# Report on the assessment of the environmental impact of Tank Containers compared with other handling methods

Research and White Paper prepared independently for the International Tank Container Organisation using LCP Consulting's Carbon-to-Serve® methodology

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# Executive Summary

The risk of climate change is now recognized and the science is well established. Governments around the world have committed to reductions in $CO_2$ of 60% or more by 2050. Their challenge is 'how to encourage the right practices through fiscal and other incentives?' For industry, consumers and governments alike the key question is 'how to contribute to the reductions needed?'

Broader international agreement on the risks of climate change is evolving from greater clarity on the impact of a failure to act. As a result, emissions trading and control schemes are being put in place which are effectively a tax on 'emissions-inefficient' operations. They are not yet global measures and, as such processes are devised and settle in, there will be significant regional and national variations. However all initiatives are in line with the Kyoto Protocol; Copenhagen in 2009 can be expected to set tougher targets to wider areas of industry.

The message is clear, energy inefficiency and emissions performance will carry penalties in the future that will raise operating costs; relative failure by any business will become a competitive disadvantage.

As a result companies that are concerned about their costs, corporate social responsibility and achieving sustainability will be well advised to understand their 'carbon footprints' and the reduction strategies that are available to them. 'Forewarned is forearmed' is the adage.

In 2008, LCP Consulting developed and applied for the first time a carbon footprinting methodology called Carbon-to-Serve®. It was designed to overcome gaps identified by LCP in carbon emissions assessment tools; these tend to give neither an end-to-end evaluation nor sufficient transparency of the assessment to be able to conduct sensitivity analysis and scenario modelling.

With this in mind, the International Tank Container Organisation: ITCO, commissioned LCP Consulting to evaluate the environmental performance of tank containers compared with their main alternatives of drums and bulk bags. The Board of ITCO considered that the tank container industry's stakeholders (customers, suppliers and operators) would benefit from this evaluation as they all start to formulate and operationalise their carbon reduction strategies.

There were two objectives for this evaluation: first, to support the industry and its stakeholders by providing a reference point on the emissions status of tank containers: second to provide a comparison and sensitivity analysis against alternative handling media.

This report details our evaluation of the environmental performance of the tank container to transport non hazardous materials vs. the use of either steel drums or bulk bags; it uses the Carbon-to-Serve® toolset. The evaluations were based on a representative supply chain between the Shanghai region of China and the Ruhr valley in Europe and, where appropriate, the return journey. The evaluation included the manufacture of the respective container, transportation on empty legs, cleaning and waste disposal. As such the end-to-end nature of the assessment is as complete as it can be. Emissions data on each element of the chain has been taken from British Government published standards (DEFRA) and crossed checked with other EU sources.

The conclusions are based on the basis of grams of $CO_2$ per round trip litre shipped showing the relative attributes of the different handling media for the transportation of non-hazardous liquids:

- Tank Container holding 24,000 litres — 268.9 g/litre
- Bulk bags holding 24,000 litres — 276.9 g/litre
- Drums of 213 litres each with 80 shipped in a container — 502.3 g/litre

An equivalent and more tangible measure is that the carbon creation for the tank container is about the same as driving two economy class cars to Shanghai and back.

The evaluation provided some powerful insights into the carbon intensity of liquids' supply chains; some were unexpected. The key points are summarised as follows:

- The most significant carbon steps in the tank container and bulk bag chains are the loaded ocean legs which account for more than 95% of emissions.
- This applies even though the CO2 / tonne-km for shipping is very much better than for all other modes of freight – weight and distance are the drivers.
- For drums, the emissions generated by the manufacture of the single trip drum are the majority of its difference with the other handling methods but it is also less effective in loading and transportation.
- The manufacture of the bag and its disposal are not significant drivers of emissions.
- The result is surprisingly insensitive to running the return ocean leg empty and the carbon impacts of the local movements, cleaning, repositioning and disposal.
- There is a discrepancy of as much as 40% in the published emissions statistics for international shipping from different sources; if companies are to be held accountable for their chain emissions, this gap needs to be narrowed or made more specific to vessel types. Energy efficient liner companies will have a competitive advantage.

In summary, the tank container appears to be the most energy efficient way of moving intermediate quantities of bulk liquid materials between and within continents with a sea leg. It is very much better than drums and marginally better than bulk bags. Operators and shippers should be most concerned going forward with the specific emissions credentials of their carriers, the routings used and the return load balancing; these factors offer major opportunities to contain or reduce emissions.

As businesses start to formulate their responses to the challenges of climate change and global regulation of emissions, prioritisation of focus and action on changes will be vital to deliver the improvements required. This can only be achieved through transparency, comparison and scenario modelling.

We hope that this report will provide a platform for understanding, debate and discussion in the industry based on the facts presented. We invite readers to study the detail with care as it is vitally important to understanding this type of assessment and the options that are available.

We will welcome feedback and the opportunity for dialogue; we believe that measurement and dialogue are a core part of the maturing process of achieving emissions reductions in line with international goals.

## Introduction and overview

The body of this report takes the following sequence. First we expand briefly on the imperative for action on climate change, purely to emphasise that this is an issue of global importance. We then discuss the cost consequences and penalties for companies that do not take their carbon reduction obligations seriously; we conclude that there will be increasingly demanding charges and regulatory actions. In the next section we point to the key to control and improvement is measurement of carbon emissions with an end-to-end perspective. The Carbon-to-Serve® methodology and toolset is designed to overcome gaps identified in carbon foot-print measurement and reporting. We then describe the application of the Carbon-to-Serve® toolset to the assessment of the emissions resulting from the movement of tank containers, bulk bags and drums for non-hazardous material. We detail the key factors and the outputs.

While this is not an academic paper, we have provided some references for those interested to read more on this important topic.

## The global imperative for action on climate change

The context of this paper has been well-established through the science of global warming and predictions of the catastrophic potential effects of climate change. The seminal work titled ‘An inconvenient truth’ (Gore[1]) is widely attributed as having raised the perception of global energy consumption and its impact on the eco-system to the point where it can no longer be denied. Through the associated film, it has reached and touched the perceptions of many in the political arena. While doubters and naysayers are still active, such as the former British Chancellor - Lord Lawson[2], they are now in the minority. The new Obama administration has signalled clearly that it will commit the United States to emissions reduction and a green economy. The stalled Kyoto Protocol looks as though it will give way to a more positive outcome from Copenhagen 2009.

The British Government commissioned Stern[3] to review the economic impact of climate change; he concluded that sustainability was still a practical goal. He reported that the choice between being ‘rich and dirty’ or ‘clean and green’ was avoidable; we can be ‘green and rich enough’.

It appears that people are more prepared to make rapid changes than their leaders and many companies have moved to exploit this with ‘green’ products and services. A recent survey by Populus found that 60% of respondents would try to buy the ‘most ethical and environmentally friendly products’ that they could[4]. That proportion did not seem to have changed in the face of the downturn.

The stage is set for faster change than has been experienced to date; the question is ‘what changes will be appropriate and effective?’ It is clear that there is a real interest right across the spectrum from the public to companies and governments to understand the underlying drivers of emissions and how they can best change their practices. This means that measurement and reporting is central to making progress.

## The cost implications of non-compliance to carbon standards

Kyoto called for a reduction in emissions of 60% by 2050. Some have gone further in their commitment; the UK Government has established an Office for Climate Change and has committed to lowering emissions by 80% by the year 2050. Attainment of these goals will require regulation and taxation to achieve the right behaviours and change.

The first mechanism that has been selected by the European Community to drive emissions downward is ETS – Emissions Trading Scheme. This is an allowance and cap approach designed to incentivise companies to become more energy efficient. Where they cannot achieve their objectives they must purchase the allowances from companies that are over-performing against their allowances.

As yet, ETS does not cover all areas of industry such as transport. However there can be no doubt that measures will be extended or introduced. For example, the UK is to introduce in April 2010 the CRC (Carbon Reduction Commitment) which will extend the coverage to 20,000 companies. This approach responds to EU regulation requiring Governments within the community to set an allowance and 'cap' for specified installations based on a unit of allowance being equivalent to one tonne of $CO_2$.

All of this is in its infancy and most organisations have limited actual experience of what it all means and how they will need to change. The only fact that is beyond doubt is that emissions will cost money in the future; governments only have the taxation and regulation levers to influence operating and consumption practices.

Taxation and regulation requires measurement, registration and validation.

To this end, software vendors have got involved in the process of helping companies evaluate their emissions as part of their accounting systems, or model the carbon implications of their transport networks. Measurement and standards bodies are getting involved in the specification of lifecycle analysis and carbon efficiency assessment. Governments and institutes are publishing a wide range of emissions measures for specific activities. There is no shortage of work being done, but the results are not always consistent.

The challenge presented by this requirement to measure should not be underestimated. The following points underline the issues being faced:

- The scope and boundaries of any assessment that involves just the focal firm or organisation will be limiting as different outsourcing and off-shoring policies can externalise the emissions; there will have to be an end-to-end measurement process.
- Experts often do not agree on the emissions characteristics of activities in the chain and the variations can be significant; this may be the result of either different coverage of the measurement or technical specifications of the activity.
- The allocation of emissions, between companies and products, for shared services such as retail and logistics can become both a competitive factor and a means to minimise future carbon taxes; as such it is open to conflict and distortion. Some of this problem is visible in the PAS 2050 document covering emissions evaluation.
- Jurisdiction activities along the chain are a major challenge; who has what 'ownership, coverage and responsibility' can be difficult to regulate. The jurisdiction of marine transport is an especially difficult area to regulate.

Schemes are still being put in place and the experience is evolving. It is not straightforward and the economic charges have yet to have an impact. Nonetheless, companies need to start to understand their 'carbon footprints', their big drivers of emissions and their options.

## LCP's Carbon-to-Serve® methodology

The two previous sections highlighted the importance of measurement to gain an understanding of the emissions characteristics. It is also clear that measurement needs to be 'end-to-end' so that full attribution of the emissions is achieved and all the boundaries and interfaces of the chain are visible.

It is only from such a platform of information that new supply chain structures can be evaluated and corporate social responsibility programmes devised and supported. This is the fundamental principle of supply chain management; value potential is associated with better management of the interfaces in the chain as much as the functional excellence of the individual links. Christopher[5] is one of the most referenced sources on this core concept.

The identification of value requires analysis and quantification along the chain and crossing the boundaries of functions and businesses. The possibility to identify the way to operate fundamentally differently can only be achieved through this end-to-end understanding. The successful application of supply chain management is largely dependent on two proven approaches:

- ❖ First is the ability to visualise a supply chain using mapping and, from that, develop the implications of doing things differently; LCP have found this is a profoundly valuable way to consider changes by re-balancing the supply chain. The critical skill of mapping supply chains in support of their redesign to increase effectiveness is well established in the literature by both Hines[6] and Christopher[5].
- ❖ Second is the ability to evaluate the cost build up along the end-to-end chain in order to identify waste and its scale in relation to products, customers and supply chain routings. The Cost-to-Serve® method is now well established as part of the supply chain redesign toolbox. (Braithwaite[7]) The fundamental concept sitting behind Cost-to-Serve® is that the cost of chains is not optimised by adding the lowest possible costs of each of the functions.

These themes apply equally to carbon emissions. We identified that there is a major gap in the measurement and reporting of supply chain emissions. Most tools and methods fail on one or more of the following requirements:

- ❖ They take a local rather than an end-to-end chain view; the boundaries between organisations and functions are not included or explored.
- ❖ Carbon evaluation is not differentiated by product, customer or flow; as a result it fails to identify all of the physical and operational drivers that can cause cost and carbon variations of +/- 50% from average.
- ❖ Other published methods are not transparent in their scope and assumptions; this makes it difficult to discuss, challenge and consider options.
- ❖ The outputs are often an absolute value (e.g. Kgs of CO2) and do not support an understanding of the relative carbon intensity of the chain in relation to its output.

LCP determined that an adaptation of our Cost-to-Serve® and Time-to-Serve® methods would overcome these gaps. As a result we developed the Carbon-to-Serve® methodology[8] which incorporates a supply chain mapping approach with a normalised carbon accumulation calculation along the chain to give a total carbon value for the chain in relation to its output.

This overcomes all of the gaps as it is visual, interactive, data transparent and chain specific. It can be completed in a short time period; scenarios can be evaluated and priorities for improvement quickly set.

The approach has been applied to the Tank Container supply chain and its alternatives; the results are described in the following section.

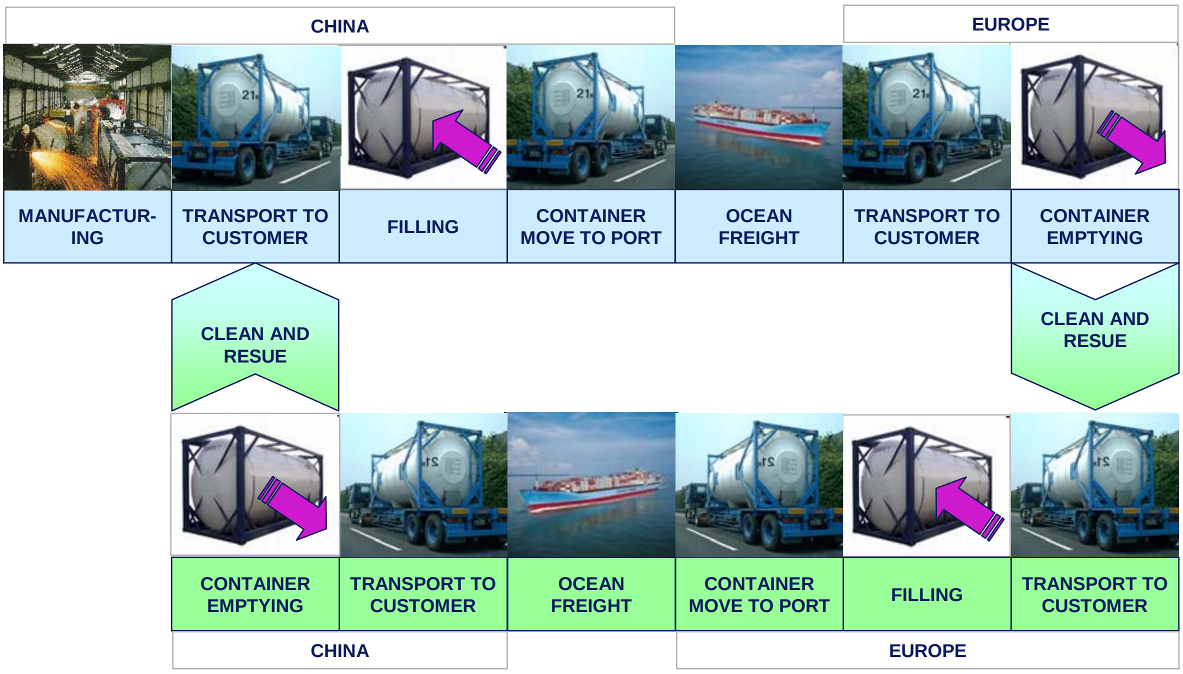
## The evaluation of a tank container chain vs. drums vs. bulk bags

Stakeholders of the tank container industry will not be immune to either the financial penalties of future emissions or the obligations of corporate social responsibility. The Board of ITCO decided to commission LCP to apply the Carbon-to-Serve® methodology to provide a benchmark and support the opening of a dialogue on the key drivers. The evaluation was completed in a matter of weeks and is now available for interrogation and discussion by any interested parties.

### *Scope of the evaluation*

The scope of the evaluation was the transport of non-hazardous liquids from the Shanghai region of China to the Ruhr Valley in Germany. The options evaluated were a 20 foot tank container, steel drums loaded into a standard dry box and a bulk bag loaded into a standard dry box. The scope of the chain is illustrated in the diagram and extends from the manufacture of the container, drum and bag to the transport of the container both empty and full. It includes the return leg, either empty or full and for the normal container makes assumptions about the proportion of return legs that are shipped full or empty. The carbon impacts of incinerating the bag are factored in. The life span of the tank container and dry box is also factored in.

Figure 1 – Overall schematic of the supply chain

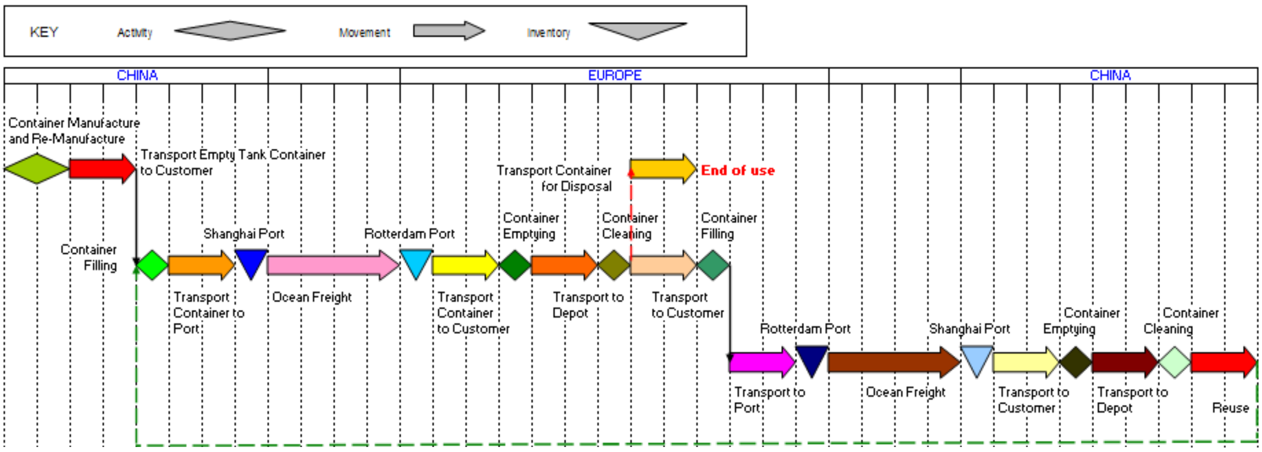


### *Supply chain mapping*

With the full scope of the chain set out schematically including returns, container manufacturing, transportation and waste disposal, the next step is to chart the chain using time as the axis. Supply chains are essentially simple and consist of only three types of activity – conversion, movement and inventory; these events are strung together in a particular sequence for the specific supply chain. Our experience is that creating supply chain charts allows visibility of the whole chain on a single page and that the use of time as the axis helps to focus on the core activities. The Carbon-to-Serve® tool allows these charts to be automatically created from input tables. It also creates a platform from which the emissions data can be calculated, consolidated and presented.

The supply chain chart for tank containers is shown in the diagram following. Because of the large amount of time, the scale of time is varied by activity from weeks to days. This helps to keep the chart visible on a page. It shows clearly the branches in the chain for manufacturing and disposal of the container.

Figure 2 – The supply chain map for tank containers from China to Germany and return



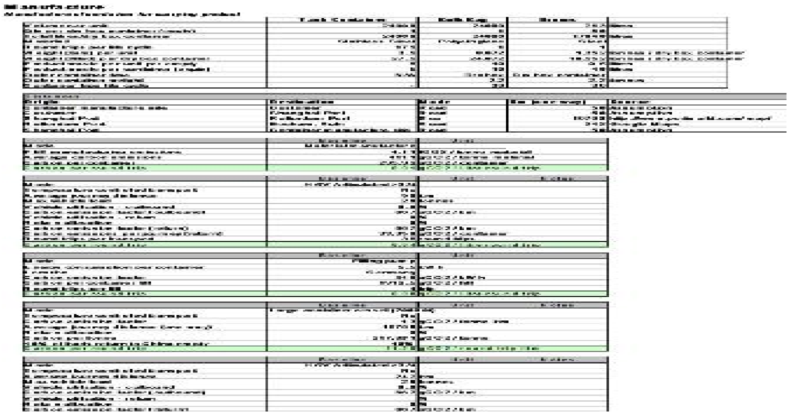

### *Data capture and normalisation*

This is the key stage. Emissions data is captured for every aspect of the chain for the unit of activity in which the chain is operated. Data is obtained from recognised sources and is referenced. LCP generally uses data published by the UK Government Department of Environment, Food and Regional Affairs (DEFRA)[9]. This data is commonly expressed in terms of CO2/ tonne kilometre carried.

The data normalisation process is the most crucial and also the most difficult to understand. Carbon-to-Serve® brings the emissions from the activity to the carbon per tonne of goods carried, or in this case the carbon in grams per round trip litre. This is a comparative basis from which options can be assessed for relative merit. It is difficult to understand because the basis of calculation changes along the chain and for the options. So for example, tank containers carry 24 tonnes and weigh 3.5 tonnes; the emissions standards are the grams of carbon per gross tonne kilometre carried and the measure must therefore be converted to net weight and then into litres carried. In our assessment drums and bags have a different net weight per unit moved and a different energy factor per container manufacture.

This normalisation calculation is made in a huge table as illustrated in Figure 3. This is to illustrate the complexity rather than to invite the reader to study the detail.

Figure 3 – Data Capture and Normalisation Table



It is important to understand that emissions data is not stable with different sources publishing different data with wide variations for nominally the same activity. For example, an ocean going ship (as opposed to short sea shipping) from the WRI/WBCSD greenhouse gas protocol initiative provides a figure of 15 gms of CO2 per metric tonne km, and the Swedish organisation NTM a figure of 10 gms of CO2 per metric tonne km. The DEFRA number used in the Carbon-to-Serve® is a mid point of 13 gms. A web search discloses that the world's largest shipping line, Maersk, is quoting numbers in the range 7.5 to 8.4. The difference may be attributable to the difference between gross and net weight but the measure in not clarified in the publication. This is typical of the state of play in emissions calculations and reporting; as we will show later this particular discrepancy would have a huge effect on the result for tank containers and its alternatives.

The data table and normalisation process allows these assumptions to be open to inspection and debate; they can be quickly tested for their impact by entering a new value and recording its source. While this is not practical in the space of this white paper, we invite interested parties to enter dialogue and discovery.

### *Key factors in the comparison*

The data for the key factors in the modelling are shown in Figure 4. The key points are as follows:

- ❖ A round trip for the model is a load being sent from China, via ocean freight to Rotterdam and then road freight to the Ruhr Valley in Germany and back again from Germany to China.
- ❖ All road transport distances are taken as the same and a standard of 50km per journey is used, except for Rotterdam to Germany where the distance was taken as 242km.
- ❖ Each of the options is assumed to have a transport container. Both the drums and bulk bag require a 20ft dry box while the tank container is a self contained unit.
- ❖ Each of the transport options were assumed to perform 3 of these round trips per year with the tank container running full both ways while the dry boxes were assumed to travel 40% empty on the return leg.
- ❖ The tank container was assumed to have a life of 35 years with one re-manufacturing point in its life. Tank containers have a tare weight of 3.5 tonnes. A residue of 5 litres of product is wasted when the tank container is emptied.
- ❖ The dry box container is assumed to have a life of 12 years. It has a tare weight of 2.2 tonnes. Drums and bulk bags operate a single trip.
- ❖ Bulk bags are taken as made from single layer PET with a tare weight of 72kg. A residue of 10 litres of product is wasted when the bulk bag is emptied.

- The drums were 213 litre industry standard units made of steel. A 20 foot container will hold 80 of them. A residue of 0.5 litres of product is wasted when each drum is emptied (40 litres per container). The lower round trip litres figure for drums in Figure 4 is due to the inability to load the container to its full potential.
- Drums are assumed to be 'unofficially repurposed' (disposal attracts no emissions) while the bulk bag was assumed to incinerated and the emissions for this have been factored in.
- The 'net round trip litres' which is used in the normalization calculation is a key assumption. The term net is used to denote the application of a waste factor when the container is emptied; the round trip litres are the volume carried by the transport mode on the round trip from China to Germany and back.
- As can be seen from Figure 4 the volume moved is greater for the tank container as the assumption is made that the tank container will always travel a long distance leg full. The model assumes that the bags and drums carry a 40% responsibility for return empty return journeys back to China as container repositioning.

Figure 4 – table of key factors in the modelling

| Type of container | Life of container | Net round trip litres carried | Shipping round trips pa. | Round trips per life cycle |
|---|---|---|---|---|
| Tank Container | 35 years | 47,990 | 3 | 105 |
| Drums | Single Use | 17,000 | 1 | 1 |
| Bulk Bag | Single Use | 23,990 | 1 | 1 |
| *Dry box container* | *12 years* | *n/a* | *3* | *36* |

### *Graphical representation of the carbon accumulation*

The Carbon-to-Serve® tool automatically accumulates the data from the normalization table and plots it as an accumulated area graph aligned in time and colour with the supply chain chart. This immediately gives visibility of the major components of carbon in the chain and provides the visual basis for discussion and challenge. It is important to read this graph as an accumulating bar height and relate it visually to the colour coding of the events.

Figure 5 shows the supply chain chart and carbon build up for bulk bags. Similar graphs have been prepared for the other handling mediums but are not displayed here for reasons of space. They are available for inspection.

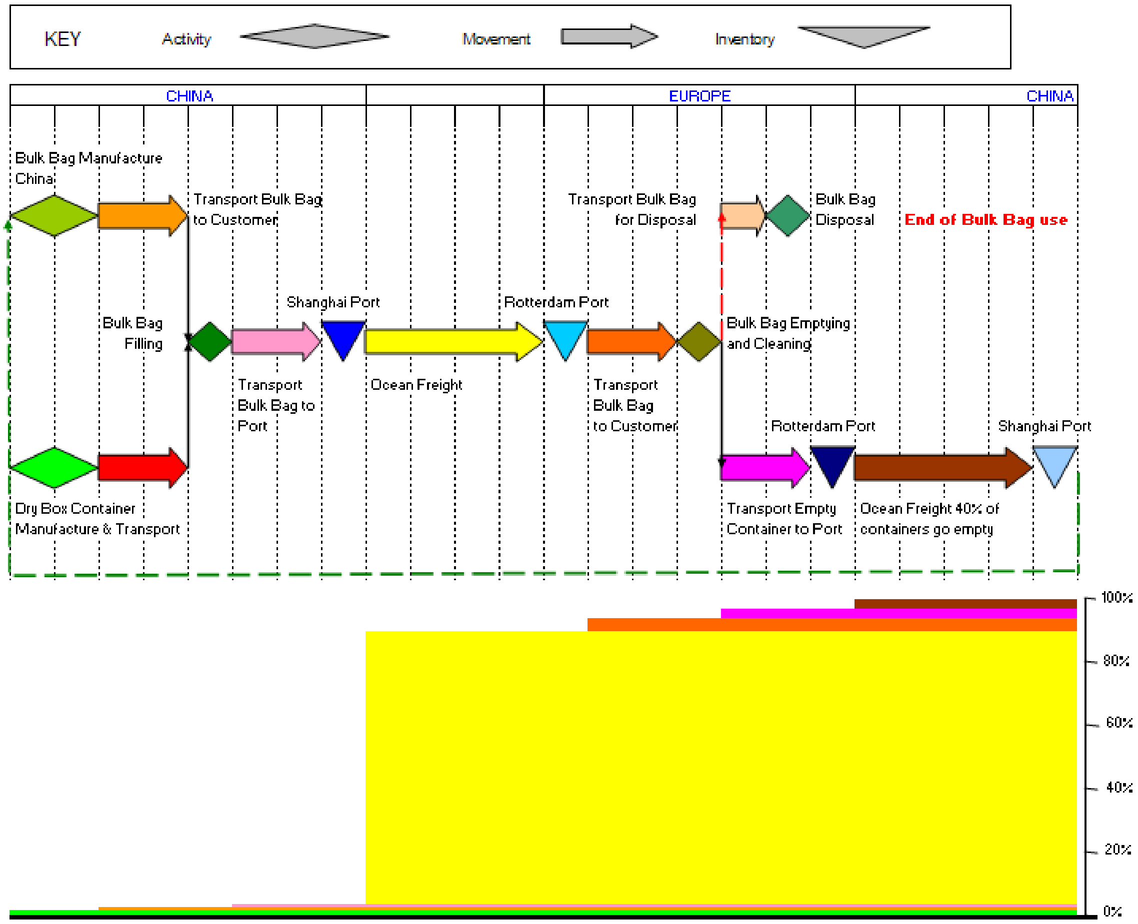



Figure 5 – the Carbon-to-Serve® build up of shipping non-hazardous material in bulk bags

### *Results comparison, sensitivity analysis and commentary*

Figure 6 shows the high level comparison of the tank container, bulk bag and drum. The results of the analysis show that the tank container and bulk bag are broadly similar while the drums are much less effective in carbon terms.

| | Tank Container | Bulk Bag | Drum |
|---|---|---|---|
| Manufacturing | 2.1 | 6.0 | 193.8 |
| Transportation & Handling (Empty) | 3.0 | 17.8 | 19.6 |
| Filling, Emptying & Cleaning | 0.3 | 0.3 | 0.4 |
| Transportation & Handling (Full) | 263.5 | 251.7 | 288.5 |
| (of which is ocean freight) | (249.8) | (238.7) | (271.2) |
| Disposal | - | 1.2 | - |
| *Usable litres transported / round trip* | *47,990* | *23,990* | *17,000* |
| **Total gCO2 / round trip litre** | **268.9** | **276.9** | **502.3** |

Figure 6 – high level relative comparison table

The key conclusions from the analysis and sensitivity testing are as follows:

- The loaded ocean leg is the dominant factor in the entire chain – the combination of weight with the extended distance more than offset the fact that container shipping is the most carbon efficient of transport modes.
- The emissions factors for this leg are the key assumption. As a result, the variation in published data, observed earlier, is a concern.
- The use of gCO2 per tonne-km in ocean shipping as a linear factor is probably not accurate. An emptier ship is unlikely to be proportionately less in its carbon emissions; albeit if it is regularly empty it is unlikely to continue to run, making its replacement better loaded.
- Return legs when the box or container is empty do not have a significant impact – a change of +/- 10% results in the return leg running full results in a less than 0.5% change in emissions for drums and bulk bags.
- This means that the intercontinental repositioning of an empty tank container is not a significant penalty but will make it worse than a bulk bag by 1%.
- Drums are penalised by their carbon intensive manufacture for a single trip use; we recognise that they will often be unofficially re-purposed but that this will not be with reputable users and can introduce safety and security issues. The disposal of the drum has not been factored into the model.
- Increasing round trips from 3 to 4 lowers the normalised emissions for the manufacture of the tank containers and dry box containers, resulting in a ~0.5% reduction in emissions for drums and bulk bags and 0.2% reduction for tank containers.
- Reducing to 2 round trips has similarly small impact; an increase of ~1% for drums and bulk bags, ~0.4% for tank containers.

These results were not entirely what was expected; we had thought before the work that the carbon impacts of making and disposing of the bags would be more significant and that the drums would be less so. The low sensitivity to empty legs was also unexpected and might be challenged with the publishers of the measures used.

For the tank container industry stakeholders – shippers, owners, operators and the key conclusion is that the tank container and bulk bag are equally effective. Mode selection will depend on operational, safety and network factors amongst many. For hazardous material, the tank container is clearly the only secure option.

For shippers who will become accountable (and taxed) on their emissions, the choice of a liner company that can certify superior environmental credentials will be important by as much as 30% to 40%. For liner companies, green technology and design will clearly be a competitive advantage.

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## ITCO and LCP Consulting Profiles

ITCO, the International Tank Container Organisation, is a pro-active international trade association promoting the interests of the Tank Container Industry. The purpose of ITCO is to act as a voluntary non-profit trade association representing the international tank container industry to the public and governmental bodies and to advance the interests of the industry. Issues dealt with by ITCO may relate to safety, the publication of technical literature, the use of technology in the industry and raising the profile of the use of tank containers. Membership includes companies in the tank container manufacturing, leasing, operating and related sectors including tank service providers such as depots, inspection, certification societies and others. ITCO currently represents a substantial segment of the global tank container industry.

LCP Consulting is a leading specialist in customer-driven supply chain management. With over 20 years' experience in the field, we identify where supply chains make major contributions to how businesses operate profitably and compete effectively. We support businesses review, re-design and implement changes to their end-to-end operations. Our fact-based diagnostics pin point exactly where & how to cut costs, enhance operational efficiency and invest for the future. The Carbon-to-Serve® analytical methodology is exclusive to LCP. It has been developed and applied to a range of industries over the last year in response to the market need to prepare a holistic supply chain picture and evaluation of emissions and the options for change.


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