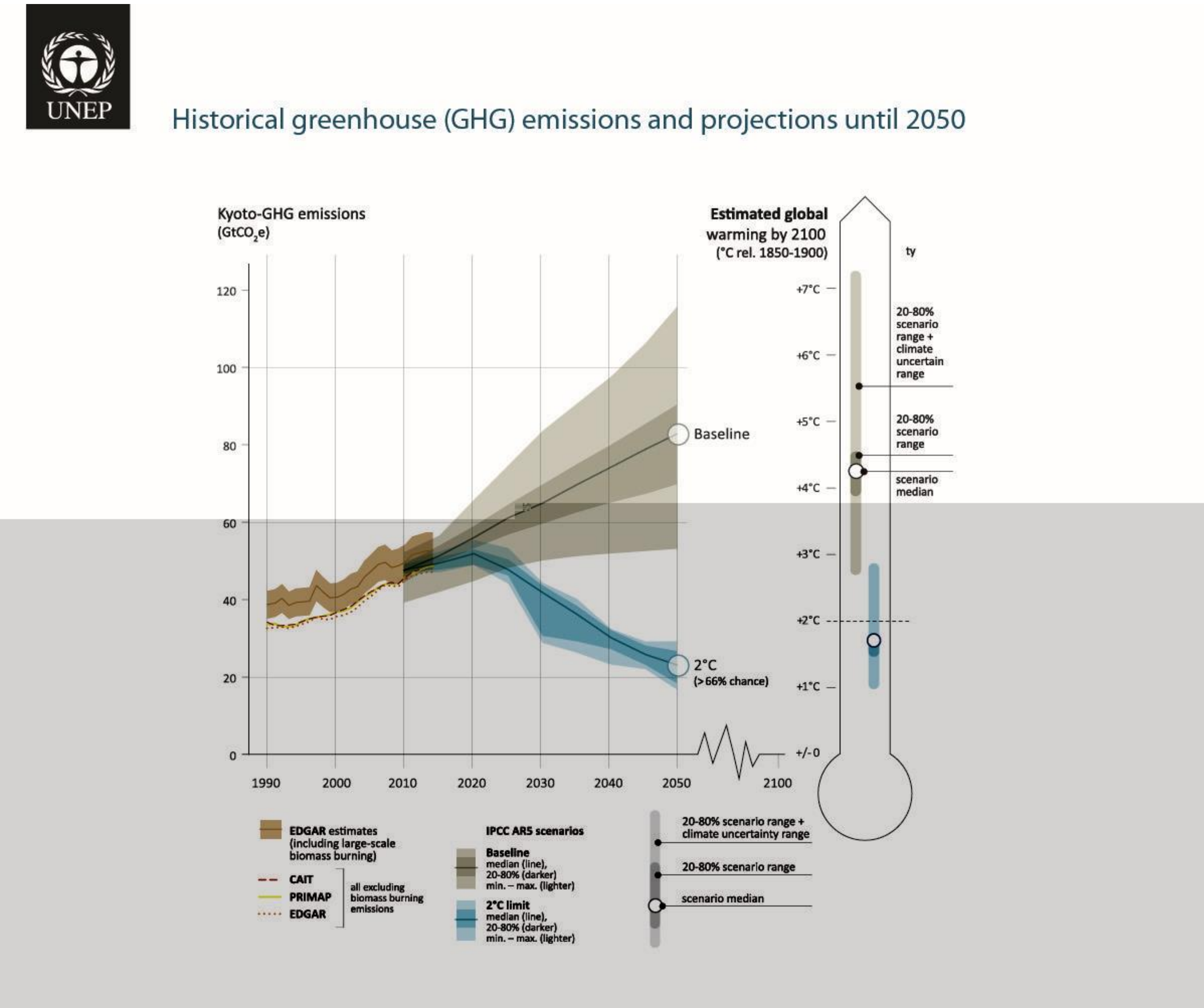

Figure 1: Historical Greenhouse (GHG) Emissions and Projections until 2050 (UNEP 2016)

In response to these challenges, innovative approaches and concepts to logistics and freight transportation are needed, developed and tested. They aim at decoupling the growth of freight traffic from economic growth.

One of these concepts is the Physical Internet, named in analogy to the Digital Internet. It is defined as “an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols” (Montreuil, Meller, Ballot 2012a). Despite the fact that it is still a new concept, the Physical Internet is anticipated to be a game changer in logistics and expectations are raised that it can and will contribute to the improvement of transport chain efficiency and therefore to the reduction of freight transport related emissions, both on a regional, as well as on a global level. Current targets envisaged by the Alliance for Logistics Innovation through Collaboration in Europe ALICE are a reduction of CO_2 emissions of 10% by 2020 (Phase 1 of the ALICE Roadmap), 25% by 2030 (Phase 2) and 40% by 2040 (Phase 3) compared to current levels. With the realization of these targets the Physical Internet would significantly contribute to the agreed emission targets for freight transport in Europe and on a worldwide scale (ALICE 2017).

If we really want to reach those targets though, we have to be able to measure emissions of freight transport (ex-post emission calculation) to compare different transport solutions. We also have to be able to steer transport so that it causes as little Greenhouse gas emissions as possible (ex-ante emission calculation). Furthermore, in a transport network with de-central routing decisions, mechanisms need to be integrated which take Greenhouse gas emissions into account. And the integration of these mechanisms has to extend up to the point where they provide the right signals to production and intra-logistics systems to encourage efficient and sustainable decisions for entire supply chains.

The purpose of this research is to analyze how far ongoing efforts for transport chain emission calculation standardization are able to support the evaluation of Greenhouse gas emissions of the PI, because if we want to reach the climate targets we need meaningful and transparent emission controlling now. At its core is the question, whether the characteristics of the Physical Internet are compatible with the currently developed approaches towards transport chain emission calculation standardization and whether, subsequently, these approaches are suitable and ready yet to measure the emissions of transport solutions of the Physical Internet.

First, this paper reflects upon how far the basic principles of the PI are further developments of existing logistics concepts or whether they are entirely new, requiring fundamental changes to the way logistics and transport are organized (section 3: The Physical Internet and a change of game). In a next step, the paper gives an overview on the current status of efforts for transport chain emission calculation standardizations on a global level (section 4: Emission calculation standardization – an overview on the current status of developments). The paper analyzes to which extent the current global standardization approaches support those aspects of the PI which have been identified as fundamental changes and innovations, and it is analyzed in how far these two developments are compatible already (section 5: Relation of basic principles of PI to current emission calculation standardizations – challenges and gaps). The paper closes with an outlook on the further developments of the PI and of emission calculation standardization needed to steer freight transport towards the established climate goal (section 6: Conclusion and outlook – are we there yet?).

2 The Physical Internet and a change of game

Transporting goods from shipper to consignee is per se a linear process, as it is the move of an object from one starting point to its final point of destination. In the past, freight documents travelled with “their” goods, and the routing of the freight was chosen prior to its departure, with price, transport mode and estimated time of arrival agreed between the involved partners. The introduction of electronic documentation for freight, so called e-freight, has enabled the separation of goods from their freight documentation. Freight related information can be processed in data network structures, whilst goods transported still move along a linear process (Ehrler 2011). With the introduction of the Physical Internet it is suggested that also this predefined linear process of goods’ movements is changed into a network structure where goods’ routings are decided ad hoc as they move through the network in smart containers.

Benoit Montreuil (2011) describes the basic principles of the Physical Internet, which is attributed with the potential of being a game changer in logistics. The following section investigates, whether these principles are a further development of existing characteristics of current logistics structures or whether they require a completely new way of thinking and organizing logistics and freight transport:

1. Encapsulating merchandise in world-standard smart green modular containers: Goods will be transported in modular, standardized containers, with all information relevant for routing decisions and handling processes included on the "packet header," an electronic label of the container. These PI-containers (also called "π-containers") are standardized worldwide and modularized, from small sizes up to current TEU container size and they are to be made of environment friendly materials with minimal tare weight. Standardized containers exist in various elements of the transport chain already (e.g., TEU containers, Euro-palettes or also standardized shapes and sizes for parcels sent by mail or couriers). Therefore, the development of a further modularized container system, here the PI container, is a logical next step of standardization of packaging and can be considered a further development of existing concepts.

2. Aiming toward universal interconnectivity: The PI is a network of transport networks, with operations and processes functionally standardized on a global scale. Logistics nodes of the PI are routing sites, accumulation sites, logistics' services facilities and interface to players outside the Physical Internet at the same time. Aviation and sea transport, as well as road transport have realized this principle of interconnectivity and multi-purpose nodes to a large extent already, unlike rail systems. Developments of long-distance train connections such as Asia-Europe lines promote a better interconnectivity though.

3. Evolve from material to PI–container handling and storage systems: The standardized and modular format of PI-containers and their smart labelling in combination with dedicated PI-handling and storage systems build the basis for the optimization of efficiency of the PI. Therefore, the focus of system optimization is shifting from a material based focus of current transport systems to a container flow-oriented focus within the PI. Similar concepts are realized for handling of luggage in aviation, at transshipment centers and in warehousing concepts already. It is to be kept in mind though, that also in those systems and despite a standardized containerization, variations in handling are often required, e.g. for dangerous goods or due to weight issues when loading and unloading transport vehicles, such as vessels.

4. Exploit smart networked containers embedding smart objects: The use of smart labels enables a fully traceable and trackable self-routing of the standardized PI-containers through the interconnected transport networks. The seamless, ubiquitous introduction of electronic documentation and full e-freight coverage of the transport system is a prerequisite for a full exploitation of the introduction of smart labels. The concept of e-freight is introduced, a swift completion of the shift is necessary.

5. Evolve from point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport: Supported by web software, networks of all participating providers of transport and handling services are connected with one another. Containers chose ad-hoc and from node to node which transport mode, handling or network provider to use. Such a self-routing system requires an ex-ante calculation and comparison of costs, time and emissions of the next route element from node to node in order to establish which routing option is best. The decision of the routing is therefore not taken by those who pay for the transport any more. Instead, parameters have to be set according to the preferences of the customer and they have to be embedded on the smart label of the π-container, thus driving the decisions taken at each node en-route. This shift of decision-taking is considered a major change to current structures. It is expected to be one of the central aspects related to the issue of emission calculation of transport chains and shall be analyzed further within section 5 of this paper.

6. Embrace a unified multi-tier conceptual framework: Like fractals, the PI transport system is characterized by the same basic structures being reproduced on all of its scales: international, national, regional, urban. Such a concept is interesting and research is investigating the efficiency this approach supports especially for urban transport (Batty 2008). The granularity of emission calculations is related to the level of detail of the transport network planning and analysis. The structure being repeated on the various scales should simplify the approach, as the logical concept of one emission calculation approach can be transferred to the other levels, as long as the data for the calculation is available in the necessary granularity. This aspect therefore poses a data availability issue, rather than a conceptual challenge for the emission calculation.

7. Activate and exploit an Open Global Supply Web: This aspect of the Physical Internet might contain one of the more challenging implications and changes of game. The World Wide Web so far could be hindered from shifting to a differentiation in data transport speed, despite many providers pushing for it. In logistics and transport services though, the speed of delivery often is a USP (Unique Selling Proposition) and an aspect of high strategic relevance. Opening up its supply web could substantially weaken the competitive advantage of an organization, for producers or sellers of goods as well as for logistics providers. Therefore, logistics structures are well kept secrets and infrastructures usually are not openly available. Changing this structural element of commercial principles requires new business models (Montreuil et.al. 2012b) as well as a mind shift, a concept shift and most probably a paradigm shift in economics as well as a shift in international politics. Throughout the development of standardization approaches for the calculation of transport chain emissions, logistics providers have mentioned their concern on having to reveal more information than desirable on their transport structures, concepts and customers. An Open Global Supply Web might lead to further worries. Impacts related to the emission calculation standardization approach structures are further discussed in section 5.

8. Design products fitting containers with minimal space waste: Products that fit into predefined containers (i.e., function following form and perhaps even function following wrapping) is a principle already introduced by flat-pack product developers. This aspect would be brought to the next level if wrapping is standardized on a global scale.

9. Minimize physical moves and storages by digitally transmitting knowledge and materializing objects as locally as possible: In its full development, open distributed flexible production centers support local productions based on digitally transmitted information. This is, like aspect 7, an aspect requiring a change of game on the level of general principles of our economic system. At the moment it is most attractive for businesses to maximize their profit over their entire value chain. With low transport costs percentage in overall production costs combined with massive variations in salaries over the world, a maximization of profit is not necessarily realized when objects are materialized as locally as possible. This concept becomes attractive though where production processes are fully automated, e.g. in the form of 3d-printing. Such a shift therefore requires or a dramatic change in transport costs, a global assimilation of salaries or the complete replacement of human work force in production processes. General concepts of current approaches to emission calculation standardization are not related to this aspect.

10. Deploy open performance monitoring and capability certifications: Key performance indicators (KPI) of supply chain will provide for the necessary information for its further optimization. These KPIs need to support the monitoring of the transport chain,

including the transport time needed, quality, emissions, costs, services level, safety and security. Similarly to principle 5 this aspect has a direct interference to the topic of emission calculations of the transport chain and will be further investigated within section 5;

Looking at the basic principles of the Physical Internet, several aspects of it are already en route, whilst others require a change of game of business and economic principles, before the Physical Internet can become a game changer itself.

The following analysis will focus on those aspects of the PI which have been identified as being directly related to the calculation of emission calculation of transport chains: principle 5 ”Evolve from point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport,” 7 “Activate and exploit an Open Global Supply Web”, and principle 10: “Deploy open performance monitoring and capability certifications”.

The next section gives a short overview on the current status of emission calculation standardizations, before the changing requirements for emission monitoring implied by the Physical Internet on these standardization efforts are analyzed.

3 Emission calculation standardization - an overview on the current status of developments

“Businesses that measure their emissions have the opportunity to make informed decisions that lead to improved efficiency and reduced emissions” (LEARN 2017). This sentence introducing the project LEARN, Logistics Emissions Accounting and Reduction Network, summarises the core motivation of the transport industry and its related stakeholders for their ongoing efforts to develop a standard for measuring emissions of transport chains.

These players and stakeholders include logistics providers, governmental bodies, research organizations, consultancies, NGOs as well as combined consortia of these. Tools developed range from internationally applicable standards to transport mode specific methods, to data basis or calculation tools. An analysis carried out within the EU project COFRET, Carbon Footprint of Freight Transport, analyzed over 140 different tools in 2011 already (Kiel et.al.2014). More tools have been developed since. To be able to compare measured and calculated emissions of different transport solutions it is necessary though, to define unambiguous principles which can be applied to entire transport chains and on a global scale; the development of an internationally applicable standard for the calculation of transport chain emissions is needed.

Such a standard needs to include the calculation of emissions of logistics hubs. It needs to specify which data is to be used for the calculation and how the data used is to be sourced and communicated within the emission reporting scheme. As it is not always possible to track data over entire transport chains, default data should be used for emission calculation instead. Such default data needs to be tagged though and sourcing procedures of default data have to be standardized, too, if true transparency on the emission calculation is to be achieved.

International standards suitable as a basis for the calculation of transport are mainly ISO 14064 (Greenhouse Gases - Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals), ISO/TS14067 (Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification and communication), the GHG Protocol Scope 3, the European Standard EN16258 and the Global Logistics Emission Council GLEC Framework for logistics emissions methodologies.

The ISO standard 14064, the ISO/TS 14067 as well as the GHG Protocol support the calculation of emissions for organizations (ISO 14064), products (ISO/TS 14067), and value chains (GHG Protocol Scope 3) (see also Table 1: Emission Calculation Standards for Transport Chains and their scope). They build an established and implemented framework for further developments of transport chain emission calculations; they do not provide transport chain specific guidelines though. An unambiguous comparison of transport chains including various transport modes is therefore not possible based on these standards only.

Table 1: Emission calculation standards for transport chains and their scope

Emission Transportation Standard	**Scope**
ISO 14064	methodology for the calculation and declaration of energy consumption and GHG emissions of transport services, freight and passengers
ISO/TS 14067	methodology for the calculation of carbon footprint of products
GHG Protocol Scope 3	methodology for the assessment the impact of emissions of companies entire value chains; no explicit focus on transportation
EN 16258	methodology for the calculation and declaration of energy consumption and greenhouse gas emissions of transport services,
GLEC Framework	framework combining existing standards and methodologies to calculate logistics emissions

The European Norm EN 16258 "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)", addresses transport chain related issues for both freight and passengers, as its title states. The standard does not provide guidance on how to calculate emissions from logistics nodes though. It is left up to the user of the standard to describe how they included nodes in their calculations. Different approaches, and subsequently different calculation results, are therefore allowed within the standard, rendering a comparison of calculations impossible. Also, the standard allows the use of different levels of data quality and accuracy for different levels of detail of calculation. Boundaries of vehicle operation systems (VOS) are not clearly defined and the standard allows the use of different units for the allocation of GHG emissions, weight or tonne-kilometers, putting the fairness of allocation in question (Ehrler et. al. 2016). Beyond these considerations and perceived issues, the EN 16258 is a European norm. It might prove difficult for a European norm to be accepted on a global scale.

To close the identified gaps and to lift the transport chain specific standardization efforts on a global scale, the Global Logistics Emission Council GLEC has developed the GLEC framework for logistics emissions methodologies, which was published in 2016 (Smart Freight Center 2016). Based on the Greenhouse Gas Protocol, the GLEC framework is in line with the EN 16258.

GLEC itself is "a group of companies, industry associations and programs that want to make carbon accounting work for industry; it is backed by leading experts, governments and other stakeholders." (GLEC 2017) With this motivation and backing, the GLEC framework is providing simplicity and flexibility as necessary for being applicable by industry, balancing these characteristics with accuracy and transparency as requested and expected by research, governments, and other stakeholders (see Figure 2: Tenets of the GLEC Framework, adapted from Diekmann, COFRET).

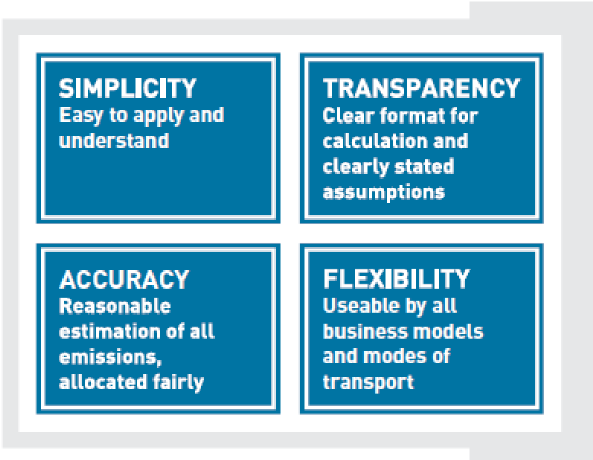

Figure 2: Tenets of the GLEC Framework, adapted from Diekmann COFRET (Smart Freight Center 2016)

It is covering all transport modes, is internationally applicable and provides clear guidance on the sourcing and use of data, both for trackable data as well as for default data. In its targeted scope the GLEC framework states that it aims to cover the full well-to-wheel approach for the fuel life cycle and the inclusion of the following Greenhouse gas emissions: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3. Furthermore, the inclusion of short-lived climate pollutants like Black Carbon and fugitive GHG emissions like methane slip and HFC leakages as well as air pollutants, such as NOx and particulate matter is aimed for with a future version of the GLEC framework.

The document describes its gaps, which are to be covered in future editions, as the following:

- Inclusion of black carbon into GLEC (part of 2016-2017 planned activities)
- Refining modal default factors, organized by TSC (Transport Supply Chains) and geographic region
- Improved accounting of scope 3 emissions
- Identifying sources of uncertainty and quantifying the degree of uncertainty within default and primary data in order to better understand the accuracy of emissions estimates
- Challenges in data collection by SMEs and in developing countries
- Transshipment center methodology, including application of TSCs in large and small businesses
- Development of default dataset of transshipment center TSCs
- Further research into weight of contents of containerized loads
- Harmonization of approach to allocation between passengers and freight in instances of shared transport
- Consistent accounting for leakage of gaseous fuels and refrigerants
- Translation into other languages

Taking these gaps into consideration, the GLEC framework meets the requirements mentioned for a globally applicable standard for the calculation of emission of a transport chain.

In the next section it is discussed whether the current status of a standard as developed with the GLEC framework is also able to cover the requirements of emission calculation and monitoring within the PI, taking into consideration its basic principles.

4 Relation of basic principles of PI to current emission calculation standardizations challenges and gaps

Following the reflection on the basic principles characterizing the PI (see section 3), it is mainly three aspects that are directly related to the calculation of transport chain emissions: characteristic 5 (the evolution from a point-to-point hub-and-spoke transport to distributed multi-segment intermodal transport) characteristic 7 (the activation and exploitation of an Open Global Supply Web), and characteristic 10 (the deployment of open performance monitoring and capability certifications).

Emission calculations approaches distinguish between three different levels of calculation (IWA 16:2015):

1) Level of operation of transport chain element (TCE), where a TCE is a logistics operation; the sum of all TCEs builds the transport chain (see Figure 3: Transport Chain and TCEs)

2) Level of network including company level

3) Level of cargo.

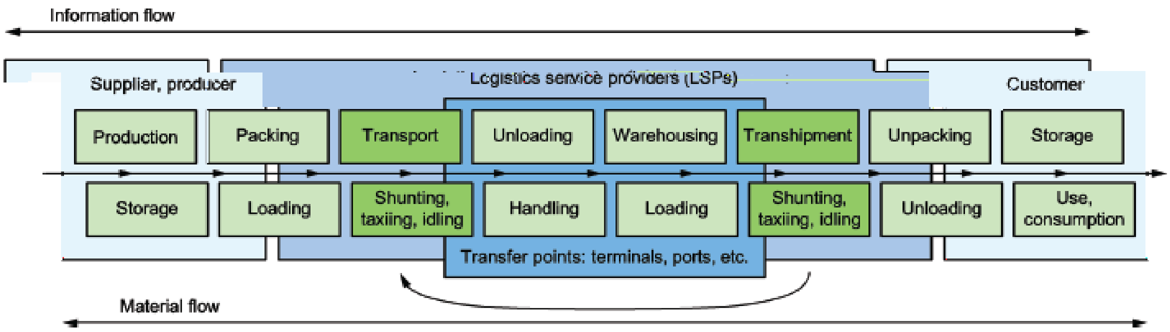

Figure 3: Transport Chain and TCEs (IWA 16:2015)

In the following these levels shall be considered separately in relation to the mentioned characteristics of the Physical Internet relevant for emission calculation. Emission calculations need to be based on measured energy consumption, in order to be meaningful. Measured data of completed transport can be used to evaluate existing transport structures and to identify best practice (ex-post emission calculation). To steer transport in a PI in a way that it causes as little greenhouse gas emissions as possible it will be necessary to evaluate expected emissions at each node (ex-ante emission calculation) and to integrate mechanisms which take Greenhouse gas emissions into account when they provide signals to production and intra-logistics systems so efficient and sustainable decisions for entire supply chains are taken. Therefore, the impact of the PI principles on ex-ante and ex-post emission calculations will be considered separately.

Level of operation of transport chain element

The concept of TCEs is compatible with the node-to-node concept of the Physical Internet. It is therefore to be expected, that the impact of a shift from current structures to the PI has no major impact on the requirements for a calculation of emissions for transport chains, neither ex-ante nor ex-post.

Level of network including company level

Calculation of emissions of transport chains on a network level are at the heart of current standardization efforts. Currently, decision makers of logistics are customers, shippers or consignees, who usually decide on the transport mode, and logistics providers, who organize their network and steer its utilization. A shift to PI results in a shift of decision maker: customers of transport will set parameters for the shipment. According to the basic principles of the PI though, decisions on routing details will then be taken at each node automatically. These decisions on routings, taken at each node will have to take into account the energy consumption and emissions expected for the next leg of a shipment's routing. Choices will be made ad hoc on the basis of ex-ante calculations for each of the possible legs. A direct steering and active contribution of the transport network provider toward minimization of network emissions is not possible anymore.

The ex-post tracking of emission will be easier as far as following the moves of a shipment is concerned, since the smart π-container provides information on its "live and historical performance" (Montreuil 2011). Capturing energy consumption of a specific transport vehicle with the transport of a shipment will have to be supported by software which is able to align specific vehicles with specific shipments. Otherwise, default data for emission calculation will have to be allocated to a shipment for the emission calculation.

Level of cargo

Decisions on the transport of a container from one node to the next can be taken with different levels of autonomy in the aimed for distributed multi-segment intermodal transport network. During the shift from the current point-to-point system to the full Physical Internet all degrees of decentralization are thinkable. In the ideal PI of an open supply web with a high percentage of distribution and production centers available to many clients, shippers would define the final destination, the requested time of arrival as well as the monetary budget at disposition for the shipment (Montreuil 2011). Furthermore, for ensuring an optimized energy efficiency of the shipment's transportation, parameters defining an "emission budget", have to be programmed prior to the shipment's departure. Based on these parameters for the budgets of money, time and emissions, ex-ante estimations have to be carried out at every node before it is decided, which route the shipment takes. The challenge is though, that the estimation for one node-to-node connection is not a sufficient basis for the identification of the optimized solution for the shipments entire route. With the sum of emissions being the total of the emissions of the legs constituting the entire journey of a shipment, the full amount of emissions is only available once all elements of the transport chain are known.

$$\begin{pmatrix} v_1 \\ v_2 \\ v_3 \\ \vdots \\ v_n \end{pmatrix} \longrightarrow \boxed{\sum_{i=1}^{n} (v_i)}$$

with v_n= CO_2e per TCE

Decisions which seem best for the instant pending next leg might result in restricting later legs to poor solution. The identification of the next best leg cannot be separated from the analysis of emissions of the entire transport chain. At each node it would therefore be necessary to anticipate options and their probability of the nodes following throughout the remaining network through which a shipment is travelling on the way to its final destination, similar to the calculations of a chess computer. The complexity for such a program will be challenging.

Summarizing, the following aspects currently pose the central challenges regarding emission calculation in the PI:

- ex-ante calculation of emissions in an ad-hoc network as basis for identification of overall lowest emission transport choice,
- optimization of transport networks which require the steering of usage of the network by its provider, and
- linking information of a shipment to information on the transport device it was carried with on every leg of its journey.

These are important aspects though for the optimization of the efficiency of freight transport and its emission reduction.

5 Conclusion and outlook   are we there yet?

To reach the agreed climate targets, it is necessary to decouple growth of economy from growth of transport demand by improving freight transports efficiency. PI is expected to support this improved efficiency, thus contributing to the realization of the emission reduction. The precise emission reduction that can and is realized by a change in transport chain concepts and structures has to be measured though. The currently existing transport chain emission calculation standardization efforts provide for a good basis for such a measuring.

Still though, important gaps need to be closed, both related to the PI as well as to the emission calculation standardization. Beyond the list of developments that are targeted for a future version of the GLEC framework, the gaps that we need to address are mainly the following:

- Empty containers need to be included in the emission calculation standard based on an analysis of their routing within the PI;
- Categories of goods suitable for the PI need to be identified, their transport requirements specified, their volume estimated and their transport routing established in order to estimate the potential maximum impact of the PI on the freight transport system’s efficiency;
- The impact of PI on sustainability including environmental, economic and social aspects needs to be established;
- The paradigm shift in economics and business which is needed for a successful introduction of the PI if overall efficiency of transport is to be maximized needs to be discussed and considered;

2020, the targeted and needed point in time for Greenhouse gas emission peak, is in three years. It is important to improve the efficiency of freight transport quickly, without such an efficiency improvement resulting in more transport capacity offered. Measuring the effect of changes to transport chain concepts, such as the introduction of the PI, needs to go beyond the evaluation of transport only. Instead, it has to include the entire supply system.

We are not there yet.

Acknowledgements

The paper includes findings from the work carried out within the EU co-funded project Logistics Emission Accounting and Reduction Network LEARN (H2020) as well as on work carried out within the EU co-funded project Carbon Footprint of Freight Transport COFRET (FP7).

References

ALICE (2017): *Physical Internet Roadmap*; available on ALICE's own website on: http://www.etp-logistics.eu;

Batty, Michael, et.al. (2008): *The Size, Scale and Shape of Cities*; Science 319, 369 (2008); DOI 10.1126/science.1151419

Duong Philippe, Savy Michel (2008): *Prospective Fret 2030*; Ministère de l'écologie, de l'énergie, du développement durable et de l'aménagement du territoire, France

Ehrler, Verena Charlotte (2011): *Taking Off – Does Electronic Documentation Make Air Cargo Fly High Again*; München: Huss 2011

Ehrler V., van Engel, A., Davydenko, I., Diekman, D., Kiel, J., Lewis, A., Seidel, S. (2016): *Global Standardisation of the Calculation of CO2 Emissions Along Transport Chains—Gaps, Approaches, Perspectives of the Global Alignment Process*. In: Clausen U., Friedrich H., Thaller C., Geiger C. (eds) Commercial Transport. Lecture Notes in Logistics. Cham: Springer

EU (2014): *European Climate and Energy Framework*; on: https://ec.europa.eu/clima/policies/strategies/2020_en; last viewed 28.04.2017

GLEC (2017): *What is GLEC?;* on http://www.smartfreightcentre.org/glec/what-is-glec, last viewed on 28.04.2017

IWA 16:2015: *International harmonized method(s) for a coherent quantification of CO2e emissions of freight transport*; ISO

McKinnon, Alan (2010): *CO2 Emissions from Freight Transport: An Analysis of UK Data*; Logistics Research Centre, Heriot-Watt University, Edinburgh

Montreuil, Benoit (2011): Toward a Physical Internet: meeting the global logistics sustainability grand challenge; Logistics Research, Vol. 3, p. 71-87, DOI 10.1007/s12159-011-0045-x

Montreuil, Benoit; Meller, Russell D.; Ballot, Eric (2012a): Physical Internet Foundations; Document de Travail 2012-2015 ; version originale: ISBN – 978-2-89524-380-9, série électronique mise à jour : 10-2012, Faculté des sciences de l'administration, Université Laval, Québec

Montreuil, Benoit; Rougès, Jean-Francois; Cimon, Yan; Poulin, Diane (2012b) : *The Physical Internet and Business Model Innovation*. Technology Innovation Management Review; June 2012: 32-37

Kiel, Jan; Auvinen, Heidi; Bohne, Simon; Davydenko, Igor; Diekmann, Daniel; Krietsch, Florian(2014): *Gap analysis – COFRET Deliverable 3.2*; Carbon Footprint of Freight Transport COFRET project; EU FP7

Shell, DLR (2016): Shell Commercial Vehicle Study, Shell Nutzfahrzeug-Studie – Diesel oder Alternative Antriebe – Womit fahren wir morgen, Fakten Trends und Perspektiven bis 2040; Shell Deutschland Oil GmbH, Hamburg

Smart Freight Center (2016): GLEC Framework for Logistics Emissions Methodologies, Version 1.0. Available from www.smartfreightcentre.org.

UNEP (2016): The Emission Gap Report 2016; United Nations Environment Programme (UNEP), November 2016; ISBN: 978-92-807-3617-5

WRI (2017): Understanding IPCC reports; World Ressource Institute, on www.wri.org; last viewed 28.04.2017