

Can Innovations in the Supply Chain Lead to Reduction of GHG Emissions from Food Products? A Framework

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Abstract

Innovations among actors in the supply chain of food, enabled by emerging advanced technologies, are resulting in new concepts for planning and control in the field of Supply Chain Management. The project *Smart Vareflyt* aims at creating more efficient supply chains with respect to both logistics and environmental parameters through increased information exchange and a redesign of the models for planning and controlling product flows. In order to estimate these effects, and in the future; register them, a measurement framework has been developed. The contribution to climate gas emissions are one of several indicators. The research fields Supply Chain Management and Life Cycle Assessment have been coupled and have contributed to relating logistics indicators and transport efficiency to the relative importance of embodied GHG emissions both of the products that reach the consumers, and the embodied emissions of product loss.

Keywords: Supply chain management, Food waste reduction, Green house gases

Introduction

Stating the importance of focusing on combating climate change through reducing emissions of green house gasses (GHG) seems unnecessary today. Politicians, scientists and the business sector all appear to agree upon the target of emitting less, although not always on the exact size of the target or how the target is to be met. When environmental problems related to logistics in general, and GHG emissions in particular have been discussed many have called for cleaner engines or alternative fuels, i.e. technical solutions (Rodrigue et al. 2001). There are, however, good reasons for assuming that the potential of GHG emission reductions from technical development alone will be far less than needed. Thus, to achieve larger reductions, technical and organisational measures must be

simultaneously developed. If, in addition, such measures are cost efficient, the likelihood of implementation increases.

Hence, extending the focus from transport to supply chain management is needed and perhaps more so when what is being transported is perishable, such as food. It is increasingly recognised that not only the direct burning of fossil fuels but also the consumption of goods and services give rise to GHG emissions - referred to as indirect or "embodied" emissions (Minx et al. 2007). This paper is based on the view that the products within a vehicle usually carry larger embodied GHGs than the amount of GHG related to the transport itself. Thus, avoiding product loss and ensuring that products reach the end customer can be highly important to abate GHG emissions.

The Norwegian research project *Smart Vareflyt* (Smart Flow of Goods) aims at facilitating more efficient supply chain operations with respect to logistics and environmental parameters in supply chains in the Norwegian grocery industry. Efficiency gains are proposed to come as a result of combining demand-driven supply chain control and collaboration models enabled by the sharing of real-time information and the application of RFID (radio frequency identification) technology for data capture. The three year project (2006 - 2009) is carried out in collaboration among four Norwegian research institutes (SINTEF Technology and Society, SINTEF ICT, RFID Innovation Centre and Ostfold Research) and commercial actors representing the food supply chain from fresh food and packaging manufacturers to wholesalers and retailers.

What the *Smart Vareflyt* project aims at is, in other words, to introduce a systems innovation where the technical elements of RFID are combined with increased information exchange and a redesign of the models for planning and controlling product flows from manufacturer, via wholesaler to retailer. The RFID technology in itself cannot reduce GHG emissions but the use of information from the RFID technology may facilitate new distribution systems that enable a reduction of such emissions. Thus, this paper aims to demonstrate how systems innovation related to supply chain management may lead to GHG emissions reductions. It describes how climate gas emission reductions are expected to be achieved and further proposes a framework for estimating and measuring GHG emissions and associated logistics effects. A product life cycle approach is applied on both elements.

The paper has five main sections; *background, measuring effects in the food supply chain, working method, measurement framework* and *discussion*, each presenting and combining two parallel project topics

- Supply chain management; with focus on supply chain planning and control
- GHG emissions of food products from a Life Cycle approach

Finally, in the conclusion some reflections are presented regarding to what extent the combination of these two perspectives is a path to pursue for actors in the food supply chain.

Background

Supply Chain Management

The overall objective of actors in a supply chain is to provide markets with goods while maximising profit. A product's path from raw material to end consumption involves many actors, and traditionally these aim at maximizing their own profit (Vigtil 2008). Over the last decades there has been growing awareness of opportunities for further cost reductions by cross company optimisation (ibid).

Supply chain management involves long term planning of facilities and resources as well as short term planning of production and transport activities (Vigtil 2008). The project *Smart Vareflyt* concentrates on the short term activities, namely supply chain planning and control - the act of facilitating an efficient and effective use of resources and assets, while producing and delivering products according to market demand and the customers' requirements (Dreyer et al. 2008). The aim of such supply chain planning and control is to decide what and how much to produce and deliver when and where (Dreyer et al. 2008). The concept does not only deal with how products or material flow; just as crucial is the information flow throughout the supply chain (ibid).

Traditional control in a manufacturing network has been based on push and forecasting principles (Bjartnes et al. 2008), meaning that a manufacturer plans and executes its manufacturing processes based on past sales. Similarly wholesalers and retailers generate their orders backwards in the chain based on forecasts. This has to a large extent been the situation in the Norwegian food sector; actors base their operations on historic, and in many cases outdated, information – thus increasing the time between events and corrective actions (Dreyer et al. 2008).

In order to meet the challenges facing today's complex supply chains, new concepts for supply chain planning and control are emerging. Typical characteristics of such concepts are (Bjartnes et al. 2008):

- Demand-driven control throughout supply chains, basing operations on pull rather than push principles
- Integrated and automated operations
- The use of unified supply chain control models
- Intelligent and advanced information processing, data mining, visualisation and decision-support
- Information sharing and transparent information flow

The two latter points can be seen as prerequisites for the realisation of the three first and could be strengthened if demand information is to be shared in the supply chain more or less in real-time. Significant enablers for this will be technology such as radio frequency identification (RFID), sensor technology and Electronic Product Code Information System (EPCIS) which will allow the access to real-time and standardised information more frequently than existing technology. RFID-tags can be read from a distance, which considerably increases the number of data collection points throughout the supply chain compared with today's barcode-system. Combining RFID-technology with sensor

technology, such as temperature sensors, will further enhance the intelligence and potential of such data-capturing technologies, and will allow the development of intelligent and automated planning and control concepts (Bjartnes et al. 2008). However, information such as point-of-sale data (POS) and inventory level data can be made available today without the use of RFID, so the implementation of RFID-tags is not a prerequisite for implementing demand-driven control concepts, but rather a valuable addition.

Life Cycle Approach

A life cycle approach to considering environmental impacts from a product or service implies taking cradle-to-grave implications of the related activities into account. This approach can be implemented qualitatively, as *life cycle thinking* (Baumann and Tillmann 2004), or as quantified Life Cycle Assessment (LCA) according to the standards ISO 14040 (2006) and ISO 14044 (2006). In *Smart Vareflyt*, life cycle thinking constitutes an underlying basis, while the results from LCAs on fresh food products are used as references when weighting and developing effect indicators. A relevant concept of the LCA methodology is the importance of defining a *Functional Unit*, i.e. a reference unit that describes the *performance* of the product or system (ISO 14044 2006) and to which the calculations are made - this as opposed to defining the reference unit as merely the physical constitution.

In recent years, the climate gas focus has led to various methods and labels assessing the GHG emissions of products. The British Standards Institute has introduced a specification of assessment of GHG of goods and services that is based on LCA and ISO 14040 and ISO 14044 standards (PAS 2050 2008). The PAS methodology describes how to manage the incremental addition of GHG emissions at different stages of the supply chain until the product is provided to the consumer. When a product is transferred from one actor to another in the supply chain, the GHG emission assessment “shall include all emissions that have occurred up to, and including, the point where the input arrives at a new organization” (PAS 2050 2008:12), in other words it should include all upstream emissions.

Measuring Effects in the Food Supply Chain

Fresh Food and Supply Chain Management Challenges

Since fresh food is highly perishable, efficient production planning and supply chain management is crucial. As mentioned, in the Norwegian grocery sector today production planning and supply chain control is often performed on the basis of historic demand and event information such as past sales and forecasts. This leads to a time gap between events and corrective actions (Dreyer et al. 2008). Thus, there is a substantial improvement potential with respect to responsiveness, inventory turnover, and lead times. In addition, inefficient information exchange and lack of visibility in the supply chain may lead to poor forecast quality and additional loops for adjustment and operational control (Dreyer et al. 2008). Further, actors are often reluctant to share information with other actors in the supply chain for fear it might disrupt the supplier-customer power balance. These issues lead to less efficient supply chains where manufacturing is not based on demand, total costs are higher than necessary and delivery service for customers poorer (ibid).

Due to Norway's relatively scattered population, there is a substantial amount of mixed pallets from the point of warehouses/distribution terminals. The content of different pallets on the same truck might have different requirements with regards to temperature or other conditions during its journey through the supply chain. These factors add complexity both when it comes to information control and physical handling and can also affect the extent of utilisation of the space in the vehicles as well as the food quality (Nereng and Vold 2008).

In order to keep the quality of fresh food for as long as possible, maintaining optimal physical distribution conditions are paramount. Physical distribution conditions include temperature, lighting, atmosphere and protection against mechanical damage (Nereng and Vold 2008). The lack of fulfilment of any of these condition requirements leads to shorter shelf life at best or immediate scrapping at worst. An investigation of temperature and preservation of fresh fish has demonstrated the importance of maintaining correct and constant temperature for prolonging shelf life (Sivertsvik 2008). The relation of the two parameters is not linear; the actual expiry period shortens dramatically with higher temperatures. However, surpassing recommended temperatures happen frequently in the supply chain. The transaction handlings have been found to be most troublesome. Temperature tracking studies of a food product has demonstrated great variation of temperature, and in some cases, substantial periods surpassing the maximum permitted temperature (Hanssen et al. 2005). Without tracking location and temperature it is difficult in hindsight to identify where exactly the temperature increases took place. And further it is difficult for the food producer to improve these conditions when responsibility is not placed (Nereng and Vold 2008). The combination of these two studies (Sivertsvik 2008 and Hanssen et al. 2005) shows that temperature monitoring and swift correction when the temperature rises is essential, a fact which represents an important challenge in the food supply chain.

The challenge that many of the mentioned topics lead up to is the food waste generated along the supply chain and the associated environmental problems. The amount of edible food waste is substantial, i.e. food that was edible before it became waste, as opposed to production waste such as bones and fat (Ventour, 2008, Hanssen and Olsen, 2008). A study performed in Norway found that the more downstream in the supply chain, the more waste arises - with the largest amount generated at the end consumer, and a considerable amount at the retailers' (Hanssen and Olsen, 2008). A British study shows that 61% of household food waste is avoidable and could have been eaten if it had been managed better (Ventour, 2008). Even though the cause-effect chains are complex, and further mapping of these are required, it is reasonable to claim that a substantial share of this waste can be attributed to long lead times and the resulting short shelf life.

GHG Emissions Findings in LCA Studies of Food Products

Life cycle assessment of fresh food products are used as guidance for the measurement framework in the *Smart Vareflyt* project. Roy et al. (2009) and Schau and Fet (2008) both present extensive literature reviews on LCA studies on agricultural and industrial food products. The majority of the studies assessed the phases from primary manufacture to

retailer. The reviewed literature indicates that agricultural production, primary production, by far has the largest environmental impact, among them GHG emissions (Roy et al. 2009, Schau and Fet 2008). The relative sizes between this phase compared to those of processing, transport, packaging manufacture and retailing do vary according to the type of food, as also shown in the exemplifying figures below from Ingvarsson and Ahlmén (2002). Five of the reviewed studies included the consumption and waste handling phases and the research indicated, in general, that the direct environmental impact of the consumption and waste handling phases were of minor importance relative to the manufacturing phase (Schau and Fet (2008). Food LCAs performed by Ostfold Research also support these findings (e.g. Hanssen et al. 1999).

The following figures are examples of such LCA findings from a Swedish publication (Ingvarsson and Ahlmén 2002), the *blue* columns showing GHG emissions from beef and salad, including the consumer stage. Both are relevant products for the participating companies in *Smart Vareflyt*. The beef represents a relatively higher primary production emission compared to the salad – and the other phases then become less important, but for both it is the primary production that undisputedly contributes the most. Since salad is a voluminous product compared to its weight and hence a packaging intensive product, the packaging manufacturing and transport from retailer to consumer make up a relatively large part of the carbon footprint compared to that of beef (Ingvarsson and Ahlmén 2002).

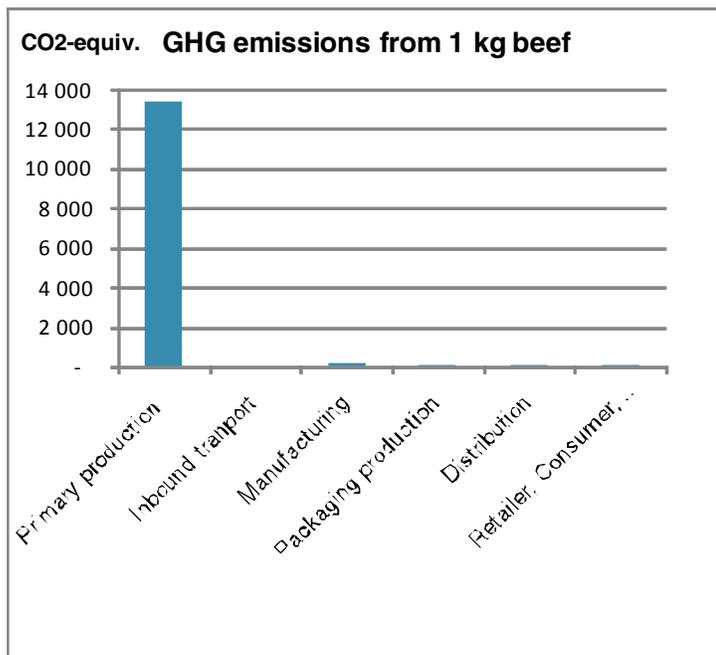


Figure 1. Embodied GHG emissions from 1 kg beef, from primary production to consumer stage. Ingvarsson and Ahlmén (2002), translated.

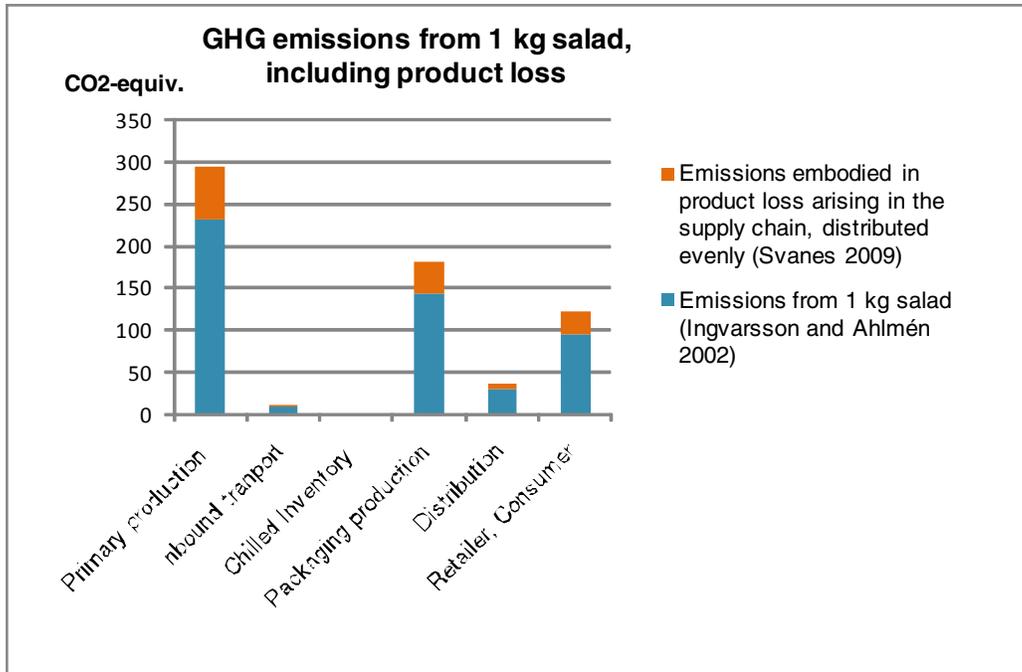


Figure 2. Embodied GHG emissions from 1 kg salad, from primary production to consumer stage. Including percentage of product loss (orange column). Blue column; Ingvarsson and Ahlmén (2002), translated. Orange column: A separate study on salad includes the embodied emissions from product loss arising in the supply chain (Svanes 2009). The percentage increment in emission is here included for illustration of the importance of accounting product loss and distributed evenly on the phases, the even distribution being a simplification of reality.

Both figures and the literature highlight the importance of the PAS methodology principle of the incremental addition of embodied GHG emissions, or as Schau and Fet (2008) articulates this:

“the minimization of product loss in the consumption phase was important because all the environmental impact in the life cycle is related to the product which is actually consumed” (ibid: 257)

In addition to including embodied emissions stemming from upstream activities Ostfold Research adds another feature in their so called ‘*Environmental Value Chain Assessment*’ method (Vold et al. 2005; 2009): The environmental effects from products that actually reach the consumer should be calculated with respect to product loss generated in the whole distribution chain, and included in the measured functional unit (ibid). The reason for this is that the function of food is to nurture people. In other words – food that has not reached the consumer has not fulfilled its function, but should be accounted for (Nereng and Vold 2008). The method suggests functional unit as *the amount of product that is necessary to manufacture and pack 1.000 kg product useable for the final consumer* (Vold et al. 2009).

Included in Figure 2 of the salad carbon footprint, is a percentage increment of embodied emission from product waste found in another salad LCA study (Svanes 2009). These orange parts of the columns show the significance of including product loss in the carbon footprint accounting.

Measurement within Environmental Supply Chain Management and Green Logistics

The concept of Environmental Supply Chain Management is presented along with other inter-organisational management aspects such as industrial ecology in a literature review by Seuring (2004). Common to the presented definitions is the screening and criteria setting of suppliers' environmental performance, in other words environmental considerations during product development and purchasing. Sometimes this is also referred to as "greening the supply chain". Other definitions are broader, including also the production, distribution, use, reuse and disposal of a firm's goods and services, but presented within a purchasing context (Seuring 2004) and without detailing for example the relative importance of distribution compared to the other activities. Although taking life cycle considerations into account, the literature claiming to pertain within the Environmental Supply Chain Management concept seem to be focused on long term planning, rather than short term operational planning and control that is the focus of the *Smart Vareflyt* project. However, the methods developed by Fet et al. (2001), Mason et al. (2008) and the SCOR model (Blanchard 2008) could be defined as belonging within that frame.

The Supply Chain Operations Reference (SCOR) Model is a process reference model for supply chain management that is developed and endorsed by the international non-profit organisation Supply-Chain Council. The SCOR Model is used to describe, measure, evaluate and benchmark supply chains in support of strategic planning and continuous improvement (Blanchard 2008). The most recent version includes environmental parameters (Blanchard 2008) and merges environmental management with supply chain management in order to integrate environmental considerations into the entire supply chain process (Paquette 2005). The open information about this proprietary set of indicators is limited; however some metrics are mentioned by Blanchard (2008): carbon and environmental footprint, emissions cost per unit, and waste produced as a percent of product produced.

Fet et al. (2001) developed a set of eco efficiency indicators for supply chain functions such as purchasers, distribution, supply chain management as well as retail chain management. The purchasing indicators evolve around eco labels, and do not include embodied GHG. It was probably premature in the year of publication. Transport indicators are similar to those that will be mentioned below; warehouse and retailer indicators are concentrated on energy consumption and economisation as well as waste generation. When it comes to the latter, the loss of edible food is not distinguished from e.g. packaging waste, and further; it is presented in mass value per time (ibid), hence not indicating the relative importance of the waste types.

Mason et al. (2008) propose the method "Sustainable Value Stream Mapping", linking lean SCM with climate gas accounting in operational activities. In the presentation of the mapping method, food products are used as cases. The method includes GHG emissions caused by energy and fuel consumption in manufacturing, warehousing and retailers, even implementing a scenario based consumer stage (ibid). The Lean concept focuses on time optimisation and value adding activities, Mason et al. couples this with a target of a total GHG gas minimisation and relates it all to the value and mass or units of the product (ibid).

The latter seem to be rather unique and resonate to some extent to the *functional unit* of LCA.

When considering only the distribution steps, these are covered within the concept of Green Logistics (Sanchez-Rodrigues 2006, McKinnon 1999). The tendency within green logistics seem to be transport optimisation through energy and fuel minimisation, often highlighting the trade-offs with cutting inventory level, improving warehouse productivity and customer service, for example through Just-In-Time delivery (McKinnon 1999). Within the fast moving consumer goods sector – including food, these quick-response principles are manifested as shortening order lead times, increasing delivery frequency and declining order sizes which all tend to lead to reduced transport efficiency, i.e. higher frequency of delivery, lower pallet load sizes (ibid).

Other transport indicators are vehicle fill, empty running or two-way load factor, time utilisation, deviations from schedule and fuel efficiency (McKinnon 1999, Mason et al. 2008). Consideration of the product that is transported is hence included indirectly through vehicle fill, or fill rate, as one of several indicators demonstrating transport efficiency (Sanchez-Rodrigues 2006), but again; not comparing the environmental consequences of transport to that of product loss.

Summary: The Gap

In the above review there are several elements that have influenced the proposed measurement framework. From LCA studies and the PAS 2050 principles: The importance of seeing all GHG emission indicators in the supply chain in relation to the embodied GHG emissions arising in the primary production, and the importance of including the embodied emissions generated in vain, due to product loss. From Environmental SCM and Green Logistics several inputs on the indicator level have been pursued.

However, a gap between the two fields has been discovered: The lack of linking the indicators to the magnitudes of the two mentioned embodied GHG emissions: Primary production and product loss. The suggested framework will intend to mend this gap. Embodied GHG emissions arising in the primary production of food products should be included in the *Smart Vareflyt* project. This could be done through one of the following:

- Indicator weighting, i.e. downplaying the importance of transport fuel and energy efficiency compared to the importance of transporting the food to the consumer as fresh as possible
- Develop indicators including a fixed embodied GHG emission factor according to product or product class

Further, indicators should include the amount of product loss or waste itself, and the associated embodied GHG emissions.

Working method

Systems Innovations

The innovations in supply chain management in the *Smart Vareflyt* project were developed using the *control model methodology* (Alfnes, 2005). A control model is a description of the material and information flows in a supply chain with the purpose of improvement. The model highlights quantities and frequencies of material flows between the various supply chain actors, as well as processes, transportation modes, and the detailed principles and rules used to control material flows. Similarly, information flows between actors/processes are described in terms of content, frequency, means, etc. Control models consist of both text and visualisations such as graphs, pictures, diagrams, etc.

In the project, control models were used to map, analyse and improve the involved supply chains – thus creating innovations related to the way materials and information were controlled from packaging supplier, through manufacturer to wholesaler and retailer. Initially, an AS IS control model describing the starting point for each supply chain was developed. The main purpose of this AS IS model was to make all involved actors aware of and agree on the structures and policies that were currently used to control the supply chain. The required information was collected through workshops, meetings, interviews, observation, written documentation, databases, etc. The supply chain actors were responsible for providing the information requested by researchers, who then systematised the information into an illustrated, structured AS IS control model document that all the involved participants agreed on. This was a vital first step in the systematic improvement work. An important benefit of this process was the initiation of collaborative improvement efforts among supply chain actors. Already during development of the AS IS control model, numerous improvement opportunities were identified and discussed.

After an analysis of the AS IS control model and a mapping of improvement opportunities, a TO BE control model was developed introducing new aspects such as RFID and collaboration through real-time information sharing. The TO BE model specified how the supply chain should be controlled in the future, taking into account the introduced innovative solutions. The future model was developed in a creative collaborative process consisting of workshops, meetings, discussions, etc. among key supply chain actors and the involved researchers. The solution development process drew heavily upon existing theoretical knowledge and concepts, best practice principles, researchers' experience and decision-makers' detailed knowledge of the supply chain. Finally, a detailed implementation plan for the TO BE control model was developed, mapping out the requirements and prerequisites for successful implementation necessary for achieving increased collaboration and improved operations in the supply chain as a whole.

Indicator development

The approach for developing the framework for measurement and the associated indicators has been inspired by Fet et al. (2001)

- Performing a literature review on expected effects of increased information sharing in the supply chain of perishable goods, RFID-enabled and otherwise. This was supplemented by the results from a workshop with some of the project participants.
- Performing the above summarised literature review on existing frameworks and methodologies in the fields of SCM and quantitative environmental assessments, with perishable goods as a limiting factor
- Developing and describing the framework by combining the above fields

The next step in the project will be to test the framework in industrial cases, using estimations and to some extent real measured data.

Framework for Measuring Effects - or How to Get from Information Sharing to GHG Emissions

Purpose of Measurement Framework

The *purpose* of the proposed framework is to integrate the identification and capture of both environmental and logistic effects from introducing real-time information sharing and/or RFID in the food supply chain. The framework fulfils two functions:

1. Before and after measurements: Evaluating both GHG emission and logistics effects from implementation of new supply chain control concept
2. Continuous measurements: Running or frequent measurements to enable monitoring and improvement efforts after implementation of new supply chain control concepts

The first function will support industrial decision-makers in evaluating the cost/benefit of implementing new control concepts. Before implementation *estimations* will be made with regards to expected effects, while following the implementation real data will be used to document whether the expected effects were achieved. The continuous measurements will be based on actual data in order to capture long term effects. Another important function of the continuous measurement is to act as input for day-to-day decision-making as part of the new demand-driven supply chain control concept. Since the principles are some way ahead of being implemented, the focus of the paper is on estimations, but when relevant, reflections on the measurement usage are presented. A purpose for the framework is further to capture the interrelations between the indicators to the extent possible.

Framework for Measuring or Estimating Effects

As mentioned, as part of the *Smart Vareflyt* project, a literature review on actual and expected effects of implementing real-time information sharing and/or RFID technology in general, and the food supply chain in particular, was conducted.

In Vigtil (2008) an extensive literature review on expected and experienced benefits from a specific concept of real time information sharing is presented. Relevant findings from this review have been extracted and presented, the effects that are actual experiences are indicated by "(Vigtil 2008, experienced)". Since RFID is an emerging technology, not many

references were found on effects demonstrated in actual case studies. However, mentions of expected effects were plentiful. Often the sources were interest organisations or RFID suppliers; hence there is the risk of exaggeration of positive consequences (Nereng et al. 2009).

Building on this literature, the supply chain management perspective and the use of the LCA approach described above, expected effects were organised in the following three areas, each described in more detail below:

1. Supply chain efficiency leading to resource efficiency
2. Transport efficiency
3. Logistics efficiency

The presentation of logistics effects is limited to those that imply a indirect change on climate gas emission, but that are not already mentioned; the categories do overlap. The project as a whole covers a larger variation of logistics effects and related indicators.

Supply chain efficiency leading to resource efficiency:

- reduction of energy and GHG emissions in general (Kowl 2008)
- reduction of embodied GHG due to less product loss (Edwards 2008, Kowl 2008)
- less product loss due to reduced inventory level (Vigtil 2008)
- less product loss due to more accurate forecasts (Swedberg 2007)
- less product loss due to error reductions (Swedberg 2007)
- less product loss due to temperature and humidity monitoring (Edwards 2008)
- less product loss through precise take back due to tracing (Edwards 2008)
- the reuse of packaging resources, particularly Returnable Transport Items (AIM Global 2008)

The points being made about product loss reduction related to reduced inventory level and more accurate forecasts are persuaded further in this paper. All other product loss effects will be included in the framework. The effect regarding more efficient use of reusable packaging, so called Returnable Transport Items, is also highly relevant to the *Smart Vareflyt* project as three of the participating companies are producing and/or administrating returnable crates and pallets that are to be RFID tagged. However, this paper will not go into detail about this.

Transport efficiency:

- transport reduction due to supply chain visibility (AIM Global 2008, Swedberg 2007)
- emission reduction through monitoring of vehicle park (AIM Global 2008, Edwards 2008)
- less idle running in ports and discharging plants due to transport planning (Edwards 2008)
- efficiency through better filling degree of vehicles (Waller et al. 1999)
- less shopping trips performed by end consumer due to less stock-out (Kowl 2008, Swedberg 2007)

- emission *rising* due to just-in-time logistics comprising of smaller quantities of goods delivered more frequently in smaller vehicles (Mason et al. 2008)

The last reference about a negative effect is not directly related to implementation of real time information sharing, but it is a plausible negative effect to consider in this context. Further, it *might* be balanced by the visibility enabling better planning of just-in-time delivery. Nevertheless, it is important to include transport efficiency indicator in order to capture possible trade-offs.

Less idle running is not met by the control concepts that the participating companies in *Smart Vareflyt* are developing, and is hence omitted from the framework. End consumers' reduction of shopping trips is considered out of the scope of this project and paper, and would be extremely cumbersome to measure, if at all possible (Nereng et al. 2009).

When taking a closer look at the relations between the cause-effect elements mentioned, especially regarding resource efficiency, it becomes evident that many of them are indirect effects linked to general cause concepts. The links that explain how the effect arises are missing. The project group found that it is the typical logistics effects that make up these links (Nereng et al. 2009).

Logistics efficiency

Effects that are not already mentioned (the categories do overlap), but that are likely to impact directly or indirectly on GHG-emissions

- Improved forecasting inventory (Vigtil 2008, experienced)
- reduced inventory level due to less need for safety inventory (Vigtil 2008,experienced)
- improved inventory turns/ throughput time (Vigtil 2008, experienced)
- reduced delivery lead times, (Vigtil 2008, experienced, Holmström 1998)
- reduced non-value added time due to supply chain visibility (Sanchez-Rodrigues 2006)
- Lower obsolescence (Vigtil 2008)

Proposed indicators and estimation guideline: Time and product loss

The above effects, in addition to more logistics effects, were organised by the project R&D participants into hypotheses articulated in cause-effect chains and a myriad of possible indicators as well as links between them emerged. One possible cause-effect chain illustrating steps from Information sharing and RFID introduction towards Green House Gas Emission reduction is shown in the figure below. Suggested effects that can be reformulated into indicators are singled out by a thick frame. All the cause-effect chains that were worked out are ending up in three coarse *end indicators*: Revenue change, Cost change and GHG emission change. The indicators further to the left are more specific. In the following this will be referred to *indicators to the left or right*.

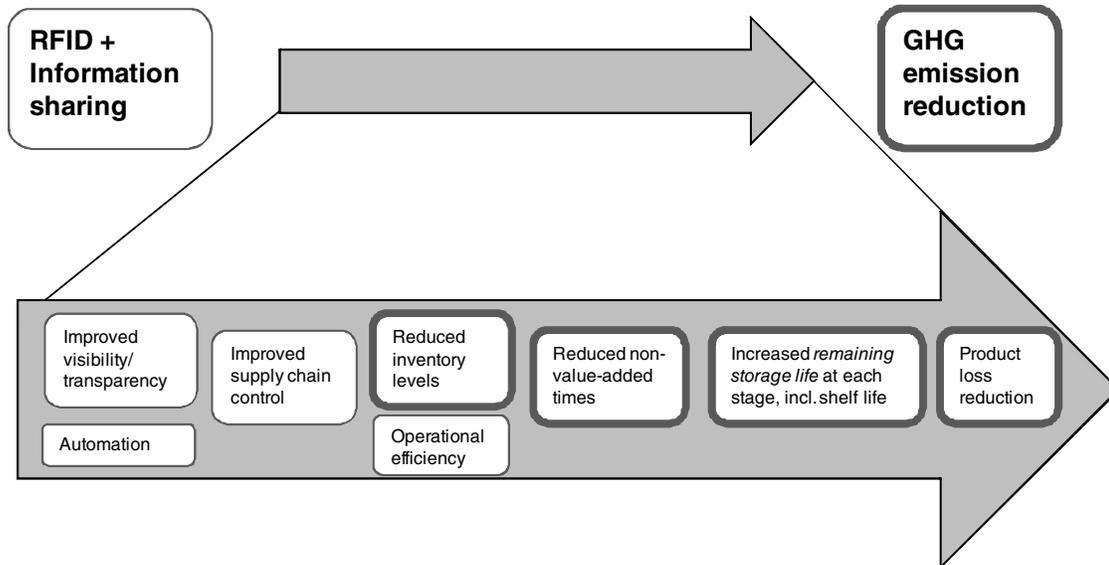


Figure 3. A cause-effect hypothesis chain, illustrating steps from information sharing and RFID introduction towards green house gas emission reduction.

As mentioned in the section about the framework *purpose*, it should be applicable for both measuring and estimating effects. Due to the topic of this paper, and the fact that the implementation of new control concepts are expected ahead in time, the focus is now on *measuring* the situation before implementation, and *estimating* the effects of new concepts. Measuring effects after the implementation, both for control of project fulfilment, as well as a monitoring objective, will be touched upon.

It seems clear that in an estimation scenario, one would have to start with indicators to the left and make plausible estimations for those indicators' influence on the effects further to the right – such as *Product loss*. Then the product loss effect estimations would have to be aggregated and finally, through emission factors be recalculated into what this represents in embodied GHG emissions. For simplification and illustration, the focus of the paper from now on will be on time effects leading to product loss effects.

Since it is evident that both terminology and definitions of words vary not only in different research fields but also within same fields, it was necessary to clarify the definitions in this project. This was done with the help of a figure that also was used as a tool to analyse the time indicators that have come into question. The figure further pinpoints the similarities and slight differences between logistics indicators and the time parameters influencing product expiry, as well as suggesting what indicators could be used for estimations and for measuring performance.

The figure below is an attempt at a generic depiction of the supply chain. Depending on the type of product, it will include one more stage: A central storage owned by the producing company. Other times the wholesaler in the figure is replaced by a central storage. Note that the *Distribution time* here includes the retailer storage.

Lead time in the Smart Varellyt project describes time from order/need to the product being received by the ordering actor. The dashed line illustrate that where this measurement starts depends on the different inventory levels at the given time of need/order.

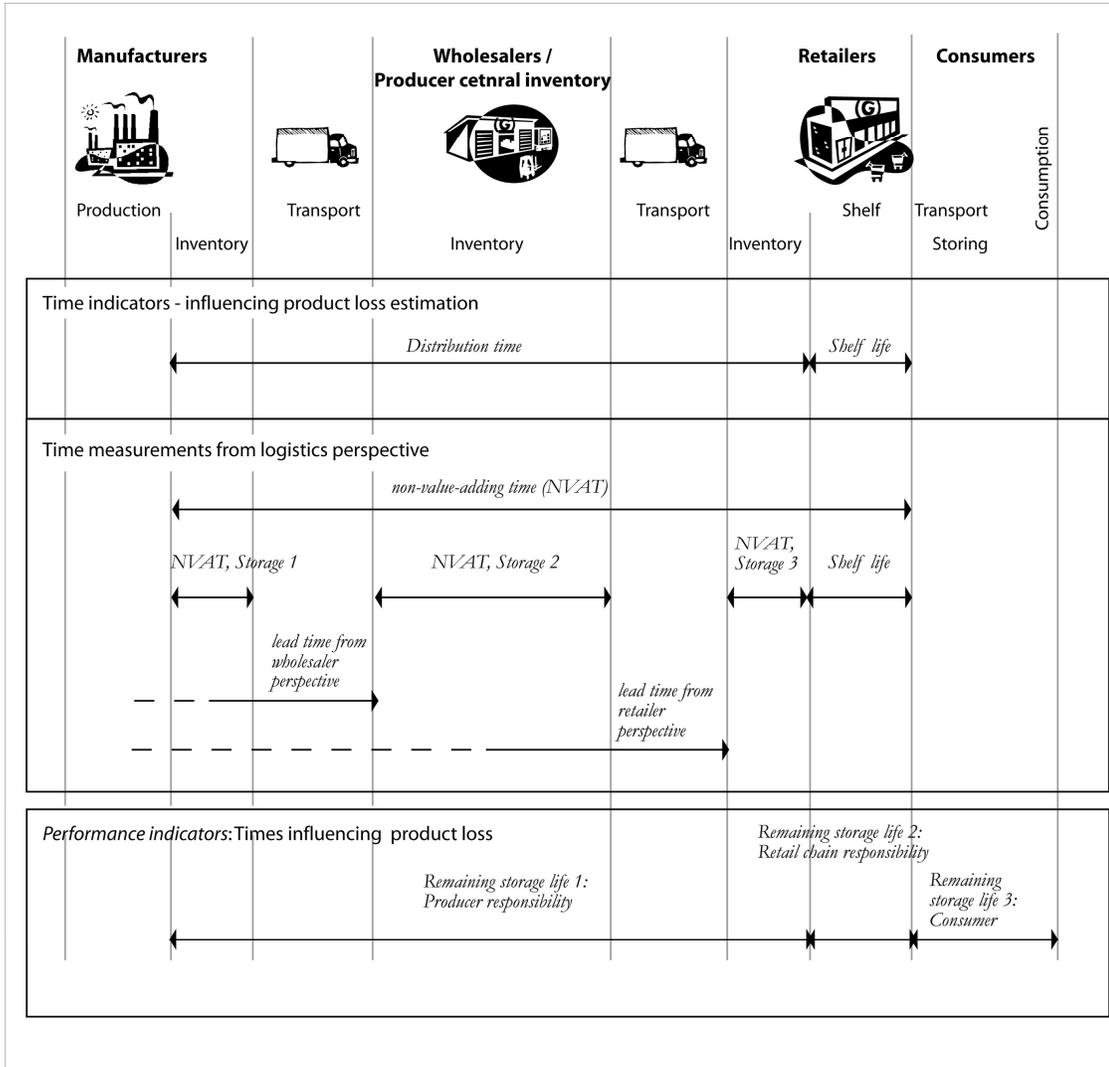


Figure 4. Time parameters influencing product expiry: Definitions and tool for analysis

The following steps should be applied at the supply chain of a product or product class sharing expiry time characteristics. It could be used on one supply chain string individually, or several strings aggregated.

For the particular chain of time to product loss indicators, the following procedure will be recommended:

- 1) *Analyse the situation now, basis description:*
 Register and analyse the present situation for the product (class) in question over a fixed amount of time, aggregated in the supply chain as well as in some of the stages

- Average distribution time
- Average Non Value Adding Time
- Through this: Average shelf time
- Average storage times at each step
- Product loss

Ideally –product loss should be registered due to probable cause in the data collection period, If not possible, a probability exercise will have to be performed during step 2. Due to former research experience, it is predicted that data registration will have to be initiated as part of the project since the supply chain actors do not normally register all the relevant parameters, for example shelf life.

2) *Present Cause-Effect probability*

Analyse qualitatively: To what extent does the present, total average *Distribution time* influence *what amount* of the present product loss level? What is the improvement potential? It is assumed that the food producing company and the other supply actors themselves are the best to perform this exercise due to experience, but experts on food preservation could also be involved.

3) *Time reduction estimation*

Analyse the potential to reduce the *Distribution time* after implementing the new planning and control concept in question. This must be done seeing the supply chain as a whole and most likely focus on the storage times, seeing as those are the ones expected to be influenced the most by the new control concepts.

4) *Product loss estimation*

Based on the relations defined in 2), estimate a percentage of product loss influence that the time parameters can have on product loss

5) *Comparing and calculating corresponding GHG emissions*

The estimated product loss amount should be compared to that of point 2) and calculated into GHG emissions, ideally this should be compared to the amount of the same product that was sold during the same period of time as data were collected during step 1). This due to the findings presented in the chapter *measuring effects in the food supply chain*. It will then be possible to compare to transport indicators, for example.

Note that for this estimation exercise, the “remaining storage life” indicators are not included. This is an important guidance and performance indicator in the industry today, as already mentioned. The project group recommends that this indicator continues to be used as performance indicator. There exist also some expectations that new planning and control systems might enable a rearrangement of the “remaining time” obligations, at the end leaving more time for the consumer, as indicated in the lower part of the figure.

It should be pointed out that depending on product being analysed, characteristics of actors involved and proposed new control system, the chosen indicators and how to register the needed underlying data will probably need to be adjusted.

Proposed indicators: Transport efficiency

For transport efficiency, the same exercise has been done, separately for the transport legs as well as aggregated.

Two indicators have been identified:

- Filling degrees on pallets
- Transport work as tonne-kilometres based partially on the pallet filling degree

The indicators should be measured and estimated for 1000 kg of the product in question that reaches the retailer, and through fuel emission factors the findings should be translated into GHG emissions. In that way it will be possible to compare to GHG emission reduction due to product loss improvements, and see the relative importance between the indicators.

Discussion

This paper rests on the idea that GHG emission reductions may be obtained by changing the way supply chains are operated and controlled enabled by increased information sharing and the application of RFID technology. Some indicators for measuring effects or supporting decision-making have been presented. Examples of how the indicators may contribute to GHG emissions reductions has been outlined, particularly related to product loss and the contribution of embodied GHGs in food waste. There are, however, a number of additional aspects that need to be considered before we can start to celebrate the reduced GHG emissions from implementing new supply chain control models and introducing RFID.

Obviously, the proposed framework does not cover all relevant aspects in a supply chain. The most obvious shortcoming is the exclusion of the final customer. Reducing the amount of waste throughout the supply chain to the retailer has no effect if the amount of waste produced at the final customers increases just as much. In fact, the latter alternative may be worse due to the better waste handling systems available throughout the supply chain than that at the end consumers. However, the possibility of leaving more remaining storage life for the consumer is expected to mitigate that effect to some extent. To include this in a measurement framework could become possible after more research on consumer behaviour is undertaken. This might be underway in Norway, since food wastage reduction is currently an issue on the political agenda of the agricultural ministry.

Further, the proposed framework do not include negative as well as positive effects at the end of life of the food packaging, including the RFID tag itself, such as: The potential for facilitating packaging material recycling, the potential tag material contamination of recycled

packaging material and the WEEE related issues of the tag and heavy metals. However, research is ongoing on these topics. The users of the proposed measurement framework should be made aware of these issues.

Although making sure to include transport efficiency indicators in order to capture possible trade-offs between environmental indicators, the users must be made conscious about the danger of limiting the methodology and not being able to capture *unexpected* effects.

A challenge regarding the framework is the desire that it should work both for an estimation scenario as well as for monitoring purposes. This paper has not dealt with this in detail, but it seems clear that some adjustments will have to be done according to use of the framework and the intentions of the new control concepts it is supposed to measure. The coherence between coarse and more specific indicators can so far only be described as qualitative probabilities resting on literature and on some extent on actual experiences (Vigtil 2008).

A practical and methodological challenge is data availability and registration routines for the measurements, both for the current situation, but it could also be the situation in the future. The underlying data for documenting effects are not always the same as the data captured by the new technologies. This could to some extent be avoided through implementing effect data needs in the set up of the new systems. For instance, the availability of GHG emission data for different life cycle stages may be limited. The information on which both daily operational decisions and long-term strategic decisions rest, needs to be correct in order to avoid misleading conclusions.

Further, there are practical challenges before new supply chain concepts are implemented and could be evaluated. Increasing information sharing between organisations may be hampered by companies' need for control and established power structures. The will to cooperate may vary among supply chain members and even competition laws can create barriers to increased information sharing. In relation to this, companies along a specific product's supply chain are to a varying degree connected to the product. To one manufacturing company, the product may represent a large share of its turnover, while for another, such as the transporter, the product may only be of minor importance. Such variations may make it difficult to establish the necessary agreement on objectives and the need for improving the supply chain control model. However, as shown in Vigtil (2008), new collaboration models are starting to get implemented.

Technical challenges may also impose difficulties that limit the potential for the implementations of the new control concepts. This is particularly the case when it comes to the new technology of RFID tags. There are still hardware and software challenges to be solved before implementation on a large scale within the food sector is probable.

The importance of all these shortcomings is difficult to evaluate before the implementation of the proposed innovations are to be tested in real life.

A justifiable question is whether or not undertaking these estimations and measurements is necessary at all. Does the redesign of supply chain control models with the aim of achieving

more efficient operations need an environmental justification? One of the aspects of cost reductions is that they may be unevenly distributed along the supply chain. Although the total costs associated with a supply chain are reduced, some companies in the supply chain may even experience higher costs. To appeal to more societal efficiency does not necessarily convince firms experiencing economical losses. Thus, the argument of reduced GHG emissions may be a valuable addition to supporting mechanisms and contracts for distributing cost reductions across the supply chain. Further, proposed measurement framework might create awareness on the importance of viewing environmental effects from a holistic perspective.

Conclusion and Suggestions for Further Research

Although not yet quantified, a probability of the contribution from increased information sharing in the supply chain of food to reducing climate gas emissions have been supported by this paper. Further, it is clear that it is the collaboration among the actors that is the most important factor towards changes.

What remains in the *Smart Vareflyt* project is the testing and adjusting of the proposed estimation activity in some of the case supply chains, then quantifications of product related GHG emission changes may be calculated. Possibly it will also be feasible to aggregate this into figures representing various products distributed through networks of supply chain actors.

For further research, it would be interesting to utilise and evaluate the framework on new and *implemented* planning and control concepts. In the relatively short term, it could be interesting to focus on the information sharing element of the research presented, while downplaying the RFID contribution. This is due to the fact that the implementation without RFID is more feasible in the short term. Having stated that, it should be pointed out that the process of working with issues related to this new, enabling technology seem to have opened up for new forms of collaboration: The actors involved are demonstrating a growing readiness towards increased integration with supply chain partners.

Further research could contribute to a refinement of the proposed framework. As stated in the discussion, these challenges include: The consumer behavior's influence on food waste in general, and the implementation of this in the method framework and equally the end-of-life properties. It is expected that in Norway, more studies will be undertaken when it comes to the reasons and quantities of food waste generated in the supply chain and at the consumer's, ideally gathering information on a detailed level. In other words, a win-win situation could arise when it comes to introducing new considerations on what underlying data are important and relevant to gather in order to increase knowledge on the matter. Further, on an international level, research within the LCA field on food and climate issues is constantly developing. This should be taken into account if developing the framework further.

The gap between the found literature on Sustainable Supply Chain Management, particularly supply chain control, and the perspectives on embodied GHG originating from LCA, has been attempted to mend in this project through focusing on the food itself over transport emissions. This approach should be developed further and to a larger extent be communicated to the research and business fields of Supply Chain Management. The cooperation between the research institutions from SCM and LCA in *Smart Vareflyt*, in combination with the participation from companies, can be seen as one important step in this direction.

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