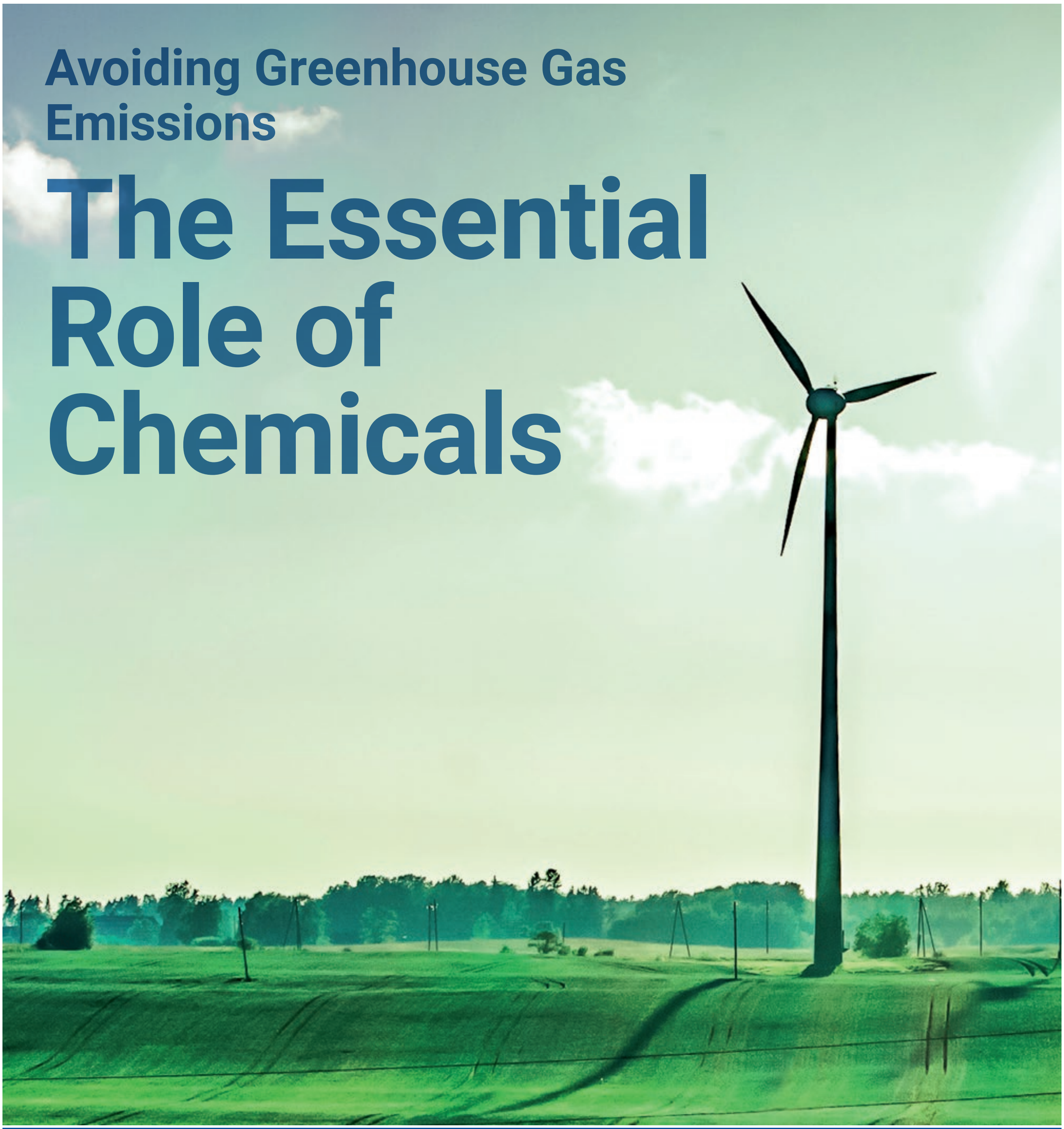
Avoiding Greenhouse Gas Emissions

The Essential Role of Chemicals



17 Case Studies

Summaries

Applying the ICCA & WBCSD Avoided Emissions Guidelines

December 2017

INTERNATIONAL COUNCIL OF CHEMICAL ASSOCIATIONS

Foreword

The chemical industry has a key role to play on a game-changing path towards a low-carbon future. Reducing further its greenhouse gas emissions during the manufacturing phase of chemical products is one part of this contribution. But the chemical sector can and will contribute via further supporting high efficiency processes and products in the many value chains where chemicals play a role.

Looking ahead in 6 key solution areas, ICCA estimates that by 2030, light materials for transportation, efficient buildings and lighting, electric cars, wind & solar power and improved tires together have the potential, at global scale, to avoid 2.5 Gigatons of greenhouse gas emissions globally every year. That's twice the amount currently emitted by all the cars in the world!

However a accounting for the reductions of these efficient processes and products can be complex and not always straightforward. Typically, the majority of chemical products are part of an assembly or more complex end products. This leads to challenges when quantifying the emission reductions enabled by chemical components/ingredients in individual final solutions. The amount of the calculated emissions ("avoided emissions") depends greatly on the system boundaries used and the choice of the reference products.

The International Council of Chemical Associations (ICCA) and the World Business Council for Sustainable Development (WBCSD) Chemical Sector have together recognized the importance of establishing specific guidelines to help quantify and report the contribution of chemical products in reducing greenhouse gas emissions over the product life cycle. Guidelines were published in 2013 and revised in 2017.

The goal of the present report is to illustrate and quantify, through examples offered by ICCA members and associations, to what extend efficient processes and solutions can contribute to greenhouse gas savings. It demonstrates how to quantify such "avoided emissions" in an unbiased way, applying the ICCA/WBCSD guidelines to individual cases. We hope this will encourage all chemical companies to apply the guidelines when calculating the avoided emissions enabled by their products. We expect this report will demonstrate that the evaluation of the avoided emissions must be carefully conducted, ensuring consistency and transparency.

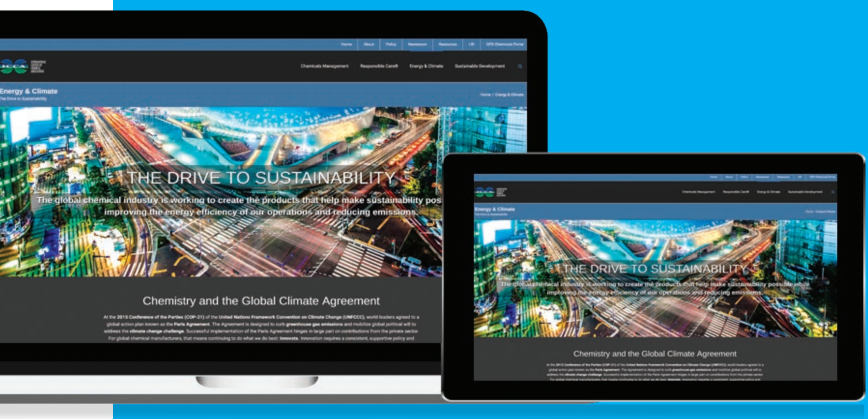
We encourage all concerned parties, and especially chemical companies to develop robust studies. This will, I am sure, further enhance the credibility of industry as solution provider for a low carbon economy.

Bunro Shiozawa
Chair of ICCA Energy and
Climate Change Leadership Group

Related ICCA documents

Available on www.icca-chem.org/energy-climate

- Avoiding Greenhouse Gas Emissions - the Essential Role of Chemicals: 17 Case Studies - Technical Reports
- Accounting for and Reporting Greenhouse Gas Emissions Avoided along the Value Chain based on Comparative Studies: Guidelines
- Greenhouse gas emission reductions enabled by products from the chemical industry: Quantifying the global potential



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Setting the scene

The Paris Agreement promotes the development by member countries of long-term strategies for lowering GHG emissions. Beyond 2030, breakthrough technological innovations will be required to achieve the 2 degree temperature target. Right now, chemicals have enormous potential in enabling a low carbon future. Longer term it will be necessary to empower the chemical industry's role as a global "solutions creator" with new innovations and enhanced collaboration between value chain partners.

The chemical industry plays an essential role in enabling other industries to improve their energy efficiency and reduce their greenhouse gas emissions (GHG). Several reports by ICCA International Council of Chemical Associations) have underpinned the scale of the chemical industry's contribution to enabling emissions reduction, also known as "avoided emissions". "Innovation for Greenhouse Gas Reductions: A life cycle quantification of carbon abatement solutions enabled by the chemical industry" (2009) and "ICCA Building Technology Roadmap: The Chemical Industry's Contribution to Energy and Greenhouse Gas Savings in Residential and Commercial Construction" (2013) are the most relevant examples. Subsequently, to improve consistency in the assessment and reporting of avoided emissions, ICCA and WBCSD (World Business Council for Sustainable Devlopment) published a practical guidance document entitled "Addressing the Avoided Emissions Challenge" (2013).

Building on this past work, ICCA recently conducted a study on the maximum potential for annual GHG emissions reduction enabled by the chemical industry for six selected solutions in a specific year: wind and solar power, efficient building envelopes, efficient lighting, electric cars, fuel efficient tires and lightweight materials. This study showed that global emissions would be over 9 $GtCO_2e$ per year lower if the selected six solutions were used to their full potential right now; this exceeds the annual emissions of the United States.

Why case studies?

The main purpose of this publication is to demonstrate, via robust, quantified, concrete examples that solutions enabled by chemical products can contribute to significant greenhouse gas savings. The case studies in this report were offered by ten chemical companies and two associations. They exemplify the application of the ICCA & WBCSD Chemical Sector guidelines"Addressing the Avoided Emissions Challenge: Guidelines from the chemical industry for accounting for and reporting greenhouse gas (GHG) emissions avoided along the value chain based on comparative studies". Assembling these case studies is aimed at motivating all stakeholders to feed climate change discussions with robust greenhouse gas life cycle assessments, and to motivate chemical companies to generate high quality case studies. The present report on 17 case studies can also be used as an educational material to develop robust and more transparent LCA case studies.

Fact sheets and technical reports

Case studies are presented in the form of summary "fact sheets" assembled in the present document, complemented with technical reports giving more details on the assumptions and calculations, in agreement with the ICCA/WBCSD guidance.

The case studies illustrate how the reduction of greenhouse gas emissions can be enabled by chemical products. They are part of a series brought to you by ICCA. The studies were adapted from original work by companies by applying the ICCA/WBCSD Chemical Sector guidelines. Chemical industry members offered life cycle assessment [LCA] case studies for the purpose of showing illustrative examples on how to calculate avoided greenhouse gas (GHG) emissions. The avoided emission calculations were based on the guidelines developed by ICCA and WBSCD – Chemical Sector, with the support of Arthur D. Little and Ecofys. Other life cycle environmental impacts such as water and land use change were outside the scope and usually not considered.

Discover the technical reports on the ICCA website at www.icca-chem.org/energy-climate

Objectives

Through the publication of this series of 17 case studies, and of the guidance on how to quantify avoided emissions along life cycles, the ICCA would like to achieve the following objectives:

1. **Raise awareness about emission reduction potential of chemical products:** Raise the awareness of stakeholders including customers, investors, policy-makers and citizens, about the emission reduction potential enabled by chemical products when taking a life cycle perspective.
2. **Illustrate the application of the guidelines:** The case studies provide practical examples on how to apply the ICCA & WBCSD guidelines, and illustrate how to interpret some of the requirements. This may help other companies start using the guidelines and can help them structure their studies.
3. **Motivate other chemical companies to use the guidelines:** The case studies will inspire and motivate other chemical companies and chemical industry associations to create and publish similar information. It is the intention of ICCA to complement the current case studies with additional ones over time. In this way, the collection of case studies will grow, and cover a broader range of chemical products from various geographical regions. Ultimately, value chain partners and companies from other sectors may apply the guidelines to their own business sector as well, which could lead to an increased number of publications on the ICCA website and elsewhere. The findings from those studies could feed and illustrate the global picture of the overall potential of GHG emissions reductions by the chemical industry (and other sectors).
4. **Promote full life cycle approach:** With the case studies, the ICCA wants to promote the use of Life Cycle Assessment (LCA) and Life Cycle Thinking (LCT) as comprehensive decision-support tool and concept for the chemical industry and its stakeholders.

Fact sheets illustrating the essential role of chemicals

The case study illustrate how the reduction of Greenhouse Gas Emissions can be enabled by chemical products. Chemical industry members of ICCA offered life cycle assessment [LCA] case studies for the purpose of showing illustrative examples on how to calculate avoided greenhouse gas (GHG) emissions. The avoided emission calculations were based on the guidelines developed by ICCA and WBSCD (World Business Council for Sustainable Development) – Chemical Sector, with the support of Arthur D. Little and Ecofys. Other life cycle environmental impacts such as water and land use change were outside the scope and usually not considered. The case studies have been reviewed by Ecofys and Quantis. The review meant to check that case studies follow the ICCA/WBCSD Guidance in terms of structure as well as requirements. The review was also an opportunity to assess whether the case studies used sound methods to calculate the avoided emissions, in terms of life cycle assessment calculation and of robustness of input data.

External thermal insulation composite system for the refurbishment of a house in Germany

A BASF case study

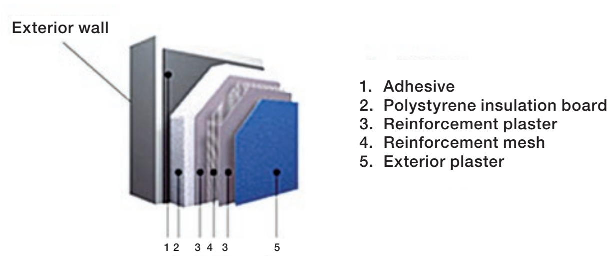
Chemical insulation products such as expanded polystyrene (EPS) have excellent thermal insulation properties. They are used as part of an External Thermal Insulation Composite System to improve the thermal insulation of outer walls, thereby reducing energy consumption and GHG emissions.

Insulation materials play a vital role in combatting climate change by saving heating and cooling energy in buildings. The study compares two alternatives for an existing detached house in Germany: one in which the house is left as is (representing the weighted average of non-refurbished and already refurbished houses in Germany), and one in which the façades are refurbished to current German standards using an External Thermal Insulation. Composite System based on expanded polystyrene (EPS).

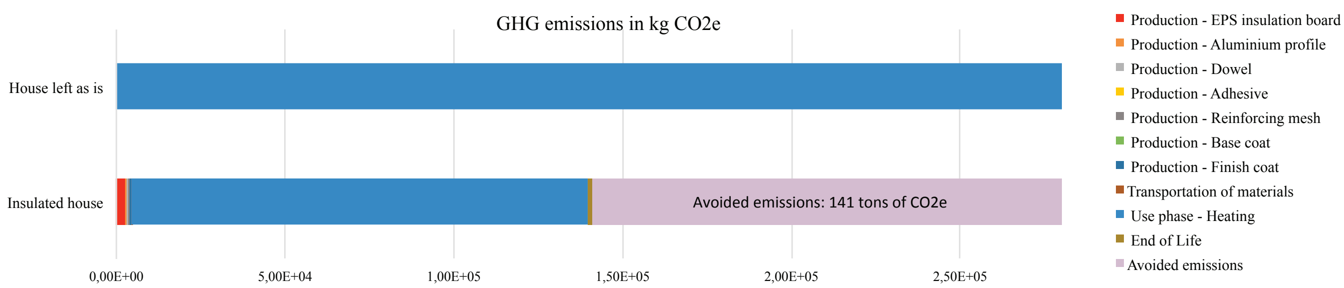
EPS is a lightweight, rigid, plastic foam insulation material produced from solid beads of polystyrene. The difference between the cradle-to-grave GHG emissions of the house left as is, and the newly-insulated house with the ETIC System amount to 141 tons of avoided emissions over a service life of 40 years. The result is largely dominated by the use phase, that is the combustion of heating fuel with associated GHG emissions. The impact of the manufacture and disposal of the ETIC System is very small and hence not visible in the result figure below.

Full study available at: www.icca-chem.org/energy-climate

External Thermal Insulation Composite System based on expanded polystyrene



Cradle-to-grave GHG emissions of the detached house in Germany over 40 years left as is, in comparison to the house with modern façade insulation



Polypropylene (PP) containers for water-based paints

A Braskem case study

Replacing tinplate rigid containers by Polypropylene containers for waterbased paints in Brazil can lead to a 18% reduction in GHG emissions amounting to 0.6 kgCO_2e per container, over the whole lifecycle of the paint containers.

If one million liters of paint were packaged in such polypropylene containers instead of tinplate containers, this would avoid GHG emissions equivalent to those of a passenger car giving 5.5 laps around the Earth and the equivalent of 1.26 Olympic pools of acid rain.

Brazil is one of the five largest markets for paints. In 2014, 1.397 billion liters of paint were produced, and this market is essentially dominated by tinplate (TP) pails.

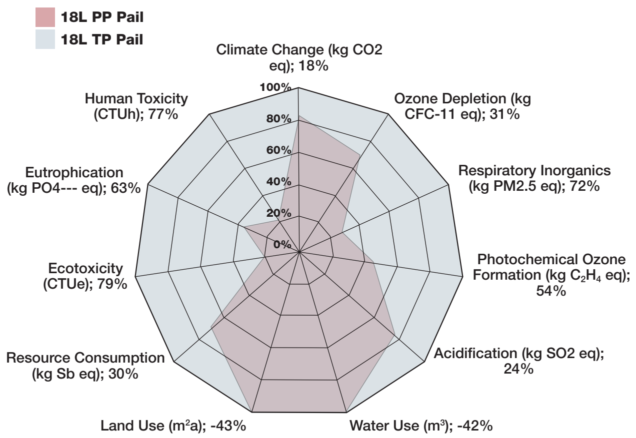
With the objective of proposing a solution to the paint pail market to reduce environmental impact, Braskem developed an alternative packaging that is lighter and more resistant to corrosion, based on polypropylene (PP).

Life cycle GHG emissions for a typical 18 litre tinplate container amount to 3.33 kgCO_2e/container whereas PP containers have a total emission of 2.73 kgCO_2e/container. The majority of impact in the life cycle of these containers are concentrated in the production process of the materials (tinplate and polypropylene).

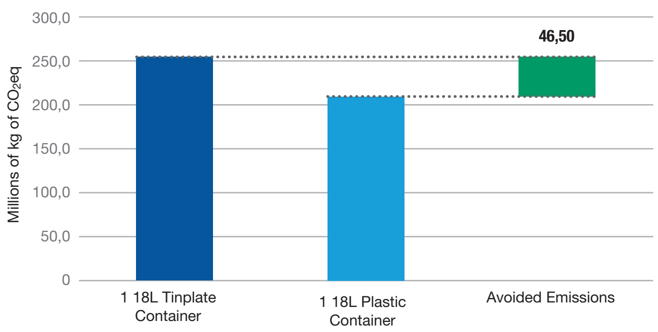
The main trade-offs of the polythelene container in the life cycle are in the impact categories of Land Use and Water Use.

Full study available at: www.icca-chem.org/energy-climate

Full Life Cycle Impact Assessment Profile
Comparative environmental profile of tinplate containers for Water-based Paints against polypropylene containers – Climate change + all other environmental impact categories



CO_2eq Emissions: 1,397 billion litres of paint in market



	kg CO_2eq
1 18L Tinplate Container	3.33
1 18L Polypropylene Container	2.73
Avoided Emissions	0.60

Considering the Brazilian 2014 market (1,397 billion litres of paint) for the studied 18L containers, the graph highlights the emissions in CO_2eq for both solutions and the emissions avoided by the substitution of tinplate by plastic containers (46.5 millions of kg CO_2eq).

Feed additives – 4 amino acids for pig and broiler production:

DL-Methionine, L-Lysine, L-Threonine and L-Tryptophan

An Evonik case study

Supplementing animal feed with essential amino acids can save significant amounts of feed raw materials, resulting in minimized use of arable land for crop production and thus, fewer CO_2eq emissions.

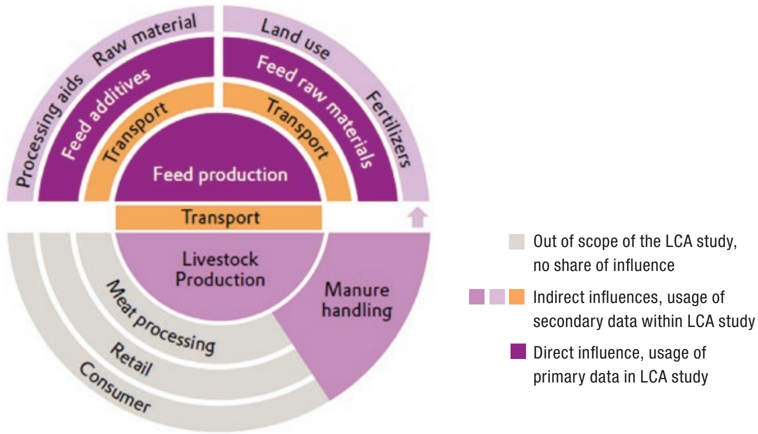
Furthermore, feed supplementation with these essential amino acids reduces both nitrogen and greenhouse gas emissions resulting from feeding and excretion.

Animal feed is specifically formulated to meet the physiological nutrition needs of animals, particularly the necessary shares of essential amino acids. Lack of certain amino acids in pig and broiler feed can be compensated either by adding a higher percentage of protein-rich feed components such as oil seed, or by fortifying the feed with essential amino acids produced by Evonik for this purpose.

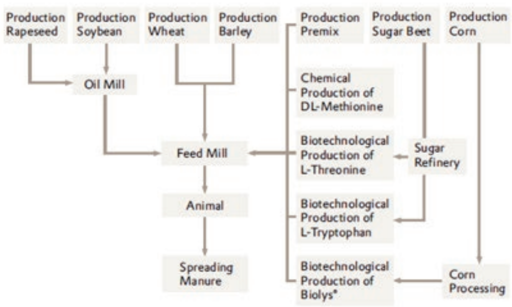
The present case study compares a supplemented feed mix including cristalline amino acids with two non-supplemented feed mixes based on soybean as protein rich feed ingredient in one case, and on soybean and rapeseed in the second case. The study addresses both animals, broiler and pigs.

Full study available at: www.icca-chem.org/energy-climate

System boundaries and share of influence of Evonik's products

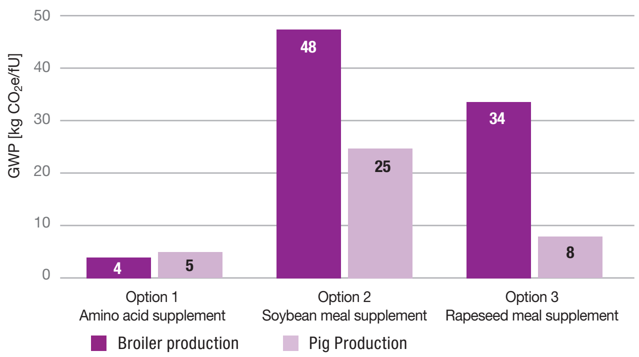


Processes and systems analyzed in broiler and pig production



The scope of the study includes production of agricultural raw materials and amino acids, as well as typical feed formulation and the differences in animal performance and excretion by feeding supplemented low protein diets instead of diets with higher crude protein content.

Global Warming Potential GWP100 [CML2001] of broiler and pig production



Broiler production

The global warming potential of the supplemented feed mix for broiler production shows lower environmental impacts due to substitution of protein rich feed ingredients like oil seeds by feed ingredients with lower crude protein contents.

Pig production

The global warming potential of options 2 and 3 with oil seeds as source for the additional amino acids have a higher GWP than the supplemented feed mix option 1. The portion of soybean meal originating from land that has caused land use change has a significant influence on the estimated GWP.

Bio-Mono Ethylene Glycol (MEG) from renewable source

An India Glycols Limited case study

INDIA GLYCOLS LIMITED

The Bio-based MEG ensures lesser GHG emission at the raw material phase during lifecycle of MEG production. The lower GHG emissions ensured by the bio-route is predominantly due to use of renewable material (sugarcane molasses) as raw material compared to MEG production via the petro route which causes significant GHG emission during crude oil excavation and processing stages.

A case study comparing GHG emissions of Bio MEG production at India Glycols Limited (IGL) with the conventional petro route has been carried out. The results are presented using the IPCC 2013 GWP100a methodology. The Eco Invent data of Petro-MEG for this study are mainly focused on plants in Europe. The total CO_2 generated is 1,221 kg CO_2 equivalents per MT of Bio-MEG production, compared to 1,628 kg CO_2 equivalents for the Petro-MEG production.

The avoided emissions are presented as the difference of GHG emissions over an MEG life cycle (Cradle-to-Gate). Avoided emission of Bio-MEG production compared to Petro-MEG production is significant. The avoided emission amount to 407 kg CO_2eq/MT MEG produced.

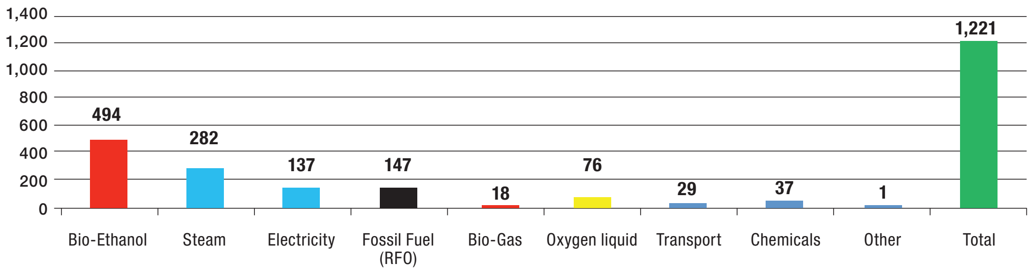
MEG is used worldwide. Global demand for MEG was estimated to be 22 million tonnes in 2012 with a capacity of 28 million tonnes. The demand for MEG continues to increase steadily. IGL alone produces around 150,000 tonnes per annum of Bio-MEG.

By using the per annum production data of Bio-MEG by India Glycols Limited, total avoided CO2e emissions stemming from Bio-MEG production amounts to ~ 61,030 MT-CO_2e compared to petro route MEG production.

Full study available at: www.icca-chem.org/energy-climate

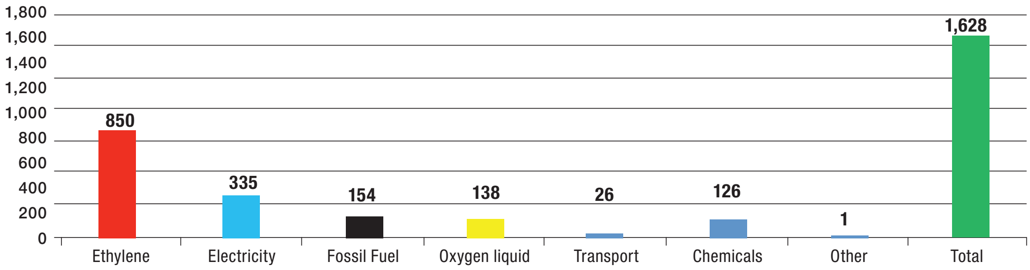
CO_2eq emissions stemming from the manufacturing of Bio-MEG (Cradle-to-Gate)

Emission in kg CO_2 eq per MT of Bio-MEG Production



CO_2eq emissions stemming from the manufacturing of MEG via the Conventional Petro route (Cradle to gate)

Emission in kg CO_2 eq per MT of Conventional-MEG (Petro route) Production



Summary

Raw material plays key role in MEG production. In Petro route MEG production, the raw material is crude oil compared to sugarcane molasses for bio route. Sugarcane molasses is a renewable material as raw material is cultivated again and again. During cultivation stage, it absorbs CO_2 from atmosphere and reduces GHG load of atmosphere.

Aircraft materials (CFRP, Carbon Fibre Reinforced Plastic) for weight reduction

A JCMA case study

The Japan Carbon Fiber Manufacturers Association

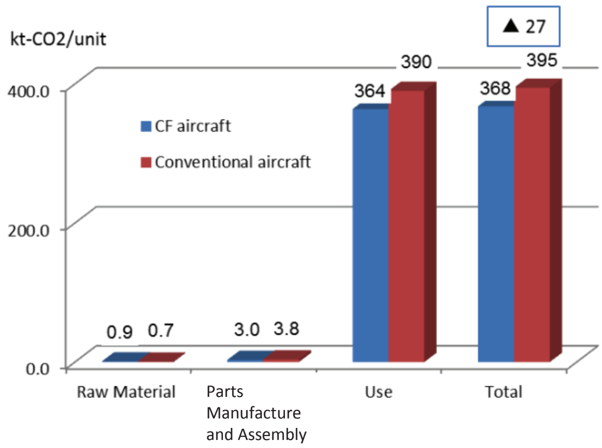
The use of Carbon Fibre Reinforced Plastic (CFRP) reduces the weight of the aircraft while maintaining the same strength and safety. As with automobiles, weight reduction in aircraft directly leads to improved fuel consumption, thereby significantly contributing to reduction in CO_2 emissions in the transportation sector.

The study compares two alternative aircrafts, one consists of 3 wt% CFRP based on Boeing 767 (called "conventional aircraft"), the other consists of 50wt% CFRP, where metal materials are replaced with CFRP (called "CFRP aircraft"). Consequently, CFRP aircraft has a reduced Body weight of 20%.

A comparison of the two alternatives demonstrates that the CFRP aircraft has a lower carbon footprint and reduced CO_2 emission: the avoided emissions amount to 27 kt-CO_2/unit over a 10 year use period, calculated as the difference in CO_2 emissions over the aircraft's life cycle. The CO_2 savings are dominated by the use phase of the aircraft.

Full study available at: www.icca-chem.org/energy-climate

The avoided CO_2 emissions per aircraft unit (kt-CO_2/unit)



	CFRP Aircraft	Conventional Aircraft
CO_2 emissions during the stages of raw material procurement - manufacture of materials of body structure materials (ktCO_2/unit)	0.9	0.7
CO_2 emissions during the stage of manufacture - aircraft assembly of body structure parts (kt-CO_2/unit)	3.0	3.8
CO_2 emissions during the usage stage (kt-C_2/unit 10 years)	364.0	390.0
CO_2 emissions over the entire life cycle (kt-C_2/unit 10 years)	368.0	395.0
CO_2 emissions abatement (kt-C_2/unit 10 years)	▲27	

Materials for fuel efficient tires

A Japan Chemical Industry Association case study

Fuel efficient tires play a key role to improve an automobile's fuel consumption. The entire chemical products formulation, the specific structure of synthetic rubber and the dispersion technology of higher content silica in the rubber bring significant Greenhouse gas emissions reduction during the lifetime of tires.

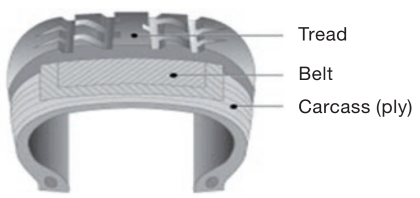
The fuel efficient tires ensure less friction while an automobile is moving and reduce rolling resistance compatible with maintaining grip at the use phase during the car's complete lifecycle.

The study compares the GHG emissions of vehicles equipped with fuel efficient tires to emissions from vehicles with conventional tires. The avoided emissions represent 228 kg-CO_2e for the selected passenger car model (over 30,000km car use for both types of tires) with 4 tires. They represent 4,423kg-CO_2e for the selected truck/bus model (over 120,000km use) in Japan (see Figure 1 and 2).The results show that the avoided emissions at the use phase of automobiles are dominated by the GHG emissions related to fuel consumption.

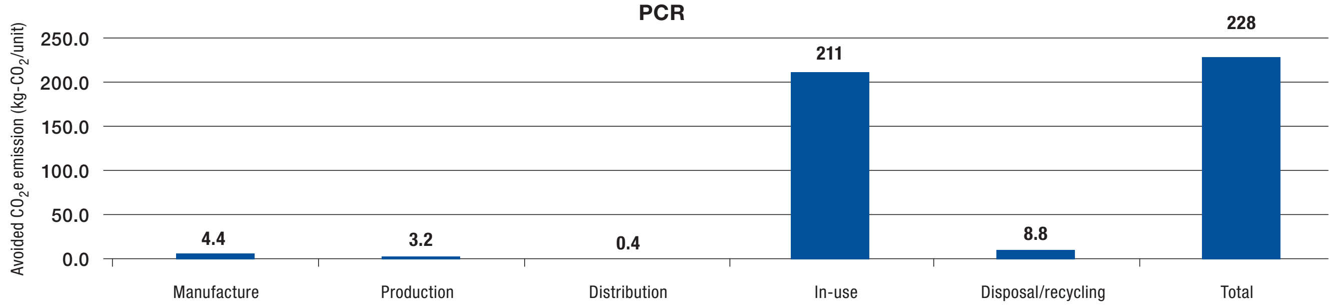
On the basis of 2012 data and forecasting the Japanese market size by 2020, the total expected avoided CO_2e emissions from fuel efficient tires is calculated to reach 6.37 million t-CO_2e in Japan.

Full study available at: www.icca-chem.org/energy-climate

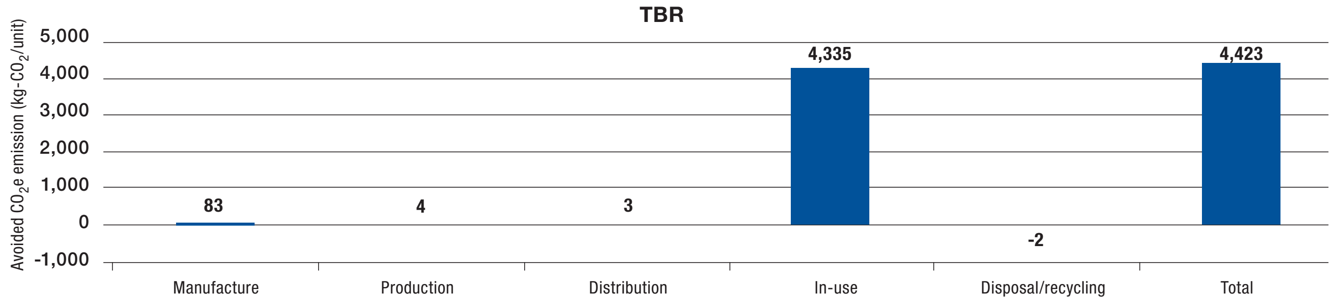
The tread portion of tire



Avoided CO_2e emissions for the studied passenger car model (with 4 tires) over 30,000km use



Avoided CO_2e emissions for the studied Truck/bus model (with 10 tires) over 30,000km use



Multilayer Polyethylene packaging films

A SABIC case study

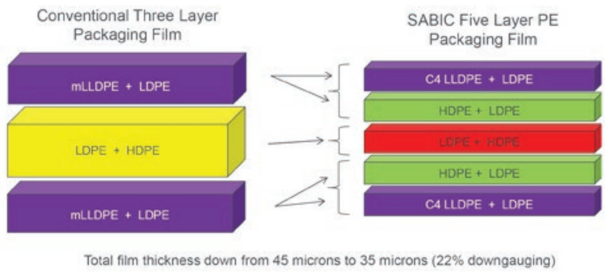
Efficient packaging solutions through material effectiveness can help reduce greenhouse gas (GHG) emissions throughout the entire life cycle of packaging solutions. A study was conducted to calculate the reduction in greenhouse gas (GHG) emissions during the life cycle of 2 types of packaging: a five layered packaging film compared to a conventional three layered packaging film for collation shrink film application.

The primary role of packaging is to prevent packaged products from getting damaged during transporting, storing, handling, shelving, preservation, opening and usage. Multilayer PE packaging films are used for applications such as bottle water packs, beer cans pack, beverage collation shrink film.
SABIC has developed a recipe for multilayer PE packaging film, which enhances material properties of the film and improves its effectiveness allowing 22% reduction in film thickness. SABIC's five layer packaging film matches the three layer reference film specification with respect to shrink force, optical and tensile properties. However it is 22% lighter in weight for equivalent functional unit basis i.e. 1000 m² of film area.
The study shows that 22% reduction in film thickness of the packaging film results in close to 22% reduction in lifecycle greenhouse gas emissions. Every 1000 m² of five layer PE film results in 40 kg of avoided GHG emissions compared to conventional three layer film. The study demonstrates that increase in material effectiveness through product innovations has a strong and linear impact in reducing the lifecycle environmental footprint of plastic packaging.

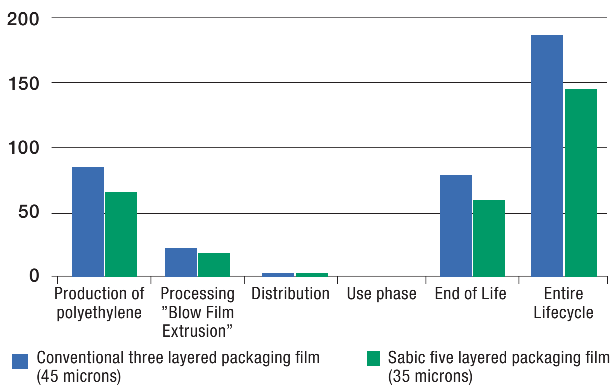
Full study available at: www.icca-chem.org/energy-climate

Multilayer polyethylene packaging film (a) and Packaging of pack of six beverage bottle with multilayer PE packaging film (b).

Conventional three layer packaging film (45 μm) and SABIC five layer packaging film (35 μm)



Avoided Greenhouse Gas Emissions over the lifecycle of five layer PE packaging film versus conventional three layer packaging film



The avoided CO_2e emissions per 1000 m² of packaging film

Emissions per life cycle phase (kg CO_2e)	SABIC five layer packaging film (35 microns)	Conventional three layer packaging fil (45 microns)	Avoided Emissions kg CO_2 eq./functional unit
Production of Polyethylene	66	85	19
Processing- «Blown Film Extrusion»	18	22	4
Distribution	1	1	0
Use phase	-	-	
End of Life	60	78	18
Entire Lifecycle	145	185	40
Avoided Emissions	40		

Engineering plastics for vehicle light-weighting

A Solvay case study

Lightweight car parts play a key role in designing more fuel-efficient cars. Even small and specific car parts like the engine mount housing made of 280 grams of Technyl®, an engineering plastic, demonstrates that it brings significant greenhouse gas savings as compared to the traditional version made of 400 grams aluminum alloy equivalent.

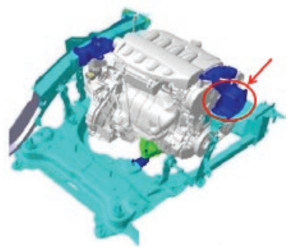
In the studied case, the avoided emissions for this very small part represent 2.0 kg CO_2 eq. per car during its complete life cycle. Considering the total production of the specific car model under study (280,000 cars/year, with a 10 years lifetime), the emissions avoided due to this technology change amount to 5,600 t CO_2 eq.

The “engine mount housing” is a small car part that ensures one attachment point between the engine/gearbox and the vehicle structure in a small-medium size car. The comparison takes place at the end-use level and focuses on the specific car part (e.g. the remainder of the car is outside the system boundaries).

The comparison shows that car part made of Technyl® enables to avoid emissions both because of lower emissions at the production phase, and because it reduces fuel consumption during the use phase (i.e. when driving the car) as a result of the reduced weight.

Full study available at: www.icca-chem.org/energy-climate

An engine mount housing

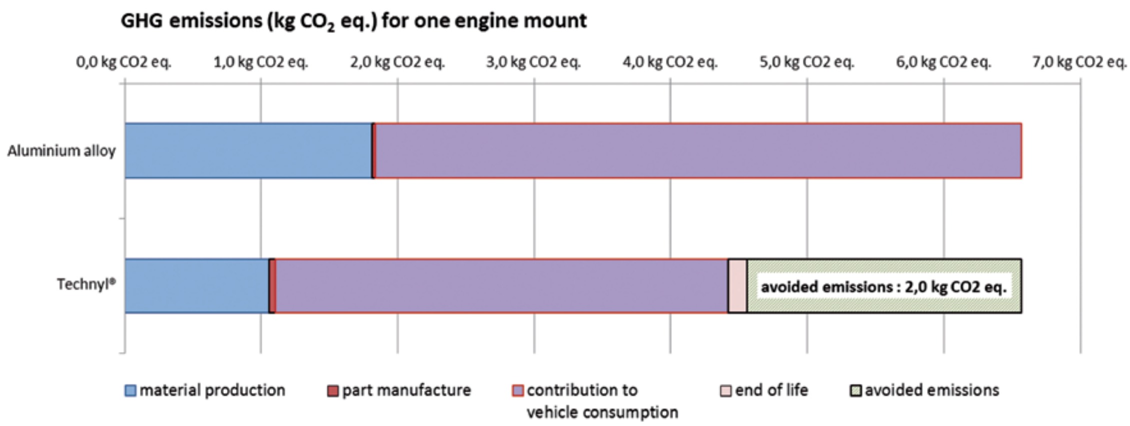


Technyl® versus aluminium alloy

Engine Mount
Al Si9 Cu3 alloy

Engine Mount
Technyl® A218V50 Bk 21N
Polyamide 6.6 compound (50% glass fiber)

Avoided emissions over the life cycle of an engine mount housing: comparing Technyl® with the reference (metal alloy).



Broiler production with feed additive DL-Methionine

A Sumitomo Chemical Co. Ltd. case study

SUMITOMO CHEMICAL

Since methionine is the first limiting amino acid in broiler feed, the supplementation with DL-Methionine plays a key role to reduce nitrogen content in broiler feed.

Reducing the nitrogen content in the feed is an effective way to reduce nitrous oxide (N_2O) emission - which has a greenhouse effect around 300 times greater than carbon dioxide - during manure management process, by decreasing nitrogen excretion of the animals.

In this case study, two options for broiler feed with different protein contents are compared in life-cycle GHG emissions: a study feed supplemented with DL-Methionine and a control feed without DL-Methionine. Both feeds satisfy the nutrient requirements of the animal for adequate growth.

The life cycle assessment case study shows that, while having a slightly higher impact in the raw material production, supplementing feed with DL-Methionine results in avoided emissions over the life cycle as a result of reduced nitrogen excretion. The estimated contribution of the studied feed to GHG emission reduction amounts to 0.114 kg CO_2e per kg of broiler meat, based on the difference in life-cycle GHG emissions between the two feed options.

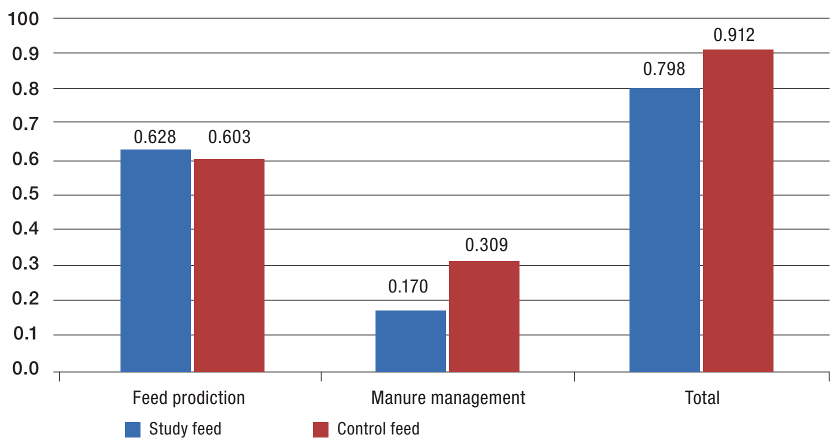
The overall contribution to GHG emission reduction in Japan is forecasted to amount to 161.77kt CO_2e in 2020.

Full study available at: www.icca-chem.org/energy-climate

GHG emission and reduction contribution (kg-CO_2e/Kg-Broiler meat)

Control feed - Study feed = 0.114 (kg-CO_2e/kg -broiler meat)

Study feed vs Control feed CO_2equiv. emission on production and manure management step and that descrepancy



A comparative life cycle study of three fouling control systems for marine vessels

An AkzoNobel case study

Intersleek 1100SR is a biocide-free fluoropolymer fouling control system, which improves the coating's performance compared to the silicon based fouling control system Intersleek 700 and the biocide fouling control system Intersmooth 7460HS.

Intersleek 1100SR ensures lower surface hull roughness, better coefficient of friction and better foul release properties, which relatively to the Intersmooth 7460HS system, leads to reduced fuel consumption and avoided in-service emissions of up to 9%. This lifecycle study covers the vessel's full life-cycle. Fuel and lube oil consumption have been considered separately.

The settlement of fouling organisms on the underwater hull is well known to adversely influence the fuel consumption of vessels. A layer of slime (multi-culture comprised of bacteria and phytoplankton) is said to result in increased fuel consumption of between 2%-10%, weed growth in the region of 10%-30%, and animal growth (such as tubeworms or barnacles) in excess of 40%.

This study focuses on three products:

1. Intersleek 1100SR, a biocide-free fluoropolymer fouling control system;
2. Intersleek 700, a silicon-based fouling control system;
3. Intersmooth 7460HS, a widely used biocide fouling control system.

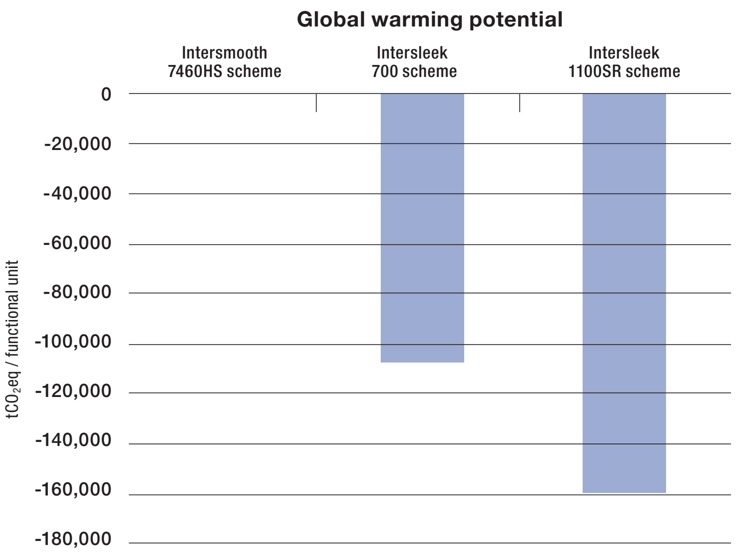
Differences in fuel consumption between the considered solutions by far outweigh environmental impacts from production, distribution, application, maintenance and end-of-life. The ratio between the emissions to create the solution and the avoided emissions during use can be up to 600:1, and only slightly differs between solutions (1) and (2).

Full study available at: www.icca-chem.org/energy-climate

GHG emissions during the entire life cycle of fouling control system

Avoided emissions relative to the reference system

Functional unit for the 3 systems considered: travelling 2,365,200 nautical miles of a 300 meter long container ship, with an underwater area of 12,000 m^2 and a loading capacity of 70,000 dead weight tonne, during 15 years of operation, including 3 maintenance cycles.



	Intersmooth 7460HS scheme*	Intersleek 700 scheme*	Intersleek 1100SR scheme*
Production of ingredients	-	- 81	- 84
Trp of ingredients and thinner	-	- 12	- 12
Paint and thinner manufacturing	-	- 2	- 2
Containers manufacturing	-	- 3	- 4
Trp of paint and thinner	-	- 3	- 3
Application NB	-	- 33	- 31
In service	-	- 106,550	- 159,819
M&R and removal	-	- 106	- 105
Waste treatment end of life	-	-	-
SUM	-	- 106,790	- 160,060
Avoided emissions (rel.)	0%	- 4%	-6%

* Unit: tCO_2eq / functional unit

The Green Sense® Concrete solution – optimizing concrete mixtures by reducing cement content

A BASF case study

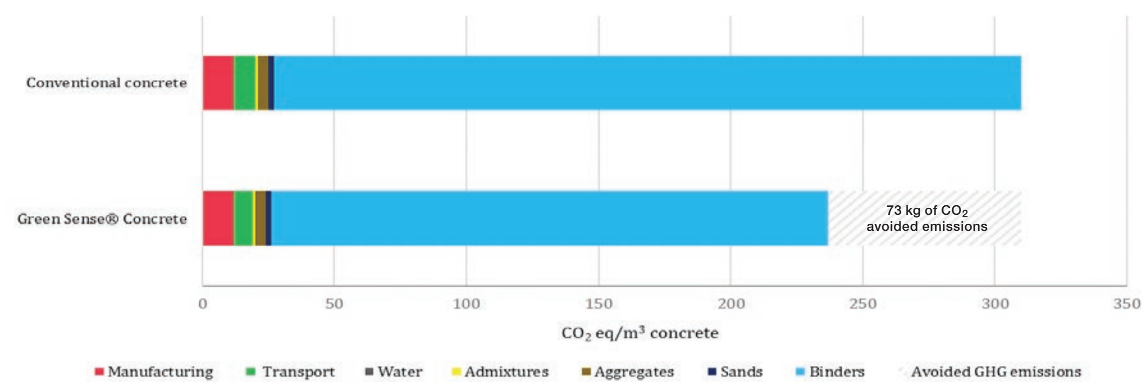
Concrete is generally produced from a mixture of paste and aggregates. The paste is composed of cement and water and coats the surfaces of the fine and course aggregates. Chemical admixtures are added to modify or improve specific concrete properties. The cement production process results in high levels of greenhouse gas (GHG) emissions. The Green Sense® Concrete optimization process from BASF offers an environmentally preferable concrete solution that meets and often exceeds performance targets.

Cement, a fundamental component of concrete, generates a large carbon footprint during its production from the two processes of combustion and calcination. The life cycle assessment study compares the environmental impacts of a conventional concrete mixture with an optimized Green Sense® Concrete mixture. This optimized mixture incorporates cement replacement materials and innovative concrete admixtures without impacting the required fresh and hardened concrete properties. The avoided GHG emissions associated with this optimized Green Sense® Concrete mixture are 73 kg CO_2 eq/m³ of concrete. For a project requiring 100,000 m³ of concrete, this example would result in over 7.3 million tons of avoided CO_2 emissions. In addition to a reduction in GHG emissions, the Green Sense® Concrete mixture also shows lower environmental impact in ozone depletion and human toxicity.

Full study available at: www.icca-chem.org/energy-climate

432 Park Avenue Tower built with Green Sense® Concrete. It is the tallest residential tower in the western hemisphere.

Cradle-to-gate GHG emissions per m³ of Green Sense® Concrete mixtures in comparison to conventional concrete



Rigid containers for chocolate drink powder in Brazil

A Braskem case study

Replacing tinplate rigid containers with polypropylene containers for chocolate drink powder in Brazil can lead to a 56% reduction in GHG emissions.

Considering the Brazilian market size in 2010, a full replacement of tinplate containers by polypropylene containers could lead to total GHG reductions by 10 ktonCO$_2$e.

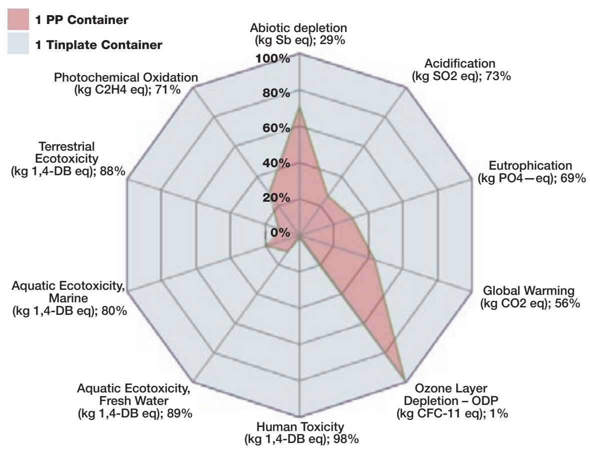
241 million tinplate containers for Chocolate Drink Powder were sold in 2010 on the Brazilian market. In the same year, 87 million polypropylene containers were used to package the same product.

Life cycle GHG emissions for tinplate containers amount to 0.21 kgCO$_2$e/container whereas polypropylene containers are responsible for a total emission of 0.09 kgCO$_2$e/container. The majority of GHG emissions in the life cycle of these containers are concentrated in the raw material (polypropylene or tinplate) production and processing.

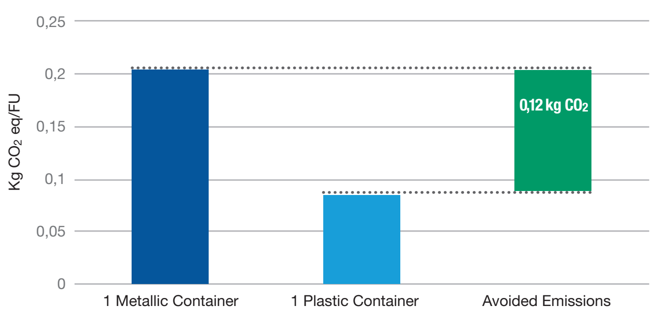
No trade-offs in other environmental impact categories were found in the full Life Cycle Assessment study that supports this case-study as can be seen.

Full study available at: www.icca-chem.org/energy-climate

Full Life Cycle Impact Assessment Profile
Comparative full environmental profile of polypropylene containers as compared to tin containers (100% = tin containers) showing the absence of trade-offs.



Scenario Analysis



Life Cycle Stage	1 Plastic Container kCO$_2$/400g of chocolate powder	1 Metalic Container kCO$_2$/400g of chocolate powder
Raw Material	0.06	0.12
Manufacturing/Processing	0.02	0.10
Transport	2.54E-03	5.11E-03
End of Life/Disposal	3.82E-03	-0.02
Total	0.09	0.21
Avoided Emissions	0.12	

Alternative product distribution logistics and greenhouse gas emission reduction

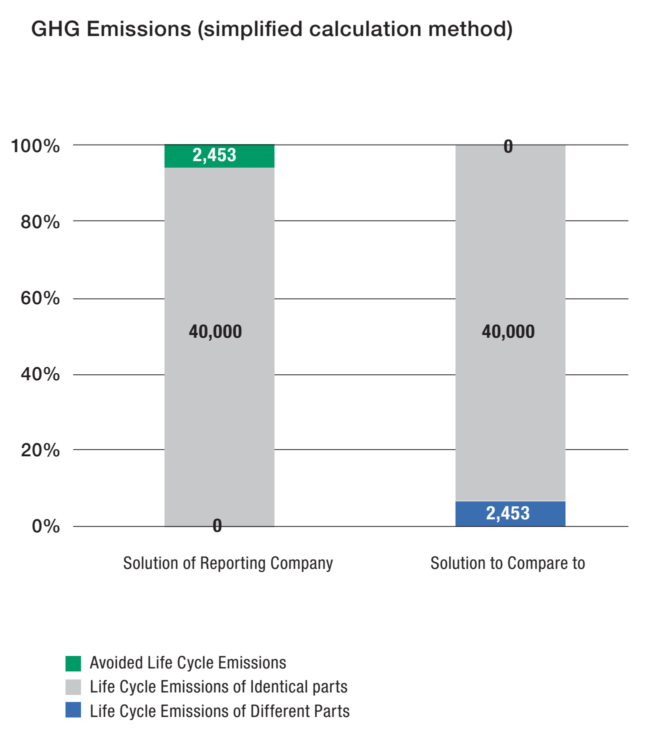
An Eastman Chemical Company case study

A study has been carried out to characterize the avoided emissions associated with an innovative mode of chemical product distribution logistics between Eastman and other chemical company partners, called "Alternate Methods of Supply" (AMS). This study was initiated and performed by Eastman Chemical Company to better understand the life cycle impacts of the Eastman supply chain, and of distribution swaps between 2 chemical companies.

AMS can be used when two chemical companies produce a practically identical and mutually interchangeable chemical product in two separate geographic regions. If both companies are willing to engage in AMS then a specific quantity of chemical product to be sold can be swapped in order to reduce the amount of inter-continental transportation required to distribute that product to customers. Such a swap takes place under a bilateral agreement and represents an alternative method of shipping as compared with standard shipping methods where each company distributes its own products globally.

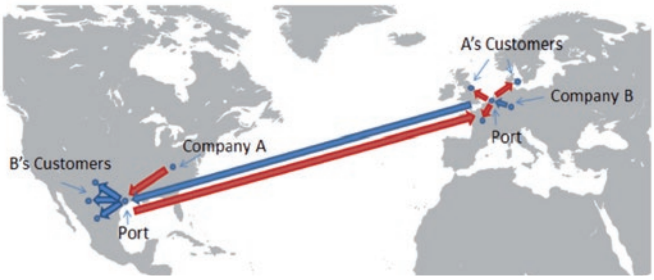
This study shows that such bilateral agreements do contribute to significant reductions in greenhouse gas emissions. For the yearlong period studied, an estimated 2,450 tonnes of CO_2 equivalent emission were avoided as compared against conventional logistics. The simplified assessment approach recommended by the WBCSD/ICCA guidelines has been used to calculate the difference between the 2 different distribution patterns.

Full study available at: www.icca-chem.org/energy-climate



How to save shipping using bilateral agreements

The map shows the transportation routes using conventional methods (left) and bilateral exchanges (right). The names of Eastman's AMS partners and the chemical products being distributed and swapped, are confidential.



Feed additives - DL-Methionine, L-Lysine, L-Threonine, L-Tryptophan and L-Valine in broiler and pig production

An Evonik case study

Supplementing animal feed with essential amino acids can save significant amounts of feed raw materials, resulting in minimized use of arable land for crop production and thus, fewer CO_2eq emissions.

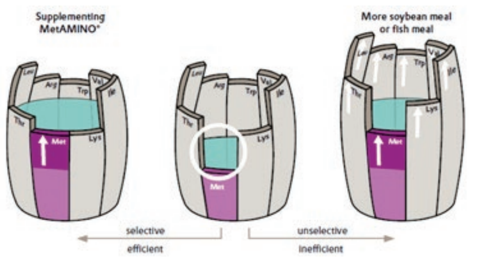
Furthermore, feed supplementation with these essential amino acids reduces both nitrogen and greenhouse gas emissions resulting from feeding and excretion.

Animal feed is specifically formulated to meet the physiological nutrition needs of animals, particularly the necessary shares of essential amino acids. Lack of certain amino acids in animal feed can be compensated either by adding a higher percentage of protein-rich feed components such as oil seed, or by fortifying the feed with essential amino acids produced by Evonik for this purpose.

In this case study, a supplemented feed mix incl. cristalline amino acids is compared to two non-supplemented feed mixes based on soybean as protein rich feed ingredient in one case and soybean and rapeseed in the second case. This is conducted for both animals, broiler and pigs. This study presents an update of Evonik's LCA on feed additives from 2011, now including L-Valine (ValAMINO®) as fifth limiting amino acid in addition to DL-Methionine (MetAMINO®), L-Lysine (Biolys®), L-Threonine (ThreAMINO®) and L-Tryptophan (TrypAMINO®).

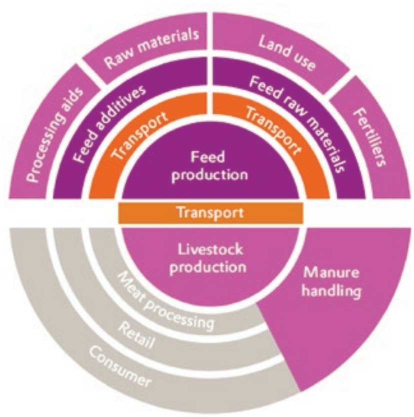
Full study available at: www.icca-chem.org/energy-climate

The barrel of Liebig, an example to overcome the limiting minimum



The example is explained through the specific lack of methionine in a typical broiler diet. The deficiency of methionine (barrel in the middle) can be balanced either through additional consumption of feed (barrel on the right side) or specific supplementation with pure MetAMINO® (Barrel on the left side).

System boundaries – Availability of primary data for modeling the individual scenarios for the functional unit

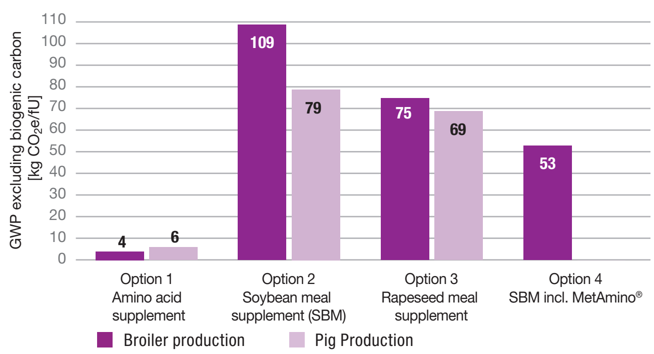


Out of scope of the LCA study, no share of influence

Indirect influences, usage of secondary data within LCA study

Direct influence, usage of primary data in LCA study

Global Warming Potential GWP100 [CML2001] excl. biogenic carbon of broiler and pig production



Broiler production

The global warming potential of the supplemented feed mix for broiler production shows lower environmental impacts due to substitution of protein rich feed ingredients like oil seeds by feed ingredients with lower crude protein contents. Option 4 shows the reduction potential by supplementing MetAMINO® only. The portion of soybean meal originating from land that has undergone land use change has a significant influence on the extent of GWP.

Pig production

The global warming potential of options 2 and 3 with oil seeds as source for the additional amino acids have a higher GWP than the supplemented feed mix option 1. The portion of soybean meal originating from land that has undergone land use change has a significant influence on the extent of GWP.

Renewable Polyethylene based on HVO (Hydrotreated Vegetable Oil) diesel

A SABIC case study

A Life Cycle Assessment study evaluated GHG emissions linked to polyethylene produced via two renewable routes: 1. Waste animal fats based renewable diesel and 2. Palm oil fatty acids based renewable diesel. These are compared with fossil naphtha route to produce polyethylene. Results indicate that the animal fats based route leads to a significantly lower carbon footprint than the fossil route. For the palm oil route, complete capture of methane emissions during palm oil processing is critical to ensure lower carbon footprint. Likewise, palm oil plantation must not have been associated with recent land transformation (forests to plantation) for it to have lower GHG emissions than the fossil route.

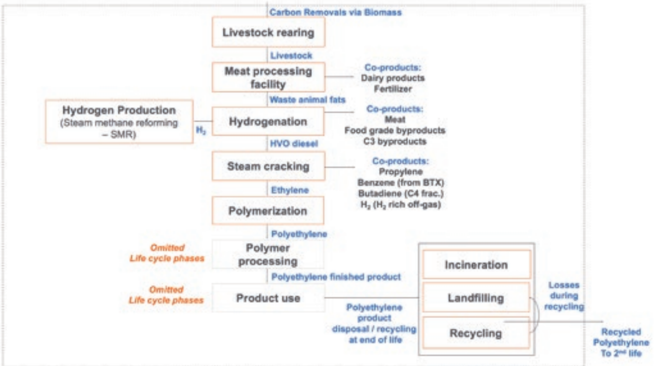
In the quest towards GHG mitigation, recent advancements in climate science warn of a dire need for drastic acceleration of efforts and significantly steeper reduction in global GHG (Green House Gas) emissions. SABIC has developed a renewable polyethylene product that is produced based on renewable feedstock for ethylene production via steam cracking prior to subsequent polymerization of the produced ethylene to polyethylene. Renewable feedstock for the cracker is Hydrogenated Vegetable Oil (HVO) diesel, which is produced from hydrogenation of waste animal fats. This feedstock does not interfere with food chains. On the other hand, it offsets requirement for fossil naphtha feedstock for the cracker on a proportional scale.

The study shows that polyethylene based on waste animal fats can lead to substantial avoided emissions. In parallel, the study shows that the palm oil based route may have avoided emissions potential but only if 00% or near 100% of the methane is captured.

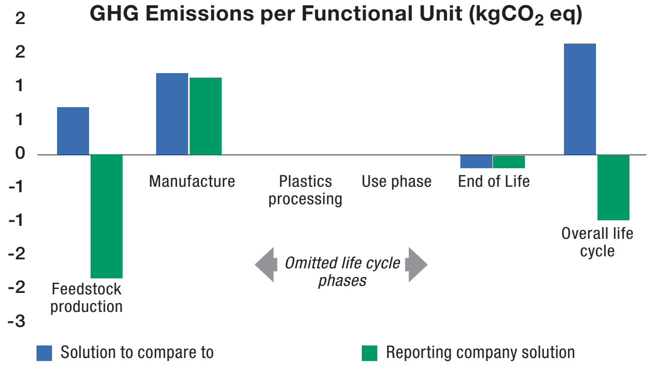
The significance of contribution of the chemical product (polyethylene in this case) to avoided emissions along the value chains is assessed to be "extensive" according to ICCA's guidance criteria. Use of renewable feedstocks towards production of polymers that are recyclable at end-of-life is a good example of circular economy concept and it can provide important advantages in terms of GHG mitigation.

Full study available at: www.icca-chem.org/energy-climate

Product life cycle schematic of Polyethylene from waste animal fats



Avoided Greenhouse Gas Emissions over the lifecycle of renewable polyethylene based on waste animal fats versus conventional fossil naptha route



The avoided CO_2e emissions per functional unit			
Emissions per life cycle phase (kg CO_2 eq.)	Reporting company's solution (renewable polyethylene)	Solution to compare to (fossil polyethylene)	Avoided Emissions kg CO_2 eq./functional unit
Feedstock production	-1.88	0.68	2.56
Manufacture	1.13	1.18	0.05
Plastics processing	0	0	0
Use phase	0	0	0
End of Life	-0.24	-0.24	0
Overall life cycle	**-0.99**	**1.62**	2.61

Double-glazed windows in buildings and contribution of sodium carbonate in avoiding greenhouse gas emissions

A Solvay and AGC Glass Europe case study

GHG emissions can be avoided by replacing existing single glazing with double glazing windows in houses in Europe. Overall estimated avoided emissions resulting from such replacement amount to 3,400 kg CO_2 eq. per m² of glazing over a 30 year service lifetime.

Extrapolation to the real European market gives a figure of 360 million tonnes CO_2 emissions that will be avoided for every single year of replacement of windows in Europe. The contribution of sodium carbonate, a key raw material for glass, is essential to avoid these emissions. Its quantification relies on specific assumptions.

The contribution of sodium carbonate is "extensive" according to the ICCA/WBCSD guidance, because this chemical is an indispensable raw material to make glass.

For every m² of double glazing, sodium carbonate can be estimated to be responsible for 19% (441 $kgCO_2$) of the total avoided emissions thanks to double glazing (2,322 $kgCO_2$), assuming a mass allocation, and excluding the effect of the low e-coating (1,092 kg CO_2). On the basis of the selected assumptions (presented in the full study), sodium carbonate can be estimated to contribute 90 kg CO_2 avoided for every kg emitted during its manufacturing for this market.

Overall calculated avoided emissions would of course be affected if the ratio of renewable low carbon energy in the European mix would significantly increase in the coming 30 years.

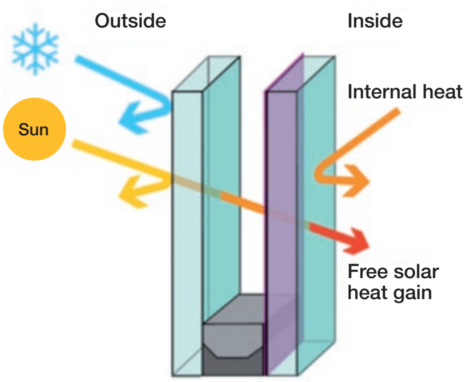
Full study available at: www.icca-chem.org/energy-climate

Double glazing unit with a low-e coating

The computation of energy consumption for house heating is based on hypotheses representative of the 6 European representative zones considered: (North (Helsinki), Central Maritime (Brussels), Central Continental (Frankfurt), Central (Prague), South Central (Sofia), South (Roma).

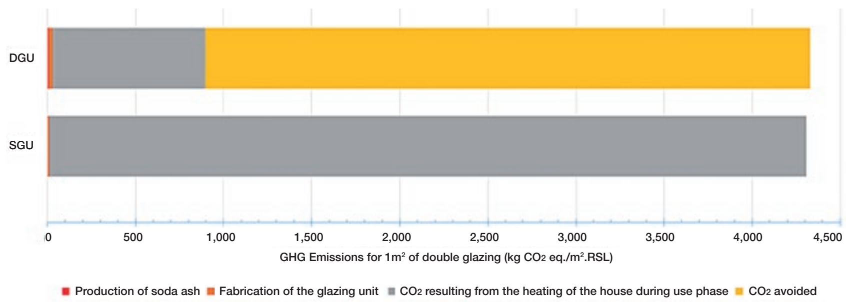
It takes into account:
- Distribution of outside temperatures (meteorological data),
- Energy mix for heating housing buildings.

Source: Glass for Europe



GHG emissions during the entire life cycle of glazing (DGU = double glazing / SGU = single glazing)

The figure highlights the emissions avoided during 30 years when substituting 1m² of single-glazed windows by 1m² of low-e coated double-glazed windows in European houses.



100% Bio-based Polyethylene Terephthalate (PET)

A Toray case study

In shifting towards a low carbon and oil independent society, plastic products from non-petroleum based feedstocks are desired, while innovation in petroleum usage as energy sources has been progressing. Toray's solution is the 100% bio based polyethylene terephthalate (PET) for materials of polyester fibers, which are one of the most widely-used textiles in the world.

The study compares the lifecyle GHG emissions of one kilogram of two alternative kinds of PET as the material to make polyester textile products. Toray's solution is a 100% bio based PET, while the reference solution to compare to is the conventional petroleum based PET.

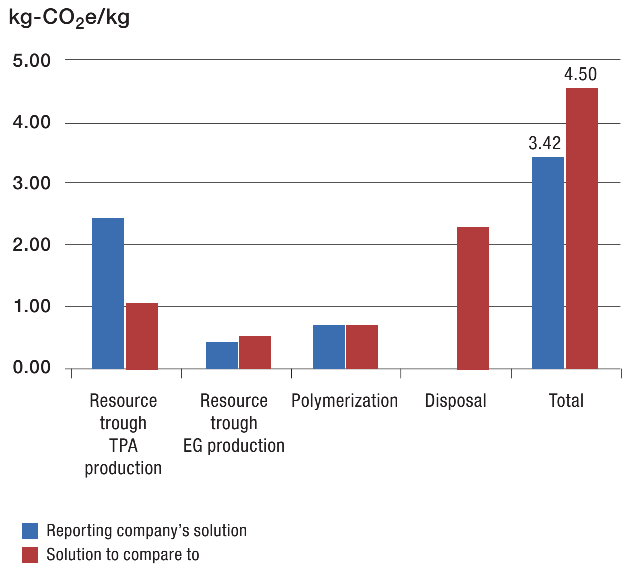
In the base case calculation, the feedstock for the raw materials of the reporting company's solution are: sugarcane in Brazil and India, and corn in the USA. While the raw materials of the solution to compare to are from petroleum.

The avoided emissions in the base case amount to 1.08 $kgCO_2e/kg$ of PET. The carbon neutrality of bio based carbon in incineration of the disposal stage contributes to the reduction of emissions.

The possible impact of the land use change due to bio-based feedstocks has been estimated at 15.1 m^2 of cropland during a year to produce the bio based feedstock for 1kg of PET.

Full study available at: www.icca-chem.org/energy-climate

GHG emissions of reporting company's solution and solution to compare to by process ($kgCO_2e/kg$-PET)



	Reporting company's solution	Solution to compare to
Resource through TPA production	2.39	1.04
Resource through EG production	0.37	0.50
Polymerization	0.67	0.67
Disposal	0	2.29
Total	3.42	4.50

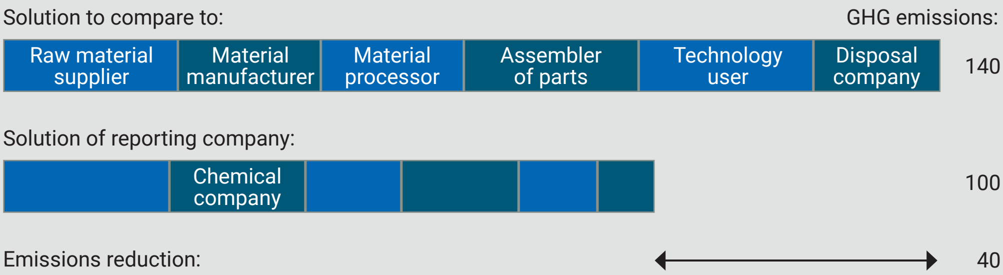
Calculating avoided emissions: the ICCA/ WBCSD guidance

Life cycle approach

The chemical industry contributes to almost every modern technology and has long been developing innovative products that improve sustainability. With that in mind, the industry supports the use of life cycle assessment (LCA) methodologies because these enable the assessment of the environmental impact of products and technologies over their complete life cycle, including production, use and end-of-life handling. As such, they are critical to assessing – and ultimately improving – sustainability.

Greenhouse gas (GHG) emissions are one of the many environmental impacts that LCAs can quantify. By comparing GHG emissions along the life cycle of two alternative products of equal benefit to users, we can understand which technology avoids GHG emissions, improving sustainability. LCA standards help to improve the quality and reliability of these assessments.

A reduction in GHG emissions is represented by the difference between the life cycle emissions from the solution of the reporting company and the solution to compare to



The WBCSD/ICCA guidance: version V1 and V2

The consistent measurement and reporting of LCAs increases credibility and comparability of the results, leading to better decision making by stakeholders along the value chain. Measuring avoided emissions of GHG over the value chain of products in particular, is an area where consistency of approach is essential. But, it has often given rise to debate among stakeholders. To address these concerns, in early 2012 the World Business Council of Sustainable Development (WBCSD) Chemical Sector project “Reaching Full Potential” and the International Council of Chemical Associations (ICCA) the formed a taskforce to develop practical guidelines to improve consistency in the assessment and reporting of avoided emissions.

These guidelines have been updated in 2017. They are aimed at improving reporting consistency across the industry. In the future, it is our intention to engage other stakeholders in the value chain so as to further improve the guidelines and the quality of the methodology. We believe this is an important step in improving the sustainability of our society.

Content of the guidance

The guidance describes how to carry out and communicate on avoided emissions calculation, in terms of: Purpose of study, Function of the product/application, data Quality requirements, and consistency of Functional unit between the solutions that are compared. The guidance addresses very important questions such as how to select the reference solution to be compared to, or the necessity of quantifying scenarios of future developments and their uncertainties.

Directions are given on how to qualitatively and quantitatively describe the contribution of a chemical product to value chain avoided emissions to individual value chain partners.

Indeed, Life cycle avoided emissions almost always result from efforts of multiple partners along the value chain. Therefore, avoided emissions calculated shall always be first attributed to the complete value chain. However, criteria to categorize the significance of the contribution of chemical products to such value chain avoided emissions as “fundamental”, “extensive”, “substantial”, “minor” or “too small to claim” are defined

The ultimate objective of life cycle thinking and calculation is to ensure that robust life cycle assessments are at the core of the solution we choose.

Acknowledgements

The case studies in this report were offered by ten companies and two associations. ICCA would like to thank the people that have been involved in the avoided GHG emissions case studies project, in particular the ICCA Energy and Climate Change Leadership Group / cLCA Task Force Co-chairs: Michel Bande (Solvay), Motozo Yoshikiyo (Japan Chemical Industry Association) (2nd phase), and the cLCA Task Force Participants: Yuki Hamilton O. Kabe (Braskem S.A.); Michael H. Mazor (The Dow Chemical Company); Barclay Satterfield, Jason Pierce and Lauren Johnson (Eastman Chemical Company); Abdelhadi Sahnoune (ExxonMobil Chemical Company); Rob van der Heijden (Shell Global Solutions International B.V.); Pierre Coërs (Solvay); Hiroyuki Kamata (Toray Industries, Inc.); Kiyoshi Kasai and Reiko Nonaka (Japan Chemical Industry Association).

ICCA would also like to thank the other people who have been involved in the development of the case studies, and in particular: Klas Hallberg (Akzo Nobel), Nicola Paczkowski (BASF), Yuki Hamilton Onda Kabe (Braskem), Christina Merz (Evonik), Randy Waymire and Jason Pierce (Eastman Chemical Company), Rakesh Bhartia (India Glycols), Makoto Terauch (Japan Chemical Industry Association), Rajesh Mehta and Ananda Sekar (SABIC), Jean-François Viot (Solvay) and Guy Van Marcke (AGC Glass Europe), Jiro Mori (Sumitomo Chemical).

Ecofys has reviewed the first series of cLCA case studies that were published on the ICCA website in December 2015, while Quantis has reviewed a second series of case studies in 2016, to check if they are in compliance with the ICCA & WBCSD guidelines "Guidelines from the chemical industry for accounting for and reporting greenhouse gas (GHG) emissions avoided along the value chain based on comparative studies". ICCA would like to thank Annemarie Kerkhof and Karlien Wouters of Ecofys and Sebastien Humbert from Quantis for their review of the case studies and advice on their quality.

We would also like to thank Pierre Coërs (Solvay) in his role as Chair of the cLCA Task Force (3rd phase) for coordinating the case study project, and Nonaka Reiko for her active support.

Our call

Business and policies required to realise potential savings along the value chains

Actions to deliver the potential emissions savings the chemical industry can enable will need to focus on:

- Joint cooperation and action from all partners in the value chain.
  - As the contribution of the chemical industry occurs alongside that of others.

- An enabling policy environment that:
  - Stimulates emission reductions along the value chain including use and end-of-life phases.
  - Promotes technology-neutral policies which enable cost-effective renewable energy.
  - Encourages renewables while also ensuring a reliable, affordable and consistent supply of electricity.
  - Provides financial support for innovation development but once commercialised integrates them into normal market conditions.
  - Sets energy efficient standards, encouraging manufacturers to provide clear information and taking action to raise public awareness.

- Novel business models
  - Pilot projects, LCA studies, R&D investment, value chain cooperation from architects to craftsmen.

In order to unlock its potential for emissions avoidance the ICCA, the voice of the global chemical industry, calls for:

- Recognition by governments, regulators, value chains and their aligned industries that the future is cross sectoral.
- An enabling regulatory environment endorsed and mandated at inter-governmental level.
- Action demanded of all partners in the value chain in realising the potential avoided emissions.
- Incentives for investment in pilot projects and R&D to deliver novel business models.
- Financial support focused on development of pre-commercial innovative technologies.
- All technologies should have equal access to market, gradually, removing subsidies as soon as the technology is commercial.

About the International Council of Chemical Associations (ICCA)

The International Council of Chemical Associations (ICCA) is the worldwide voice of the chemical industry, representing chemical manufacturers and producers all over the world. Responding to the need for a global presence, ICCA was created in 1989 to coordinate the work of chemical companies and associations on issues and programs of international interest. It comprises trade associations representing companies involved in all aspects of the chemical industry.

ICCA is a chemical industry sector with a turnover of more than 3,600 billion euros. ICCA members (incl. observers & Responsible Care members) account for more than 90 percent of global chemical sales.

ICCA promotes and co-ordinates Responsible Care® and other voluntary chemical industry initiatives. ICCA has a central role in the exchange of information within the international industry, and in the development of position statements on matters of policy. It is also the main channel of communication between the industry and various international organizations that are concerned with health, environment and trade-related issues, including the United Nations Environment Programme (UNEP), the World Trade Organization (WTO) and the Organisation for Economic Co-operation & Development (OECD).

ICCA operates by coordinating the work of member associations and their member companies, through the exchange of information and the development of common positions on policy issues of international significance. Three main issues focused on by ICCA are: Chemicals Policy & Health, Climate Change & Energy, Responsible Care®.

ICCA also serves as the main channel of communication between the industry and various international entities, such as inter-governmental organizations (IGOs) and NGOs that are concerned with these global issues.

www.icca-chem.org

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