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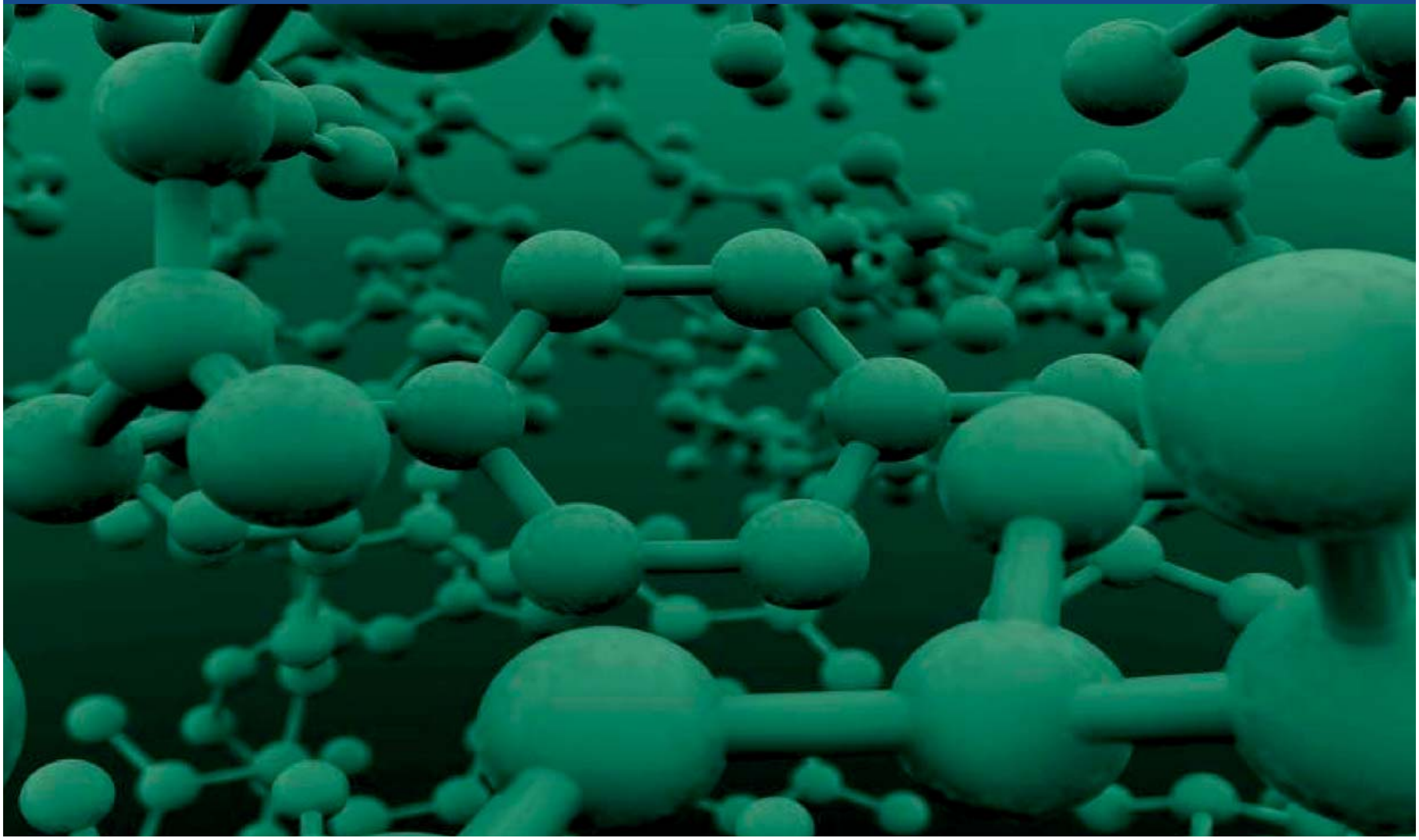

Innovations for Greenhouse Gas Reductions

A life cycle quantification of carbon abatement solutions enabled by the chemical industry

ICCA INTERNATIONAL COUNCIL OF CHEMICAL ASSOCIATIONS

Responsible Care®
OUR COMMITMENT TO SUSTAINABILITY

July, 2009

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Contents

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Foreword

The chemical industry is one of the world's largest. In 2008, its sales exceeded $3 trillion. Chemical products and technologies are used in almost every area of the world economy. As the global economy grows, it increases the demand for the chemical industry's products. This growth drives product innovation, and the industry creates new products every year while striving to improve production processes and use resources more efficiently.

Chemical products have a twofold effect on greenhouse gas emissions (GHGs): GHGs are emitted in the manufacturing of chemical products, whilst at the same time the use of many of these products enables significant reduction in global emissions. The emissions reduction enabled by the use of these products can be far in excess of the amount of GHGs emitted during their production. As explained in this report, the best illustration of this impact is insulation. High-performance foam insulation of a house significantly reduces the heating required, thereby reducing energy consumption and GHG emissions.

The **International Council of Chemical Associations** (ICCA) is the worldwide voice of the chemical industry. Amongst other initiatives, ICCA promotes and co-ordinates Responsible Care®, a voluntary program that commits the chemical industry to continuous improvement in all aspects of health, safety and environmental performance. ICCA also is committed to open communication about its activities and achievements.

In line with Responsible Care®, the chemical industry recognizes its responsibility to contribute to efforts to mitigate global warming. The industry's goals in this regard are to reduce its own emissions by improving its processes and to encourage the use of chemical products that create a net emission reduction along the value chain.

ICCA has commissioned this work as one step towards achieving these goals, and as another tool to provide transparency on the chemical industry's role in reducing GHG emissions. The report's objective is to provide reliable, independently verified facts and analyses upon which the industry and regulators can base decisions that improve chemicals' emissions impact. It analyzes the chemical industry's global GHG emission impact "from cradle to grave", i.e., through the entire life cycle of the chemical products and the applications in which they are used. The chemical industry is the first global industry to embark on such an initiative.

ICCA would like to thank **McKinsey & Company**, which was commissioned for their independent analytical contribution to the analyses and their overall project management, which included guidance on methodology and 2030 scenario modeling. ICCA also thanks the **Öko Institut** in Germany for conducting a critical review of the Carbon Life Cycle Analysis (cLCA) work and reviewing the cLCA calculations. This effort would also have been impossible without the knowledge and insights of many who supported the ICCA common views and played an active role in providing the necessary product and application information. The policy implications and recommendations in Chapter 4 that are also summarized elsewhere are solely the views of the ICCA.

		米倉弘昌
Christian Jourquin	David Weidman	Hiromasa Yonekura
President of Cefic	Chairman of ACC	Chairman of JCIA

Review statement

The International Council of Chemical Associations (ICCA) commissioned Öko-Institut to contribute to this project and to support McKinsey & Company. Öko-Institut's specific role was to conduct a critical review on the Carbon Life Cycle Analyses (cLCA). These cLCA calculations have been used in the project in order to quantify the CO_2e emissions of selected chemical industry products over their whole life cycle in comparison to non-chemical industry product emissions and to assess the differences regarding in-use emissions due to performance difference between chemical and non-chemical products. The results of these calculations are presented in this study in two ways, the gross savings ratio and the net emission abatement.

Although the international standards for Life Cycle Assessment - ISO 14040:2006 and 14044:2006 – are not applicable directly to the method being used in this project, the critical review was based on the main guiding principles laid down in the standards quoted above. Accordingly the critical review process shall ensure that:

- the methods used to carry out the cLCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified, and
- the documentation of the cLCAs is transparent and consistent.

With regard to this statement, two items have to be taken into account.

- On the one hand the following generally applies: a critical review can neither verify nor validate the goals that are chosen for a LCA by the study commissioner, nor the ways in which the LCA results are used. Thus it is not the role of the Öko-Institut to agree with the conclusions drawn in the review and with the recommendations given therein.
- On the other hand, the ICCA study consists of two parts which go beyond the cLCA work outlined above: in particular, two scenarios on the future development have been drawn up in the review (see Chapter 3) and policy implications have been presented (see Chapter 4). The calculations and findings in these chapters are not covered by this review statement and do not necessarily reflect the view of Öko-Institut.

The Critical Review has been conducted in close cooperation with McKinsey and the enterprises of the chemical industry which have been closely involved in preparation of the individual case studies and which have carried out some of the case studies under examination. In this respect, it has to be emphasised that everyone involved has adequately reacted on inquiries and comments on behalf of Öko-Institut and has been available at any time for questions and further information. In summary, Öko-Institut arrives at the conclusion that the cLCAs taken as basis for the review are methodically state-of-the-art with regard to science and technology of LCA and that the data taken as a basis are adequate with view to the applications provided in this case. It has to be added that an international standard on calculation of Product Carbon Footprint (PCF) does not exist yet; thus the results gained here have to come under scrutiny again as soon as such a standard does exist. The appendix offers a good overview over the data forming the basis of the review and over the crucial assumptions. Only the time-related coverage might have been better documented. A more detailed critical acclaim of individual cLCAs relevant with view to the overall result, is presented on the ICCA website.

Hence, the following comments focus on detected restrictions which have to be considered when assessing the results and arriving at conclusions and recommendations:

At the scenario case of "Fertilizer & Crop protection", matters on productivity of areas under cultivation as carbon adhesion capacity in humus have been intensively discussed in dependence of the different cultivation methods. From the view of Öko-Institut, the related methodical and data-related questions could not be answered exhaustively in the framework of this project, hence the results in relation to the scenario case being particularly arguable. Öko-Institut appreciates these restrictions being detected and referred to in the report and supports the quantitative separation of this scenario on account of the state of the science-based knowledge, methodological uncertainties and missing empirical evidence.

The question to which sector of industry or player in the value chain the CO_2e savings of emissions moderated by the chemical products may be imputed, has been answered in this report on the basis of the enabling principle. From our point of view, however, it is problematic to impute specific shares of products' potential of avoidance to individual players as the life cycle of many products important for the protection of the climate crosses many sectors of industry and consumers and is dependent on various political ancillary conditions.

Therefore, it is difficult to separate accurately and reasonably the contribution of individual players from each other. Irrespective of this, however, one basic principle applies in any case and is supported by Öko-Institut: ultimately the ecological benefits of the products are internalised in the prices (e.g. insulation materials). Hence, it is impossible in an economic market system that producers still may impute the ecological benefits proprietarily, especially if beyond that financial implications may be deduced (cf. p. 21 of the report). In the end, only the consumers who have bought the product and who are their owners may claim this ecological benefit. They may claim for themselves to have paid with the purchase price for the CO_2e savings involved in the usage phase, too. As far as these savings are at the same time claimed by the chemical industry according to the enabling principle, double counting would result from this. For this reason the report clarifies that the industry is not making any direct financial claims for the savings it enables.

In some systems, the CO_2e savings are achieved over a longer period of time, for example for thermal insulation over a period of 50 years. Within this period, however, the reference systems relevant for the CO_2e savings are subject to technological change too (here especially heating in buildings including all energy upstream chains) which will bring about a higher energy efficiency and thus, in the variation of time, result in less CO_2e savings due to heat insulation. Against this background, the results at such scenario cases are to be perceived with high fluctuation margins. The reliability of tendency of the results for the savings potentials of the ten most important scenario cases, however, is hereby not affected.

In the ICCA review at hand, Öko-Institut perceives a first approach to quantify and specify as far as possible the contribution of important products groups produced by the chemical industry for CO_2e avoidance potential. Öko-Institut appreciates that thereby climate protection in the chemical industry is acknowledged higher significance and in the critical acclaim of this work by all societal players realizes the option to increase these contributions. Öko-Institut encourages an updating of this review in the foreseeable future in order to account for the results of discussion of this work and of new methodical findings on Product Carbon Footprinting as well as to validate the results at hand. Additionally, further analysis should focus on possible constraints when results from particular LCAs are extrapolated onto a global level.

Executive summary

Under the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC) has reviewed the scientific literature and concluded that a significant reduction of greenhouse gas emissions is necessary to slow the rate of growth in atmospheric concentrations of CO_2. The IPCC analysis highlights that to achieve emissions reductions on the scale necessary, the world economy will need to be rapidly "decarbonized", with action taken on all of the available abatement levers. In most cases, the required shifts in behavior are unlikely to happen on a sufficiently large scale without effective policies and regulations – hence the importance of providing policymakers with reliable facts on the impact of the available options and levers most relevant to the chemical industry.

The study drew on a wide range of published data and independently audited original research to calculate the chemical industry's impact on emissions in 2005. McKinsey then assessed how this impact would change in two scenarios to 2030, a "business-as-usual" (BAU) scenario and an alternative "abatement scenario". Both future projections were based on McKinsey modeling and their global GHG abatement cost curve work.

1. A ROBUST AND TRANSPARENT METHODOLOGY TO EVALUATE THE CHEMICAL INDUSTRY'S CONTRIBUTION TO THE DECARBONIZING OF THE WORLD ECONOMY

The study utilized a full life cycle CO_2e analysis to determine emissions linked to the chemical industry, from extraction of feedstock and fuel, through production, to disposal.

Further, to assess the impact of chemicals in enabling greater carbon efficiency throughout the economy, the study conducted "CO_2e life cycle analyses" (cLCAs)[1] for over 100 individual chemical product applications. These cLCAs span the major sectors of the industry and cover a representative portion of the CO_2e savings linked to chemical products. All the production emissions of the industry are included, whereas only the major portion of the in-use savings have been covered. Further cLCA work could therefore yield a higher level of savings than reported in this study.

The cLCAs compared the CO_2e emissions of a chemical industry product in a specific application with the next best non-chemical industry alternative that preserves current life style, through the extraction, production, in-use and disposal phases. For simplicity, the term chemical product is used to define a product that is produced by the chemical industry.

The report adopts two metrics to reflect the chemical industry's impact on carbon emissions. The first is a **gross savings (or X : 1) ratio**, where the amount of CO_2e saved through the use of a chemical product is measured against the amount of CO_2e emitted

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[1] Carbon Life Cycle Analysis; assessment that focuses only on the CO_2 equivalent emissions.

during that product's entire life cycle. The second metric is the **net emission abatement**, which represents the difference between the gross CO_2e savings enabled by its use and the CO_2e emitted during its own production including indirect and supply chain emissions and disposal. The term cLCA is used throughout the report to indicate CO_2e life cycle analysis.

Two alternative principles were applied in allocating CO_2e savings. In most cases, where chemical industry products play the enabling role in GHG abatement or provide the GHG saving component, 100 percent of the CO_2e savings were attributed to the chemical industry. In three cases where the use of the chemical industry product only contributed to an improvement in CO_2e emissions, savings based on the chemical's cost share of the overall product costs were attributed to the chemical industry. By adopting this approach the authors acknowledge that other parties with an enabling contribution to the same measure may adopt the same approach, which could then lead to multiple counting. The basis for this is explained in the methodology section. Allocations of abatement volumes differ from CO_2e accounting rules within carbon markets. This report is not intended to make any financial claims linked to these GHG savings.

2. TODAY'S IMPACT – THE CHEMICAL INDUSTRY'S CURRENT EMISSIONS, AND THE SAVINGS IT ENABLES

The chemical industry has improved its energy savings at manufacturing sites and in this regard reduced its GHG emissions over the last decades significantly as illustrated by the examples below:

- Between 1990 and 2005, chemical production in the EU rose by 60 percent, while total energy consumption was stable. This meant that the chemical industry has cut its energy intensity by 3.6 percent annually. Absolute GHG emissions, meanwhile, fell by almost 30 percent;
- The Japanese chemical industry reduced unit energy consumption by 2002 to 90 percent of the 1990 fiscal year level – eight years ahead of target. By 2006, further improvements meant that the performance achieved was 82 percent of the 1990 level;
- Since 1974, the US chemical industry has reduced its fuel and power energy consumed per unit of output by nearly half. Since 1990 the US industry's absolute GHG emissions fell 16 percent, a reduction that exceeds the target of the Kyoto protocol;
- The Brazilian association members reduced specific overall energy consumption between 2001 and 2007 by 25 percent while increasing overall production by almost 30 percent. By 2007, more than 50 percent of energy came from renewable sources. Total CO_2 intensity declined by 16 percent between 2001 and 2007.

In 2005, CO_2e emissions linked to the chemical industry amounted to about 3.3 GtCO_2e +/- 25 percent. The majority of these emissions, 2.1 GtCO_2e, were a result of the production of chemicals from feedstock and fuels delivered to the chemical industry.

An additional 1.2 GtCO_2e of emissions – included in this study in line with life cycle thinking – arose during the extraction phase of the feedstock and fuel material, and during the disposal phase of the end products.

Gross savings vary from 6.9 to 8.5 GtCO_2e depending on the scope and assumptions used[2]. This translates into a gross savings ratio of 2.1: 1 to 2.6 : 1. In other words, **for every GtCO_2e emitted by the chemical industry in 2005, it enabled 2.1 to 2.6 GtCO_2e in savings via the products and technologies it provides to other industries or users.**

Depending on the assumption and scope, the net CO_2e emission abatement enabled by the chemical industry's products across the economy amounted to 3.6 to 5.2 GtCO_2e +/- 30 percent in 2005. Net CO_2e savings refer to the difference in GHG emissions with and without the use of chemical products assuming no substantive changes to current life style. In other words, and compared to total global emissions of 46 GtCO_2e in 2005, **there would have been 3.6 to 5.2 GtCO_2e, or 8 to 11 percent, more emissions in 2005 in a world without the chemical industry.**

Taking account of current societal needs and the impact of a growing global population, these savings highlight the vital role of the chemical industry in decarbonizing the economy. In reality, achieving the equivalent CO_2e savings without the benefits of chemical products and technologies would not be possible.

The biggest levers evaluated for emissions savings enabled by the chemical industry were:

- **Insulation** materials for the construction industry, which reduce the heat lost by buildings and thus the use of heating fuel. Insulation alone accounted for 40 percent of the total identified CO_2e savings. This report did not address cooling applications where additional emission reductions in the building industry would be anticipated;
- The use of **chemical fertilizer and crop protection** in agriculture, which increases agricultural yields – so avoiding emissions from land-use change. Due to the uncertainties in land-use changes, yields, soil quality effects and modes of CO_2-binding and assimilation in different conventional and organic agricultural processes, this study adopts two scopes, one with and one without this case;
- Advanced **lighting solutions**: compact fluorescent lamps (CFLs), with longer lifetimes and greater luminous efficacy than incandescent bulbs, save significant energy;
- The seven next most important levers in 2005 were **plastic packaging, marine antifouling coatings, synthetic textiles, automotive plastics, low-temperature detergents, engine efficiency, and plastics used in piping.**

[2] The lower end of the range is due to an alternative study scope that excludes the fertilizer case as explained.

3. TOMORROW'S OPPORTUNITY – TWO MCKINSEY SCENARIOS TO 2030, AND CHEMICALS' POTENTIAL DECARBONIZING ROLE

The business-as-usual (BAU) scenario developed by McKinsey and shown in this study was characterized mainly by volume growth, assumptions for efficiency gains and regional production shifts. No additional regulatory push for low-carbon development is assumed in this case. The abatement scenario, which was derived from McKinsey's global GHG cost curve scenario, assumes aggressive implementation of measures leading to a low-carbon economy.

The **BAU scenario** model shows life cycle emissions linked to the chemical industry almost doubling. The number is essentially derived from doubling current emissions to 6.6 $GtCO_2e$, an additional 1.5 Gt due to increased production in countries which are relatively coal dependent for their energy partly offset by assumed BAU efficiency improvements of ~1.6 Gt. The net result from this modeling is global chemical industry linked emissions of 6.5 $GtCO_2e$ +/- 35 percent in 2030.

Depending on the assumptions and scope, the industry's gross savings ratio improves to approximately 2.7 : 1 to 3.1 : 1 in the BAU scenario. The net emission abatement enabled by use of the chemical industry's products will more than double to 11.3 to 13.8 $GtCO_2e$ +/- 40 percent under the BAU scenario.

In the **abatement scenario**, the McKinsey model assesses the full abatement potential across all sectors. This means that industries further reduce both their direct and indirect production emissions, and includes also a reduction of the carbon intensity of the utilized power. Under this scenario, the chemical industry's CO_2 intensity would fall by about 25 percent. Its emissions would be 5 $GtCO_2e$ +/- 35 percent. This equates to only a 50 percent increase on current emissions despite a greater than doubling of the production. However, this comes at significant cost at typical industry discount rates and payback periods. The CO_2 abatement costs for the final increments rise from about 50 to 150 €/t CO_2e. Thus a broadly accepted and global carbon price in the upper range would be one of the essential components to realize this scenario.

On the savings side, this scenario foresees a gross savings ratio of 4.2: 1 to 4.7 : 1 and a net emission abatement of approximately 16 to 18.5 $GtCO_2e$ +/- 40 percent. This scenario is thus also reliant on a greater use of insulation, high-efficiency lighting, lignocellulosic (LC) ethanol, solar and wind energy components, and carbon capture and storage (CCS).

The chemical industry's incremental abatement (composed of both own emissions and product savings) between the above two scenarios is 4.7 $GtCO_2e$. This corresponds to 12 percent of the 38 $GtCO_2e$ abatement opportunity identified in the GHG abatement cost curve published by McKinsey & Company in February 2009. This number assumes, of course, that all opportunities for abatement within the sector are met, and that all opportunities for abatement across the other sectors described in this report are realized. But within the context of these two conditions, the study underlines the important role of the chemical industry in global GHG reductions.

Beyond the savings projected for the abatement scenario, numerous industry innovations currently under development could further increase the chemical industry's net abatement potential. In addition to the technological abatement measures provided by the chemical industry, other measures including changes in consumption pattern will be needed to achieve the longer term aim of absolute global GHG reductions. Such behavioral changes linked to different consumption patterns are beyond the scope of this study.

4. POLICY IMPLICATIONS : OPTIMIZING THE CHEMICAL INDUSTRY'S ABATEMENT POTENTIAL

The emissions saving potential identified in this study will not materialize without effective policy and regulation. ICCA suggests the following guiding principles for consideration when devising policies directed towards a low-carbon economy:

- Develop a **global carbon framework** to accelerate GHG reductions, avoid market distortions and minimize carbon leakage[3];
- Focus first on the **largest, most effective, and lowest cost abatement opportunitiess**;
- Push for **energy efficiency,** as this is one of the largest and most cost efficient sources of CO_2e abatement, by providing incentives for the use of energy savings products and materials such as insulation;
- Support the development of **new technologies** that reduce energy consumption and abate CO_2e including new catalysts, new syntheses, process intensification & integration, use of Combined Heat and Power (CHP), and Carbon Capture and Storage (CCS). A portfolio of technology development initiatives will need to be accelerated, which will require public support and financing. This is most important during the research and demonstration phases. As technologies are commercialized, financial support should be reduced and finally removed to allow the market to work effectively;
- Support the development of the most efficient and **sustainable use of available feedstocks and energy** for the production of chemicals in conjunction with the development of the above mentioned process emission abatement technologies;
- Allow markets to incentivize fast action by **rewarding early movers** that proactively reduce their CO_2e footprint;
- Support the development of new technologies and practices that ensure the **most efficient and sustainable disposal, recovery and recycling** options are implemented;

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[2] Carbon leakage is the migration of production into non-regulated regions with higher production footprints, or substitution by less stringently regulated products with higher CO_2e footprints.

- Support a **technology cooperation mechanism** for the transfer, sharing and funding of abatement technology between developed and developing countries;
- Design the implementation of the above mentioned measures to complement a future carbon framework. The goal must be to produce GHG intensive products – taking the whole production value chain into account – as carbon efficiently as possible irrespective of the location. This future carbon framework should be designed to ensure this happens as cost effectively as possible;
- As the global framework is being developed, local policy should ensure that carbon burdens do not apply unilaterally within their regions thus avoiding market distortions and unintended consequences such as carbon leakage.

Introduction

The chemical industry is a highly competitive and essential business sector. It employs more than 3.6 million people and generates annual sales of well over $3 trillion. It is an innovative, high-tech industry whose products play a major role in the improvement of life, in areas as diverse as health, agriculture, clothing, construction, transport, and leisure.

This importance for society also brings responsibility. Slowing the rate of global warming by abating emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG) is an important challenge that will require changes in the way these societies produce, consume, regulate and behave. In recognition of this imperative, the ICCA has commissioned a study of the impact of chemicals on greenhouse gas emissions, with three objectives:

1. **Create a more data-based analysis** on the chemical industry's current impact on carbon dioxide equivalent (CO_2e) emissions – including the industry's production footprint, the effects of using its products, and the impact of disposal;
2. **Use the McKinsey 2030 methodology to develop a more data-based assessment** of the potential future contribution of the chemical industry to carbon efficiency, both through improvements in its own emissions and through solutions it provides to other industries and consumers;
3. **Provide orientation for decision makers** by highlighting which of the chemical industry's own improvements, and which of the savings induced by its products, have the optimal potential for emissions abatement in both cost and volume terms.

Energy is required to extract raw materials and transform them into the thousands of useful products made by the chemical industry. Hence, the industry's current emissions are substantial. If it is to improve its own emissions intensity, the industry will need to continue or even go beyond the efficiency improvement that it has recorded over the past 15 to 20 years.

That being said, the chemical industry also plays a vital role in reducing emissions by other industries and throughout the economy. Many chemical products enable GHG abatement, either because their production footprint is smaller than that of the non-chemical alternatives, or because their use results in fewer emissions than would be the case without their use or with non-chemical alternatives. Chemical-based building insulation products, for example, significantly reduce the energy needed to heat residential and commercial buildings.

The study attempts to quantify these effects.

This report summarizes the findings of the study and is structured in four chapters:

- **Chapter 1,** “A robust and transparent methodology to evaluate the chemical industry’s contribution to decarbonizing the world economy”;
- **Chapter 2,** “Today’s impact – the chemical industry’s current emissions, and the savings it enables”;
- **Chapter 3,** “Tomorrow’s opportunity – two McKinsey scenarios to 2030, and chemicals’ potential decarbonizing role”;
- **Chapter 4,** “Policy Implications : Optimizing the chemical industry’s abatement potential”.

The study focused on the mitigation of global warming, and therefore dealt solely with GHG emissions. This is not to downplay the other important health, safety and environmental issues that the chemical industry is actively tackling, in line with the philosophy of Responsible Care®[4]. These issues include health and safety, environmental releases, and biodiversity, to name just a few, and are covered extensively in other publications of the ICCA and its member associations.

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[4] Responsible Care© is the global chemical industry’s commitment to sustainability: a unique initiative to improve the industry’s health, safety and environmental performance. The Responsible Care© ethic helps chemical companies operate safely, profitably and with due care for future generations.

Chapter 1: A robust and transparent methodology to evaluate the chemical industry's contribution to the decarbonizing of the world economy

GLOBAL CONTEXT

December 2009 marks an important milestone: the 15th Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, where world leaders will seek to agree on a global deal to reduce man-made GHG emissions. The ICCA has expressed the commitment of its members to support these negotiations and to help find sustainable solutions to climate issues. This report is one concrete example of this commitment.

According to the Intergovernmental Panel on Climate Change (IPCC)[5], the current global GHG emissions are between three and four times the Earth's natural absorption rate of CO_2. Anthropogenic emissions have grown from 36 $GtCO_2e$ in 1990, the reference year used in the Kyoto protocol, to 46 $GtCO_2e$ in 2005 (WEF 2007). Most current research forecasts that, in the absence of major global policy action, global emissions will continue to grow at a similar pace as they have historically (i.e., to ~70 $GtCO_2e$ in 2030), driven by world population growth in connection with economic development and rising wealth.

Stabilizing the CO_2e concentration in the atmosphere will require that the world economy is rapidly "decarbonized", with significant changes in the way societies produce, consume, regulate and behave. The challenge will be to achieve these changes in a way that strengthens rather than damages the world economy. A number of studies have been conducted to understand which actions would be most effective in delivering emissions reductions, and what the economic cost – or benefit – of those actions would be. For example, a GHG abatement cost curve developed by McKinsey & Company (Exhibit 1) maps and quantifies the technical measures for emissions reduction with a cost < € 60 per tCO_2e, from those with the lowest cost to those with the highest.

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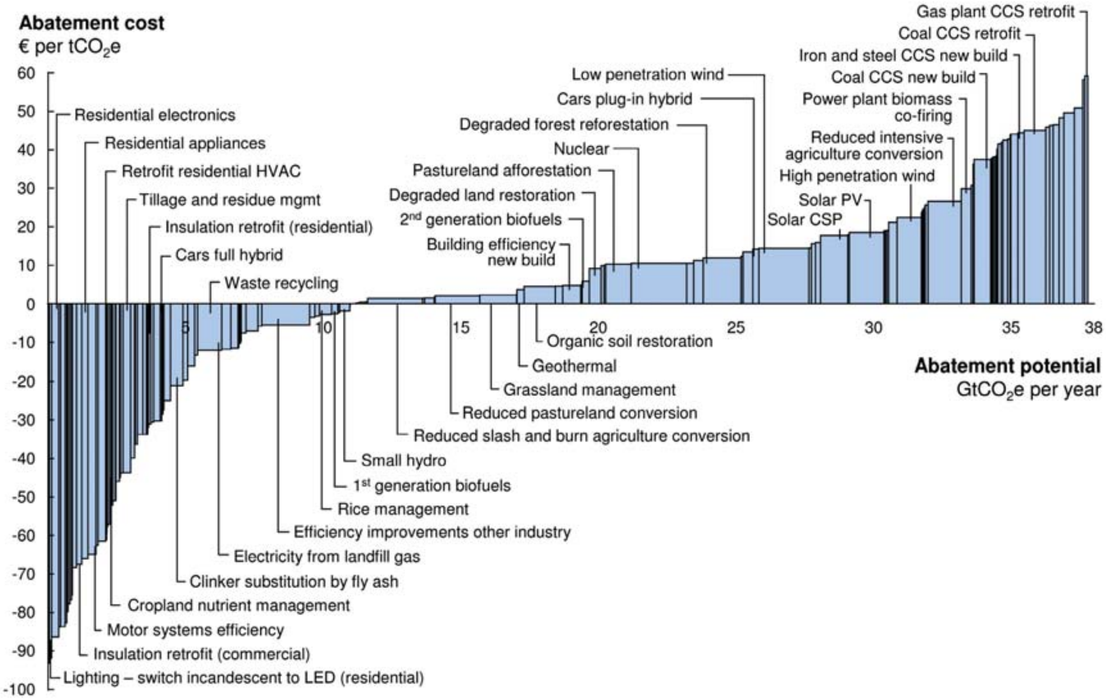
[5] The study has made no attempt to verify the IPCC numbers.

Exhibit 1

Global GHG abatement cost curve
Global GHG abatement cost curve beyond 2030 BAU
Cost of abatement below EUR 60 per tCO_2e



Note: This is an estimate of the maximum potential of all technical GHG abatement measures below EUR 60/tCO2e, if each lever was pursued aggressively, not a forecast of what role different abatement measures and technologies will play
Source: Global GHG Abatement Cost Curve v2.0, McKinsey & Company

The above McKinsey cost curve identifies a potential abatement of 38 $GtCO_2e$ in 2030, relative to "business-as-usual (BAU)" emissions of 70 $GtCO_2e$. The costs are based on a societal set of parameters as regards interest rates and payback periods. The abatement curve is used as the basis for the 2030 abatement scenario in this report.

If sufficient progress is to be made in reducing emissions, action will need to be taken on most or all of the available abatement levers. Governments and global policymakers are aware of this imperative. While some have already begun to put in place regulations and policies to catalyze a widespread decarbonization of the economy, a consistent global framework has yet to be established. Measures taken include caps, energy efficiency and greenhouse gas intensity standards, mandates, subsidies and the establishment of carbon markets.

The response from business has already been significant with investments in renewable energy, clean technology and the like realizing double digit annual growth over the past several years. Investment in renewable energy, for example, reached $150 billion in 2007 – $120 billion higher than the $30 billion seen in 2004 (UNEP SEFI 2008). Much of this has been supported by government subsidies.

Much larger investments, however, along with major technological breakthroughs, will be required to achieve decarbonization of the economy on a large scale. Significant further changes in regulation and public policy will be needed to unlock more and more abatement opportunities. For example, substantial abatement is possible – at negative net cost to the economy – through wider use of insulation in buildings and through switching from incandescent to Compact Fluorescent Lamps (CFL) and LED lighting. These shifts are unlikely to happen on sufficiently large scale, however, without incentives or regulatory intervention. The need for adequate policy intervention is even more pertinent in the case of some of the important new technologies. Carbon capture and storage (CCS) for instance will require policy support if it is to be developed. Another example relates to the development and commercialization of lignocellulosic (LC) ethanol, which will be highly influenced by regulation and incentives.

The complex task of guiding the world's transition to a low-carbon economy will, therefore, fall heavily on the shoulders of policymakers. If the interventions they decide upon are to have the effect needed, they will need to be based on a thorough understanding of both the current facts and the future impact and consequences of the policy options and levers that will likely be available. As a contribution to meet that need, ICCA has commissioned this study.

Chemical companies are the principal supplier of materials that enable many economies to be more energy-efficient and less carbon intensive. Examples from chemistry include wind power blades, solar panels, insulation materials and lightweight vehicle parts. The chemical industry is also significantly impacted by the energy and climate debates because of the energy-intensive nature of its business: it uses natural gas, coal and petroleum both as raw materials to make its products and as energy sources to power its facilities.

STUDY OBJECTIVES AND METHODOLOGY

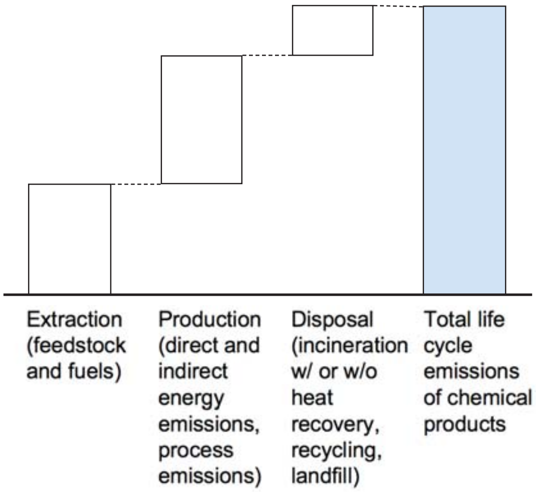
The chemical industry aims to provide better global transparency about its impact on emissions, thus providing a reliable fact base for decision makers. This report is intended as a meaningful step towards such improved transparency. It draws on a wide range of published material (listed in the Reference section) as well as study-specific interviews and original research conducted with and by ICCA member companies.

Based on this data, the study calculated the chemical industry's impact on emissions in 2005, the most recent year for which complete data is available. McKinsey then assessed how this impact would change in two scenarios to 2030 – a "business-as-usual" scenario and an "abatement scenario", which assumed aggressive implementation of measures leading to a low-carbon economy.

To arrive at these calculations, the study analyzed GHG emissions linked to the chemical industry, from feedstock and fuels extraction, through production, to disposal (Exhibit 2).

Exhibit 2

Life cycle emissions of chemicals cover entire life cycle of products

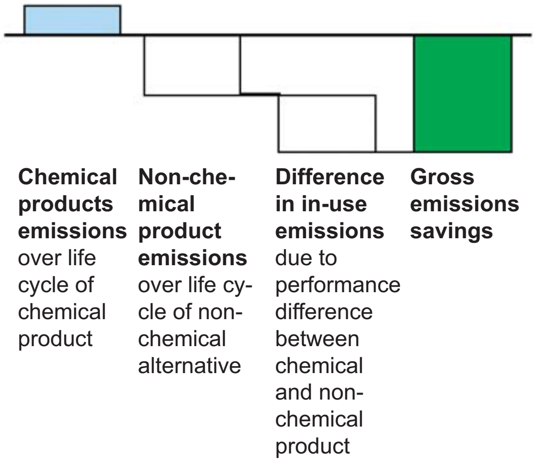


Further, to assess the impact of chemicals in enabling greater carbon efficiency throughout the economy, “CO_2e life cycle analyses” (cLCAs) were conducted for some 100 individual applications of chemical products spanning all sectors of the industry (Exhibit 3). cLCAs are not a new methodology, but for ease of understanding, the report uses a simplified terminology to describe these analyses. It does not directly follow ISO 14040 and ISO 14044 as it only focuses on GHG emissions. In cLCAs, the CO_2e emissions of a chemical in a specific application were compared with a non-chemical alternative, through the extraction, production, in-use and disposal phases.

Exhibit 3

More than 100 cases evaluated to assess savings from using products of the chemical industry

Calculation scheme for the CO_2e emissions from using a chemical industry product compared with a non-chemical industry product



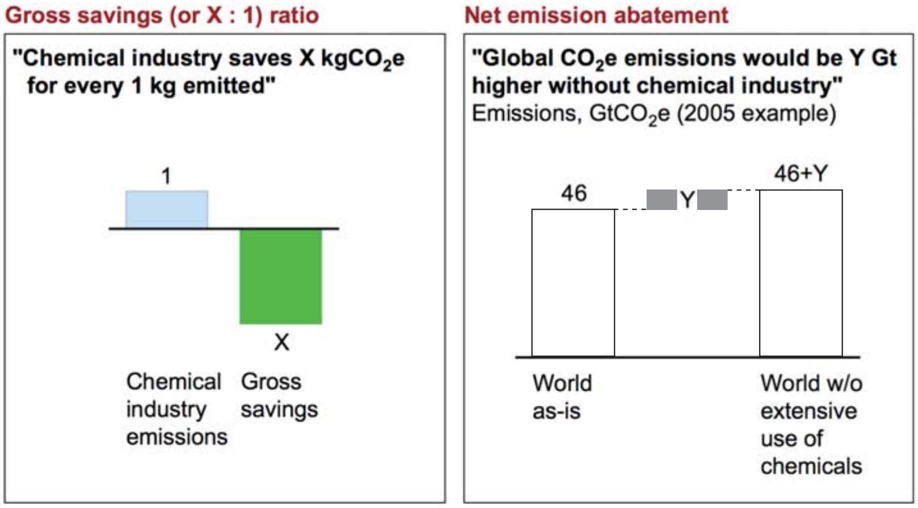
In cases where chemical products play an enabling role in a specific GHG abatement measure, 100 percent of CO_2e savings were counted for the chemical industry. The term "enabling" thereby implies that the product considered would not exist without the chemical product(s) being part of it. By doing so, we acknowledge that other parties with an enabling contribution to the same measure might do the same and allocate 100 percent of the emission savings to their industries. This will result in a multiple counting of the GHG savings of the product considered. Chemical products were defined to play an enabling role in 99 out of the 102 cases assessed in this study. In cases where the use of a chemical product contributed to a gradual improvement in CO_2e emissions, only a share of the savings (based on the value contribution of the chemical) was allocated to the chemical industry. The three case examples are wind mills, district heating and carbon capture and storage (CCS). In any case, these allocations of abatement volumes are different from CO_2e accounting under CDM for instance and make no financial claims.

This report adopts two metrics to reflect the chemical industry's impact on carbon emissions (Exhibit 4)[6]. The first is a gross savings (or X : 1) ratio, where the amount of CO_2e saved through the use of a chemical product is measured against the amount of CO_2e emitted during that product's entire life cycle compared to competitive technologies in the market. The second metric gauges the net emission abatement achieved by that product, or the difference between the gross CO_2e savings caused by its use and the CO_2e emitted during its own production and disposal compared to competitive technologies in the market.

[6] This methodology was adopted from BASF's corporate carbon footprint study.

Exhibit 4

Results presented in two ways - Gross savings ratio or X : 1, and net emission abatement



To arrive at the gross savings generated by a particular chemical product, the report calculates the CO_2e that would be emitted and saved through the life cycle of the best non-chemical substitute. Take the example of automotive plastics, a key chemical product, which in many cases is interchangeable with metal car parts. The production of these metal parts emits significantly more CO_2e than the production of plastics does, while the heavier weight of metal parts results in greater fuel consumption. When plastic parts are used instead of metal by enabling equal or better functionality, the additional production emissions are avoided, as are the in-use emissions caused by the additional fuel consumption – hence the gross emissions savings.

The Öko Institut conducted a critical review of each of the cLCA calculations and verified whether the requirements for methodology, data, interpretation and documentation were met and consistent with the principles of the cLCA calculation.

ACCURACY OF RESULTS

The results of the calculations presented in this study are by their nature not precise, but show a significant variance and therefore should always be considered as directional. The source of this uncertainty is twofold: first, there is uncertainty in the assumptions made to define the case and, second, the input data themselves are uncertain. Further variability comes into play when the study makes future projections based upon growth expectations.

Uncertainties ("standard deviations") of the results are estimated at +/- 30 percent for individual cases in 2005 and +/- 40 percent for the projection in 2030. These estimates were derived based upon the following assumptions:

- **Result of an individual case (extrapolated cLCA):** standard deviation of +/- 30 percent, based upon sensitivity analyses shown later in this report;
- **Uncertainty in the growth projection:** this is numerically modeled under the assumption of a normally distributed yearly growth of 3 percent with a standard deviation of +/- 150 percent (twice the standard deviation of US GDP growth 1950-2008). The overall standard deviation for the 2030 projection of a cLCA with the above assumption is then +/- 40 percent.

Due to the converging effect of adding up uncertain numbers (i.e., the uncertainty in percent reduces as the number of values added grows) the uncertainty for the overall abatement volume is lower than for the individual cLCAs. In order not to appear overly precise, this effect has not been taken into account.

We estimate the error margin in the calculation of the "own" emissions caused by the products of the chemical industry from feedstock and fuels extraction until disposal to be +/- 25 percent for the 2005 value. This estimate is based upon the uncertainty seen in the footprint of individual chemical process emissions as provided by sources such as the IPCC or SRI. This report did not attempt to develop a refined view on the statistical errors but used these ranges to estimate the approximate overall uncertainties. The error margin for the 2030 projections of the «own» emissions is estimated based on the above mentioned numerical modeling and is about +/- 35 percent.

Even for cases in which only a single number is provided in the text or an exhibit, these approximate inaccuracies described above should be considered when drawing conclusions from the results.

Despite these ranges of uncertainty in this first study, the direction remains robust and provides the appropriate indications of emissions, abatement volumes, and opportunities for further improvement.

Chapter 2: Today's impact – the chemical industry's current emissions, and the savings it enables

This chapter discusses the study's findings on both the chemical industry's emissions in 2005 and the emissions savings it enables across the world economy. 2005 is the most recent reference year for which the best available complete global data set could be obtained. To determine the level of savings, over 100 cLCAs were carried out.
This chapter takes a more detailed look at the emissions impact of the ten largest applications. The most significant emission savings from a volume perspective are building insulation, agrochemicals, lighting, plastic packaging, marine antifouling coatings, synthetic textile and automotive plastics.

CURRENT CO_2e EMISSIONS LINKED TO THE CHEMICAL INDUSTRY

In 2005, CO_2e emissions linked to the chemical industry amounted to 3.3 $GtCO_2e$ +/- 25 percent (Exhibit 5):

- The majority of the emissions, 2.1 $GtCO_2e$, is a result of the production of chemicals from feedstock delivered to the chemical industry. The effects of direct and indirect energy use are included in the production emissions, as are process emissions (Exhibit 6);
- 0.3 $GtCO_2e$ of emissions arise during the extraction phase of the feedstock and fuel materials;
- 0.9 $GtCO_2e$ are emitted during the disposal phase of the produced chemicals. This includes 0.4 $GtCO_2e$ for high GWP (Global Warming Potential) gases which are mainly emitted by end-users further down the value chain.

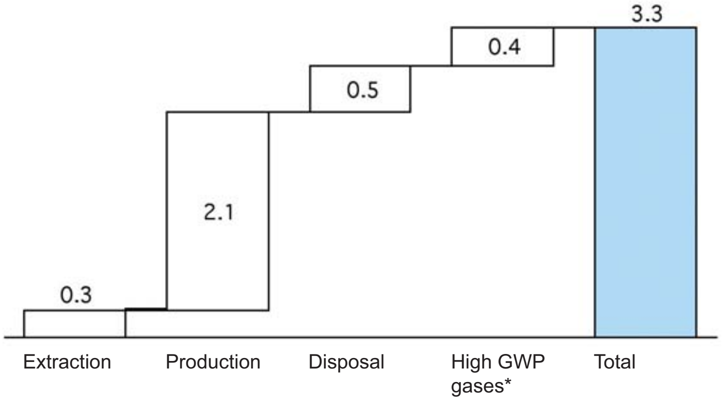
In a sector approach some of these emissions are typically not attributed to the chemical industry. For example, extraction emissions are normally reported by the oil and gas industry and the use of HFC (hydrofluorocarbons) refrigerants would typically be included in appliance and automotive figures. They have been included in this study to develop a holistic and comprehensive perspective for the entire chemical industry value chain in line with best practice life cycle thinking.

Exhibit 5

Total life cycle CO_2e emissions linked to the chemical industry amount to 3.3 Gt

GHG life cycle emissions of chemical products, 2005

$GtCO_2e$

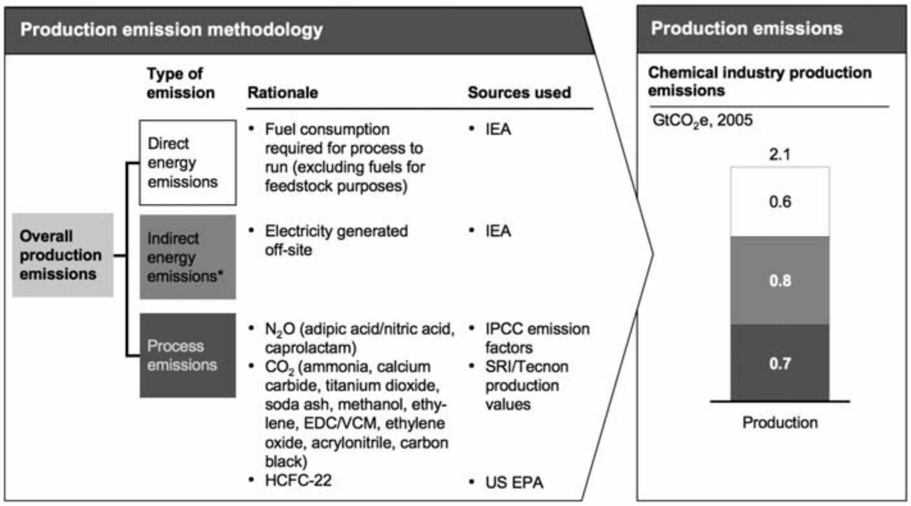


* HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HAFC-1521, HFC-227ea, HFC-236fa, HFC-4310mee, CF_4, C_2F_6, C_4F_{10}, C_6F_{14}, SF_6; GWP factors according to IPCC 1996

Source: IEA, EPA, IPCC, WEF ("Contribution of the chemical industry to greenhouse-gas reduction" December 2007); McKinsey analysis

Exhibit 6

Production emissions are composed of energy and process emissions



Production emission methodology

Overall production emissions

Type of emission	Rationale	Sources used
Direct energy emissions	• Fuel consumption required for process to run (excluding fuels for feedstock purposes)	• IEA
Indirect energy emissions*	• Electricity generated off-site	• IEA
Process emissions	• N_2O (adipic acid/nitric acid, caprolactam) • CO_2 (ammonia, calcium carbide, titanium dioxide, soda ash, methanol, ethylene, EDC/VCM, ethylene oxide, acrylonitrile, carbon black) • HCFC-22	• IPCC emission factors • SRI/Tecnon production values • US EPA

Production emissions

Chemical industry production emissions

$GtCO_2e$, 2005

Source: McKinsey analysis

As already indicated under the chapter “Accuracy of results” above, the choice of data sources can drive important differences in the results. For the “own emissions”, the study opted for a combination of IEA and IPCC data, as these seemed more complete and conservative than SRI data. As research in this area continues, it is likely that the results from different data sources will converge towards a slightly different value.

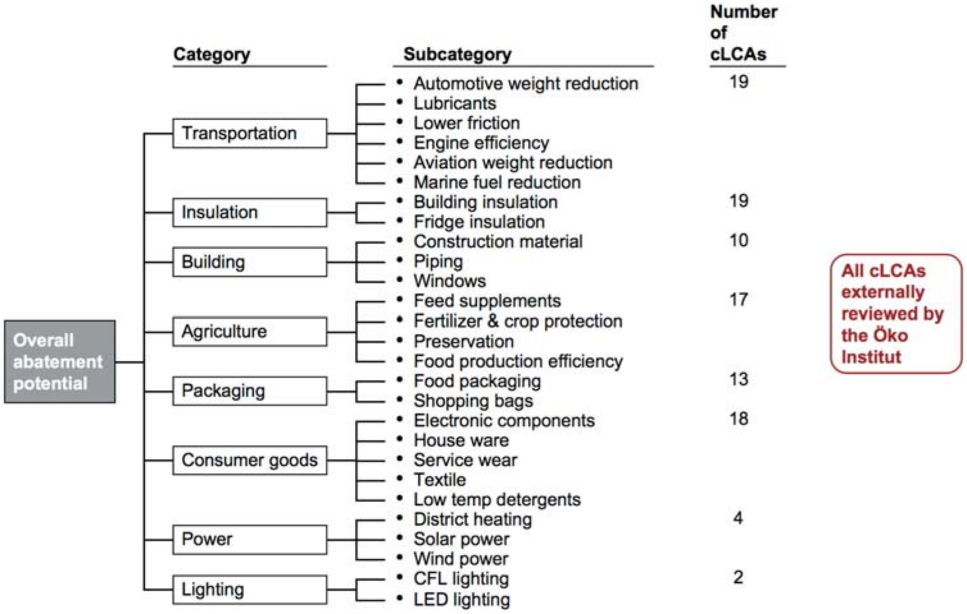
EMISSIONS SAVINGS ENABLED BY THE CHEMICAL INDUSTRY

The chemical industry is a carbon-intensive industry as shown by its CO_2e footprint. However, the chemical industry is unique in its ability to enable other industries and society at large to save energy and reduce GHG emissions.

To assess this enabling role of the chemical industry the study developed more than 100 CO_2e life cycle analyses (cLCAs). ICCA member companies from across the globe submitted cLCA results or data for new cLCAs to McKinsey. These cLCAs were selected to cover the major savings by industry’s products. Exhibit 7 shows the number of cLCAs by 8 end use areas: transportation, heating, construction, agriculture, packaging, consumer goods, power, and lighting. All cLCAs were reviewed by the Öko Institut.

Exhibit 7

cLCAs* cover 8 broad end-use areas and were all externally validated



* cLCA = CO2e life cycle analyses

Each cLCA compares the CO_2e emissions of a chemical industry product in a specific application with the next best non-chemical industry alternative that preserves current life style. For simplicity, the term chemical product is used to define a product that is produced by the chemical industry. Clearly, the more than 100 cLCAs don't cover the entire chemical universe, and for some products, there is no non-chemical alternative. For those chemicals not covered in the analysis, the results of the cLCAs therefore needed to be extrapolated in a careful and conservative manner so that conclusions could be drawn for the chemical industry as a whole. To arrive at this extrapolation, the study segmented the emissions linked to the chemical industry into three groupings (Exhibit 8):

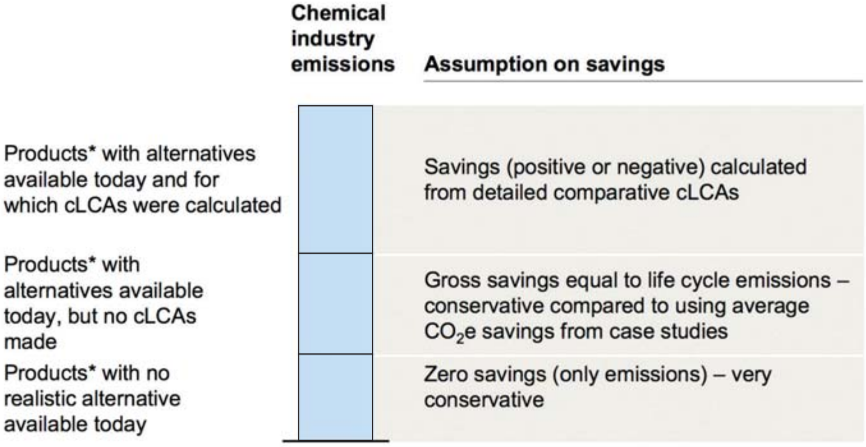
1. **Chemicals in applications for which cLCAs were calculated**. This category contains chemicals for which explicit numbers for gross and net savings were available from the cLCA calculations. One example from this category is the replacement of metals by light-weight plastics in cars;

2. **Chemicals in applications for which cLCAs were not calculated but non-chemical industry solutions exist**. This includes low-volume applications of polymers and many specialty and fine chemicals. One example is food preservatives that avoid significant food wastage and the associated CO_2e emissions. Another example is the use of catalysts in oil refining which enable higher process efficiencies that yield CO_2e savings. Also the fertilizers are in this category when the savings were neutralized with respect to their production emissions. For reasons of time constraints, cLCAs for such cases were not included in this phase of the work besides the fertilizer case. For this category, the assumption was made that net savings were zero. This is conservative because in the vast majority of the cases that were analyzed through cLCAs, the CO_2e net savings were actually positive;

3. **Chemicals in applications for which realistic alternatives from other industries are not available** without destroying performance or severely compromising living standards. These include some solvents, and industrial gases such as nitrogen, oxygen and argon, which are needed to meet specific performance standards. It also includes inorganic chemicals such as soda ash for glass making. Other examples are polymers for medical applications and active pharmaceutical ingredients. For this category, the study took an even more conservative approach and assumed gross savings of zero (and hence negative net savings, thereby negatively impacting the industry's savings ratio).

Exhibit 8

Extrapolations were made for products/applications not covered by cLCAs



	Chemical industry emissions	Assumption on savings
Products* with alternatives available today and for which cLCAs were calculated		Savings (positive or negative) calculated from detailed comparative cLCAs
Products* with alternatives available today, but no cLCAs made		Gross savings equal to life cycle emissions – conservative compared to using average CO_2e savings from case studies
Products* with no realistic alternative available today		Zero savings (only emissions) – very conservative

* Or applications

Applying this methodology, the study calculated the CO_2e emissions and savings linked to the chemical industry's products, over the life cycle of those products. As will be illustrated below, a large contributor to the savings enabled by the chemical industry is the application of fertilizers and crop protection chemicals. As there is still ongoing debate about how to account for GHG emissions or savings from agriculture and forestry, this case was assessed as an alternative scenario with the assumption of zero net savings.

Gross savings are 6.9 GtCO_2e +/- 30 percent, translating into a savings ratio of 2.1 : 1 without the fertilizer case, and 8.5 GtCO_2e +/- 30 percent, translating into a savings ratio of 2.6 : 1 with the fertilizer case – in other words, for every 1 GtCO_2e emitted by the chemical industry in 2005, it enabled 2.1 to 2.6 GtCO_2e in savings by other industries and end users (Exhibits 9 and 10). **The net emission abatement enabled by chemicals in 2005 amounted to 3.6 to 5.2 GtCO_2e +/- 30 percent** – in other words, and compared to total global emissions of 46 GtCO_2e in 2005, there would have been 3.6 to 5.2 GtCO_2e or 8 to 11% more emissions in 2005 in a world without chemicals.

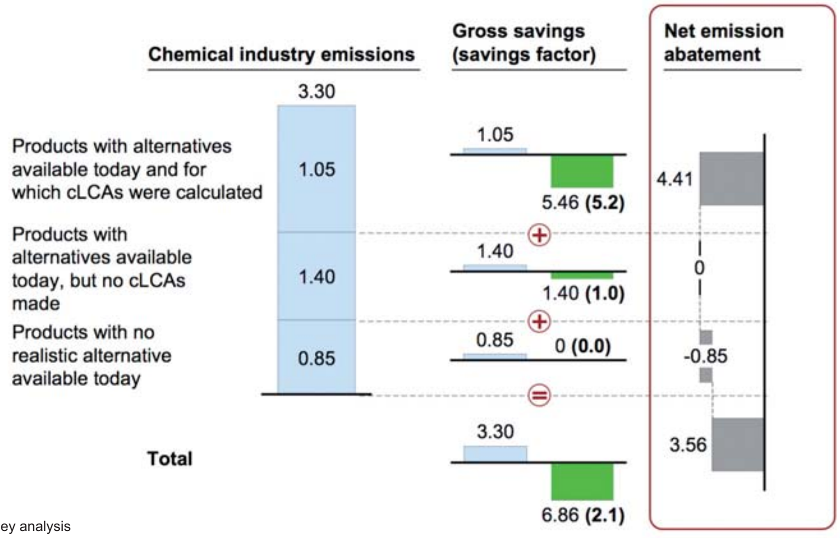
The largest contribution to these net savings comes from those applications, for which the life cycle CO_2e emissions were calculated – that is, the bulk of chemical applications for which realistic alternatives exist. In this segment, the average savings ratio was 5.1 : 1, and the identified net abatement was 6.0 GtCO_2e (with the fertilizer case).

Exhibit 9

In a scenario without the savings from the fertilizer case the chemical industry saves 2.1 tons of CO_2e per ton emitted, net abatement is 3.6 Gt

Emission abatement of chemical industry

$GtCO_2e$



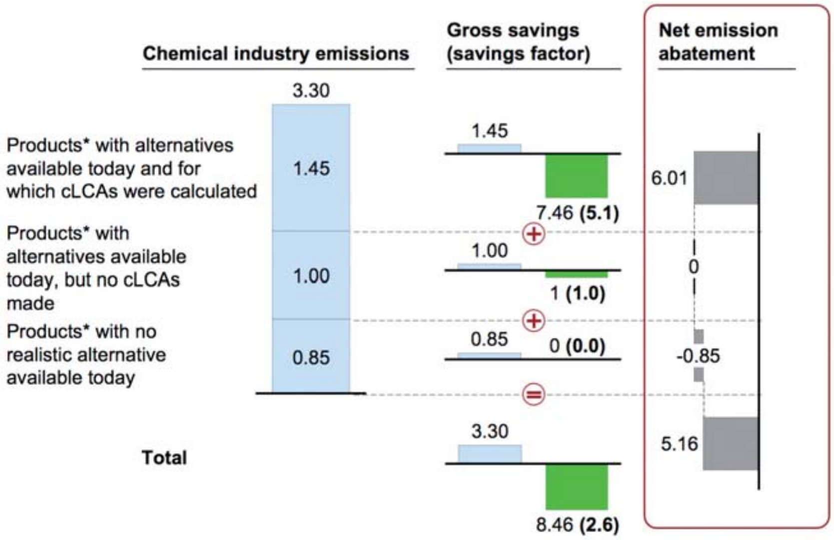
Source: ICCA/ McKinsey analysis

Exhibit 10

With the fertilizer case, the chemical industry saves 2.6 tons of CO_2e per ton emitted. The net abatement of 5.2* Gt equals ~11% of 2005 global emissions

Emission abatement of chemical industry

$GtCO_2e$



* Includes savings from avoided CO_2e emissions from land-use change enabled by fertilizer & crop protection use

Source: ICCA/ McKinsey analysis

For the segment of realistic alternatives but not explicitly calculated cLCAs, the assumption was made that the emissions and gross savings are equal. This translates into a savings ratio of 1 : 1 – a conservative approximation, given the calculated result for similar applications above which led to the 5.1 : 1 ratio. The net abatement for this category was 0 $GtCO_2e$.

For the category where realistic alternatives from other industries do not exist, an even more stringent assumption was made. As there was no reference the gross savings could not be quantified in the methodology used. The most conservative assumption is to use a value of zero. This translated into a savings ratio of 0 : 1, and a negative net abatement of 0.85 $GtCO_2e$, equal to the emissions originating from this category.

THE APPLICATIONS THAT DRIVE THE GREATEST SAVINGS

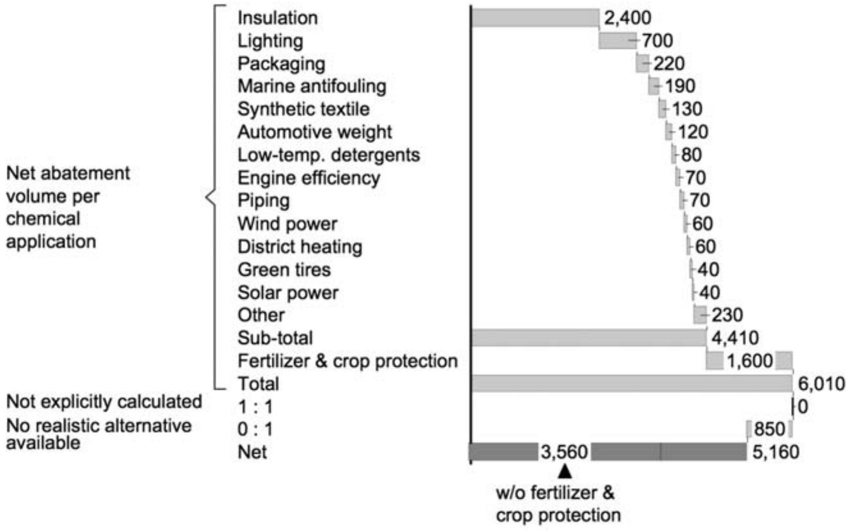
The cLCAs analyzed show that the biggest levers for emissions savings enabled by the chemical industry are insulation materials for the building industry, the use of chemicals in agriculture, and advanced lighting solutions (Exhibit 11).

Exhibit 11

The main contributors are insulation, fertilizer & crop protection, and lighting

Net abatement 2005

$MtCO_2e$



Source: ICCA/ McKinsey analysis

The figures in Exhibit 11 are derived from a wealth of data on the impact of individual chemical products on CO_2e emissions. The following paragraphs provide a more detailed description of the ten most important ones. They are: building insulation, fertilizers and crop protection, lighting, plastic packaging, marine antifouling coatings, synthetic textiles, automotive plastics, low-temperature detergents, engine efficiency, and plastics used in piping.

Building insulation

Insulation of buildings is, at 2.4 $GtCO_2e$, the largest contributor to the net emissions savings. Insulation greatly reduces the heat lost by buildings, and so significantly decreases the need for energy for heating. If cooling savings were to be included the net GHG abatement would further increase. The study calculated the savings, by region, arising from the global annual consumption of three key chemical insulation materials – expanded polystyrene (EPS), extruded polystyrene (XPS), and polyurethane (PU). The material used in these applications was 1,121 kt for Asia, 850 kt for Europe, and 882 kt for North America. Volumes in Africa and South America were not significant.

Within the three regions considered, a total of 60 cases was analyzed, differing by climate zone, building standard and house part (roof, wall or floor). Savings were calculated based on a heat flux model. This model comprises the U-value difference, indicating the improved thermal characteristics; the temperature difference integrated over a lifetime of 50 years, expressed in Heating Degree Days; and the surface treated by insulation, calculated from the annual production volume and the thickness derived from the U-values (for an example of this calculation – for wall insulation in North America – see the box below). The reference case for roof insulation is mineral wool – the only material with a significant market share apart from the chemical-based insulation materials.

Overall, insulation foam has a very high X : 1 ratio of 233 : 1, and contributes 2,400 $MtCO_2e$ net savings. The savings derived from Asia, Europe and North America are roughly equal.

Example of wall insulation in North America

Here we provide an illustration of the calculation of savings realized through insulation.
For each factor in the heat flux model, illustrative values are given for a wall exposed to a moderate climate in North America.
Without insulation the U-value, a measure for the thermal conductivity, would be 0.30 Watts per square meter Kelvin for a wall (W/m^2K). After insulation with 1.5 inches of XPS insulation foam, this would be reduced to 0.215 W/m^2K. There is thus a U-value difference of 0.085 W/m^2K. Secondly, the moderate climate zone corresponds to 3,500 Heating Degree Days.
The third factor is the surface: given the volume of 17.4 kt and a thickness of 1.5 inches, a surface of 16.7 million square meters is treated.
Multiplying the three factors above provides the saved heating energy for one year: 430,000 GJ. This needs to be further multiplied by the insulation lifetime of 50 years and the carbon intensity of heating of 0.107 $kgCO_2e$ per MJ of heating energy (which includes the extraction, transport and combustion of fuels as well as an efficiency of 90 percent of the heating system).
The result is 2.3 $MtCO_2e$ savings over the lifetime of the insulation. The production emissions of the insulation material, with a footprint of 2.8 $kgCO_2e/kg$, amount to only 49 $ktCO_2e$.

Fertilizer and crop protection

Agrochemicals are the second largest contributor to emissions savings. Use of fertilizer and modern crop protection has helped to increase yield dramatically over the past few decades. The importance of fertilizer for world food supply was reflected in a Nobel Prize in chemistry for the Haber-Bosch process, which is critical for the production of ammonia, a key precursor for N-fertilizer. The main driver of the CO_2e savings enabled by agrochemicals is avoided land-use change due to yield increase. In this study, the effects of using fertilizers and crop protection on emissions were combined to account for synergistic effects of those products. As a reference case, we used organic farming. (It should be noted that this analysis considered farming from the perspective of GHG emissions only, and did not consider other environmental effects related to farming, such as nitrification, water consumption, or biodiversity. ICCA is addressing these and other environmental issues in line with its Responsible Care® program.)

Agriculture creates emissions in two ways – from the farming activity itself, and from converting land to agricultural use.

"Farming emissions" are those created by working the land with machines such as tractors and applying products to the land such as fertilizers. The farming emissions of conventional farming with fertilizers and crop protection were found, on a per mass of crop basis, to be close to those of organic farming, with some regional variation. This can be explained by the fact that the CO_2e savings in organic farming due to avoided use of fertilizer and plant protection are largely compensated by organic farming's considerable yield loss. So, while per hectare CO_2e emissions are lower in organic farming, there are cases where per ton yield emissions are similar to those of conventional farming. However, as there are big yield differences, soil quality effects and CO_2-binding and assimilation processes in different conventional and organic agricultural practices, an LCA cannot deliver unambiguous results. For the purpose of the study, conventional and organic farming emissions were assumed to be equal.

If fertilizers and crop protection were not available, the yield from agriculture would drop significantly – by between 30 and 85 percent, depending on the crop type, soil, technology and climate zone (these percentages were obtained from agriculture production data and expert interviews). For the purpose of this study, the middle of the range was used and a yield decrease of 50 percent assumed. To produce the same amount of crops with this lower yield, double the amount of land would be required. The CO_2e cost of this extra land use, resulting from the release of fixed carbon from the vegetation and the soil, is calculated according to the PAS2050 guidelines. To be conservative, the lowest cost per hectare of additional land is used: 1.5 tCO_2e/ha for perennial grassland in the US.

In the calculations, the focus was on the five most important crops (corn, rice, soy, sugar cane and wheat), as they cover 56 percent of the global agrochemical use. Cultivation of these five crops uses 600 million hectares of arable land (FAO, 2006). Switching to organic farming for all crops would therefore require an additional 1,100 million hectares of land. At 1.5 tCO_2e/ha, this translates to 1,600 $MtCO_2e$ emissions saved by the use of fertilizers and crop protection.

FAO data for the different regions of the world confirms the strong correlation between fertilizer use and yield, and also gives a clear indication of the improvement potential of agriculture in developing countries in Africa and other regions (FAO 2006).

Due to the above uncertainties and the controversies around land-use changes, different binding capacity of organic grown crops and soil, side effects and the lack of a full LCA in regard to this application this study has adopted two scopes, one where chemical agricultural contributions lead to net savings and one where these net savings are neutralized.

Note about this case

The calculations in this case focus solely on the GHG impact of fertilizers and plant protection chemicals. Other eco-relevant factors were not considered in this assessment.
In line with the overall definition for reference cases in this study, we assumed that the type and volume of products available for society will remain constant and therefore, the consumption pattern does not need to change. If society changes consumption patterns, e.g., significantly reduces the share of meat in its diet, then food production could have a lower GHG impact than with current consumption pattern.

Lighting

Lighting has already been identified by many industries and governments as a major lever for carbon emission abatement. Modern Compact Fluorescent Lamps (CFL) offer superior luminous efficacy compared to incandescent bulbs – meaning that they deliver more light for every watt of energy. The CFL luminous efficacy is more than four times that of incandescent. In addition to this, the lifetime of CFLs is typically four times longer than that of incandescent bulbs.

The analyses in this study deal with the emission savings stemming from electricity savings earned due to the current global production of CFLs – some 2.82 billion of these bulbs are manufactured annually. Research into the major markets of these lamps shows that 47 percent are sold in the US, 34 percent in the EU and Japan, and 19 percent in the rest of the world, allowing the calculation of the weighted average of lighting electricity emissions: 590 kgCO_2e/MWh. During an average lifetime of 7,000 hours, a CFL bulb can save 434 kWh of electricity, i.e., 256 kgCO_2e per bulb. Nevertheless, low quality CFLs are in the market showing a reduced lifetime by 70 percent and an energy efficacy of 50 percent compared to high quality CFLs. Hence 2.82 billion CFLs enable emission savings of 700 MtCO_2e over their lifetime.

Plastics used in packaging

Packaging is one of the major applications of plastics. Compared to alternative materials, a plastic package has significantly lower weight (between two and eight times lighter, depending on the application).This advantage results in a lower overall carbon footprint, despite a higher production footprint per kilogram of material (about 2-4 $kgCO_2e$ per kg plastic versus 0.7 $kgCO_2e$ per kg for glass and paper, 3 $kgCO_2e$ per kg for thin steel and 8 $kgCO_2e$ per kg for aluminum).

To quantify the savings, the packaging market is segmented in seven applications: “Small packaging”, “Beverage bottles”, “Other bottles”, “Other rigid packaging”, “Shrink and stretch films”, “Carrier bags”, and “Other flexible packaging”. In total seven different plastics (LDPE, HDPE, PP, PVC, PS, EPS, PET) were considered against seven reference materials (white glass, thin steel, aluminum, corrugated board, paper/cardboard, beverage carton, wood).

For each application, the mass ratio of plastics and reference materials was determined. The majority of these data stem from an existing study (GUA 2005), supplemented by cLCAs provided by the ICCA member companies. The calculation uses the aggregated footprints of the listed materials in the overall analysis. The extrapolation uses annual production data extracted from the GUA study and the annual report of the plastics producers (PlasticsEurope, 2007). Films and bottles, with 67 $MtCO_2e$ and 97 $MtCO_2e$ respectively, are the largest contributors to the total savings of ~220 $MtCO_2e$.

Marine antifouling coatings

Modern marine shipping plays an important role in the global economy. The fuel consumed by the marine shipping industry is reduced significantly through the use of coatings that not only protect ships from corrosion, but also prevent organic material from growing on the outside of ships. In this context, antifouling coatings have a strong effect on minimizing drag and thus, the optimizing of the fuel consumption of ships.

It was estimated that the average fuel consumption of ships without antifouling coatings would be 29 percent higher. With a yearly fuel consumption of 220 Mt of fuel in the marine shipping industry, this translates into fuel savings of 63 Mt, which corresponds to gross savings of 200 $MtCO_2e$ per year. After taking into consideration the production footprint of the coatings and average coating lifetime of 12 years, the net abatement volume is ~190 $MtCO_2e$.

Synthetic textiles

In this case, the CO_2e impact of producing cotton textiles was compared with that of producing nylon and polyester substitutes. The source of CO_2e abatement stems from the lower GHG impact of synthetic fibers in the production phase compared to cotton, when taking into account the longer lifetime of the synthetic material. This calculation uses a life cycle footprint of 5.5 $kgCO_2e/kg$ for polyesters, 8.2 $kgCO_2e/kg$ for nylon, and 7.3 $kgCO_2e/kg$ for cotton. Based on results by Autex[7] the lifetime for textiles made of synthetics is twice that for cotton products. In order to make conservative estimates, it was assumed there were no in-use CO_2e advantages of synthetic fibers over cotton (tests have shown that drying cotton towels requires significantly higher amounts of energy than for synthetic alternatives). Yearly consumption of polyester and nylon for textiles is 14,760 kt and 1,566 kt, respectively. This leads to net saving of about 130 $MtCO_2e$

Automotive weight reduction

The use of polymers and composite materials (e.g., glass or carbon fiber reinforced polymers) in the automotive industry has been rising steadily over the past 30 years. In this industry, polymers not only reduce costs and allow for more appealing and functional design, they also enable significant weight reduction. This weight reduction helps to reduce fuel consumption, thus reducing GHG emissions.

30 different applications in automobiles in which polymers are used were identified. These applications are aggregated into four categories: chassis, under-the-hood, body and interior. For each of the applications identified, the life cycle emissions created by the use of polymer (from extraction, through production, to disposal), the life cycle emissions created by use of the next best alternative (in most cases steel, aluminum or glass), and the weight difference between the two materials were calculated. For example, traditional aluminum air intake manifolds are gradually being replaced by polyamide (PA). The weight difference factor is 100 percent: an aluminum air-intake manifold weighs 3 kg, twice the weight of a PA manifold. The production and disposal footprint of an aluminum manifold is only 24 percent higher than PA (mainly due to the higher recycling rate of aluminum).

For calculating fuel savings related to the weight reduction the following key assumptions were used: a car lifetime of 150,000 km and fuel efficiency of 0.35 liter/100km/100kg. These key assumptions, though widely used among LCA practitioners, are conservative as industry average car lifetime is longer than 150,000 km.

Some 10.4 million tons of plastics are used every year in the global automotive industry across these 30 applications. After considering the gasoline and diesel CO_2e footprint, the diesel/gasoline car park split, and ethanol/biodiesel impact on transport emissions the total emission saving from the use of plastics in the automotive industry is ~120 $MtCO_2e$.

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[7] Autex (Association of Universities for Textiles) Research Journal Vol.1, No. 1, 1999.

Low-temperature detergents

The low-temperature detergents case describes the combined CO_2e impact of modern surfactants and laundry enzymes. Both components of modern washing agents have contributed to the effect that modern washing leads to excellent results at much lower temperatures than in the past and therefore reduces energy consumption and CO_2e emissions. Compared to soap-based systems for which the washing temperature is typically 60°C or higher, the temperature can be reduced to 30°C if modern washing agents are applied. This reduces the energy demand per washing cycle from ~1 kWh to ~0.6 kWh. Considering the CO_2e intensity of power, this translates into CO_2e savings of 321 gCO_2e/load.

Apart from the in-use phase, modern detergents also have a lower CO_2e footprint than soaps. For modern detergent systems, life cycle emissions of 65 gCO_2e/dosing were estimated, compared to 309 gCO_2e/dosing for soap. This difference is largely driven by the fact that modern detergents are more efficient and require only one third of the amount of soap.

Worldwide, modern detergents are applied in about 158 billion washing cycles every year. There are, however, regions where washing laundry at room temperature is a common practice irrespective of the use of soap or modern detergents. Taking such regional differences into account, the use of modern washing agents leads to a global net CO_2e abatement of ~80 $MtCO_2e$ per year.

Engine efficiency

Under the umbrella of “engine efficiency” fall three cLCAs: diesel and gasoline fuel additives for deposit control and synthetic lubricants. All three reduce fuel consumption of the engine and together, create annual global net savings of ~70 $MtCO_2e$.

Diesel fuel additives – The fuel consumption of an average car when consuming diesel with fuel additives is 2 percent less than without additives. A typical car with a diesel engine has a lifetime of 200,000 km and a fuel consumption of 8 liter/100 km. So, over the lifetime, fuel consumption is reduced by 320 liters of diesel. The well to wheel footprint of diesel, is 2.9 $kgCO_2e$/kg. This results in emissions savings of 930 $kgCO_2e$.

In Europe, the Middle East, and Africa (EMEA), a total of 30 kt of diesel additives for deposit control is consumed annually (Frost & Sullivan 2005) and in the United States, 37 kt (EMEA volume scaled by diesel consumption). From these consumption volumes, annual global net savings are 24 $MtCO_2e$.

Gasoline fuel additives – The calculation for the savings resulting from gasoline fuel additives is analogous to that of diesel additives. The fuel consumption is higher (8.7 liter/100 km), which results in savings of 348 liters over the lifetime of a gasoline car.

The well to wheel footprint of gasoline is 2.9 kgCO_2e/kg. On a net basis, this results in 966 kgCO_2e savings per car over the life of the car.

Annually, 90 kt of gasoline fuel additives for deposit control are consumed in EMEA (Frost & Sullivan) and 184 kt in the US (Freedonia). From these consumption volumes, annual global net savings are 28 MtCO_2e.

Synthetic lubricants – The footprint to produce lubricating oil is 2 kgCO_2e/kg for synthetic oil (ICCA member company) and 1.07 kgCO_2e/kg for mineral oil (SimaPro). Annually, 12.7 Mt of engine oil are consumed; 7.1 percent of this (903 kt) is synthetic oil (Freedonia 2005). To produce the synthetic oils, 1.8 MtCO_2e is emitted; producing a similar amount of mineral oil would produce 1 MtCO_2e emissions.

Synthetic engine oil, compared to mineral lubricating oil, reduces the fuel consumption of an engine by 5 percent (AMSoil gives a range of 2 to 8 percent). Globally, 516 billion gallons of fuel are consumed (Tecnon). Of the total, 36.6 billion gallons are used by cars lubricated with synthetic oil. If the latter used mineral oil, they would consume 5 percent more or 5.7 Mt. Given the footprint of 2.9 kgCO_2e/kg for fuel, this translates into 17 MtCO_2e per year. From this in-use savings and the difference in production emissions of the mineral and synthetic oils, the annual global net savings are calculated to be 16 MtCO_2e.

Plastics used in piping

More than 70 percent of plastic pipes are water pipes, primarily for drainage and sewage (~50 percent) and drinking water (~20 percent) pipes. The primary polymers used for piping are PVC (~70 percent) and HDPE (~25 percent).

In order to calculate the savings potential, global PVC and HDPE production was broken down into eight regions as follows: Africa, Asia-Pacific, Europe, the Former USSR, Latin America, the Middle East, North America, and Northeast Asia (Tecnon). For each region, the total amount of pipe production was calculated based upon the fraction of PVC and HDPE that is used for pipe production – 41 percent (ECVM[8] – except for Europe 25 percent) and 11 percent (SRI). The total calculated use is 16,958 kt of PVC (80%) and HDPE (20%). This number was checked against an industry report (Freedonia) and found to be consistent.

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[8] ECVM European Council of Vinyl Manufacturers.

Two cases were defined for this cLCA:

- Waste water pipes: 20 percent cast iron, 30 percent stoneware, 30 percent concrete, and 20 percent fiber cement;
- Drinking water pipes: 25 percent zinc-coated iron, 30 percent cast iron, 30 percent copper, and 15 percent fiber cement.

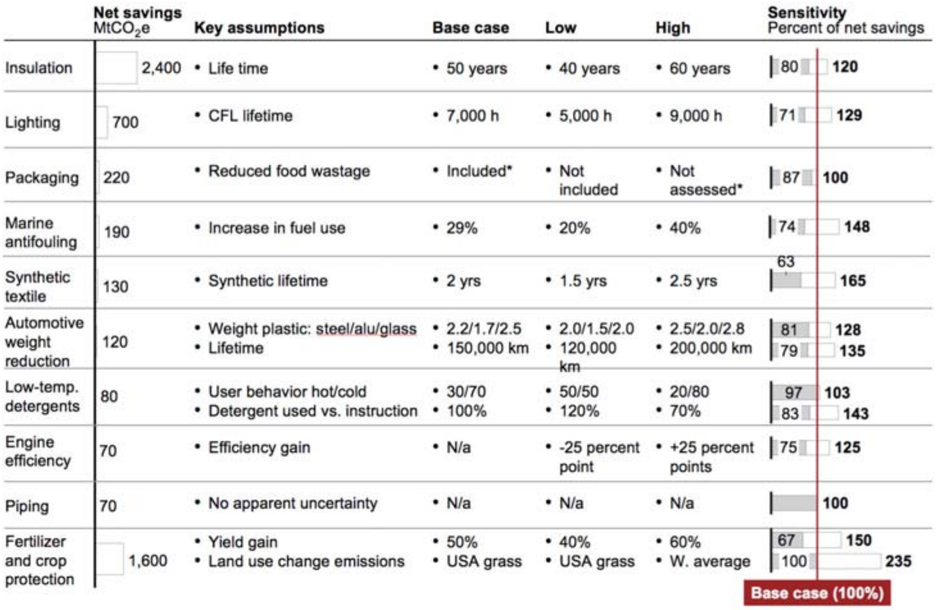
The lifetime of plastic pipes and their reference cases is broadly similar. All CO_2e savings stem from lower raw material use combined with production, and disposal footprint differences. The calculated total CO_2e of both plastic pipe applications is 33.4 $MtCO_2$e, whereas the reference case is 75.2 $MtCO_2$e. This gives a net emissions savings of 41.8 $MtCO_2$e per year. As the calculation covered only 64 percent of total plastics used in piping, this number was extrapolated to 65.4 $MtCO_2$e.

SENSITIVITY ANALYSIS

In all life cycle work, the result obtained is heavily dependent on the scope of the study and the assumptions used. Ideally one would present cLCA numbers as ranges, as opposed to single figures. However, for reasons of simplicity the report uses single numbers to describe the results and sensitivity analyses were performed to investigate the impact of assumptions made on the results obtained. The sensitivity analyses for the most important cases are shown in Exhibit 12. A guiding principle when making assumptions in the calculation of cLCAs is to take a conservative stance. This is reflected in the fact that the sensitivities often show large upsides compared to the base case.

Exhibit 12

Sensitivity analyses confirm conservative approach
Sensitivity analyses of largest cLCAs



	Net savings $MtCO_2$e	Key assumptions	Base case	Low	High	Sensitivity Percent of net savings	
Insulation	2,400	• Life time	• 50 years	• 40 years	• 60 years	80	120
Lighting	700	• CFL lifetime	• 7,000 h	• 5,000 h	• 9,000 h	71	129
Packaging	220	• Reduced food wastage	• Included*	• Not included	• Not assessed*	87	100
Marine antifouling	190	• Increase in fuel use	• 29%	• 20%	• 40%	74	148
Synthetic textile	130	• Synthetic lifetime	• 2 yrs	• 1.5 yrs	• 2.5 yrs	63	165
Automotive weight reduction	120	• Weight plastic: steel/alu/glass • Lifetime	• 2.2/1.7/2.5 • 150,000 km	• 2.0/1.5/2.0 • 120,000 km	• 2.5/2.0/2.8 • 200,000 km	81 79	128 135
Low-temp. detergents	80	• User behavior hot/cold • Detergent used vs. instruction	• 30/70 • 100%	• 50/50 • 120%	• 20/80 • 70%	97 83	103 143
Engine efficiency	70	• Efficiency gain	• N/a	• -25 percent point	• +25 percent points	75	125
Piping	70	• No apparent uncertainty	• N/a	• N/a	• N/a		100
Fertilizer and crop protection	1,600	• Yield gain • Land use change emissions	• 50% • USA grass	• 40% • USA grass	• 60% • W. average	67 100	150 235

* cLCA adopted very conservative assumption from GUA. The likely (large) upside was not assessed in this study
Source: ICCA/ McKInsey analysis

Chapter 3: Tomorrow's opportunity – two McKinsey scenarios to 2030, and chemicals' potential decarbonizing role

The previous chapter examines the chemical industry's current emissions and the abatement it enables in other industries and by end users. This chapter examines the follow-on question: "How might this change in the future?". To answer this question, McKinsey defined and assessed two scenarios to 2030: a business-as-usual (BAU) and a more ambitious "abatement scenario".

The BAU scenario is mainly characterized by volume growth of the chemical industry linked to GDP growth and current regulations and policies, minor improvements across its portfolio of processes, and ongoing geographic shifts in production capacity. It assumes no additional regulatory push for low-carbon development.

The abatement scenario, on the other hand, assumes effective implementation of measures leading to a low-carbon economy. These include globally consistent regulation and initiatives that incentivize the reduction of the industry's CO_2e emissions, and regulation to increase the use of products and applications with a positive abatement effect.

This chapter sets out the findings for each of these two scenarios. It also outlines a range of possible future chemical innovations that could achieve emissions savings beyond even the abatement scenario.

BUSINESS-AS-USUAL SCENARIO

To calculate the BAU scenario, growth rates needed to be applied to the production volumes of the various categories of chemical products. Industry-specific growth rates, taken from analysts' reports[9], were used for the largest emission subcategories. For the remaining subcategories, the analysis used an overall growth rate of 3 percent, i.e., similar to GDP growth.

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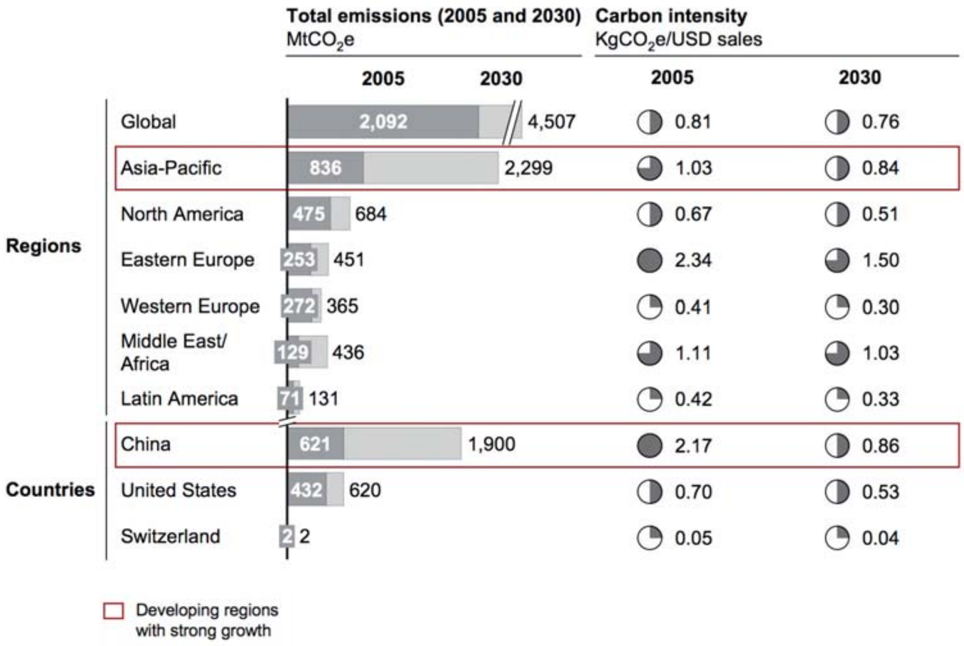
[9] For example SRI, Tecnon, Freedonia.

In terms of own emissions, key drivers in this scenario are volume growth, efficiency gains and geographic shift. These drivers result in an increase of the own emissions from 3.3 Gt CO_2e +/- 25 percent (in 2005) to approximately 6.5 GtCO_2e +/- 35 percent:

- The industry could meet the future doubling of demand by increased production volumes in more efficient plants and processes. Doubling the output in highly efficient plants will increase the emissions by 1.7 Gt CO_2e. These improvements are in line with previously observed efficiency gains, driven by a shift of fuel from oil and coal to gas, improved asset utilization and other efficiency improvements;
- However, a further ~1.5 GtCO_2e are due to increased production in coal-based (and hence more carbon-intense) economies, such as China and India (Exhibit 13).

Exhibit 13

Higher carbon intensity in Asia-Pacific and China
Regional comparison of chemical industry CO_2e intensity*



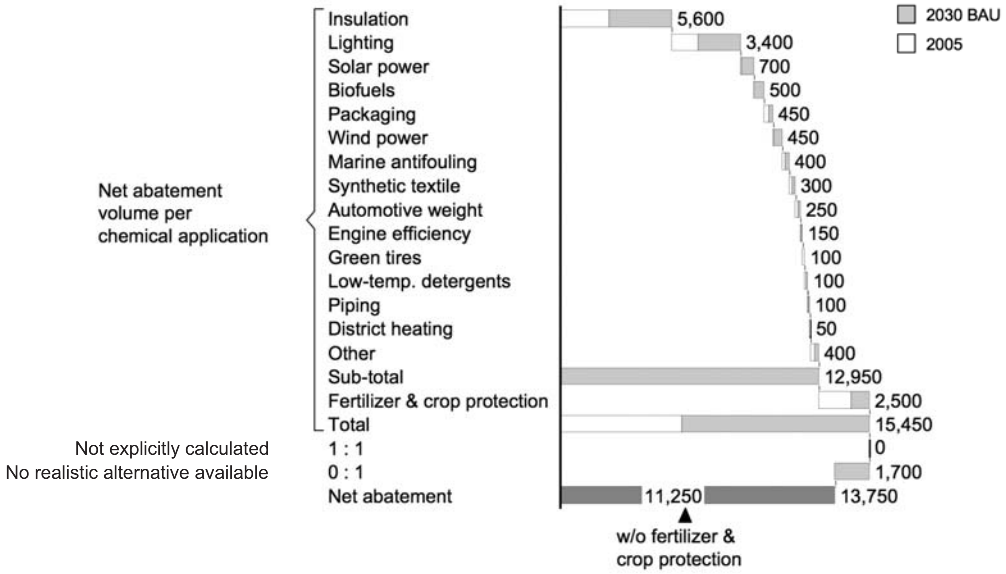
* Production emissions only, not including extraction and disposal emission
Source: ACC production forecast (2005-17), SRI, Tecnon; McKinsey analysis

Under the BAU scenario, the energy-efficient applications grow stronger than in the past, therefore the industry's **gross savings increase from 6.9 to 8.5 $GtCO_2e$ +/- 30 percent (in 2005, without, respectively with the fertilizer case) to 17.3 to 20.3 $GtCO_2e$ +/- 40 percent, resulting in an improved ratio from 2.1 : 1 to 2.6 : 1 (in 2005) to 2.7 : 1 to 3.1 : 1.**

The net emission abatement enabled by the chemical industry increases from 3.6 to 5.2 $GtCO_2e$ +/- 30 percent (in 2005) to 11.3 to 13.8 $GtCO_2e$ +/- 40 percent. The net abatement ranking per subcategory remains very similar to the current picture, with insulation remaining the highest abatement lever at 5.6 $GtCO_2e$ (Exhibit 14). Lighting is next, surpassing fertilizer and crop protection, at 3.4 $GtCO_2e$. Two significant emission abatement levers in 2030 are solar power and biofuels (including LC ethanol). Solar power is expected to reduce emissions by 0.7 $GtCO_2e$, based on the projection that installed solar capacity will increase by 20 percent per year until 2020 and by 10 percent per year thereafter. Meanwhile, biofuel used as a gasoline and diesel substitute will create emission savings of 0.5 $GtCO_2e$ by 2030.

Exhibit 14

Net abatement grows to 13.8 Gt in 2030 under BAU assumptions (with the fertilizer case)
Net abatement
$MtCO_2e$



Source: ICCA/ McKinsey analysis

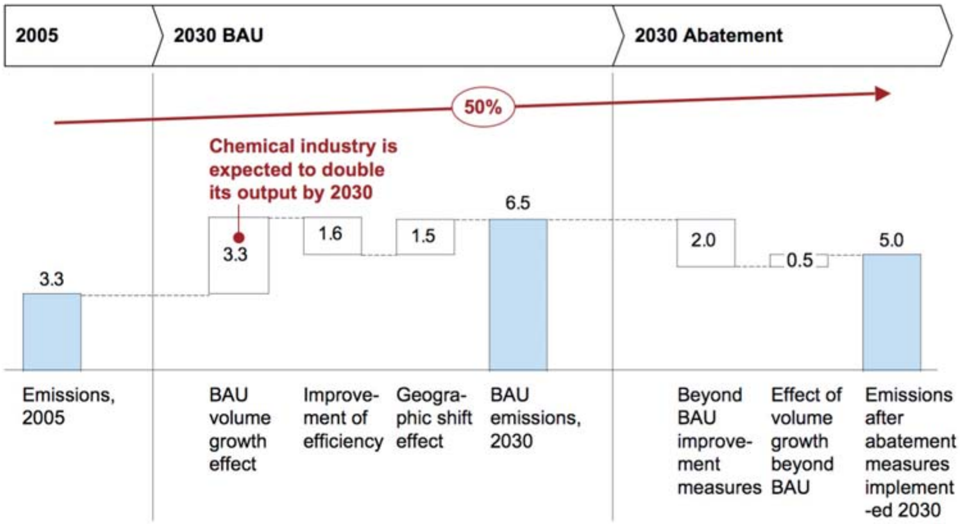
ABATEMENT SCENARIO

The abatement scenario is closely aligned with McKinsey's 2030 GHG abatement cost curve. It includes a further reduction of the industry's CO_2e emissions, and an increased use of products and applications with a positive abatement effect.

In terms of own emissions, the abatement scenario results in a reduction from 6.5 GtCO_2e (under the BAU scenario) to 5 GtCO_2e +/-35 percent. This assumes that all levers of the McKinsey chemicals sector abatement cost curve, worth 2 GtCO_2e, are implemented whilst increased volumes for supporting CO_2e-efficient applications offset this number by 0.5 GtCO_2e (Exhibit 15).

Exhibit 15

BAU emissions almost double due to geographic factors - this increase is reduced by half in the abatement scenario
Calculated evolution of chemical industry emissions*

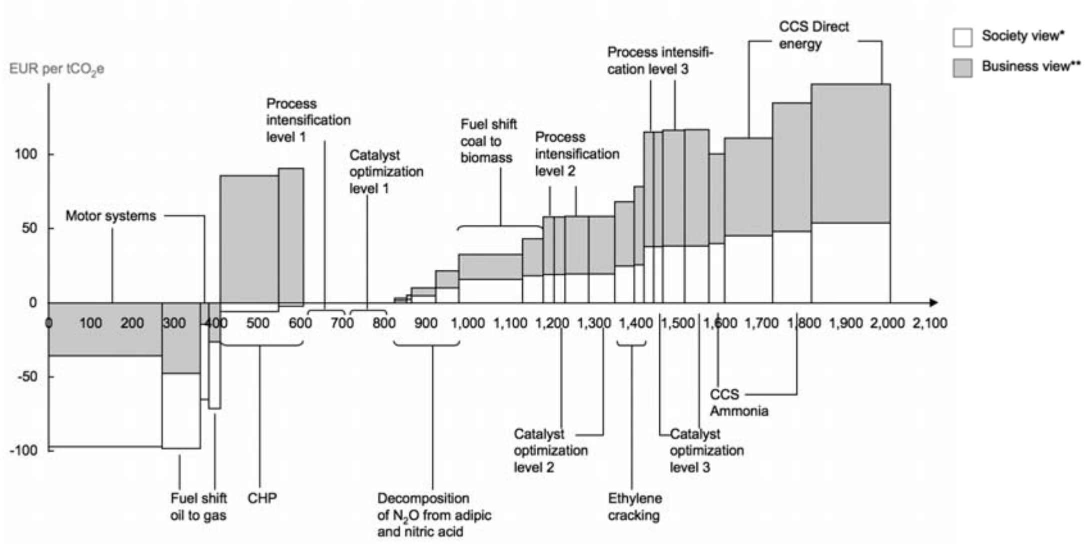


* From extraction of feedstock and fuel, through production, to disposal
Source: ICCA/ McKinsey analysis

Adopting all the measures from the McKinsey abatement cost curve would increase the industry's annual improvement rate significantly above the historic rate. However, this also comes at a significant cost for the industry. Whilst the measures in the abatement cost curve cost less than € 50 per tCO_2e taking a societal perspective (4% interest rate, depreciation over the lifetime of the equipment) and therefore it would make sense from a societal perspective to implement and prioritize them vs. more expensive measures in other areas, some of them surpass € 100 per tCO_2e when taking a business perspective (10% interest rate, depreciation over 10 years) (Exhibit 16). Governments should create favorable business conditions to bridge this gap.

Exhibit 16

GHG abatement cost curve for the chemical industry



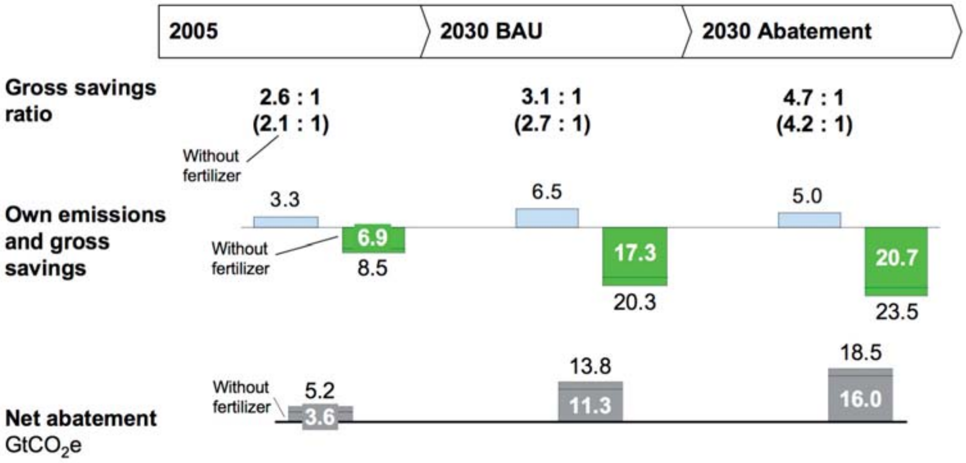
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below EUR 60 per tCO2e (society view) if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play
* 4% interest rate, depreciation over life time of equipment
** 10% interest rate, depreciation over 10 years
Source: ICCA/ McKinsey analysis

Under the abatement scenario, the energy-efficient applications grow even stronger than in the past, therefore **the industry's gross savings improve from 17.3 to 20.3 $GtCO_2e$ (under the BAU scenario, without, respectively with the fertilizer case) to 20.7 to 23.5 $GtCO_2e$ +/- 40 percent, resulting in an improved ratio from 2.7 : 1 to 3.1 : 1 (under the BAU scenario) to 4.2 : 1 to 4.7 : 1.** These numbers take into account that energy production will be less carbon intensive in 2030. This result takes account of both wider use of chemical industry products as well as their more efficient production.

The net emission abatement improves from 11.3 to 13.8 $GtCO_2e$ (under the BAU scenario) to 16.0 to 18.5 $GtCO_2e$ +/- 40 percent (Exhibit 17). The improvement of 4.7 $GtCO_2e$ compares to the total global potential across all sectors in the McKinsey abatement curve (beyond BAU) of 38 $GtCO_2e$, which implies that the chemical industry would contribute 12 % of this potential (Exhibit 1).

Exhibit 17

Gross savings ratio could reach 4.7 : 1 and net emission abatement could reach 18.5 $GtCO_2e$ (with the fertilizer case) if the appropriate abatement measures are taken



Source: ICCA/ McKinsey analysis

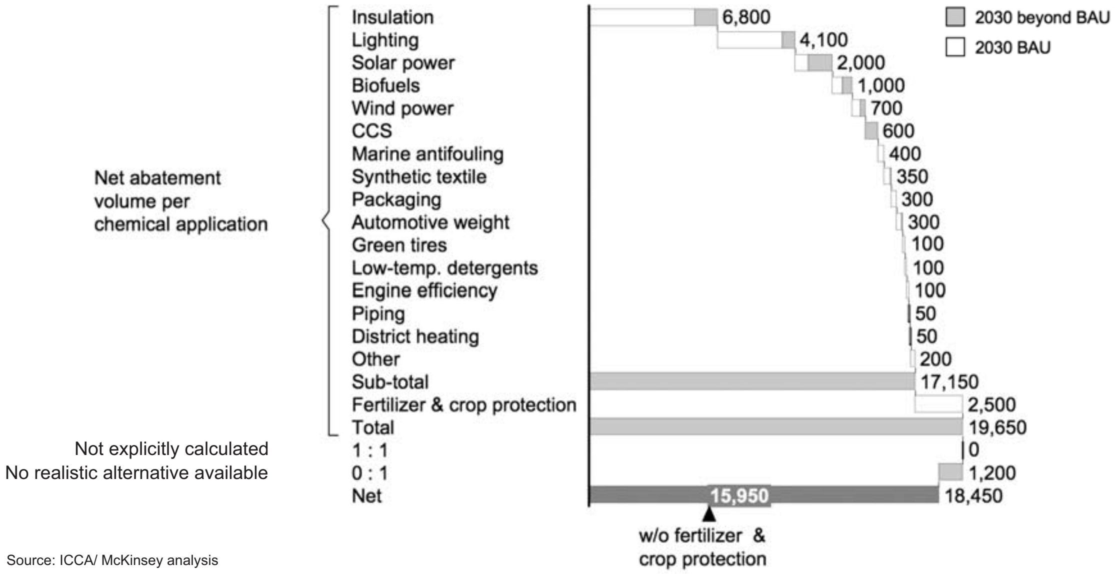
Insulation remains the leading emission abatement lever (Exhibit 18). The installation of insulation to improve the energy efficiency of commercial and residential buildings results in an additional ~1.2 $GtCO_2e$ saved, most of it from developing countries. In lighting, the scenario sees LEDs replacing nearly all incandescent and CFL lamps, resulting in an additional ~0.7 $GtCO_2e$ emission abatement. Biofuels penetration almost doubles under the scenario, resulting in a doubling of the abatement. In this scenario, solar and wind power will account for 10 percent and 15 percent of global electricity demand respectively in 2030. Solar is expected to reach CO_2e abatement of ~2.0 and wind ~0.7 $GtCO_2e$. CCS abatement potential is ~0.6 $GtCO_2e$. As a reminder, the abatement potential stated here is the one allocated to the chemical industry, e.g., 20 percent of total CCS abatement is allocated to the chemical industry.

Exhibit 18

Additional 4.7 Gt abatement potential beyond BAU identified

Net abatement

$MtCO_2e$



Source: ICCA/ McKinsey analysis

NEW INNOVATIONS LIKELY TO FURTHER INCREASE ABATEMENT

Only technologies that are either already commercially available to the chemical industry, or have already been scientifically proven and will be available by 2030, have been included in the BAU and abatement scenarios. The industry is working on breakthrough technologies, which – if successful – could increase the industry's net abatement potential substantially beyond that identified in the abatement scenario.

Examples of in-use innovations include:

- Conductive polymers for printable electronics – a low-energy/ resource technology for simple electronic devices;
- Reverse osmosis membranes for water desalination, which increase process energy efficiency;
- Low-cost CO_2 separation membranes for carbon capture and storage (CCS);
- Materials for advanced solar cells under development, which include organic photovoltaics, high-efficiency compound semiconductors and ultra-high-efficiency thin-film solar cells, which may increase solar power penetration due to their advantageous economics;

- Materials for advanced fuel cells, including polymer electrolyte fuel cells (PEFC), solid oxide fuel cells (SOFC) and molten carbonate fuel cells (MCFC), which enable drastic cost reductions and durability improvements;
- Materials for high-performance power storage devices, such as advanced lithium-ion and nickel-hydride batteries and capacitors, based on new concepts and technologies, which will lead to drastic performance improvements and cost reductions.

Breakthrough innovations in the area of the industry’s own emissions could come from:

- Continued process and catalyst improvements and process intensifications;
- The use of renewable feedstock (white biotechnology), including key building block raw materials from biomass;
- Advanced recovery and recycling technologies.

Chapter 4: Policy implications: optimizing the chemical industry's abatement potential

The findings of this study highlight the importance of considering all key stages of a product's life cycle, i.e., extraction of feedstock and fuels, production, use and disposal. The overall impact of the product can be improved at each stage.

Effective legislation within a global framework is essential to ensure that the net emissions savings potential identified in this study does materialize and the study does create the basis and data to assess the need for better regulation that takes an integrated approach.

The cLCA work together with the McKinsey 2030 scenarios show that the increased abatement from the appropriate use of chemical products is significant today and could grow considerably in the years to come.

However, a number of challenges exist that could hinder or slow the implementation of CO_2e savings measures using these chemical products.

The ICCA suggests the following guiding principles for consideration when devising policies directed towards a low-carbon economy based on a cLCA viewpoint.

- **Develop a global carbon framework to accelerate GHG reductions, avoid market distortions and minimize carbon leakage**[10]. The challenge of GHG emissions must be tackled globally as emissions are global. Global policies will help minimize carbon leakage and reduce the risk of market distortions. Such distortions would be created where higher costs are incurred by some, but not all major industries and/or regions through stricter regulations.
    - → Recommendation: Harmonized global policies for global markets – or one global policy – are an essential element that authorities must strive for. In the interim, the trade-exposed chemical industry needs local transitional provisions such as free carbon allowances to avoid market distortions.
- **Focus on the largest, most effective and lowest cost abatement opportunities.** Given that funds are limited and that a rapid reduction in CO_2e emissions is required to stabilize the climate, it is vital to spend wisely and focus on those measures that can have the greatest impact.
    - → Recommendation: Policy should focus on scale, cost, and implementation speed.

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[10] Carbon leakage is the migration of production into non-regulated regions with higher production footprints, or substitution by less stringently regulated products with higher CO_2e footprints.

- **Push for energy efficiency.** Energy production and use is one of the greatest sources of CO_2e emissions and needs to be a priority focus area in the drive towards a low-carbon future. Reducing energy usage is the most effective means of abating CO_2e. In many cases, the measures that lead to greater energy efficiency pay for themselves.
    - → Recommendation: Government policies should give more support to those products and applications that offer greater energy and resource efficiency, e.g., building insulation.

- **Support the development and implementation of new technologies.** Only through new technology can the world economy slow, stop, and reverse its growth of CO_2e emissions to reach the proposed stabilization range of 450-550 ppm CO_2 (IEA 2008). The research on and development of new technologies to meet this challenge will need funding and support. In a field of rapid technological progress, however, it is important to avoid locking in sub-optimal solutions. In general, regulation should ask for performance targets as opposed to the implementation of specific solutions.
    - → Recommendation: Despite the current economic situation, governments should continue funding research and development. The important role of the chemical industry and its products should be reflected in these programs.

- **Support the development of the most efficient and sustainable use of available feedstocks and energy.** The chemical industry can use a wide range of products for both feedstocks and energy. Governments should promote improving energy and GHG efficiency rather than imposing legislation that restricts the use of a specific feedstock. Any system that imposes a regional cap or restriction on one specific feedstock has the potential to harm the economy without actually reducing global GHG emissions.
    - → Recommendation: Changes in the choice of feedstock will require technology development, which eventually will be driven by the market. Greater use of bio-feedstocks needs to consider feedstock and energy aspects, local availability, and food versus fuel concerns.

- **Provide incentives for faster action by rewarding early movers that proactively reduce their CO_2e footprint.** Policy should ultimately reward those companies that are most advanced in implementing CO_2e reduction measures. This needs to be matched by effective measures to accelerate action in those companies and regions that have fallen behind.
    - → Recommendation: Policies should use performance-based measures as an approach to establish practically achievable emission targets.

- **Push for the most efficient and sustainable disposal, recovery and recycling options.** The way chemistry-based products are disposed of (e.g. landfill, incineration with or without heat recovery and recycling) is still fairly unequal across regions and has a significant impact on the total emissions over the life cycle of a product.

  - → Recommendation: Support the development of new technologies and practices that ensure that the most efficient and sustainable disposal, recovery or recycling options are implemented.

- **Technology cooperation to support abatement in developing countries.** Two thirds of the industry's abatement potential is in the developing world. However, several hurdles stand in the way of realizing this abatement potential. Many of the abatement levers have a direct impact on production costs, leading to concerns regarding the impact of technology cooperation on competitiveness (WEF 2007). To realize the CO_2e savings potential in the developed world, regulations that ensure a level playing field for all industry participants, but recognize regional differences and imperatives, and incentives for the introduction of capital-intensive measures will accelerate the decarbonization of the industry.
  - → Recommendation: A technology cooperation mechanism between companies in the developed and the developing world could create positive business opportunities for both technology owners and receivers. Ensuring adequate financial incentives to compensate for risks and to ensure continued focus on innovation can promote this.

The implementation of the above-mentioned measures should be designed to complement the future carbon framework. The goal must be to produce GHG intensive products – taking the whole production value chain into account – as carbon efficiently as possible irrespective of the location. This future carbon framework should be designed to ensure this happens as cost effectively as possible. As the global framework is being developed, local policy should ensure that carbon burdens do not apply unilaterally within their regions thus avoiding market distortions and unintended consequences such as carbon leakage.

THE IMPORTANCE OF A RELIABLE AND STABLE REGULATORY FRAMEWORK: SOME EXAMPLES

Insulation

The study has shown that insulation has the greatest potential for CO_2e abatement enabled by the chemical industry. However, the nature of the market for insulation poses implementation challenges that require policy support if they are to be overcome. These hurdles include a lack of general awareness of the advantages of insulation, and ownership or agency problems, i.e., a lack of alignment between landlords' and tenants' interests.

- → Recommendation: Governments should mandate a policy mix comprising information campaigns, tighter building codes focusing on overall economy and energy efficiency, as well as financial incentives for owners and end users to boost the use of insulation materials.

Renewable Energy and CCS

Investments in renewable energy and CCS are at different stages of development. Public support and financing is most important during the development and demonstration phase. As these technologies are commercialized, financial support should be reduced and ultimately (finally) removed to allow the market to work effectively.

→ Recommendation: Regulators should target development support according to the maturity of the technology. Less mature technologies should mainly be supported via research while more mature innovations should receive more demonstration support to bridge deployment gaps. All technologies need a transparent support phase out plan.

Fertilizer and crop protection

The appropriate use of high-quality fertilizer and crop protection shows the important role of agriculture in land-use changes that impact climate protection. Ensuring food security whilst addressing climate protection is a truly global challenge and regulations addressing this, need to take a global perspective. In future, agricultural practices that impact land use should be included in any climate change regulation. Intensification of farming, especially in poor or developing countries, could reduce the destruction of forest and native land. Policies that give farmers access to agrochemicals should include education about best agricultural practices.

→ Recommendation: A future global climate framework should include the impact of land-use change. Considerable additional research in this area should be supported by the global community.

REGULATION TO UNLOCK EMISSIONS ABATEMENT WITHIN THE CHEMICAL INDUSTRY

The chemical industry submits that it has already gone a considerable way towards sustainability and will – especially in the current economic crisis – rely on policy support to continue its efforts to reduce its own CO_2e footprint and to innovate for a low-carbon future.

The chemical industry accepts that it must address its own GHG footprint as part of a larger global effort to tackle climate change. However, the industry has already made impressive progress in this regard. It has improved its efficiency and reduced emissions of all kinds over the past years. The next steps on this path will be increasingly challenging, especially in the current economic situation. It would be detrimental to penalize the industry for its early steps by putting tight limits on its CO_2e emissions without simultaneously implementing regulations that facilitate an expansion of its broader emissions abatement role.

Conclusion

This study has reconfirmed the necessity of taking a global approach to addressing climate change. It has also demonstrated the value of integrating life cycle thinking into future policy work.

The overriding conclusion of this work is that the best options to reduce global GHG reductions will involve a full life cycle approach to ensure each stage of the value chain provide their optimum contributions. Conversely by not taking an optimized life cycle approach, reductions at one stage may prevent larger reductions elsewhere and thus not in fact contribute to net global reductions.

This project has contributed an important step to develop a robust and more transparent methodology to improve future GHG abatement options. One important aim of this work was to provide better facts as a basis for developing more effective policies and regulations. This study is therefore also intended to provide helpful factual background to facilitate this required closer discussion and cooperation between governments and industry.

The growing consensus that significant GHG emission reductions are needed represents a daunting challenge. This may not only require continued changes in industry production, but eventually major societal changes involving more sustainable consumption. This study made no attempt to quantify such potential life style changes. It is however logical to assume that higher performance materials will play an essential role in any realistic scenario involving these more sustainable consumption patterns. This means that the innovations of the industry that are currently enabling GHG reductions will become even more critical in the future.

The CO_2e life cycle analysis conducted in this study demonstrates that under various assumptions the chemical industry enables significant net GHG reductions and thus the overall use of its products saves more than the emissions linked to its production processes.

The McKinsey 2030 scenarios have highlighted that under a business as usual scenario global chemical industry emissions would approximately double to 6.5 $GtCO_2e$ by 2030. A large portion, about 1.5 Gt, comes from the substantive growth in regions relying on more carbon intensive energy mixes such as China and the Middle East. This can be viewed as an opportunity to deploy new policy measures and improved technology cooperation to address such carbon intensity concerns. This growth projection assumes continuing and significant savings from efficiency improvements (1.6 Gt) and therefore reinforces the importance of accelerating the deployment of additional innovations.

For more information on the climate study, visit
www.americanchemistry.com/ClimateStudy.

This document illustrates the current magnitude and the future potential of the GHG emission abatements enabled by the chemical industry. Grasping this future potential will largely depend on optimizing the balance between economics and regulation. The industry can and will continue to strive to make its technologies more cost effective. At the same time, governments and regulators will need to ensure that the global regulatory framework takes into account full life cycle impacts. This will enable the chemical industry to play a more effective role in shifting the world's economy towards a lower carbon pathway.

Achieving absolute global GHG reductions will require all of the above measures combined with breakthroughs in how new technologies are developed and deployed. This project was also intended to help set priorities for this future work. A life cycle driven approach will ensure the use of more efficient solutions is accelerated while the processes to provide those solutions are also made more GHG efficient. Regional contact details are provided on the back cover of this report as an invitation to all interested stakeholders to participate in constructive dialog to facilitate these future improvements.

Glossary

X : 1	X : 1 ratio. Compares the emissions of the chemical over its life cycle and the enabled gross savings. Any X : 1 ratio bigger than 1 : 1 leads to net CO_2e savings
BAU	Business-as-usual scenario. Assumes implementation of current policies – no additional policies
CCS	Carbon capture and storage
CFL	Compact fluorescent lamp. Type of fluorescent lamp that fits into a standard light bulb socket or plugs into a small lighting fixture
cLCA	Carbon Life cycle analysis; assessment that focuses only on the CO_2 equivalent emissions (see LCA)
CO_2e	Carbon dioxide equivalent. Quantity that describes, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (in this project 100 years)
GHG	Greenhouse gas
GHG cost curve	McKinsey global greenhouse gas cost curve v.2. The cost curve was published in February 2009
Gt	Gigaton
In-use phase	Phase in life cycle in which product is being “used”, i.e., after production and before disposal
IPCC	The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body tasked to evaluate the risk of climate change caused by human activity
Land-use change	Changing use of land from grass/ forest land to cropland. PAS2050 gives guidelines for calculation of CO_2e emissions arising from specified changes in land use for a selection of countries
LCA	Life cycle assessment. Investigation and valuation of the environmental impact of a given product or service caused or necessitated by its existence
Mt	Megaton. 1 million tons
PAS2050	Publicly Available Specification (PAS) for a method for measuring the embodied CO_2e emissions from goods and services. Development of PAS2050 commenced in June 2007 at the request of Defra (Department for Environment, Food and Rural Affairs) and the Carbon Trust

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Appendix I – Summary of cLCA results

The tables below list the applications that were identified and calculated. For each application, the net emission abatement was listed, as well as the own emissions and the X: 1 value. For a number of applications, there are several cLCAs that were aggregated in order to get to the result. For instance, the automotive weight reduction cLCAs aggregate the calculations for replacing aluminum with PA, steel with HDPE, glass with PC, and textile with PUR into the overall application abatement.

Some of the data required to create this report is confidential and the participating companies have requested not to publish them. This includes for instance data regarding production and disposal emissions for certain applications.

DETAILED LIST OF PRIMARY ASSUMPTIONS USED IN CALCULATIONS

Many data sources were used in order to calculate each cLCA. For the sake of transparency, the key assumptions have been listed for the 15 most important cases. Various key assumptions are not shared due to confidentiality reasons – yet most important assumptions even confidential ones were included in the Critical Review process of the Öko-Institut.

USE OF FOAM INSULATION – BROKEN DOWN BY REGION, CLIMATE, BUILDING STANDARD, TYPE OF FOAM, RETROFIT/NEW BUILD

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
10	233	2,407	25

General comments

Comment	Assumption	Source/rationale
Reference case	Mineral wool for roofs, none for walls and floors	
Regions considered	Europe, North America, Asia (incl. Japan)	Main relevant regions (incl. majority of insulation usage)
25 different cases	Differing in climate zone, building standard	Relevant differences for insulation
Annual volume of insulation materials PUR/XPS/EPS (kt)	North America: 533/157/192	Tecnon, SRI, GUA
	Europe: 336/110/404	
	Asia: 295/139/687	
Fuel mix	Oil: 45%	Conservative mix (no electricity), GUA
	Gas: 45%	
	Wood: 10%	
Carbon intensity fuel mix (incl. pre-chains)	346 gCO_2e/kWh	GUA
Efficiency heating system	90%	GUA

Own emissions

Input		Value	Source
Production footprint ($kgCO_2/kg$)	PUR	4.4	Participating companies, GUA
	XPS	2.8	Participating companies, GUA
	EPS	3.2	Participating companies, GUA
Production volume (kt)	PUR	1,165	Tecnon, SRI, GUA
	XPS	406	Tecnon, SRI, GUA
	EPS	1,283	Tecnon, SRI, GUA
End-of-life emissions ($kgC0_2/kg$)	PUR	0	GUA
	XPS	0	GUA
	EPS	0	GUA
Own emissions chemicals ($ktCO_2$)	PUR	5,124	
	XPS	1,136	
	EPS	4,106	
Global own emissions ($ktCO_2$)		10,366	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2/kg$)	Mineral wool	1.6	Participating companies, GUA
Production volume (kt)	Mineral wool	1,726	
End-of-life emissions ($kgC0_2/kg$)	Mineral wool	0	
Global own emissions non-chemicals ($ktCO_2$)		2,762	

In-use savings

Input		Value	Source
Insulated surface (m²)	Walls & floors	1,861,173,257	
	Roofs	465,732,476	
Difference in U-value (W/m²K)	Walls & floors	-1.00	Company data for North America and Asia, GUA for wall data, Ecofys data for roof and floor (modified as in GUA study)
	Roofs	0	Company data for North America and Asia, GUA for wall data, Ecofys data for roof and floor (modified as in GUA study)
HDD (kdays)		2,793	Participating companies, GUA
Heat efficiency		0.6897	GUA
CO_2 footprint of heating energy ($kgCO_2/MJ$)		0.074	Participating companies, GUA
Lifetime of insulation (years)		50	Participating companies, GUA
CO_2 in-use savings ($ktCO_2e$)	Walls & floors	2,414,682	
	Roofs	0	
Global in-use savings ($ktCO_2e$)		2,414,682	

USE OF SYNTHETIC FERTILIZER AND CROP PROTECTION

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
312	6.17	1,614	5

General comments

Comment	Assumption	Source/rationale	
Reference case	Organic farming		
Crops covered	Wheat	Biggest cash crops	
	Corn		
	Rice		
	Sugar cane		
	Soy		
Total farming emissions ($kgCO_2e/kg$)	Wheat: 602	Ecoinvent	
	Corn: 434		
	Rice: 466		
	Sugar cane: 20		
	Soy: 507		
Production footprint ($kgCO_2e/kg$)	N-fertilizer: 3.14	Ecoinvent	
	P-fertilizer: 0.7		
	K-fertilizer: 0.75		
	Pesticide: 11		
Annual production (Mt)	Wheat: 607	FAO	
	Corn: 785		
	Rice: 652		
	Sugar cane: 1,558		
	Soy: 216		
Amount of land currently used for crops	For each crop type, production and yield analyzed in 5 largest producing countries per crop; then extrapolated for entire crop produce	FAO, McKinsey analyses	

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)	Weighted average	2.4	Ecoinvent
Volume of ammonia consumed (Mt)		153	
Share of ammonia used in fertilizer industry		85%	
Global own emissions ($MtCO_2e$)	Fertilizer and pesticide	312	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Global own emissions ($MtCO_2e$)	Organic farming	312	Assumes same footprint as for conventional farming

In-use savings

Input		Value	Source
Land in use today (million ha)	For all five crops	604.84	FAO Stat
Average yield reduction without use of synthetic fertilizer and crop protection	For all five crops	50%	Report European Fertilizer Manufacturers Associaton: 50% for fertilizers only + Expert View: 66% for fertilizers & pesticides, Defra, FAO, Expert interviews (ranging from 25-85%)
Land-use change emissions (ton CO_2e/ha/year)		1.5	PAS2050, Defra (most conservative, US grass land)
Share of fertilizer used for 5 largest crops		56%	FAO fertilizer used by crop, McKinsey analyses
Global own emissions ($MtCO_2e$)		1,614	

LIGHTING WITH COMPACT FLUORESCENT LAMPS (CFL)

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
37	19.75	688	1

General comments

Comment	Assumption	Source/rationale
Reference case	Incandescent lighting	
Market share in light markets	US: 47%	GIA
	EU + Japan: 34%	
	ROW: 19%	
Energy footprint	US: 611 kgCO2e/MWh	IEA
	EU + Japan: 500 kg-CO_2e/MWh	
	ROW: 700 $kgCO_2e$/MWh	

Own emissions

Input		Value	Source
Production footprint ($kgCO_2$)	CFL	13	LCA by Rocky Mountain Institute
Production volume (lamps needed)	CFL	2,823,529,412	Worldwatch Institute
End-of-life emissions ($kgCO_2$)	CFL	0	
Global own emissions ($ktCO_2e$)	CFL	36,706	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2$)	Incandescent	0.65	LCA by Rocky Mountain Institute
Production volume (lamps needed)	Incandescent	2,823,529,412	
End-of-life emissions ($kgCO_2$)	Incandescent	0	
Global own emissions ($ktCO_2e$)	Incandescent	1,835	

In-use savings

Input		Value	Source
Efficiency gain CFL	CFL	0.8	Philips, Osram
Power needed (Watt)	Incandescent	78	
	CFL	16	
Time (hours)		7,000	Osram
Energy needed (kWh)	Incandescent	543	
	CFL	109	
Energy footprint ($kgCO_2e$/MWh)		590	Weighted average based on IEA and GIA
CO_2 in-use savings ($kgCO_2e$/lamp)	CFL	256	
Global CO_2 in-use savings ($ktCO_2e$)	CFL	723,011	
Gross savings ($ktCO_2e$)	CFL	724,847	
Net CO_2 savings ($ktCO_2e$)	CFL	688,141	

POLYMERS REPLACING TRADITIONAL PACKAGING – STEEL, CARTON, ALUMINUM, GLASS, PAPER, WOOD – BROKEN DOWN BY TYPE OF PACKAGING – BEVERAGE, FLEXIBLE, FILM, BOTTLES, OTHER

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
295	1.75	222	13

General comments

Comment	Assumption	Source/rationale
Reference case	Tin; Aluminum; Glass white; Corrugated board; Paper, cardboard; Beverage carton; Wood	
Mass ratio breakdown of plastics used for each application	Detailed mass distribution per application	GUA study for Plastics Europe

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		3.15	SimaPro, participating company
Production volume (kt)		90,838	Participating company, GUA study for Plastics Europe
End-of-life emissions ($kgCO_2e/kg$)		0.11	SimaPro, participating company
Global own emissions ($ktCO_2e$)		295,914	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		4.28	SimaPro, participating company
Production volume (kt)		90,838	Participating company, GUA study for Plastics Europe
End-of-life emissions ($kgCO_2e/kg$)		1.12	SimaPro, participating company
Global own emissions non-chemical alternative ($ktCO_2e$)		490,617	

In-use savings

Input		Value	Source
Difference in in-use footprint ($kgCO_2e/kg$)		0.30	Taking into account reduced food losses
Production volume (kt)		90,838	Participating company, GUA study for Plastics Europe
Global in-use savings ($ktCO_2e$)		27,614	

MARINE FUEL REDUCTION DUE TO USE OF ANTI-FOULING COATING

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
10	20.00	190	1

General comments

Comment	Assumption	Source/rationale
Reference case	Without anti-fouling coating	
Annual production of anti-fouling paint (million liters)	193	SRI, company information, McKinsey analysis
CAGR of annual production of anti-fouling paint	0.8%	SRI

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e$/liter)		4.50	AkzoNobel
Production volume over 12 years of corrosion paint (million liters)		2,219	SRI, company information, McKinsey analysis
End-of-life emissions ($kgCO_2e$/liter)		0	
Global own emissions ($ktCO_2e$)		9,986	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint (kgCO_2e/liter)	None	0	
Production volume (million liters)	None	0	
End-of-life emissions (kgCO_2e/liter)	None	0	
Global own emissions (ktCO_2e)	None	0	

In-use savings

Input		Value	Source
Annual marine fuel consumption (kt)		219,934	IEA
Fuel consumption reduction due to use of anti-fouling paint		29%	Participating company info, triangulated with IMO
Marine fuel footprint (incl. pre-chain) (kgCO_2e/kg heavy fuel)		3.65	Eco-invent, company info
Share of savings realized in one year		9%	
Time horizon (years)		10	
Global CO_2 in-use savings (ktCO_2e)		199,689	

SYNTHETIC TEXTILES – REPLACEMENT OF COTTON WITH POLYESTER

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
82	2.64	134	1

General comments

Comment	Assumption	Source/rationale
Reference case	100% cotton	
Volume distribution	GDP:	GDP as reasonable proxy for distribution
	Europe + Japan: 40%	
	US: 40%	
	ROW: 20%	

Own emissions

Input		Value	Source
Production footprint (incl. CH_4) ($kgCO_2/kg$)	50/50 Polyester/Cotton	5.6	Autex Research Journal Vol 1,No.1, 1999
Production volume (kt)		14,760	fibre2fashion
End-of-life emissions ($kgCO_2/kg$)		-0.06	Autex Research Journal Vol 1,No.1, 1999
Global own emissions ($ktCO_2e$)		81,705	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint (incl. CH_4) ($kgCO_2/kg$)	Cotton	7.3	Autex Research Journal Vol 1,No.1, 1999
Lifetime factor		2	Lifetime half as long as for 50/50 textile
Production volume (kt)		14,760	fibre2fashion
End-of-life emissions ($kgCO_2/kg$)		0	Autex Research Journal Vol 1,No.1, 1999 (100% landfill assumption)
Global own emissions ($ktCO_2e$)	Reference for Polyester	215,496	

In-use savings

Input		Value	Source
Global CO_2 in-use savings ($ktCO_2e$)	50/50 Polyester/Cotton	0	Ignored (conservative)

POLYMERS FOR AUTOMOTIVE WEIGHT REDUCTION

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
66	2.89	124	8

General comments

Comment	Assumption	Source/rationale
Reference case	Steel/Aluminum for PE/PP/PEEK/PA; Glass for PC; Textile for PUR	
Polymer production footprints	Based on company data where available; Plastics Europe database used when not available	Participating companies, Plastics Europe, SimaPro
Other material production and disposal footprints ($kgCO_2e/kg$)	Steel - production: 2.9, disposal credit: 0.92	SimaPro
	Aluminum - production: 12.2, disposal credit: 8.24	
	Glass - production: 0.98	
	Textile - production: 6.5	
Weight ratios	Steel - polymer: 220%	GUA, BCC, SLC consortium, McKinsey analysis
	Aluminum - polymer: 170%	
	Glass - polymer: 250%	
	Textile - polymer: 120%	
Plastics use in US automotive industry, 2005 (kt)	1,983 in total, of which 1,589 is replaceable	Automotive Plastics Report 2003 & 2004, SLC consortium, BCC report, Press searches, McKinsey analyses
Regional plastics demand for automotive industry	Europe: 32.2%	CAIR
	US: 19.1%	
	Asia: 35.5%	
	ROW: 13.2%	

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		6.91	Participating companies, Plastics Europe, SimaPro
Production volume (kt)		10,360	GUA, BCC, SLC consortium, McKinsey analysis
End-of-life emissions ($kgCO_2e/kg$)		-0.58	Participating companies, Plastics Europe, SimaPro
Global own emissions ($ktCO_2e$)		65,504	

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Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		9.72	SimaPro
Production volume (kt)		16,883	GUA, BCC, SLC consortium, McKinsey analysis
End-of-life emissions ($kgCO_2e/kg$)		-6.15	SimaPro
Global own emissions ($ktCO_2e$)		60,332	

In-use savings

Input		Value	Source
Global weight difference (kt)		8,305	GUA, BCC, SLC consortium, McKinsey analysis
Fuel savings factor (liters/100 km for every 100 kg of car weight)		0.35	Expert interviews, most predominant number in LCA calculations
Car lifecycle (km)		150,000	Average used by industry for automotive LCAs
CO_2 emissions (incl. pre-chain) ($kgCO_2e/liter$)	Gasoline	2.92	Gemis
	Diesel	3.13	
Gasoline/diesel car parc split	Gasoline	80%	OICA
	Diesel	20%	
CO_2 in-use savings ($ktCO_2e$)	Gasoline	101,228	
	Diesel	27,790	
Total CO_2 in-use savings ($ktCO_2e$)		129,018	

LOW-TEMPERATURE DETERGENTS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
11	9.08	81	2

General comments

Comment	Assumption	Source/rationale
Reference case	Soap	
Washing cycle energy (kWh)	US:	Eco design, Consumer guide to home energy savings
	60C - 4.3 (vertical axis), 1.8 (horizontal axis)	
	37C - 2.3 (vertical axis), 1.0 (horizontal axis)	
	EU:	
	60C - 0.998	
	37C - 0.719	
Energy footprint ($kgCO_2e/MWh$)	EU: 500	IEA
	US: 611	
	ROW: 700	
Global detergent distribution	EU + Japan: 35%	Euromonitor
	US: 20%	
	ROW: 45%	

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Own emissions

Input		Value	Source
Production footprint (gCO_2eq/wash load)	Synthetic detergents	32	Company data
	Addition of detergent enzymes	5	Company data
Production volume (million wash loads)	Synthetic detergents	158,516	Consumer market for detergents, Euromonitor, McKinsey analyses
	Addition of detergent enzymes	130,000	
End-of-life emissions (gCO_2eq/wash load)	Synthetic detergents	33	Company data
	Addition of detergent enzymes	0	Company data
Global own emissions ($ktCO_2e$)	Synthetic detergents	10,331	
	Addition of detergent enzymes	650	
Total own emissions ($ktCO_2e$)		10,981	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint (gCO_2eq/ wash load)	Soap	197	Company data
Production volume (million wash loads)	Soap	158,516	Consumer market for detergents, Euromonitor, McKinsey analyses
End-of-life emissions (gCO_2eq/ wash load)	Soap	112	Company data
Global own emissions ($ktCO_2e$)	Soap	49,009	

In-use savings

Input		Value	Source
CO_2 in-use savings (gCO_2eq/ wash load)	Synthetic detergents Europe + ROW	171	Eco design, IEA
	Synthetic detergents US	599	Eco design, IEA
	Addition of detergent enzymes (corrected for overlap)	77	Eco design, IEA
Production volume (million wash loads)	Synthetic detergents Europe + ROW	93,275	Euromonitor, McKinsey analyses
	Synthetic detergents US	31,952	Euromonitor, McKinsey analyses
	Addition of detergent enzymes (corrected for overlap)	103,020	
CO_2 in-use savings ($ktCO_2e$)	Synthetic detergents Europe + ROW	15,965	
	Synthetic detergents US	19,132	
	Addition of detergent enzymes (corrected for overlap)	7,881	
Global CO_2 in-use savings ($ktCO_2e$)		42,978	

ENGINE EFFICIENCY

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
3.4	20.78	68	3

A. SYNTHETIC GASOLINE ADDITIVES – FUEL ECONOMY IMPROVEMENTS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
1.4	20.76	28	1

General comments

Comment	Assumption	Source/rationale
Reference case	Without fuel additives	
Middle class car lifetime (km)	200,000	Company data
Gasoline consumption per 100 km (liter)	8.7	Company data
Reduction in fuel consumption due to additives	2%	Company data
In-use savings due to fuel consumption reduction ($kgCO_2e/l$)	2.9	Literature
Annual consumption of gasoline fuel additives (deposit control) (kt)	EMEA: 90.1	Frost & Sullivan 2005
	US: 183.9	Freedonia 2008

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		Undisclosed company data	Company data
Production volume (kt)		Undisclosed company data	Company data
End-of-life emissions ($kgCO_2/kg$)		0	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		0	
Production volume (kt)		274.1	Frost & Sullivan 2005, Freedonia 2008
End-of-life emissions ($kgCO_2e/kg$)		0	
Global own emissions ($ktCO_2e$)		0	

In-use savings

Input		Value	Source
Production volume (kt)		274.1	Frost & Sullivan 2005, Freedonia 2008
Global CO_2 in-use savings ($ktCO_2e$)		29,018	

B. SYNTHETIC DIESEL ADDITIVES – FUEL ECONOMY IMPROVEMENTS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.2	111.35	24	1

General comments

Comment	Assumption	Source/rationale
Reference case	Without fuel additives	
Middle class car lifetime (km)	200,000	Company data
Fuel consumption per 100 km (liter)	8	Company data
Reduction in fuel consumption due to additives	2%	Company data
Annual consumption of diesel fuel additives (deposit control) (kt)	EMEA: 30.24 US: 37.15	Frost & Sullivan 2005, for US: derived from EMEA and diesel volumes in EMEA and US

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		Undisclosed company data	Company data
Production volume (kt)		Undisclosed company data	Company data
End-of-life emissions ($kgCO_2/kg$)		0	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)		0	
Production volume (kt)		67.39	Frost & Sullivan 2005
End-of-life emissions ($kgCO_2e/kg$)		0	
Global own emissions ($ktCO_2e$)		0	

In-use savings

Input		Value	Source
Production volume (kt)		67.39	Frost & Sullivan 2005
Global CO_2 in-use savings ($ktCO_2e$)		24,111	

C. SYNTHETIC LUBRICANTS FOR IMPROVING AUTOMOTIVE POWER TRAIN EFFICIENCY

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
1.8	9.93	16	1

General comments

Comment	Assumption	Source/rationale
Reference case	Lubricating mineral oil	
Fuel consumption resulting from use of synthetic lubricants	Average of 5%	Synthetic lubricant producer websites, interviews (range: 2-8%)
Global engine oil demand (t)	12,720	Freedonia
Share of synthetic lubricants in global engine oil demand	7.1%	Freedonia
Global gasoline and diesel consumption 2005 (billion gallon)	516	Tecnon

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)	Synthetic lubricant	2.00	Participating company
Production volume (kt)		903	Freedonia
End-of-life emissions ($kgCO_2/kg$)		0	
Global own emissions ($ktCO_2e$)		1,806	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)	Lubricating mineral oil	1.07	
Production volume (kt)		903	Freedonia
End-of-life emissions ($kgCO_2e/kg$)		0	
Global own emissions ($ktCO_2e$)		966	

In-use savings

Input		Value	Source
Fuel consumption of cars using synthetic oil (billion gallon)		36.64	Tecnon, Freedonia
Fuel consumption reduction		5%	Synthetic lubricant producer websites, interviews
Fuel footprint ($kgCO_2e/gallon$)		8.8	
Global CO_2 in-use savings ($ktCO_2e$)		16,968	

POLYMERS REPLACING CONCRETE, GLASS, ALUMINUM AND STEEL IN DIFFERENT TYPES OF PIPING

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
52	2.25	65	6

General comments

Comment	Assumption	Source/rationale
Reference case	Zinc coated iron, cast iron, copper, fibrecement, stoneware and concrete to replace HDPE and PVC drinking and waste water pipes	GUA
Share of drinking and waste water pipes	64%	GUA
Annual production (Mt)	HDPE: 31.6	Tecnon
	PVC: 35.8	Tecnon
Fraction of production used for pipes	HDPE: 11%	SRI
	PVC: 40%	ECVM

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/kg$)	Drinking water pipes	2.98	Participating companies, GUA
	Waste water pipes	2.55	Participating companies, GUA
Production volume (kt)	Drinking water pipes	3,609	GUA
	Waste water pipes	8,862	GUA
End-of-life emissions ($kgCO_2e/kg$)	Drinking water pipes	0	Negligible (GUA)
	Waste water pipes	0	Negligible (GUA)
Global own emissions ($ktCO_2e$)	Drinking water pipes	10,763	
	Waste water pipes	22,616	
Global own emissions for all pipes ($ktCO_2e$)		52,155	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Production footprint ($kgCO_2e/kg$)	Drinking water pipes	2.01	Participating companies, GUA
	Waste water pipes	0.59	Participating companies, GUA
Production volume (kt)	Drinking water pipes	16,425	Participating companies, GUA
	Waste water pipes	72,224	Participating companies, GUA
End-of-life emissions ($kgCO_2e/kg$)	Drinking water pipes	0	Negligible (GUA)
	Waste water pipes	0	Negligible (GUA)
Global own emissions ($ktCO_2e$)	Drinking water pipes	32,952	
	Waste water pipes	42,262	
Global own emissions for all pipes ($ktCO_2e$)		117,522	

In-use savings

Input		Value	Source
CO_2 in-use savings ($ktCO_2e$)		0	No in-use emissions

GLASS AND CARBON FIBER USE IN WIND TURBINES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.5	123.29	63	1

General comments

Comment	Assumption	Source/rationale
Reference case	Non-chemical construction emissions subtracted from emission savings	Conservative
Wind turbine chosen as base for calculation	Vestas V90 - 3.0 MW	
Production footprints	Detailed per material and construction phase	Vestas
Electricity footprint per region (kgCO2e/MWh)	EU + Japan: 500	IEA
	US: 611	
	ROW: 700	
Wind turbine power generation (MWh/year)	Onshore: 7,890	Vestas
	Offshore: 14,230	
Wind turbine lifetime (years)	20	
Wind turbine installed capacity 2007 (MW)	NA: 5,815	BTM
	EU: 8,085	
	South and East Asia: 5,010	
	Pacific: 597	
	Africa: 86	

Own emissions

Chemical components

Input		Value	Source
Production footprint (tCO_2e/lifetime)	Onshore	79	Vestas
	Offshore	79	Vestas
Annual new installed capacity (MW)	Onshore	19,593	BTM
	Offshore	200	BTM
End-of-life emissions (tCO_2e/lifetime)	Onshore	0	
	Offshore	0	
Global own emissions ($ktCO_2e$)	Onshore	513	
	Offshore	5	
Total own emissions ($ktCO_2e$)		518	

Non-chemical components

Input		Value	Source
Production footprint (tCO_2e/lifetime)	Onshore	654	Vestas
	Offshore	1410	Vestas
Annual new installed capacity (MW)	Onshore	19,593	BTM
	Offshore	200	BTM
End-of-life emissions (tCO_2e/lifetime)	Onshore	0	
	Offshore	0	
Global own emissions ($ktCO_2e$)	Onshore	4,269	
	Offshore	94	
Total own emissions ($ktCO_2e$)		4,363	

Gross savings

In-use savings

Input		Value	Source
Total in-use savings (tCO_2e/lifetime)	Onshore	88,259	IEA
	Offshore	137,780	IEA
Share of epoxy value in wind turbine value		12%	Vestas, SRI, LME, Steel business briefing, netfabrics, McKinsey analyses
Annual new installed capacity (MW)	Onshore	19,593	BTM
	Offshore	200	BTM
CO_2 in-use savings ($ktCO_2e$)	Onshore	67,211.57	
	Offshore	1,071.02	
Total CO_2 in-use savings ($ktCO_2e$)		68,283	

USE OF FOAM COATING IN DISTRICT HEATING

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.24	231.24	55	1

General comments

Comment	Assumption	Source/rationale
Reference case	None	
Pipe lifetime (years)	30	Froling LCA
Design of system	4 MW network	Logstor network proposal
Detailed network design	2000m 150mm pipe 2000m 100mm pipe 4000m 80mm pipe 1000m 50mm pipe	Logstor network proposal
Average district heating footprint (g CO_2e/kWh)	139	Euroheat, McKinsey analysis - 38% coal, 7% oil, 21% gas, 8% waste, 25% renewables
Reduction of overall heating footprint over lifetime	1% p.a.	Conservative assumption
Average alternative heating footprint (alternative to district heating) (g CO_2e/kWh)	450	EuroHeat, McKinsey analysis
Annual mass of PUR in piping	Undisclosed	Company info

Own emissions

Input		Value	Source
Production footprint (tCO_2e/system)		98	Chalmers University of Technology
Production volume (Number of systems)		2,434	Froling LCA, Huntsman, IAL consultants
End-of-life emissions ($kgCO_2e$/system)		0	
Global own emissions ($ktCO_2e$)		240	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Global own emissions ($ktCO_2e$)		0	

In-use savings

Input		Value	Source
CO_2e savings over lifetime ($kgCO_2e/kWh$)		8.12	
Heat delivery of 4 MW-system (MWh)		6,257	EuroHeat
CO_2e savings over lifetime (t CO_2e/system)		50,811	
Production volume (Number of systems)		2,434	Froling LCA, Huntsman, IAL consultants
Share of plastics in 4 MW-system		45%	Logstor, Steel business briefing
Global CO_2 in-use savings ($ktCO_2e$)		55,403	

TRICHLOROSILANE USE IN SOLAR CELLS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
8	5.30	35	2

General comments

Comment	Assumption	Source/rationale
Reference case	None	
Annual output of solar cells (kWh/Wp)	1.7	Weighted average, cross-regional, Miasole
Degradation of solar cells	1% p.a.	Joint research center - EU
Global installed solar power, 2007 (MWp)	2,258	Aggregated industry reports, McKinsey analyses
	Regional breakdown: Germany 1,135.00 - Spain 512.00 - Japan 210.40 - US 206.50 - Italy 70.20 - South Korea 42.87 - France 31.30 - Portugal 14.45 - Australia 12.19 - Switzerland 6.50 - Canada 5.29 - UK 3.81 - Austria 2.12 - Netherlands 1.61 - Sweden 1.39 - Mexico 1.02 - Israel 0.50 - Norway 0.32 - Denmark 0.18	

Own emissions

Input		Value	Source
Production footprint ($kgCO_2e/Wp$)		3.63	Company info
Production volume (installed MWp)		2,258	Aggregated industry reports, McKinsey analyses
End-of-life emissions ($kgCO_2e/Wp$)		0	
Global own emissions ($ktCO_2e$)		8,202	

Gross savings

Own emissions non-chemical alternative

Input		Value	Source
Global own emissions ($ktCO_2e$)		0	

In-use savings

Input		Value	Source
CO_2e savings ($kgCO_2e/Wp$)		1.13	IEA
Average electricity output		91%	Miasole, Joint research center – EU
Production volume (installed MWp)		2,258	Aggregated industry reports, McKinsey analyses
Lifetime of solar panel (years)		20	Industry average
TCS share of all solar cells		94%	Company info
Global CO_2 in-use savings ($ktCO_2e$)		43,479	

SYNTHETIC METHIONINE AS A FOOD SUPPLEMENT

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
2.3	23.12	51	1

ELECTRONIC CASING 6 COMBINATIONS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
25	2.93	48	6

MANUFACTURING OF SYNTHETIC VITAMIN C INSTEAD OF EXTRACTION OF NATURAL VITAMIN C OF ORANGES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
2.5	19.39	46	1

USE OF POLYMERS TO REPLACE GLASS IN AGRICULTURAL GREEN HOUSES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
61	1.50	30	1

EASY-CARE FINISHING FOR COTTON WARE (EASIER IRONING)

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
30	1.90	27	1

SUGAR CANE ETHANOL REPLACING GASOLINE

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
7	4.51	25	1

POLYMERS REPLACING WOOD AND ALUMINUM IN WINDOW FRAMES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
11	2.73	19	2

CLOTHING – REPLACEMENT OF COTTON WITH NYLON

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
13	1.79	10	1

AVIATION WEIGHT REDUCTION – CARBON FIBER REPLACING ALUMINUM

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.14	70.55	10	3

‘GREEN TIRES’ –
USE OF SILICA/SILANE FOR IMPROVING ROLLING RESISTANCE

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.19	50.76	9.6	1

USE OF MORE SYNTHETIC RUBBER INSTEAD OF NATURAL RUBBER FOR TIRES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
348.08	1.02	8.2	1

MANUFACTURING OF SYNTHETIC VITAMIN E INSTEAD OF EXTRACTION OF NATURAL VITAMIN E FROM SOY OIL

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.44	3.39	1.05	1

GRAIN PRESERVATION USING CHEMICALS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.39	2.85	0.72	1

POLYMER USE IN HOUSEWARE – LARGE (BASED ON WASTE BINS)

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
1.41	1.50	0.71	1

USE OF ENZYMES TO INCREASE LIFE TIME OF BREAD

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.60	2.15	0.69	1

USE OF SUPPLEMENTS TO FERTILIZER

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.42	1.93	0.39	1

USE OF ENZYMES TO IMPROVE FEED UPTAKE

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.00	88.27	0.33	1

FRIDGE INSULATION

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
15.64	1.00	0.05	1

USE OF POLYMERS IN CARPETING

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
5.85	1.05	0.03	1

INCREASING THE YIELD OF FRUIT JUICE PRESSING BY USING ENZYMES

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.00	17.78	0.01	1

USE OF ENZYMES TO DEGUM SOY OIL

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.00	8.33	0.01	1

USE OF ENZYMES TO STABILIZE WINE INSTEAD OF STABILIZING BY COOLING

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.00	3.71	0.00	1

BIOFUEL REPLACING GASOLINE

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.00	4.00	0.00	1

MELAMINE COVER ON PARTICLE BOARD REPLACING VENEER

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
0.24	0.29	-0.17	1

POLYMER USE IN HOUSEWARE – MEDIUM (BASED ON BUCKETS)

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
4.66	0.96	-0.18	1

SERVICEWARE – CUPS: PLASTIC REPLACING GLASS

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
1.86	0.88	-0.22	1

SERVICEWARE – PLATES: PLASTIC REPLACING PORCELAIN

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
3.24	0.86	-0.46	1

POLYMER USE IN HOUSEWARE – SMALL (BASED ON KEEP FRESH BOXES)

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
4.66	0.84	-0.75	1

PVC FLOORING REPLACING LINOLEUM

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
8.98	0.88	-1.11	1

SERVICEWARE – CUTLERY: PLASTIC REPLACING STEEL

Summary

Own emissions ($MtCO_2e$)	X : 1	Net emission abatement ($MtCO_2e$)	Number of cases evaluated
4.72	0.51	-2.32	1

DISPOSAL ASSUMPTIONS

The following disposal general assumptions were used in the calculations unless specific information for a cLCA was available

- Plastics

	Recycling rate	Landfill	Incineration with heat recovery
EU, Japan	20%	50%	30%
US	15%	75%	10%
ROW	10%	80%	10%

- Metals (no regional distribution)

	Recycling rate	Landfill
Steel	70%	30%
Aluminum	60%	40%
Copper	85%	15%

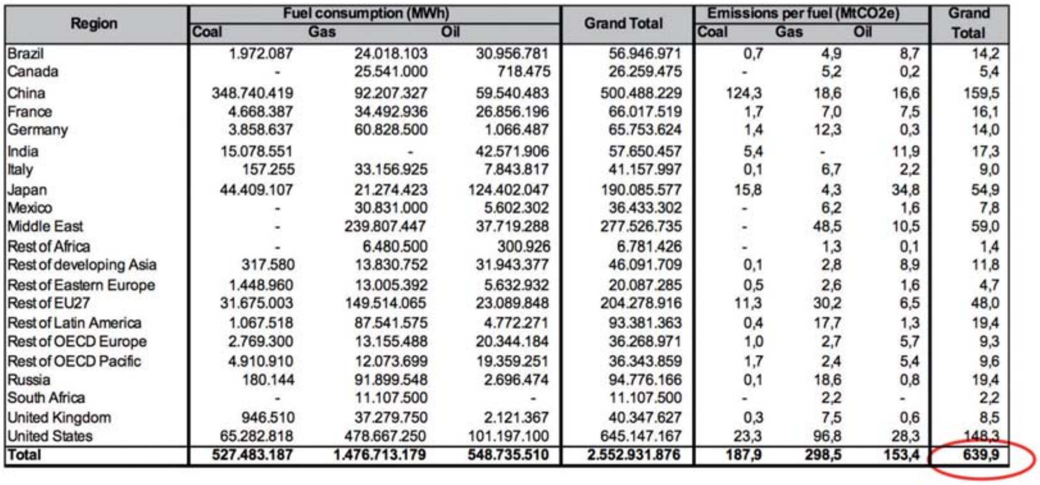
- Any material other than plastics/ glass and metals that are disposed on landfills are associated with emissions of 2.3 $kgCO_2e/kg$
- CO_2e credit from incineration with heat recovery is calculated as follows: Regional waste heat recovery x Combustion energy (kilojoules/kg) x 30% conversion factor to power x Regional power intensity (CO_2e/MWh)
- Regional power intensity used: EU, Japan – 500 $kgCO_2e/$ MWh, US – 611 $kgCO_2e/MWh$, ROW – 700 $kgCO_2e/MWh$
- Combustion energy - kilojoules/kg: PE 46,000, PP 46,000, PS 42,000, PVC 20,000, PMMA 26,000, PA12 34,000, Polyester 18,000. Source: Plastemart

For more information on the climate study, visit
www.americanchemistry.com/ClimateStudy.

Appendix II – GHG emissions linked to the chemical industry

Exhibit A.II.1

GHG emissions linked to the chemical industry - Direct energy GHG emissions
(2005)



Region	Fuel consumption (MWh)			Grand Total	Emissions per fuel (MtCO2e)			Grand Total
	Coal	Gas	Oil		Coal	Gas	Oil	
Brazil	1.972.087	24.018.103	30.956.781	56.946.971	0,7	4,9	8,7	14,2
Canada	-	25.541.000	718.475	26.259.475	-	5,2	0,2	5,4
China	348.740.419	92.207.327	59.540.483	500.488.229	124,3	18,6	16,6	159,5
France	4.668.387	34.492.936	26.856.196	66.017.519	1,7	7,0	7,5	16,1
Germany	3.858.637	60.828.500	1.066.487	65.753.624	1,4	12,3	0,3	14,0
India	15.078.551	-	42.571.906	57.650.457	5,4	-	11,9	17,3
Italy	157.255	33.156.925	7.843.817	41.157.997	0,1	6,7	2,2	9,0
Japan	44.409.107	21.274.423	124.402.047	190.085.577	15,8	4,3	34,8	54,9
Mexico	-	30.831.000	5.602.302	36.433.302	-	6,2	1,6	7,8
Middle East	-	239.807.447	37.719.288	277.526.735	-	48,5	10,5	59,0
Rest of Africa	-	6.480.500	300.926	6.781.426	-	1,3	0,1	1,4
Rest of developing Asia	317.580	13.830.752	31.943.377	46.091.709	0,1	2,8	8,9	11,8
Rest of Eastern Europe	1.448.960	13.005.392	5.632.932	20.087.285	0,5	2,6	1,6	4,7
Rest of EU27	31.675.003	149.514.065	23.089.848	204.278.916	11,3	30,2	6,5	48,0
Rest of Latin America	1.067.518	87.541.575	4.772.271	93.381.363	0,4	17,7	1,3	19,4
Rest of OECD Europe	2.769.300	13.155.488	20.344.184	36.268.971	1,0	2,7	5,7	9,3
Rest of OECD Pacific	4.910.910	12.073.699	19.359.251	36.343.859	1,7	2,4	5,4	9,6
Russia	180.144	91.899.548	2.696.474	94.776.166	0,1	18,6	0,8	19,4
South Africa	-	11.107.500	-	11.107.500	-	2,2	-	2,2
United Kingdom	946.510	37.279.750	2.121.367	40.347.627	0,3	7,5	0,6	8,5
United States	65.282.818	478.667.250	101.197.100	645.147.167	23,3	96,8	28,3	148,3
Total	**527.483.187**	**1.476.713.179**	**548.735.510**	**2.552.931.876**	**187,9**	**298,5**	**153,4**	**639,9**

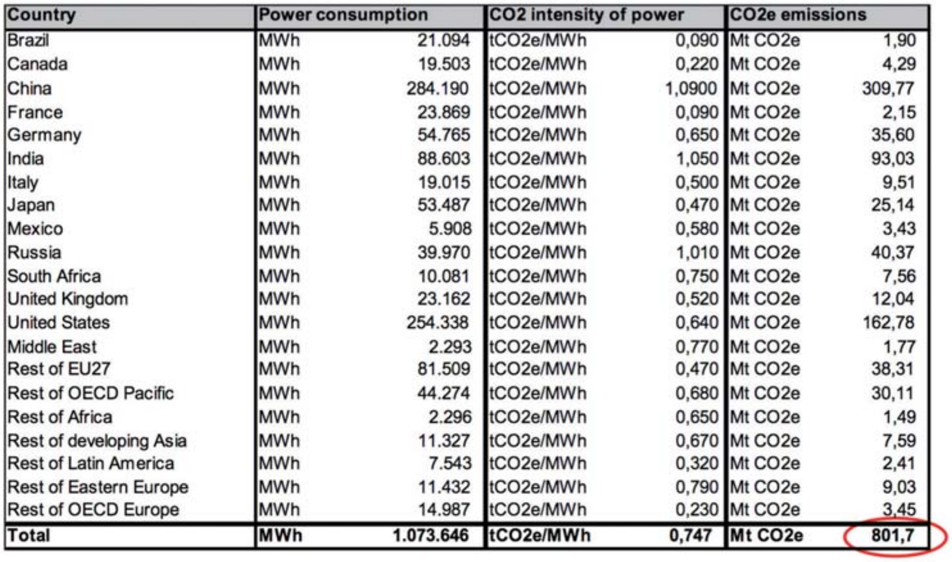
* Collapsed from over 15 different fossil fuels

** Emission factors - coal: 3.563x10-7 MtCO2e/MWh; gas: 2.0215x10-7 MtCO2e/MWh; oil: 2.7954x10-7 MtCO2e/MWh

Source: IEA

Exhibit A.II.2

GHG emissions linked to the chemical industry's - Indirect energy GHG emissions
(2005)

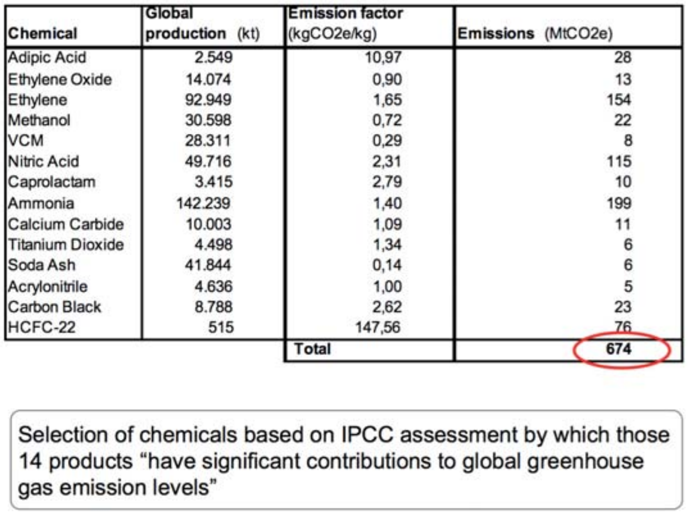


Country	Power consumption		CO2 intensity of power		CO2e emissions	
Brazil	MWh	21.094	tCO2e/MWh	0,090	Mt CO2e	1,90
Canada	MWh	19.503	tCO2e/MWh	0,220	Mt CO2e	4,29
China	MWh	284.190	tCO2e/MWh	1,0900	Mt CO2e	309,77
France	MWh	23.869	tCO2e/MWh	0,090	Mt CO2e	2,15
Germany	MWh	54.765	tCO2e/MWh	0,650	Mt CO2e	35,60
India	MWh	88.603	tCO2e/MWh	1,050	Mt CO2e	93,03
Italy	MWh	19.015	tCO2e/MWh	0,500	Mt CO2e	9,51
Japan	MWh	53.487	tCO2e/MWh	0,470	Mt CO2e	25,14
Mexico	MWh	5.908	tCO2e/MWh	0,580	Mt CO2e	3,43
Russia	MWh	39.970	tCO2e/MWh	1,010	Mt CO2e	40,37
South Africa	MWh	10.081	tCO2e/MWh	0,750	Mt CO2e	7,56
United Kingdom	MWh	23.162	tCO2e/MWh	0,520	Mt CO2e	12,04
United States	MWh	254.338	tCO2e/MWh	0,640	Mt CO2e	162,78
Middle East	MWh	2.293	tCO2e/MWh	0,770	Mt CO2e	1,77
Rest of EU27	MWh	81.509	tCO2e/MWh	0,470	Mt CO2e	38,31
Rest of OECD Pacific	MWh	44.274	tCO2e/MWh	0,680	Mt CO2e	30,11
Rest of Africa	MWh	2.296	tCO2e/MWh	0,650	Mt CO2e	1,49
Rest of developing Asia	MWh	11.327	tCO2e/MWh	0,670	Mt CO2e	7,59
Rest of Latin America	MWh	7.543	tCO2e/MWh	0,320	Mt CO2e	2,41
Rest of Eastern Europe	MWh	11.432	tCO2e/MWh	0,790	Mt CO2e	9,03
Rest of OECD Europe	MWh	14.987	tCO2e/MWh	0,230	Mt CO2e	3,45
Total	**MWh**	**1.073.646**	**tCO2e/MWh**	**0,747**	**Mt CO2e**	**801,7**

Source: IEA

Exhibit A.II.3

GHG emissions linked to the chemical industry's - Process GHG emissions



Chemical	Global production (kt)	Emission factor (kgCO2e/kg)	Emissions (MtCO2e)
Adipic Acid	2.549	10,97	28
Ethylene Oxide	14.074	0,90	13
Ethylene	92.949	1,65	154
Methanol	30.598	0,72	22
VCM	28.311	0,29	8
Nitric Acid	49.716	2,31	115
Caprolactam	3.415	2,79	10
Ammonia	142.239	1,40	199
Calcium Carbide	10.003	1,09	11
Titanium Dioxide	4.498	1,34	6
Soda Ash	41.844	0,14	6
Acrylonitrile	4.636	1,00	5
Carbon Black	8.788	2,62	23
HCFC-22	515	147,56	76
		Total	**674**

Selection of chemicals based on IPCC assessment by which those 14 products "have significant contributions to global greenhouse gas emission levels"

Source: IPCC, Tecnon

Appendix III – GHG abatement cost curve for the chemical industry

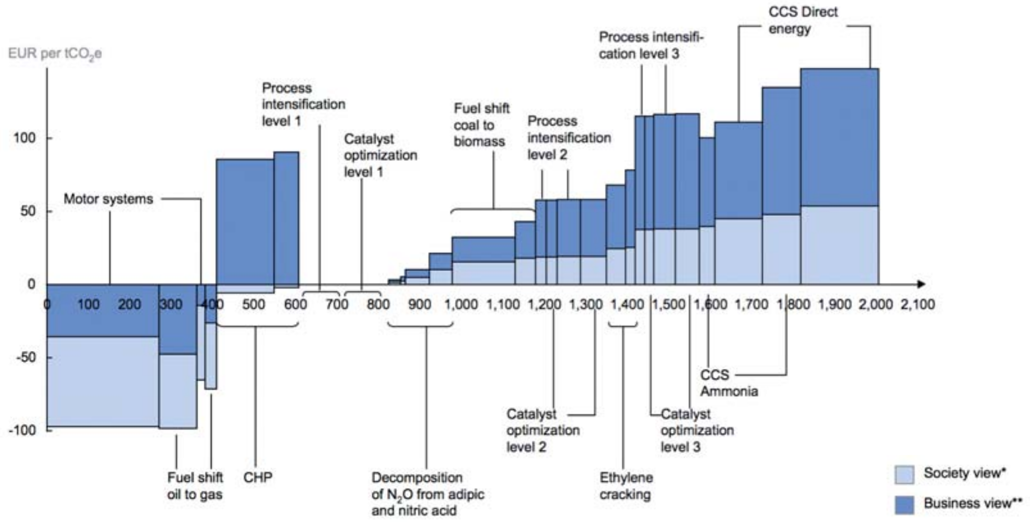
(Courtesy of McKinsey & Company – based on the report “Pathways to a Low-Carbon Economy”, complemented with additional analyses)

POTENTIAL ABATEMENT

The global chemicals industry can achieve a substantial reduction in its emissions by 2030 through concerted abatement efforts. While some of the measures identified will be net-profit-positive (and will at least partially occur as part of the BAU case), other steps will require a considerable financial and technological effort, especially when one takes a business view (10% interest rate, depreciation over 10 years), rather than a societal view (4% interest rate, depreciation over lifetime). 30 abatement measures have been identified that can be grouped in four categories (Exhibit A.III.1, same as Exhibit 16):

Exhibit A.III.1

GHG abatement cost curve for the chemical industry



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below EUR 60 per tCO2e (society view) if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play
* 4% interest rate, depreciation over life time of equipment
** 10% interest rate, depreciation over 10 years
Source: ICCA/ McKinsey analysis

A. Energy efficiency. At about 1,100 $MtCO_2e$, energy-efficiency measures contribute 55 percent of the total abatement potential, and are mostly net-profit-positive (under a societal view). Examples include motor systems, combined heat and power (CHP), ethylene-cracking improvements, and the optimization of catalysts.

B. Fuel shift. About 320 $MtCO_2e$, or 16 percent, of the total abatement potential, can be achieved by increasing the share of alternative, cleaner fuels, for example from oil to gas and from coal to biomass. Most of the measures in this category come at a relatively low cost or offer a net benefit to society. If fuel-shift efforts are undertaken aggressively, about 50 percent of the current use of coal can be replaced with biomass by 2030, taking total global demand and supply into account.

C. Carbon Capture and Storage (CCS) – CCS in the chemicals industry is estimated to account for a possible 21 percent of the total abatement potential, or around 420 $MtCO_2e$. CCS is a new technology that sequesters CO_2 after it has been emitted from a point source in the production cycle through methods such as placing it in subterranean storage. Two different CCS technologies are applicable to the chemicals sector: the capture of a pure CO_2 stream coming from ammonia production; and the capture of CO_2 from fuel-combustion emissions, similar to CCS in the power sector; however, economies of scale could hinder smaller industrial scale applications.

D. Decomposition of non-CO_2 **GHG gases.** The destruction of highly potent GHGs accounts for roughly 8 percent, or 150 $MtCO_2e$, of the abatement potential in the chemicals sector. Levers in this category include the decomposition of N2O that accrues in the production of nitric acid and adipic acid.

The identified abatement measures for the chemicals sector would eliminate approximately 2.0 $GtCO_2e$ per year worldwide in 2030.

A further abatement potential of possibly several hundred megatonnes CO_2e per year in 2030 could be achieved through the replacement of ozone depleting substance (ODS) substitutes used in refrigeration, air conditioning, and foam blowing agent application, but this possibility has not been assessed in depth in this analysis.

For the abatement measures in aggregate and taking a societal perspective, the cost would be negative at the outset at minus € 3 per tCO_2e in 2020, but would turn positive during the period of our analysis, increasing to around € 5 per tCO_2e in 2030. This increase is caused primarily by the introduction of CCS, which is a high-cost lever. The large potential overall of about 600 $MtCO_2e$ that would offer net benefits to society could be achieved through fuel shift, the replacement of motor systems, and increased use of CHP. Abatement in the chemicals sector as a whole is characterized by high upfront investments followed by large and increasing savings of operational costs. The abatement case calls for a total of € 520 billion in capital investment from 2010 to 2030. During this timeframe, operational cost savings of about € 280 billion can be realized through savings of energy, primarily fuel.

Societal view	Average cost (€ per tCO_2e)	CapEx (€ billion per year)	OpEx (€ billion per year)
2015	0	24	-7
2020	-3	24	-15
2025	5	29	-15
2030	5	27	-20

There are broad regional variations in carbon and energy intensity within the chemicals industry. While China and the rest of the developing world currently show significantly higher carbon intensities than Western countries, this difference is expected to decline over time as production technologies are improved and standardized globally, and abatement levers are implemented in developing regions.

The biggest abatement potential exists in regions with higher carbon intensities. For example, about 40 percent of the total abatement potential is in China, primarily due to an expected shift to biofuels and the implementation of CCS. Investment in abatement levers in the developing world also yields a higher return than in developed countries. For instance, China represents less than 36 percent of total investment requirements for its 40 percent share of the total potential in 2030.

IMPLEMENTATION CHALLENGES

Some conditions must be put in place for the chemicals sector abatement levers to succeed in reducing emissions:

- **Development and availability of alternative fuels.** Shifting from oil to gas and from coal to biomass is a key step in reducing carbon emissions. In certain regions, ensuring adequate supplies of biomass in order to replace fossil fuels as the primary fuel for production could be challenging;
- **Technology and infrastructure.** CCS is a nascent technology that has yet to be tested for use in the chemical industry, and adequate liability and infrastructure programs are not in place yet. CCS is not expected to be rolled out until 2020;
- **Economics.** Upfront investments are important and even more so when one takes a business view as opposed to a societal view. Governments should create favorable business conditions to facilitate these upfront investments (especially for technologies under development like CCS) and work towards bridging the important gap between the societal view and the business view.

Appendix IV – Cost curve methodology

(Courtesy of McKinsey & Company)

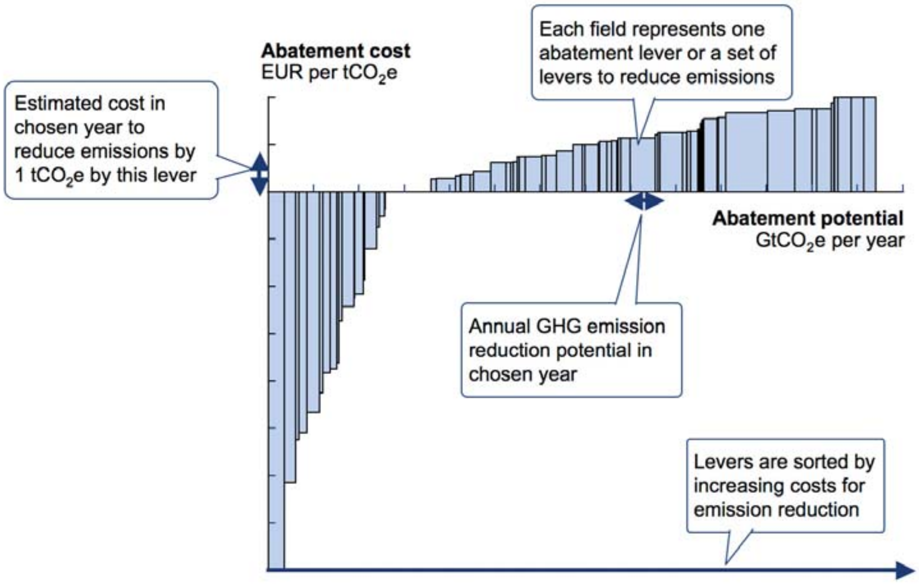
This section describes the methodological approach to the analysis of abatement potentials, costs, and investments.

DEVELOPMENT OF THE ABATEMENT COST CURVE

The combined axes of an abatement cost curve depict the available technical measures, their relative impact (emission volume reduction potential) and cost in a specific year (Exhibit A.IV.1). Each bar is examined independently to quantify both dimensions.

Exhibit A.IV.1

Key cost curve dimensions



Source: Global GHG Abatement Cost Curve v2.0

The basic logic of the cost curve is that it displays the abatement potential and corresponding cost for abatement "levers" relative to a business-as-usual (sometimes referred to as "reference case") scenario in a given year.

The width of each bar represents the economic potential (not a forecast) to reduce annual GHG emissions from that opportunity. The volume potential assumes concerted global action starting in 2010 to capture each opportunity. The potential reflects the total active installed capacity of that abatement lever in the year of the analysis, irrespective of when this capacity has been built.

The height of each bar represents the average cost of avoiding one metric ton of tCO_2e in the year of the analysis by each opportunity. The cost reflects the total active capacity of that opportunity, thus is a weighted average across sub-opportunities, regions, and years.

To ensure comparability across sectors and sources, all emissions and sinks have been measured in a common way, using CO_2 equivalents measured in metric tons (tCO_2e). The merit order of abatement levers is based on the lowest cost measures (in € per tCO_2e) as of 2030.

Viewed as a whole, the abatement cost curve illustrates the "supply" of abatement opportunities independently from a target (the possible "demand") for abatement. By definition, abatement potential is attributed to the sector in which the abatement lever is implemented. For example, if an abatement lever in a consuming sector (e.g., LEDs in buildings) reduces electricity consumption, the resulting emission reduction in the power sector is attributed to the consuming sector.

Therefore, the baseline for all consuming sectors includes indirect emissions from the power sector. The same relation as for electricity holds true for fossil fuel between the transport and petroleum and gas sectors. To avoid double counting of reductions, the production output in the producing sectors (power, petroleum and gas) is reduced accordingly before abatement measures in that sector are applied.

The uncertainty can be significant for both volume and cost estimates. There are two key sources of this uncertainty: what implementation is feasible to achieve in reality (highest in the forestry and agriculture sectors) and the cost development for key technologies.

CALCULATING ABATEMENT POTENTIAL

Abatement potential is defined as the volume difference between the emissions baseline and the emissions after the lever has been applied. The emissions baseline is calculated from several driver values, such as carbon intensity of a specific fossil fuel, production volume of a basic material or fuel consumption of a vehicle. Each abatement lever changes (usually reduces) specific driver values, for which the quantification is determined by literature and expert discussions. An illustrative example would be that fuel consumption can be reduced to 70% by passenger car improvements. This leads to an abatement potential of 30% of initial fuel combustion emissions.

Due to merit order logic of levers adhering to "lowest cost first" principle, the lever with the next higher cost is applied on a new baseline after reductions from all previous levers. Each abatement lever is assessed independently in each region.

CALCULATING ABATEMENT COSTS

Abatement costs are defined as the incremental cost of a low-emission technology compared to the reference case, measured as € per tCO_2e abated emissions. Abatement costs include annualized repayments for capital expenditure and operating expenditure. The cost does therefore represent the pure “project cost” to install and operate the low-emission technology. Capital availability is not considered a constraint.

Abatement costs are calculated according to the formula in Exhibit A.IV.2. The full cost of a CO_2e-efficient alternative incorporates investment costs (calculated as annual repayment of a loan over the lifetime of the asset), operating costs (including personnel and materials costs), and possible cost savings generated by use of the alternative (especially energy savings). The full cost does not include transaction costs, communication/information costs, subsidies or explicit CO_2 costs, taxes, or the consequential impact on the economy (e.g., advantages from technology leadership).

Exhibit A.IV.2

Abatement cost formula

$$\text{Abatement cost} = \frac{[\text{Full cost of } CO_2e \text{ efficient alternative}] - [\text{Full cost of reference solution}]}{[CO_2e \text{ emissions from reference solution}] - [CO_2e \text{ emissions from alternative}]}$$

Operating expenditure is assessed as a real amount to be expensed in each year.

Capital expenditure is accounted for as annualized repayments. The repayment period is the functional life of the equipment. The interest rate used is the real long-term government bond rate of 4 percent, based on historical averages for long-term bond rates.

The cost curve takes a societal perspective instead of that of a specific decision-maker, illustrating cost requirements to society. Given country differences in taxes, subsidies, interest rates and other cost components a global decision-maker perspective does not exist. This societal perspective enables the usage of the abatement cost curve as a fact base for global discussions about what levers exist to reduce GHG emissions, how to compare reduction opportunities and costs between countries and sectors, and how to discuss what incentives (e.g., subsidies, taxes, and CO_2 pricing) to put in place. For example, with this analysis, the question can be asked and answered, “If a government wanted to make different abatement measures happen, how much would different measures reduce emissions and what is the minimum cost (to achieve this emission reduction from a societal perspective)?”

All costs in the model are based on current costs and estimated projections. Estimates are based on best available projection methods, such as models (if available), expert views, and educated extrapolation. Given the long time horizon of approximately 25 years, a certain estimation error is inherent in the approach. Macroeconomic variables such as lifetime of assets, interest rates, oil prices, and exchange rates have the highest impact on results and error margins. Individual cost estimates per lever are of lower significance and will not substantially distort overall results for each lever.

Transaction costs – costs incurred in making an economic exchange above and beyond the technical project costs (e.g., education, policing, and enforcement costs) – are not included in the cost curve. Implementation cost for abatement levers are considered part of the transaction costs, involving such aspects as information campaigns and training programs.

Behavioral changes are also excluded from the cost curve, although they do present additional abatement potential. Behavioral changes are driven by various price and non-price factors, such as public education, awareness campaign, social trend, or policy changes. For this reason, behavioral shifts are analyzed separately from the primary cost curve as “further potential” with no abatement cost attached.

SCOPE AND PARAMETERS OF THE ANALYSIS

The analysis in this study covers all known anthropogenic GHG emissions globally. The base year for the study is 2005, with emissions and abatements projected for the years 2010, 2015, 2020, 2025 and 2030.

The cost curve model analyzes 10 sectors bottom-up in detail, 3 with top-down estimates and covers the entire world dividing it into 21 regions/countries. The bottom-up covered sectors are: power and heat, petroleum and gas, cement, iron and steel, chemicals, road transport, buildings, forestry, agriculture, and waste. The top-down assessed sectors are: other industry, sea transport, air transport. The breakdown for regions/countries is: Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, Russia, South Africa, United Kingdom, United States, Middle East, Rest of Latin America, Rest of EU27, Rest of OECD Europe, Rest of Eastern Europe, Rest of Africa, Rest of developing Asia, Rest of OECD Pacific.

Following IPCC definitions, the abatement cost curve shows technical measures with economic potential under € 60 per tCO_2e.

Four criteria are applied to include a new technology in the cost curve:

- The technology is at least in the pilot stage;
- There is a widely shared point of view on the lever’s technical and commercial viability in the medium term (starting by 2025 at the latest) and it would therefore represent a significant contribution to reductions by 2030;
- Technological and economic challenges are well understood;

- There are compelling forces supporting the technology, such as policy or industry support, tangible benefits (e.g., energy security), or expected attractive economics.

Technologies excluded from the analysis include among others biodiesel from algae, biokerosene, CCS with Enhanced Gas Recovery, biomass gasification in power generation, wave and tidal power, and HCCI (Homogeneous Charge Compression Ignition) and camless valve actuation.

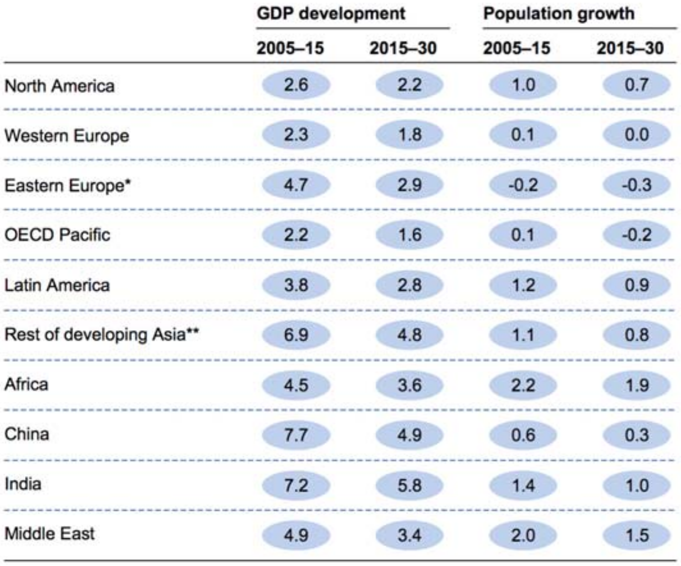
Key assumptions in this analysis include:

- Societal interest rate of 4 percent per annum;
- Prices and costs are 2005 real values;
- Oil price of $ 60 per barrel (IEA WEO 2007);
- Regional GDP and population compound growth rates shown in Exhibit A.IV.3.

These growth rates are the underlying drivers for the baseline from the IEA and are used to project GDP growth, which are then used as the basis for financial comparisons. However, no demand elasticity has been modeled (e.g., GDP is not linked to changes in our assumptions on energy prices).

Exhibit A.IV.3

Macroeconomic data: regional real GDP and population growth rates
Annual growth rates, Percent



	GDP development		Population growth	
	2005–15	2015–30	2005–15	2015–30
North America	2.6	2.2	1.0	0.7
Western Europe	2.3	1.8	0.1	0.0
Eastern Europe*	4.7	2.9	-0.2	-0.3
OECD Pacific	2.2	1.6	0.1	-0.2
Latin America	3.8	2.8	1.2	0.9
Rest of developing Asia**	6.9	4.8	1.1	0.8
Africa	4.5	3.6	2.2	1.9
China	7.7	4.9	0.6	0.3
India	7.2	5.8	1.4	1.0
Middle East	4.9	3.4	2.0	1.5

* IEA nomenclature “Transition Economies”
** IEA nomenclature “Developing Asia”
Source: IEA WEO 2007

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For more information on the climate study, visit
www.americanchemistry.com/ClimateStudy.

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