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Environmental consequences of a Norwegian-Chinese Free Trade Agreement

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Abstract

China and Norway are currently negotiating a Free Trade Agreement that will facilitate further liberalisation of trade and investment between the countries. We analyse environmental consequences of the Free Trade Agreement. Focusing on CO_2 emissions we find that the Agreement on balance is likely to have slightly higher negative than positive environmental impacts. We build this conclusion on the likely increase in transport, and on other indications. Negative impacts may be alleviated by encouraging sustainable production and consumption practices. Positive impacts should be enhanced by encouraging sustainable trade. Besides, the Free Trade Agreement should acknowledge the barriers and opportunities for vendors of environmental technology.

Unknown environmental consequences of a Free Trade Agreement between China and Norway

Trade between countries brings many benefits. Trade expands the choices of consumers and let them access goods that either are not available domestically or are superior to domestic goods. Trade also expands the choices of producers and allows them to purchase intermediate products that are cheaper and better than those found at home. If trade had not brought benefits, people would not have traded. The very existence of trade goes to prove that trade is beneficial for the trading partners.

Trade brings other benefits as well. In an interdependent world trade aligns the interests of trading partners in preserving the benefits of trade, which has important political implications. Trade also brings cultural stimulus as well as language skills.

Yet, in some areas it is unclear whether trade brings benefits or not. One important and ambiguous area is the environment. Trade involves transportation, sometimes over vast distances, and it is clear that increased transportation means increased environmental emissions, e.g., emissions of CO_2. The problem is exacerbated by the fact that the cost of transportation is too low: Sea and air transport are for practical purposes exempt from regulation of, e.g., CO_2. Trade may also increase emissions if goods that become available for consumers because of trade are environmentally inferior to domestic alternatives. This problem is accentuated when one or both of the countries involved in trade have lax environmental regulation. Hence, those who trade are not informed through price or law of the full cost of their activities. At the same time however, trade opens up the market for manufacturers of environmental technologies interested in selling their products internationally, and for countries interested in adopting environmental friendly technologies.

One pair of countries that meets both the benefits of trade and the ambiguous environmental consequence is China and Norway. Bilateral trade between China and Norway has been increasing rapidly in recent years. For instance, according to Norwegian statistics imports of goods from China quadrupled in just nine years 1999-2007. Exports from Norway to China also showed a large increase and almost tripled 1999-2006. Both countries want to maintain progress in their trade relations. The countries have recently initiated negotiations on a Free Trade Agreement (FTA). The intention is to secure recent advancements in trade that have been negotiated in the WTO, and proceed to the next stage in trade relations by means of further tariff reductions, facilitation of foreign direct investment, regulation of work permits etc.

While acknowledging the benefits of improved trade relations, stakeholders in Norway and China are concerned that the environmental consequences, particular for CO_2, may be negative. It is seen as important to bring forward knowledge about the environmental consequences of the FTA in order to prepare safeguards in domestic policies and in the negotiation treaty process itself. Based on this concern;

> *We analyze consequences of the Free Trade Agreement on the environment. In particular, we have in mind CO_2 emissions.*

The analysis has been carried out on behalf of the Norwegian Ministry of Trade and Industry by Econ Pöyry in association with Renmin University of China, Policy Research Center for Environment and Economy under Ministry of Environmental Protection, China; and Development Research Center under State Council, China.

Focus on fertilizer and cotton textiles

Two of the most important traded goods between Norway and China are fertilizer export from Norway and cotton textiles export from China. In addition, these are goods with environmental properties for which data exist. Since FTA negotiations are still ongoing, we do not know the impact of the FTA on trade of fertilizer and cotton textiles. But it is a fair speculation that trade in both will receive a boost from the FTA, and hence increase. Other goods and services may of course also receive a boost, but we choose fertilizer and cotton textiles as representative examples.

Impacts on CO_2 could be both positive and negative

Previous research (e.g. Fæhn & Holmøy, 2001; Bruvoll & Fæhn, 2006; Reinvang & Peters, 2008) has pointed out that since China exports a vast array of goods to Norway, Norwegian consumption in a sense lives off Chinese emissions. Yet trade is of course a two-way phenomenon and there are emissions embodied in Norwegian exports as well. Besides, there is a fundamental difference between the current pattern of trade, on the one hand, and the impact of policy (here FTA) on this pattern of trade. It is seldom straightforward to use one to make inferences about the other.

In principle it is not too complicated to analyze the environmental impacts of increased trade between two countries. It is helpful to begin by considering impacts if consumption in both countries is unaffected by trade. Under this assumption trade means a switch in the location of production, e.g., from Norway to China. The impact on the environment is a consequence of the transport needed to carry trade. Besides, there is an impact on the environment if the technology for production differs between the countries. A third impact arises from the fact that trade cannot be unbalanced over time: The trade stream from China to Norway (say) should sooner or later be balanced by a corresponding trade stream from Norway to China. The environmental impact of the second trade stream also depends on transportation and on any differences in technology.

A fourth and final impact arises if and when consumption is not constant in both countries: It is well known that lowering trade barriers increases economic efficiency and eventually leads to increased scale of production. This increase in the scale of production has independent environmental impacts.

Our analysis captures the impacts of trade on the environment through two complementary analyses. We apply a macroeconomic model and an extended carbon footprint analysis. The message from both modes of analysis is that the impacts of the FTA are likely to be moderate, but that negative impacts may be larger than positive.

The macroeconomic analysis indicates that impacts are moderate

As an example of our macroeconomic analysis, consider the case of increased textile exports from China. The analysis finds that per million Yuan in increased exports Chinese CO_2 emissions increase 7 tons (Table A). Given current textile and apparel export to Norway of about six billion NOK (Statistics Norway, 2008) and a rate of exchange of 1.1 the emissions in China if exports *double* are only about 46,000 tons of CO_2.

This very moderate amount begs the question of why impacts are so small. We can eliminate two possible explanations. One explanation would be that the analysis did not include emissions from the production of textiles and apparel. But the analysis does include such emissions, which primarily are related to energy consumption. The emissions primarily from energy consumption in the textile and apparel sector amounts to 22 tons per million Yuan. A second explanation would be that the analysis did not include the embodied impact, namely emissions from the production of inputs to the textile and apparel industry. But the analysis does include the embodied impact. Including it increases total emissions to 207 tons per million Yuan.

Table A *Impact of increasing textile & apparel exports from China to Norway*

Pollutant	Direct impact	Embodied impact	Economy-wide impact
CO_2	22	207	7

Note: Unit is ton per million Yuan

The explanation for the huge difference between 207 tons in embodied impact and 7 tons in economy-wide impact lies in the fact that higher production in one industry in China (in this case textile and apparel) is modified by some other industries having to contract. In other words, the train of consequences set in motion when an industry expands, which eventually leads to 207 tons of impact, is counteracted by a similar train in the opposite direction. Why? The reason, as we analyse it, is that China, despite its vast size and agricultural labour surplus has a limited stock of labour and capital resources to use for production. Hence one sector cannot simply expand without consequences for other sectors. The net impact on CO_2 is mainly the difference between higher production in textile&apparel, and lower production in other sectors. The contracting sectors are almost as dirty in terms of CO_2 as the textile and apparel sector is. Hence their embodied emissions are almost as large and the impacts of expansion in some industries and contraction in others tend to cancel. We also note that the textile and apparel industry is not the worst industry in terms of CO_2. It has greater problems in terms of water pollution.

This analysis of increased exports of textiles and apparel from China does not explicitly account for impacts in Norway and in the world at large. It may be that those impacts on balance are positive (lower CO_2 emissions) if the Chinese exports takes over for production elsewhere.

The story of increased fertilizer imports to China is similar to the story of increased textile and apparel exports from China: very moderate impacts with the main reason being that resources are not lying idle while they are waiting to be employed by the fertilizer sector. In the case of increased fertilizer import to China the impact is positive in sign (lower emissions) when we analyse the Chinese side.

The analysis of extended carbon footprint indicates that impacts are moderate too

While fairly comprehensive the analysis of macroeconomic impacts does not account for emissions during international transport. Nor does it account for emissions in Norway related to consumption of textiles and apparel, or emissions in China related to application of fertilizer. We perform an extended carbon footprint analysis to examine these impacts. The extended carbon footprint analysis also provides a check on impacts during production that are worked out in the macroeconomic analysis, as it applies data from independent sources to estimate emissions during production. Finally the extended carbon footprint analysis surveys non-CO_2 impacts.

Table B Carbon footprint of fertilizer and cotton textiles

Life Cycle Unit	Kilo CO_2-e/kg NPK fertilizer	Life Cycle Unit	Kilo CO_2-e/kg
Primary Intermediates and NPK production	1.2	Cotton production in China	16.1
		Cotton cloth production (spinning and dyeing)	2.8
Transport	0.2	Transport	0.2
Application	0.3	Consumption	2.7
Disposal	0.7 – 6.7	Disposal	0.0
Total	2.4– 8.4	Total	21.8

Note: Fertilizer refers to NPK fertilizer. Cotton textiles refer to cotton cloth with max 10 per cent polyester fibre.

In the case of cotton textiles the carbon footprint analysis indicates that 85 percent of emissions are associated with production. The rest is associated with consumption in Norway, mainly laundry. Emissions during transport are insignificant.

For fertilizer the story is a little different. Most emissions occur during the phase that here is called disposal, in the form of release of N_2O. However, how much N_2O that is released depends greatly on properties of the soil and on agricultural management practice. Therefore this emission factor is uncertain. Transport is an insignificant source of CO_2 emissions on the fertilizer footprint and we note that this is similarly to the case of cotton textiles.

One way to interpret the carbon footprint analysis is to ask the question what would happen in China if fertilizer is not available from Norway. To illustrate the point we assume that consumption of fertilizer stays the same and that resources are found to produce fertilizer in China. We also assume that the technology for producing fertilizer in China is the same as in Norway. Of course, these assumptions should be challenged in a more elaborate analysis, but they do give a broad impression. In this case, emissions associated with disposal and application of fertilizer are constant. Emissions associated with production also are constant since the Chinese production technology equals Norwegian technology. The only saving in emissions is that of transport, and we have found that emissions associated with transport are rather small. For instance, Norway exported 485,000 tons of fertilizer to China in 2007. If exports were twice as high thanks to the FTA, emissions from transport would go up 97,000 tons. The export of textile and apparel from China to Norway in 2007 had a weight of 60,000 tons. The associated emissions are 12,000 tons.

Clearly, 46,000 tons (a doubling of Chinese exports of textile and apparel in a macroeconomic context), 97,000 tons (doubling of transport of fertilizer in the context of an extended carbon footprint) and 12,000 tons (doubling of transport of textile and apparel in the context of an extended carbon footprint) are very small numbers compared to the millions, and in China's case billions of CO_2 emitted every year. Furthermore, a doubling of trade in these commodities is a quite optimistic estimate of the impact of the FTA, and in the case of Chinese exports of textiles and apparel we have not described the possibly positive impacts (lower emissions) in Norway and the world at large.

Could the FTA increase environmental technology exchange?

The impression that the FTA may have more negative than positive impacts on CO_2 could have been different had we studied the impacts of an increase in trade in environmental technology. Here we study the potential for such and increase. Most representatives of Norwegian environmental technology companies included in this study are under the perception that their respective technologies are already exempt from tariffs and quotas on the Chinese and Norwegian sides. Hence, they do not believe that an FTA would bring down any significant formal barriers. In the best case it is perceived to have the potential to tighten the legal basis for continuing to exempt environmental technology from tariffs and quotas, but it is fair to say that this is no burning issue in the eyes of the interviewees.

Our interviewees note other areas where Norwegian official assistance could make a difference. They state that official assistance is useful to open doors and establish essential contacts in China both in terms of contacts at the official level and contacts with other firms. Official representatives should also emphasise problems caused by China's institutional framework and promote more stringent routines for controls of standards and regulations. Lack of intellectual property rights is also noted as a problem by the interviewees. To the extent that the FTA can provide safeguards on these issues it will be helpful for Norwegian technology vendors. Some interviewees also wish for elements in the FTA that are more ambitious than building down barriers to trade and investment. These individuals would like to see active stimulus of environmental and energy technologies like 'carbon capture and storage' etc.

Consider linking the FTA to environmental cooperation

These messages from vendors of environmental technology to some extent also apply to technologies for producing and applying fertilizer and textiles and apparel. With cotton textiles as an example, an FTA can be coupled with consumer communication measures in Norway aimed at limiting emissions related to cotton imports. This communication can be directed at washing practices but also aimed at informing consumers of the environmental sustainability of the cotton cloth that they choose to buy. Through affecting demand, supply practices can also be altered. This kind of information is possible as China has used the textile eco-label The "Environmental Friendly Product Label" since 1996 and has reached an agreement on mutual recognition with White Swan Program products. The authorities are also planning to develop a new label related to low carbon product standards.

Finally, in order to highlight the environmental issues as brought forward in this study, China and Norway could also choose to sign an environmental cooperation agreement associated with the FTA. Such an agreement could highlight the areas of concern linked to Norwegian and Chinese trade, such as fertilizer application and initiate collaboration initiatives such as the spread of information and mutual technology development.

Introduction

Bilateral trade between China and Norway has been increasing rapidly in recent years. For instance, according to Norwegian statistics imports of goods from China quadrupled in just nine years 1999-2007. Exports from Norway to China also showed a large increase and almost tripled 1999-2006. Both countries want to maintain progress in their trade relations by way of negotiating a Free Trade Agreement (FTA).

This report analyses environmental consequences of the FTA. We focus on CO_2 emissions, but comment on other environmental impacts as well. The report is structured as follows: The remainder of chapter 1 explains our approach and methodology. Chapter 2 gives a theoretical background in the form of what is written on the issue before. Chapter 3 presents our macroeconomic analysis. Chapter 4 presents the extended carbon footprint analysis, and chapter 5 presents the analysis of impacts on environmental technology exchange.

Approach and methodology

The assessment of the environmental consequences of a Sino-Norwegian FTA has in this project been carried out through three main levels of analysis: A macro-part, a micro-part and a part on energy and environmental technologies. This three level methodology has been undertaken to provide a holistic assessment while concurrently providing more specific guidance to policy developers.

The three levels successively provide level specific perspectives on FTA related environmental consequences and on key issues such as carbon leakage[1]. Initially, a *macroeconomic* analysis provides an overview of the environmental impact of trade flows' and an analysis of the impact of increased trade at the macro-economic level. Then, a *microeconomic* sector analysis analyzes the sector specific impact in two sectors of concern for trade between China and Norway and the environmental consequences in China and Norway of their expansion. Finally, we present a *qualitative review* of the implication for environmental technology exchange of a FTA. This part estimates the likely consequences of the FTA on trade in environmental technologies, in particular Norwegian exports.

Although a liberalized trade regime would affect a wide variety of sectors, the macro- and micro level analyses focus particularly on one key export sector from each country. These are sectors of particular importance in Chinese-Norwegian trade that would probably also benefit and expand under a FTA; Cotton Textiles exported from China to Norway and NPK Fertilizers exported from Norway to China.

[1] Carbon leakage means that emission reductions in one country lead to emission increases in another country. One reason may be that firms move location from one country to the other, but more commonly, it is different firms that lose and gain.

Apparel and textiles are already the main Chinese export products to Norway and can be expected to increase if the 299 Norwegian tariff lines covering clothing and textile articles are removed. Fertilizers are also important in size as the second largest Norwegian export sector to China. However, the sector is also chosen due to the expressed Chinese interest in increased trade with fertilizers (Statement from Vice Trade Minister Qiu Hong: NHD, 2008). Details on the three methodological sections are provided below.

Macroeconomic Analysis

The FTA between Norway and China is likely to have both macroeconomic and micro-economic impacts[2]. To analyse macroeconomic impacts we draw inferences from macroeconomic models. Macroeconomic models, in particular Computable General Equilibrium (CGE) models, have often been used to analyse impacts of changes in trade policy. Early contributions are summarised in Shoven & Whalley (1984) and Shoven & Whalley (1986). de Milo (1988) is an early summary of applications in a developing country context. Recent contributions with a focus on China include Hertel, Zhai & Wang (2004) and Vennemo et al., (2007). Important studies of Norway are Fæhn & Holmøy (2001), Fæhn & Bruvoll (2006) and Bruvoll & Fæhn (2006). See section 0 for a discussion of some of these papers.

A macroeconomic analysis of impacts in China and Norway involves two macro-economies – the Chinese and the Norwegian. In principle one should even include the economies of the rest of the world, but we disregard that. We are able to analyse macroeconomic impacts in China by means of model simulations that are designed and run for our purpose. Macroeconomic impacts in Norway are analysed by means of making inferences from similar analyses in Norway that are available in the literature.

Since the trade flows we consider are small compared to total trade, it is unlikely that world market prices on traded goods will change as a result of the trade that we study. Hence we do not make use of models such as GTAP that purport to explain trade patterns and prices on the world markets[3].

The CGE-model available for China is the latest version of the model used by Hertel, Zhai & Wang (2004) and Vennemo et al., (2007), the DRC-CGE developed by the Development Research Center of the State Council of China. The model contains 34 production sectors; 2 representative households; and 4 primary production factors: capital, agricultural labor, production workers, and professionals. The 34 production sectors include 1 agricultural sector, 24 industrial sectors, and 9 services sectors. We do not use all this information in the presentation, but mention it here to indicate the extent to which the model resembles the actual Chinese economy. The model is calibrated based on the 2005 Chinese Social Accounting Matrix (SAM) developed from the 2005 national Input-Output table. Trade data per sector is split between trade with Norway and general trade. Further discussion of the model is found in Vennemo et al., (2007).

[2] Macroeconomics is the branch of economics that deals with the aggregate economy. Microeconomics deals with particular markets and agents.

[3] GTAP stands for Global Trade Analysis Project and has at its core model and database for world trade.

A CGE-model can be simulated under different assumptions about investment dynamics. Here we assume that capital is fixed in quantity and immobile between sectors. We also assume that the number of skilled workers is given, as is the sum of agricultural labour and production labour. Since it is the sum of agricultural labour and production labour that is given, we do allow for movement of labour from the countryside to manual jobs in the urban economy, a feature which figures prominently in descriptions of the Chinese miracle. Finally we assume that the level of the current account is fixed. These assumptions imply that we do not pay attention to the dynamics over time of the productive resources skilled labour, unskilled labour, capital and the current account, and work out the comparative statics response to increased trade. By contrast the literature that we draw on with respect to Norway does include dynamics of resource constraints, which by implication colours our analysis of the country.

The impact of the FTA is modelled as an exogenous increase in exports of the sector "textiles and apparel", and an exogenous increase in imports of the sector "chemical industry". These model sectors contain the commodities of interest, namely cotton textiles and NPK fertilizer. The fact that cotton textiles and NPK fertilizer are contained in model sectors of a more aggregate nature, points to a shortcoming of model-based macroeconomic analysis: The sectors of interest are often too small to fill the role of independent model sectors. This shortcoming is the price to pay for the advantage of doing an analysis of a macroeconomic nature, and illustrates why macroeconomic and microeconomic analysis complement each other.

The CGE-model is not the only model that conceivably could form the basis for a macroeconomic analysis of the FTA. An alternative would be the input-output model, e.g., Weber et al. (2008). Both models have an input-output core, but the CGE model in addition contains the resource constraints that we described above. The presence of constraints in the CGE model implies that important parts of the input-output structure are modified by price changes in order to force the model to comply with the constraints. The model is said to have a flexible production structure. The presence of constraints also implies that the models react differently to an exogenous increase in exports (and similarly, imports). The CGE-model makes room for increased exports by way of transferring resources from other sectors. The input-output model makes room for it by drawing on idle resources and expanding the economy. This makes for different conclusions with respect to environmental impacts. Typically the environmental impacts are much smaller in the CGE model framework. We find the CGE model assumption to be the most relevant for our macroeconomic analysis, but in later sections we will discuss our findings in light of alternative assumptions.

Extended Carbon Footprint Analysis

As a complement to the macroeconomic analysis, it is important also to understand the environmental consequences of trade from the micro level perspective. In a recent report from Norwegian Teknologirådet (2008), the importance of establishing carbon footprints of goods is seen as an important tool:

(i) For authorities in the development of holistic and efficient policy development;

(ii) For industry to guide its own climate impact;

(iii) For consumers to provide them with the power of choice and influence with their consumption (Teknologirådet, 2008)

The methodological tool used in this section is *Extended Carbon Footprint Analysis* of the two sectors NPK fertilizers and Cotton cloth. This method is an extended version of a traditional Carbon Footprint analysis, which focuses on carbon emissions but which also discusses other, related environmental consequences. A Carbon Footprint is a measurement of the impact that human activities have on the environment in terms of generated greenhouse gases emissions, calculated in units of carbon dioxide equivalents (CO_2-e). Carbon Footprints are typically calculated for a product, an event, other business activity or an entire business corporation.

The Carbon Footprint Analyses presented in this report focuses firstly on the direct emissions of CO_2-e from the burning of fossil fuels including energy consumption in the production and transportation. Secondly, they include measures of the indirect CO_2-e emissions associated with the wholesale and eventual breakdown of the products. Thirdly, other environmental impact related to production, transportation and usage of NPK Fertilizers and Cotton Textiles are discussed to provide a more extensive view of the environmental consequences associated with the two chosen products. This extended analysis aims at pointing out what the other important environmental impacts of the product are and where they arise. Finally, the analyses are used to analyze the sector specific environmental consequences of a FTA and implications for FTA design.

Definitions and Measurements

The definitions used for the carbon footprints are:

Box 0.1 Definitions used for NPK fertilizer Carbon Footprint

- **Product**: NPK fertilizer type: NPK 15-15-15
- **Measurement:** CO_2, N_2O and CH_4 emissions are converted to CO_2 equivalents (CO2-e) using IPCC's *Global Warming Potential* (GWP) measurement that determines the relative contribution of a gas to the greenhouse effect. The GWP (with a time span of 100 years) of CO_2, CH_4 and N_2O is 1, 25 and 298, respectively (IPCC, 2007).
- **Unit**: Kilo CO2-e /kilo NPK Fertilizers

Box 0.2 Definitions used for Cotton Textile Carbon Footprint

- **Product**: Cotton cloth of 100-200 grams/m^3 mixed with 10 per cent polyester fibre
- **Measurement:** CO_2, N_2O and CH_4 emissions are converted to CO_2 equivalents (CO2-e) using IPCC's *Global Warming Potential* (GWP) measurement that determines the relative contribution of a gas to the greenhouse effect. The GWP (with a time span of 100 years) of CO_2, CH_4 and N_2O is 1, 25 and 298, respectively (IPCC, 2007).
- **Unit**: Kilo CO2-e /kilo Cotton Cloth

Data

NPK fertilizers: It is difficult to gather emission data for one specific fertilizer type and often the data is not available on such specific levels. The emission data used for the production estimates of NPK fertilizers was collected by Wood & Cowie, (2004) to be used as inputs to agricultural and forestry Life Cycle Assessments/Analyses (LCA) and calculations of greenhouse gas balances. The Wood and Cowie data is found suitable since it has been gathered from production of fertilizers with 15-15-15 composition, which is the same composition as is most often exported from Norway to China. The data has, when possible, been confirmed against Yara's own estimates from the production of its NPK 15-15-15 in its factory in Porsgrunn. Porsgrunn produces about 2 million tonnes per year, including the bulk of exports to China (Yara, 2008).

Cotton clothing: The emission data used for the cotton clothing carbon footprint have been collected from previous Chinese studies and from studies in other countries. Due to increased import of cotton in China, used in cotton cloth production, there is so far no inventory of cotton emissions estimates to be used in LCA. There are also few studies on cotton's environmental impacts. Foreign cotton carbon inventory data have therefore been used to provide estimates when Chinese data was missing (Shen, 2006).

Environmental Technologies

As a third and final part, we present a qualitative assessment of the impact of a FTA on environmental technology exchange between Norway and China. This section is based on strategic interviews with Norwegian companies currently operating in China and Norwegian officials on trade and investment barriers, the impact of the FTA, and of market prospects.

The reason for including this final qualitative part is to present the views of some companies presently active in China in order to understand which barriers they perceive to stand in the way for increased technology exchange, and if a FTA would benefit these firms. Naturally, the views presented here can not be said to be representative for the individual companies, nor for all Norwegian technology firms active in China today. However, the views brought forward by the interviewed firms consistently highlight some issues that should be of interest for Norwegian and Chinese decision makers.

The companies included in the study were chosen in collaboration with Innovation Norway in Beijing and were interviewed during the project team's field visit in Beijing in October 2008.

Theoretical Background

Historically, international trade has played an important role in economic development through providing a mechanism to efficiently allocate resources and costs across boarders. As technology and transport has developed, trade has also grown to become an important integrating factor of countries and cultures world wide.

However, international trade is characterized not only by the flow of capital and goods, but also by flows of energy and emissions embodied in the traded goods. These embodied emissions have lately become the focus of the climate change debate as researchers are increasingly concerned that pollution embodied in international trade may undermine global efforts to curb emissions of GHGs. This concern is for instance present in the U.S. and E.U. when arguing that all countries should take part in a future climate treaty. However, it is also heard in China as a response to the criticism that Chinese CO_2 emissions are growing fast.

The reason for the concern is the fact that international trade geographically separates consumption and production and thereby presents an opportunity for richer economies to place polluting production in developing countries while preserving domestic consumption patterns. Trade provides consumers and producers with the tool to shift environmental pollution associated with their consumption to distant locations and the ability to do so increases with wealth. Recent studies show that, without fully costing environmental externalities, there is a tendency for pollution to shift from more developed nations to regions with poor environmental performance or weak environmental legislation (emission leakage) (e.g. Fæhn & Holmøy, 2001; Bruvoll & Fæhn, 2006; Metz et al., 2007; Peters & Hertwich, 2007) [4]. On the other hand, foreign direct investment seems to be cleaner than the average technology of the host country (e.g., Eskeland & Harrison, 2003), implying that the shift occurs indirectly through markets rather than directly through "green dumping".

Emissions Embodied in Trade

There are many links between international trade and emissions, including direct effects from transportation and more subtle links from foreign investment and ownership. To analyze its effect, one must take into account net trade, changing trade structure, allocation of production and emissions and domestic consumption patterns.

The most polluting aspect of consumable products is usually the pollution emitted in production. These emissions occur either directly through the production processes or indirectly in the global supply chain through electricity, transportation, manufacturing, etc. The accumulated emissions emitted in the production of the product are said to be "embodied" emissions and are often referred to as "Emissions Embodied in Trade" (EET) (Peters & Hertwich, 2007).

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[4] These findings have been linked to the Environmental Kuznets Curve (EKC) literature that connects the development of environmental quality to growth. The EKC literature emphasises that economic growth may stimulate environmental policies and technological innovations because the demand for environmental goods and regulatory policy is income elastic.

As was mentioned above, the EET measurement is of increasing concern because the expansion of international trade has led to an increasing divergence between production and consumption venues. This means that whilst countries with a balance-of-trade surplus export more than they import, countries can also run surpluses on the Balance of Emissions Embodied in Trade (BEET)[5]. With a BEET surplus, the emissions involved in producing the goods the country consumes (including those produced abroad) are less than the emissions from domestic production. This surplus can be related to three primary effects (e.g., Copeland and Taylor, 2004):

(i) *Technique effects*: Progress made in reducing emissions intensity in domestic industry may differ from other countries;

(ii) *Composition effects*: Domestic production may take place in emissions-intensive sectors;

(iii) *Scale effects*: The scale of production is increasing.

Calculating EET and BEET can be complex due to the need to itemise unique production systems in individual countries and then to link these to consumption systems. A common methodology for this type of analysis is a generalization of environmental input-output analysis (IOA) (as discussed in section 0) to a multiregional setting (Peters & Hertwich, 2007).

Using an IOA, Peter and Hertwich, (2007 & 2008) have shown that there are considerable embodied flows of anthropogenic carbon (over 5.3 Gt) in international trade. In addition, almost one-quarter of carbon dioxide released to the atmosphere is found to be emitted in the production of internationally traded goods and services (Peters & Hertwich, 2008). This is of course a gross amount since the sum of all export and import by value by definition is zero. The authors also find that Kyoto Protocol Annex B countries (developed) are traditionally net importers of CO2 emissions. This indicates that the flow of pollution through international trade flows has the ability to undermine environmental policies, particularly for global pollutants (Peters & Hertwich, 2007).

Peter and Hertwich, (2007) have also been able to show considerable country variation in the EET as a percentage of production based emissions. These variations have been traced back to country characteristics, most importantly size and geographic location. Most European countries have a high share of their domestic emissions in the production of exports (20–50 per cent), China has around 30 per cent, the USA 8 per cent, Japan 15 per cent, India 13 per cent, South Korea 28 per cent, and South Africa 45 per cent (Weber et al, 2008). Since many of these goods are consumed in the developed Annex B countries, a question sometimes raised in the negotiations for a post-Kyoto framework is whether developed countries should take responsibility for a portion of current emissions from developing exporters (Pan et al 2008). A related question that also is much discussed is whether developing countries should be brought into the commitment scheme, ideally under an international cap-and-trade system.

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[5] There are actually several ways to illustrate emissions embodied in trade. Following Antweiler (1996), Straumann (2003) prefers the relative indicator ” pollution content of export divided by pollution content of import”. He calculates this factor for Norway. Straumann notes that ”In order to secure a balanced economic development, trade deficits will sooner or later have to be followed by trade surpluses, and for this reason the (BEET) is not a good measure for embodied emissions in trade”.

Carbon Leakage

The behaviour that leads to emission reductions in Annex B countries being offset by emission increases in non-Annex B countries is often referred to as "Carbon Leakage" (Metz et al., 2007). For local pollutants this may be viewed as a rational option for consumers, but for global pollutants, such as GHGs, consumers will bear the costs regardless of where production occurs.

There are however different definitions of carbon leakage depending on the questions of interest. As opposed to the total leakage estimated by Peters and Hertwich (2007, 2008), the IPCC defines carbon leakage as a marginal effect of policy change and considers only carbon leakage that results from the Kyoto Protocol policies:

> *"The part of emissions reductions in Annex B countries that may be offset by an increase of the emissions in the non-constrained countries above their baseline levels. This can occur through (1) relocation of energy-intensive production in non-constrained regions; (2) increased consumption of fossil fuels in these regions through decline in the international price of oil and gas triggered by lower demand for these energies; and (3) changes in incomes (thus in energy demand) because of better terms of trade"* (IPCC 2007b).

Available data suggest that the marginal carbon leakage effect as defined by the IPCC is small and that there are still no large relocation of emission flows due to Kyoto policies. Instead, the existing problem of carbon leakage is seemingly linked to the traditional comparative advantages of trade and the savings-consumption choice of economies. The growth in exports from a country like China is not only due to a comparative advantage in pollution as measured by the IPCC but due to numerous of existing economic factors such as low labour costs and favourable exchange rates (Peters & Hertwich, 2008).

China's Emissions Embodied in Trade (EET)

Thirty years after its opening and reform, China has developed into what is often referred to as "the factory of the world". Rapid, export led GDP growth has lifted hundreds of millions of Chinese out of poverty and made China the fourth-largest economy and the third largest exporter in the world as of mid-2006 (Chen & Ravallion, 2008; Guan et al, 2008). Export volumes accounted for 40 percent of GDP in 2006, with the majority consisting of intermediate or consumption goods destined for developed countries (Pan et al, 2008).

The Chinese export driven growth has however come at a severe environmental cost. The country's rapidly growing economy is consuming energy and natural resources at an unsustainable speed and is creating serious environmental problems on both local and global levels. As an example, China's energy consumption doubled within the first 25 years of economic reforms, and then doubled again 2002-2007. Levels of air pollution are soaring and due to its reliance on coal, CO_2 emissions have increased three-fold since the early 1980s (Peters et al. 2007). China is probably already the largest emitter of CO_2 in the world and is facing increasing pressure to curb its emission levels and to abide to a Post-Kyoto framework (Pan et al, 2008). The unfolding global economic downturn may on the other hand reduce the pressure on CO_2 emissions, at least in the short and medium run.

Given China's sheer size and the example it is setting for other developing countries, it is becoming all the more important to understand how changes in China's technology, economic structure, urbanization, and lifestyles affect CO_2 emissions. Recent research shows that emissions from the production of Chinese exports have increased proportionally to the share of exports of GDP. Applying an environmental input-output analysis (IOA), Weber et al (2007) find that emissions from production of Chinese exports have increased from 16 per cent of total emissions in 1990 to 33 per cent (1,700 mt CO_2) in 2005[6] (Peters, 2008, Weber et al., 2007). These figures mirror very closely the rise of exports as a percentage of GDP, meaning that exports are on average no more or less carbon intensive than domestic consumption and investment (Weber et al, 2007). Large portions of recent Chinese export emissions go to the developed world, with approximately 27 per cent to the US, 19 per cent to the EU-27, and 14 per cent to the remaining Annex B countries, mainly Japan, Australia, and New Zealand (Weber et al 2008).

Pan et al (2008) find similar results in their environmental input-output analysis of Chinese trade and climate change. They show that when estimating China's emissions on a consumption basis rather than on a production basis, China lowers its responsibility for CO_2 emissions in 2006 from 5,500 to 3,840 mt CO_2. This also implies a reduction of Chinese emission growth rates from an average of 12.5 per cent per year to 8.7 per cent per year between 2001 and 2006 (Pan et al., 2008). The scale of these differences is large and rising because

- China runs a large and growing balance of trade surplus;
- China has a comparative advantage in relatively energy-intensive production; and
- China's emissions intensity of production remains high, with efficiency improvements stalling since 2001 (Pan et al 2008).

According to Guan et al. (2008), the Chinese development is also likely to continue. By combining structural decomposition and IOA Guan et al, (2008) use the driving forces of China's CO_2 emissions from 1980 to estimate scenarios until 2030. In their reference scenario, production-related CO_2 emissions, driven by household consumption, capital investment and growth in exports, increase another three times by 2030 (Guan et al, 2008). On the other hand, China's export surplus is a way of saving that sooner of later will be replaced by dis-saving. Therefore one should in our view be careful with drawing robust conclusions based on the current export surplus and even more careful with extending the export surplus into the far future.

Local regions in China are bearing direct as well as global environmental consequences. In a study focusing on the underlying mechanisms behind China's carbon export by using STEM-2K1: atmospheric chemistry and transport model, Streets et al. (2006) estimate that 10-40 per cent of emissions of primary SO_2, NO_x, RSP, and VOC in the Pearl River Delta are due to the manufacturing of export goods. The pollution is caused by the manufacturing industries themselves and by the power plants, trucks, and ships that support them. The authors also argue that one reason that goods manufactured in the Pearl River Delta are so inexpensive and attractive to consumers in developed countries is partly that pollution controls are often not utilized. The result is that

[6] To put this figure into perspective, China's export emissions in 2005 (1700 Mt) were similar to the combined emissions of Germany, France, and the UK (1850 Mt) (Weber et al., 2007).

developed countries receive the benefits of cheap goods while the environmental damages remain in China (Streets et al., 2006).

Importantly, China also is a large importer and avoids domestic emissions by importing raw materials as well as final goods and services. In their analysis Weber et al. (2008) find a rough balance between China's CO_2 emissions from the production of exports and emissions avoided by imports (1,170 mt) (Weber et al, 2008). The authors themselves do however question these calculations based on the applicability of single-region IOA model. When Peters et al., (2007) estimated the emissions embodied in Chinese trade using a global model, they found that only 216 mt of CO_2 was embodied in Chinese imports in 2001.

Impacts of trade liberalisation on China's emissions

Vennemo et al (2007) study the impacts of China's accession into the World Trade Organisation (WTO) on China's economy and emissions to air. The analysis is based on simulations on a disaggregate CGE model of China. Contrary to what one might have expected based on China's emissions embodied in trade (EET), the authors find that CO_2 emissions decline following WTO accession. The authors point out that China has a comparative advantage in pollution intensive goods, but it also has a comparative advantage in labour intensive goods. The most important element of WTO accession is the introduction of the Tariff Rate Quota (TRQ) system on textiles and apparel. In the TRQ system quotas are replaced by "equivalent" tariffs. Nevertheless the lifting of quotas, according to the analysis, stimulates the textile and apparel sector to a 50 per cent increase in production. This industry is labour intensive, but not pollution intensive in terms of air pollution. (However, it does have significant impacts in terms of water discharges, see chapter 0).

At a deeper level the reason for the different conclusion in this study compared to those we discussed above, is the object of study: The impact of a policy change versus the total "footprint" of the economy. Like we have outlined above it also matters greatly whether a policy change is analysed by a CGE model or an input-output model.

Export of Carbon from Norway to China

Norwegian trade related emissions and its potential carbon leakage have been analyzed by i.e. Fæhn & Holmøy (2001), Bruvoll & Fæhn (2006) and Reinvang & Peters (2008).

Fæhn & Holmøy (2001) applied a dynamic and disaggregated CGE model to isolate the economic and environmental implications of three multinational trade agreements:

1. The European Economic Area Agreement (EEA) (1994);
2. The EFTA Resolution on Fisheries, (1994) and;
3. The WTO Agreement from 1995.

The analysis compares a simulated trade reform path with a business-as-usual reference scenario and shows that the simulated macroeconomic effects of the trade agreements are small. While GDP is slightly reduced in the long run, aggregate consumption increases by 1.0 per cent. The increases in emissions of several GHG gases are somewhat stronger and can be explained by composition effects. Due to a structural change in favour of manufacturing industries SO_2 and Suspended Particulates increases by more than 1 per cent, while long-run increases also occur in emissions of Carbon

Monoxide and Kyoto gases (Fæhn & Holmøy, 2001). The occurrence of a rise in pollution despite a reduction of the GDP reflects the modelling fact that most of the economic welfare gain can be attributed to improved terms of trade. Thus, while domestic production is scaled down, consumption and emissions from consumption rise. This result implies that there is carbon leakage at the margin (Fæhn & Holmøy, 2001).

Fæhn & Holmøy also comment on the issue of technology. Their model contains an assumption of constant and similar technologies in the pre- and post-reform paths, i.e. that there are no endogenous links between trade policy and technology. However, in reality trade is a potential channel of technology diffusion. Whether trade related technology improvements would gain the environment, would however depend on the existing incentives to invest in cleaner technology (Fæhn & Holmøy, 2001). We will return to the endogenous links between environmental technology exchange and a Sino-Norwegian FTA in Section 0.

Also using a dynamic CGE model, Bruvoll & Fæhn (2006) advance the analysis by focusing on the linkage between emission leakages and the Environmental Kuznets Curve (EKC) theory. The EKC literature emphasises that economic growth may stimulate environmental policies and technological innovations because the demand for environmental goods and regulatory policy increases in income. However, there is also a concern in the EKC literature that the counterpart of a cleaner domestic production pattern may be increased import of dirty products, implying pollution leakages across borders (Bruvoll & Fæhn, 2006). Their case is climate gas abatement in the rich and open Norwegian economy thirty years ahead. Norway is seen as a good example of a country showing a concave relationship between income and emissions.

Bruvoll & Fæhn's calculations confirm the existence of modest emission leakages abroad related to tighter carbon policies in Norway. By focusing beyond national borders the authors conclude that the environmental gains of policies were smaller and economic costs are higher than borne by the regulating country itself. However, contrary to what is usually expected, the emission leakages were found not to be related to replacement of domestic dirty production by imports, but rather to a loss of competitiveness in the Norwegian export industries. This was partly due to a general weakening of Norwegian demand and partly explained by the long run restrictions on the current account that increases competitiveness of domestic firms in typically import competing, emission-extensive industries (Bruvoll & Fæhn, 2006).

Reinvang & Peters (2008) also discuss whether future Norwegian promises of carbon emission reductions will come at the expense of low cost countries such as China. The authors find that while the domestic Norwegian carbon footprint remains stable at 55-57 mt per year, Norway's carbon footprint abroad is growing fast. During 2001-2006, the Norwegian carbon footprint abroad grew by 33 percent to 39 Mt and it will likely continue to grow to surpass domestic emissions. In their analysis, the development is based in a trade shift towards pollution intensive countries and types of products and the authors view the development as an example of unchecked carbon leakage.

Macroeconomic analysis

This section discusses impacts that increased trade in fertilizer and textiles have on the macro economies of China and Norway. For impacts in China we present three scenarios:

- Scenario 1 assumes a 10 per cent increase in textile exports from China to Norway
- Scenario 2 assumes a 10 per cent increase in fertilizer imports to China from Norway
- Scenario 3 assumes both a 10 per cent increase in exports and a 10 per cent increase in imports

For impacts in Norway we discuss the impacts qualitatively based on the literature that was just discussed in section 0.

A 10 per cent increase in exports and imports of textiles and fertilizer is an *illustration* of what the FTA might bring. Since the FTA is not yet negotiated its actual impacts are hard to judge. However, the Feasibility Study of the FTA carried out in 2007 (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007) saw great potential for Norwegian and Chinese producers in the fertilizer and textiles sectors to benefit from increased demand and potentially better returns to exports, and for consumers in both countries to benefit from lower prices and increased supply with the introduction of a FTA (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007). Norwegian officials have expressed their interest in increased imports of Norwegian fertilizers and the most probable scenario is that exports of cotton cloth from China to Norway would increase with the implementation of a FTA.

As a rule we divide impacts by the assumed 10 per cent increase. The resulting entities are multipliers that can be attached to any impact on textile exports and fertilizer import as long as the impact is not too far from 10 per cent. We subjectively estimate 0-20 per cent as a reasonable range export and import increases that is relevant our multipliers.

Macroeconomic adjustments in China are important

Macroeconomic adjustments to higher exports of textiles and apparel are important

We start by analysing the impacts in China of increasing textile and apparel exports to Norway by 10 per cent. According to the Chinese Trade Statistics a 10 per cent increase amounted to about 450 million Yuan in the model base year 2005.

Using CO_2 as an example we may distinguish between three impacts of increasing exports of textile and apparel (Table 0.1): The *direct* impact specifies the amount of CO_2-emissions associated with manufacture of textiles and apparel. The *embodied* impact specifies the amount of CO_2-emissions associated with manufacture of textile and apparel; and with producing inputs necessary for its manufacture. The *economy-wide* impact specifies the amount of CO_2-emissions associated with manufacture of textile and apparel; and with producing inputs necessary for its manufacture; and also with macroeconomic adjustment. The macroeconomic adjustment equals the difference between economy-wide impact and embodied impact. The macroeconomic adjustment comes from the fact that the economy can not use more labour or capital than is available. Nor can it run down (or up, for that matter) the current account. Although the labour, capital and current account constraints all apply it turns out to be convenient to focus the explanation on the current account.

Table 0.1 Impacts of increasing textile & apparel exports from China to Norway

Pollutant	Direct impact	Embodied impact	Economy-wide impact
CO_2	22	207	7
SO_2	0.12	82	0.04
COD	0.17	41	0.02

Note: Increased textile & apparel export to Norway is 437 million Yuan. Unit for impact is tons/(Million Yuan in increased textile & apparel export to Norway).

It is apparent from table 1 that in a economy-wide setting the increase in emissions associated with greater exports is negligible, e.g., 7 tons of CO_2 per million Yuan. This finding contrasts starkly with the impact in terms of embodied emissions (207 tons per million Yuan) and even direct emissions (22 tons).

The reason the economy-wide emission increase is low may be illustrated by comparing the initial increase in exports to further changes in the economy. As mentioned, the initial increase in exports to Norway is about 450 million Yuan, or 437 million to be precise. However, the macroeconomic increase in *all* export of textile & apparel from China is 250 million Yuan. This is of course a much lower number. In other words, export to other countries falls. The reason textile export to other countries falls is that the stimuli provided by increased import demand from Norway creates an upwards pressure on wages and income in China. The upwards pressure is the result of increased competition for resources in production when additional demand from Norway is factored in. The pressure is of course extremely small, but all numbers are small in this marginal exercise and the pressure on wages and income has a significant relative impact. The macroeconomic consequence of the pressure on wages and income is to increase costs of production and reduce ordinary exports of textile & apparel. This is how the economy makes room in the current account for the export stimulus to Norway.[7]

The macroeconomic effect reduces exports of textiles & apparel from 437 million to 250 million. By the time the increase has filtered through to total export of all goods and services the initial increase is capped considerably once more. The total increase in export is only 23 million Yuan. The reason is that export from other sectors than textile & apparel reacts in a similar pattern as export of textile & apparel to countries except Norway: This export falls back from its initial level and modifies the initial export increase.

[7] Recall that the current account is exogenous, hence an exogenous increase in export to Norway must be modified either by lower traditional exports or by increased imports, or both. Readers familiar with analysing impacts of increased export demand for Norwegian petroleum will recognise the effect we are describing from the ”petroleum model” – traditional exports fall back, imports increase and ”sheltered sectors” grow in response to an exogenous export impulse.

The figure 23 million Yuan establishes the scale effect (see section 0 for an explanation of this term) associated with CO_2-emissions and other emissions in the economy of China. The rest of the story has to with composition effects: the expansion of some industries relative to others. Production in the textile & apparel sectors increases, while production in sectors like electronics and metal smelting & pressing fall back. Importantly, electricity production is virtually constant. This implies that the energy required for increased production of textile & apparel, which includes the energy required for producing inputs to this production, is balanced by lower energy demands from other sectors. This is an important reason why we see a big difference between the economy-wide emissions and the embodied emissions in textile & apparel.

Macroeconomic adjustments to higher imports of chemical products are important

The macroeconomic impacts of an exogenous increase in imports of fertilizer from Norway are in principle the reverse of an exogenous export to Norway. The increase in fertilizer/chemical product import from Norway is about 140 million Yuan. By comparison the type of fertilizer we investigate in our carbon footprint analysis had an export value in 2007 of 785 million NOK, equal to about 950 million Yuan. The assumed increase of 140 million by itself worsens the current account. To counteract, ordinary imports fall, and cut the increase in imports down to 40 million Yuan. At this point the composition effect takes over. It has the opposite sign from the previous case since this time it is required to increase ordinary export. Electronics, for instance, increase in importance. Domestic production of chemical products goes down, reasonably enough, while there are this time just insignificant impacts on the textile and apparel sectors.

Since the whole process works in reverse we get lower emissions, but the major conclusion is, again, that the economy wide change in emissions is extremely small (Table 0.2).

Table 0.2 Impacts of increasing imports of chemical products to China from Norway. Unit tons/Yuan in increased imports from Norway

Pollutant	Economy-wide emissions
CO_2	-6
SO_2	-0.03
COD	0.06

Note: Increased imports of Chemical Products from Norway is 139 million Yuan.

Macroeconomic adjustments to higher exports and imports are important

The case of higher exports *and* imports combines the previous two scenarios. The exogenous increase in exports is higher than the exogenous increase in imports by about 450 million to 140 million Yuan. Hence, there is an export surplus to cover and the macroeconomic effects have similar features as the case of increased export of textile and apparel. It turns out that the environmental impacts in this case are an almost exact linear combination of the two previous scenarios. See Table 0.2, which spells out the impacts of the scenarios denoted in tons.

Table 0.3 Impacts on emissions from three macroeconomic scenarios. Unit: tons

	Higher exports of textiles & apparel to Norway	Higher imports of chemical products/fertilizer from Norway	Both higher exports and higher imports
CO_2	2900	-900	2000
SO_2	17	-4	12
COD	9	3	12

In the context of a large economy producing millions of tons of CO_2, SO_2 and COD these emissions must be considered extremely small. Hence the macroeconomic modification of the direct and embodied impact seems to be quite large. Of course, a larger initial impact on trade between Norway and China would have made for larger economy-wide impacts.

The macroeconomic adjustment in Norway is probably important, too

Two relevant studies for our purpose in a Norwegian context are Fæhn & Holmøy (2001) and Bruvoll & Fæhn (2006), see section 0. They are relevant because they work out the environmental consequences of a marginal policy change in a macroeconomic model. The model contains the resource constraints that turned out to be essential in the three scenarios for China. Fæhn & Holmøy (2001) is particularly useful since it studies a change in trade policy. Concretely Fæhn & Holmøy attempt to isolate the economic and environmental implications of three broad trade agreements, see section 0. Since the exogenous driver is a broad policy change that affects several sectors, their starting point is slightly different from ours. Recall that our starting point is an exogenous increase in export/import in two sectors. Still, their study is sufficiently close to offer important lessons for our purpose.

A message from the analysis of Fæhn & Holmøy is that the macroeconomic adjustment is large in comparison with the sectoral effect. In other words, their message is similar to the one we have elaborated above. They find that Manufacture of industrial chemicals, the sector that contains fertilizer, increases 3.8 percent in production. Yet GDP contracts in the long run. This means that the macroeconomic impact on emissions is much lower than either the direct or embodied impact from the sector Manufacture of industrial chemicals. Emissions of Kyoto gases and emissions of local pollutions (except Ammonia) increase because of composition effects, but the increase ranges from 0.0 percent (NO_x) to 2.0 percent (SO_2). Kyoto gases in total increase 0.4 percent. Fæhn & Holmøy do not provide absolute figures and deriving impact coefficients similar to Table 0.3 is difficult.

As pointed out in section 0 the authors also find that trade agreements stimulate consumption to grow despite the fact that GDP contracts. This implies a carbon and environmental leakage to other countries. The message is echoed in Bruvoll & Fæhn (2006). They find that in the case of SO_2 the change in foreign emissions is almost as large as the change in domestic emissions. However, for CO_2 the leakage is small. See also Fæhn & Bruvoll (2006), who reach similar conclusions.

The leakage associated with Norwegian policy changes may to some extent come into view in China, and hence they are covered by the analysis of scenarios in China. For instance, scenario 1 analyses consequences of higher export of textiles & apparel from China. This export of course equals imports to Norway. One could say there is carbon leakage from trade policy as seen from the Norwegian side since this is a case of consumption in Norway being covered by additional production in China. Our analysis of impact of additional exports from China found that emission increases in China were small. This implies that the empirical size of the carbon leakage probably is small as far as China is concerned.

In both countries the macroeconomic adjustment is important

A summary of the analysis of the Chinese and Norwegian cases is that the macro-economic adjustment is quite large in the sense that it more or less neutralises the sectoral impacts. The reason for the large macroeconomic adjustment is the assumption that an economy cannot increase its pool of available resources; or at least, the trade policy experiment we consider will not increase the pool of resources. Given this basic assumption it is the case that any industry that expands will more or less be counter-acted by other industries that contract. Only an improvement in the efficiency of resource allocation can create a significant scale effect (the scale effect is the effect on the scale of production, in practice GDP, see section 0) and a solid case for a large increase or decrease in emissions. The composition effect, i.e. the effect of expanding some industry relative to others, has in this case not been able to build a case for a large change in emissions.

Since the resource constraints are absolute our macroeconomic framework is in a sense conservative. At least it begs the question of how one might conceivably modify assumptions to obtain a higher scale effect. The assumption of absolute resource constraints may be modified if one believes that unemployment is important and may be alleviated by the trade policy experiments in question.[8] The assumption of a fixed current account may be modified if one believes that the current account may, instead, improve from an export stimulus. However, although a flexible current account would allow an export surplus to open up (for example) there is only the composition effect available to generate additional emissions when production is constrained by labour and capital resources. In any case we find it difficult to believe that both countries' current accounts improve from the trade agreement.

Another assumption that has been handled conservatively is related to economic growth. Across time-spans and countries there is a robust *association* between trade and economic growth. Typically, trade grows when GDP grows, but faster. The Chinese economy clearly shows this pattern (e.g., Kahrl and Roland-Holst, 2008). In addition to the association between trade and GDP, it is possible to make the hypothesis that trade contributes as a *cause* of economic growth. Such a causal association is likely to work through the productivity channel as opposed to the resource constraint channel. If it works through the resource constraint channel we are back to discussing whether the resource constraints are absolute. The hypothesis that trade fosters economic growth

8 We have performed a simulation where the real wage rate is constant, instead of labour supply. A constant real wage implies a fully flexible labour supply. As expected the economy-wide impacts increase from this change in assumption. In case of scenario 3 and CO_2 emissions increase from 3,000 to 15,000 tons. The increase is a factor of five, but the impact is still extremely modest.

through specialisation is one theory to support a link between trade and macroeconomic productivity. The Chinese macroeconomic model that we have used for our analysis incorporates the gain from specialisation only imperfectly since it does not make the assumption that frequently goes together with specialisation, namely increasing returns to scale. On the other hand the Norwegian macroeconomic model contains just this assumption. That hardly seems to matter for conclusions, however.

There is also a possibility that trade fosters through growth through higher innovation. This possibility has limited macro support since a country like the U.S.A. has a high degree of innovation but limited external trade. It is more conceivable that trade leads to a higher speed of catching up. Catching up here means catching up with the best available technology and several studies indicate that foreign direct investment, for instance, contributes to catching up. A high rate of catching up means higher productivity growth in all countries except the leader. There is for instance reason to believe that China still has catching up potential.

From an environmental perspective one difficulty with establishing a causal link between trade and productivity growth is that the further link to environmental deterioration is unclear. A gain in productivity implies that more GDP may be produced without inputting more resources, which has a neutral first order impact on the environment.

Clearly, there is no definitive answer to which assumptions are the most suitable when it comes to resource constraints and the explanations for productivity growth. But it is interesting to pursue the consequences of absolute resource constraints and exogenous productivity when illustrating the potential importance of macroeconomic impacts. Knowing that the macroeconomic impacts exist and may be important is an important caveat to a micro-level analysis that focuses on the direct or embodied carbon impact of a traded commodity. This being said it is clear that the micro-level analysis has several advantages. One of them is that it allows a much more detailed empirical description of the environmental “footprint” of a good or service to be exported. The next chapter demonstrates what is learnt from the micro-level analysis in the context of the Sino-Norwegian FTA.

Micro-level analysis

This section makes an extended emission account of two main trade sectors in Sino-Norwegian trade. Similarly to chapter 0 the analysis focuses on one export sector from each country that is likely to be significantly affected by the FTA. The two sectors in focus are:

- *NPK Fertilizers* exported from Norway to China and;
- *Cotton Textiles* exported from China to Norway

NPK fertilizers are chemically combined major nutrients, nitrogen (N), phosphorus (P) and potassium (K). This is the most commonly exported fertilizer from Norway to China (Yara, 2008b). China is also the largest consumer of NPK fertilizer in the world (Norse, 2003).

As argued previously fertlizer and textiles are two sectors expected to gain a boost from the FTA. Therefore, NPK fertilizers and cotton cloth are chosen as the two micro case studies used to estimate the environmental impacts of a Sino-Norwegian FTA.

Below follows Extended Carbon footprint analyses of trade in NPK fertilizers (Section 0) and Cotton textiles (Section 0). The analyses summarize emission accounts throughout the life cycle of the products and then present an overview of other related environmental consequences.

NPK Fertilizers

The supply of nitrogen (N) determines a plant’s growth, vigour, colour and yield. Nitrogen fertilizers increase the nitrogen supply to a crop which in turn increases the crop’s content of substances that contain nitrogen such as proteins and vitamin B1. Phosphorus (P) is key to energy transfers in plants and Potassium (K) has an important role in plant metabolism. NPK fertilizers, combining the three are for these reasons used world wide to improve plant growth and to promote better yields.

Norwegian Fertilizer Exports to China

Norway is one of the world’s main producers of NPK fertilizers. The country’s main producer; *Yara*, is the world’s largest supplier of mineral fertilizer and holds seven percent of the global mineral fertilizer market share (Yara, 2008).

According to Chinese and Norwegian Custom Statistics, fertilizers are among the main Norwegian export goods to China along with petroleum and petroleum products, general industrial machinery and equipment and fish. In 2007, Norway exported 465,735 tonnes of mineral or chemical fertilizers to China to the value of NOK 785 million (Statistics Norway, 2008[9]).

[9] http://www.ssb.no/emner/09/05/uhaar/tab-22.html

Almost the entire Norwegian fertilizers export to China in 2007 contained a certain Yara NPK fertilizer type with the composition of *N15-P15-K15* (*NPK 15-15-15*)[10] (Yara, 2008b). The NPK 15-15-15 fertilizers is categorized as high-value fertilizer and used primarily for higher value segments like fruits and vegetables (Yara, 2008).

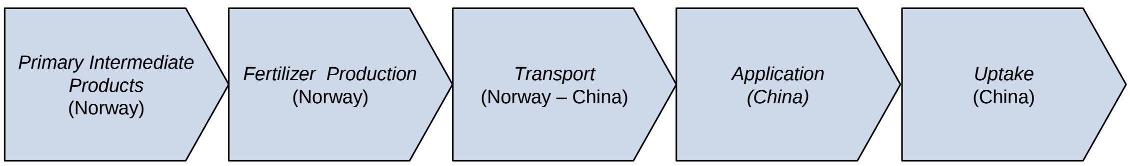
It is likely that Norwegian fertilizer exports to China will rise as emphasis on food security is projected to boost Chinese fertilizer demand (Heffer & Prud'homme, 2008). Chinese demand is driven by income growth, population increase and the limited amount of arable land. China's vast population of 1.3 billion is estimated to rise to over 1.7 million by the year 2040 while there is already only 0.1 hectares of arable land per person (University of California, 2004). Moreover, cropland is under increasing pressure from urbanization and industrialization. Some reports suggest that farmland is being lost at the rate of 500,000 hectares per year (Yara, 2008).

Recent actions of the Chinese government signal the rise in domestic demand. On 1 May, 2008, China increased its export tax on domestically produced phosphate fertilizer from 35 percent to 135 percent in order to secure domestic supply (Yara, Report Q2). On the side of imports China applies tariff quotas (TRQs) on imported chemical fertilizers (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007). The Ministry of Commerce of the People's Republic of China announced on May 6, 2008 that the import quota of Compound chemical fertilizer in 2008 would be set at 3,290,000 ton (Mofcom, 2008).

NPK Fertilizer life cycle

The components of finished NPK fertilizer are relatively simple chemicals but highly developed manufacturing technologies are employed in the production. We analyze the environmental impacts of the NPK fertilizer through dividing the NPK life cycle into five main stages. Two of these stages; *Primary Intermediate Products* and *Fertilizer Production* take place in Norway and are analyzed jointly, the third stage is the *Transport* of the fertilizer from Norway to China, the fourth stage is the physical *Application* on Chinese ground and the final stage is the *Uptake* of fertilizers of Chinese soil.

Figure 0.1 NPK Fertilizer Life Cycle boundaries



The carbon footprint analysis below will provide an account of carbon emission related to NPK fertilizers by focusing at emissions in each part of the life cycle.

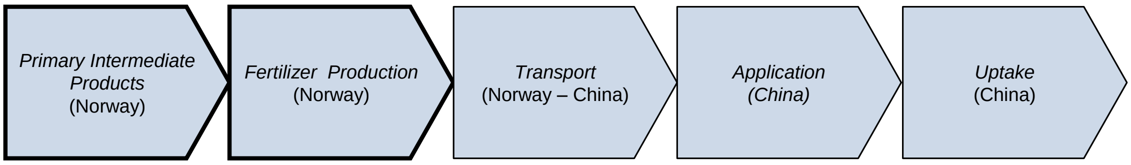
[10] Full product description in Annex B.

Carbon Footprint Analysis

Throughout its life cycle NPK fertilizer is a significant consumer of energy. Tied to this energy use are greenhouse gas emissions that account for about 1.2 per cent of the global total (IPCC, 2005).

The most significant GHG emissions arising from the production of fertilizers are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) (Wood & Cowie, 2004). However, according to the International Fertilizer Industry Association (IFIA) depending on management practices, crop fertilization can overall either produce a positive, negative or neutral impact on climate change due to fertilizers' ability to increase the carbon capture ability of plants (IFIA, 2008).

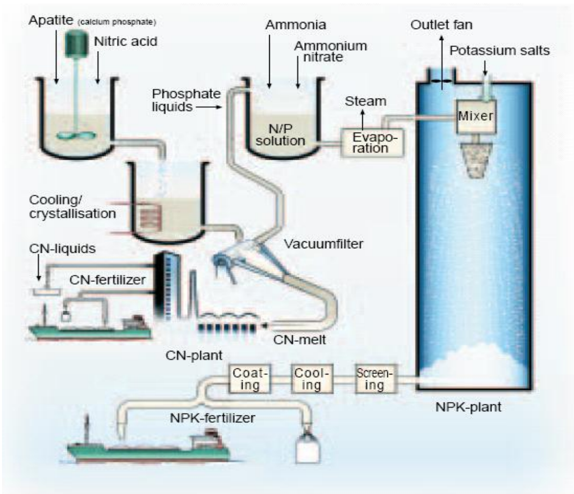
Stage 1 and 2: Primary Intermediate Products and Fertilizer Production



There are several ways of producing multi-nutrient NPK fertilisers. In Europe, the two common routes are the Nitrophosphate route and the Mixed acid route (EFMA 2000g). At Porsgrunn, Yara's NPK 15-15-15 fertiliser is produced using the nitrophosphate process using natural gas as the main energy source (Yara, 2008).

In the nitrophosphate process, the first step involves reacting phosphate rock with an excess of nitric acid to produce a mixture of nitric and phosphoric acid and calcium nitrate. The calcium nitrate is extracted, and the remaining solution is then neutralised with ammonia. Potassium is added as potassium chloride (KCl) or Potassium sulphate (K2SO4) salts (Wood and Cowie, 2004). Figure 0.2 pictures this fertilizer process at Yara's factory Porsgrunn.

Figure 0.2 Fertilizer process at Yara's factory Porsgrunn



Source: Norsk Hydro, 2003

The following activities are the most important sources of GHG emissions in the process:

- **Ammonia Synthesis:** Ammonia (NH3) is the basic building block for producing nearly all other forms of nitrogen-based fertilizers. To a lesser extent, it is also used directly as a commercial fertilizer (EFMA 2000a).

  The synthesis of ammonia is an energy demanding process. Ammonia is produced by reacting nitrogen from the air with hydrogen at high pressure and temperature in the presence of a catalyst. The hydrogen is similarly most often produced by reacting natural gas with water at high temperature and pressure in the presence of a catalyst. Natural gas is also used as a process gas (i.e. energy source) in Porsgrunn to generate the heat required in the ammonia production process. This use is however minor compared to its use as a raw material in ammonia production (Yara, 2008).

  Along with N_2O emissions from subsequent nitric acid production, CO_2 emissions from ammonia production dominate GHG emissions accounts for NPK fertilizer manufacture (Wood & Cowie, 2004).

- **Nitric acid** is used in the manufacturing of Ammonium Nitrate, Calcium Nitrate and Potassium Nitrate, which, in turn, are used either as straight fertilizers or mixed into compound fertilizers. Most nitric acid is produced by catalytic oxidation of ammonia at high-pressure and high temperature. All plants producing nitric acid are based on the same basic chemical reactions: oxidation of ammonia with air to give nitric oxide; and, oxidation of the nitric oxide to nitrous oxide (N_2O) and absorption in water to give a solution of nitric acid (EFMA, 2000b). IPCC estimates that nitric acid production is the largest industrial source of N_2O (IPCC, 2007).

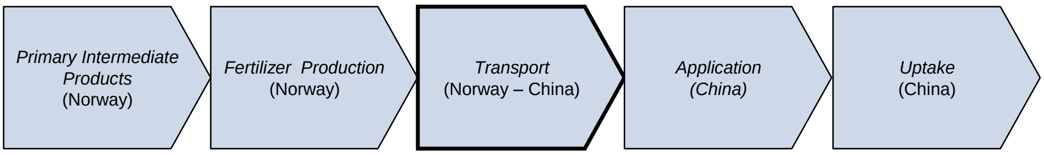
  N_2O emissions from nitric acid production are highly variable and depend on pressure, temperatures, catalyst composition, burner design and emissions abatement technologies (EFMA 2000b; IPCC, 2000).

- **The remaining processes of NPK 15-15-15 fertilizer production**, such as the extraction of rock phosphate and production of sulphuric acid and phosphoric acid, involve only minor emissions related to energy use.

Based of a European average of plants using natural gas as energy source in all stages of production, the manufacture of NPK 15-15-15 with Nitrophosphate technology is estimated to give rise to 1.2239 kilo CO_2-e per kilo NPK (Davis and Haglund, 1999). This also includes transport of materials to the factory. The majority of the CO_2 emissions in the finished NPK product originate from ammonia production because of the large consumption of fossil fuels and almost 100 per cent of total N_2O emissions is released during the production of nitric acid. The relative contribution of each GHG gas is: CO_2 (50, 8 per cent), N2O (48, 2 per cent) and CH4 (1 per cent) (Wood & Cowie, 2004).

Life Cycle Units	Kilo CO_2-e /kg NPK	Source
Primary intermediate products and Fertilizer production	1,2239	Wood & Cowie (2004); Davis and Haglund (1999)

Stage 3: Transport



According to Statistics Norway, the vast majority of fertiliser export from Norway to China is exported by maritime transport. The main GHG related to the transportation of NPK fertilizers to China are hence CO_2 emissions from sea freight.

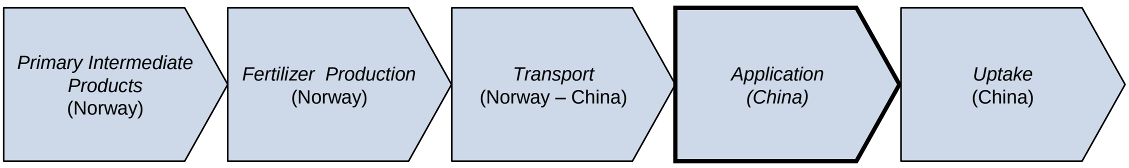
A total of 465,735 tonnes of fertilizers were shipped to China during 2007 (Statistics Norway, 2008). The fertilizer exports are shipped to the China's south east coast which is also the final destination of most of the Norwegian fertilizer exports (Yara, 2008). The eastern part has the highest population density, the highest wealth creation and hence the greatest demand for high-value crops for which the *NPK 15-15-15* is mainly used. For our carbon emission calculations, we therefore choose Shanghai as the arrival port. From Shanghai, the product could easily be transported to other parts of the south east coast. The closest sea distance between the Porsgrunn factory in Norway and Shanghai port is 10,980 kilometres via the Suez Canal (http://e-ships.net/dist.htm).

According to the International Maritime Organization (IMO) shipping is one of the lowest emitting freight transport options per kilometre. The Swedish Network for Transport and the Environment and IMO estimate that shipping emits between 15 (cargo vessel over 8,000 Deadweight tonnage (dwt)) and 21 grams (cargo vessel 2,000-8,000 dwt) of CO_2 per tonne and kilometre (IMO, 2008). Long-distance shipments of fertilizers are more likely to be shipped by ships with a dwt of 8,000 or more. We therefore chose the lower range of IMO estimations; 15 grams of CO_2 per tonne and kilometre.

Based on these estimates, 164,700 grams CO_2-e per tonne is emitted for the distance of 10,980 kilometres from Porsgrunn to Shanghai. This is 0.1647 kilo CO_2 per kilo NPK fertilizer for the full distance.

Life Cycle Unit	Kilo CO_2-e /kg NPK	Source
Transport	0.1647	Statistics Norway (2008) IMO (2008)

Stage 4: Application



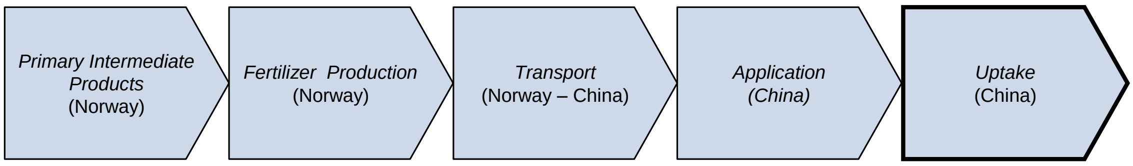
The physical application of fertilizers can be done manually or mechanically. Hand application is often used in regions where labour is plentiful and the majority of the population is involved in agriculture (Yara, 2008). This is also often the case in China with its abundant population and large agriculture population. However, since NPK 15-15-15 is a high-value fertilizer, used in China primarily for higher value segments like fruits and vegetables, we can not rule out the possibility that many of these farmers have the financial means to use mechanical application and we need therefore to include related emissions.

The main GHGs related to the mechanical application of field applied NPK fertilizers are CO_2 emissions generated through the tractors used to spread the fertilizers on the soil. These machines are typically diesel driven (Yara, 2008). According to Yara, mechanical application of fertilizers requires 3 GJ per tonne fertilizer (Yara, 2008). In lack of more specific numbers from Chinese agriculture, we use this estimate.

The IPCC estimates that average diesel releases 93 800 grams CO_2/GJ (IPCC, 2006). Hence, 0,2814 kilo of CO_2 are emitted per kilo fertilizer distributed.

Life Cycle Unit	Kilo CO_2-e /kg NPK	Source
Application	0.281	Yara (2008) IPCC (2006)

Stage 5: Uptake



As the final stage, this section trace emissions related to it’s the uptake in soil-microbiological processes. These soil-microbiological processes are also most important in the emission account related to fertilizer use. These processes occur in the uptake of fertilizers by plants and depending on the application methods and soil characteristics, they include both detrimental and beneficial climate effects. While N_2O emissions are an unavoidable consequence of naturally occurring soil-microbiological processes, plants are also one of our greatest assets in reducing GHGs (Crop Nutrients Council, 2004). The analysis below is examines the beneficial and detrimental effects in greater detail.

Beneficial effects

The role of fertilizers is to supplement naturally occurring plant nutrient supplies that support crop yields. By increasing crop growth, fertilizers enhance the CO_2 absorbing character of plants by increasing crop growth and therefore the amount of atmospheric carbon absorbed and stored in plant material. The IFIA states that when properly applied, fertilizers speed up the volume of substitution and help plants capture more carbon than is emitted during the production, transport and application of fertilizers (IFIA, 2008 & EFMA, 2003).

Grain yield improvement with fertilizers depends however on how well the fertilizer is balanced to match the soil and the amount of fertilizer used. The farmer’s aim should be to use just enough fertilizer to match total nutrient supply to the requirements of the crop, i.e. to find the optimal application rate (Yara Q&A). Experiments on wheat production with and without fertilizer use have shown that proper fertilizer application can bring a net gain of energy six times greater than the total energy used for the production, transport and spreading of the fertilizers. The same calculations showed that the extra CO_2 captured in increased biomass is more than five times the volume of CO_2-e emitted when producing, transporting and applying fertilizers (EFMA, 2003). It should however be noted that, in these calculations, CO_2 fixation can only be regarded as a real CO_2 saving if the harvested biomass is used as bio-fuel and, thus, replaces fossil fuels (Yara, 2008c). Also, as will be further shown below, the estimates depend on a careful estimation of fertilizer type and application amount to the soil.

Detrimental effects

Fertilizers do not add chemicals to the soil that are not already present, therefore, if properly balanced and applied, they should have little adverse effect on the environment.

However, the soil-microbiological processes related to fertilizer use, including N_2O uptake, depend on the soil and application methods used. If improperly applied, N_2O emissions increase sharply and the fertilizer's carbon footprint increases. This effect is generally larger than the effect of increased uptake, which occurs once as the field shifts from being not fertilized to being fertilized.

Depending on uptake, the IPCC has set an emission factor of 1.25 +/- 1 percent of the fertilizer applied being lost as N_2O (IFIA, 2008). The emission factors depend on a host of regional factors and agricultural management practices. In particular, insufficient, unbalanced or excess nutrients can trigger higher GHG emissions (Agro-Chemicals 2003). Yara has shown that the CO_2-e emissions increase and the additional CO_2 fixation decreases as the amount of Nitrogen/ha increases beyond the optimal level (Yara, 2003).

The complexity of the relationship between soil type, tillage practices, and type and placement of fertilizer makes the precise estimates of the emission factor of NPK 15-15-15 related to the uptake of fertilizers applied in China most difficult. What is well known is however that China traditionally has very unsound application rates. In China:

- NPK fertilizer ratios are often out of balance which translates to a crop utilization efficiency of only 30-45 per cent
- Average application rate is about 225 kg/hectare cropland. In some provinces the average is greater than 400kg/hectare and in some vegetable areas where up to five crops are cultivated per year, the rate is 1,000 - 5,000kg/hectare/yr
- Due to agro-climatic conditions, farmers often use fertilizer as a single application which compounds losses to the environment (Norse, 2003)

Given these numbers and the Chinese agro-climatic conditions which favour volatilization, Norse (2003) estimates that N_2O losses related to fertilizer use in China could be much greater than 1.25 percent (Norse, 2003).

Because of the uncertainty around the specific practices surrounding the application practices of the NPK 15-15-15 in China and to show the importance of sound fertilizer application, we display a range of emissions based on IPCC's estimate of +/- 1,25 percent:

- **For emission factor 0.25**: This is 2.5 grams of N_2O per kilo NPK fertilizer which, using the GWP of 298, is equivalent to is 0.745 kilo CO_2-e per kilo NPK fertilizer
- **For emission factor 1.25**: This is 12,5 grams of N_2O per kilo NPK fertilizer which, using the GWP of 298, is equivalent to is 3,725 kilo CO_2-e per kilo NPK fertilizer
- **For emission factor 2.25**: This is 22.5 grams of N_2O per kilo NPK fertilizer which, using the GWP of 298, is equivalent to is 6.705 kilo CO_2-e per kilo NPK fertilizer

These numbers show that the carbon emissions related to the uptake phase is heavily dependent on farming practices and that this stage contains a substantial share of the whole carbon footprint.

Life Cycle Unit	Kilo CO_2-e /kg NPK	Source
Uptake	0.745 – 6.705	IPCC (2006)

NPK Carbon Footprint Summary

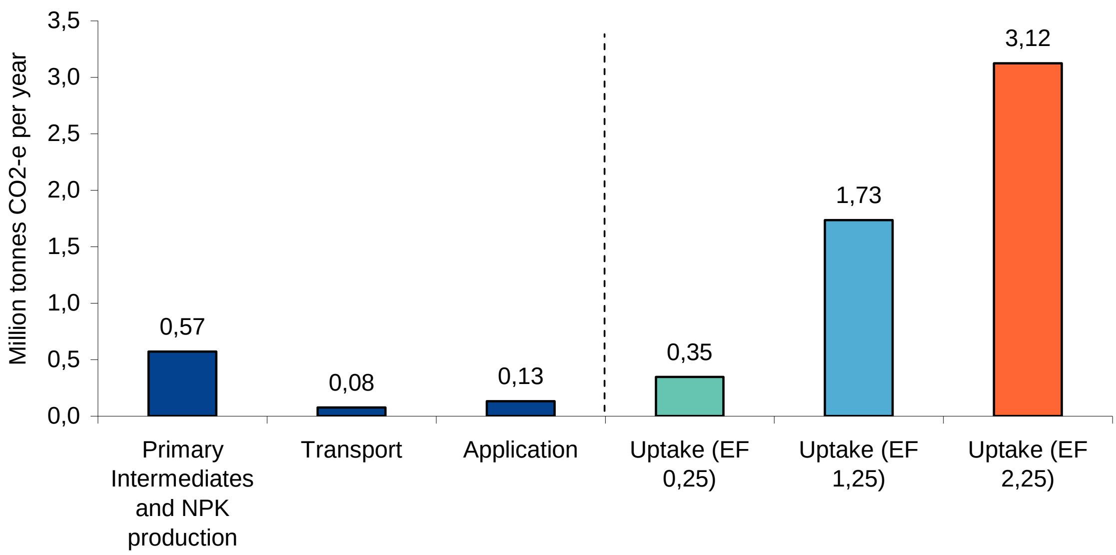
In summary, the main GHG emissions associated with NPK fertilizer production are linked to the production of the primary intermediate products and to the application of the fertilizer on Chinese soil. In the first stage, it is carbon dioxide emitted when natural gas is combusted as part of ammonia synthesis, and nitrous oxide emitted during nitric acid production. In the final stage, N_2O emissions are likely to be large due to the traditional low efficiency of Chinese fertilizer use and the agro-climatic conditions.

In numbers, the emissions related to export of Norwegian fertilizer NPK 15-15-15 to China is estimated at 2.415 – 8.375 kilo CO2-e /kg NPK or 1.12 – 3.9 million tonnes CO2-e per year.

Life Cycle Unit	Kilo CO_2-e /kg NPK	Million Tonnes CO_2-e per year[11]
Primary Intermediates and NPK production	1.2239	0.57
Transport	0.1647	0.08
Application	0.2814	0.13
Uptake	0.745 – 6.705	0.35-3.12
Total	**2.415 – 8.375**	**1.1 – 3.9**

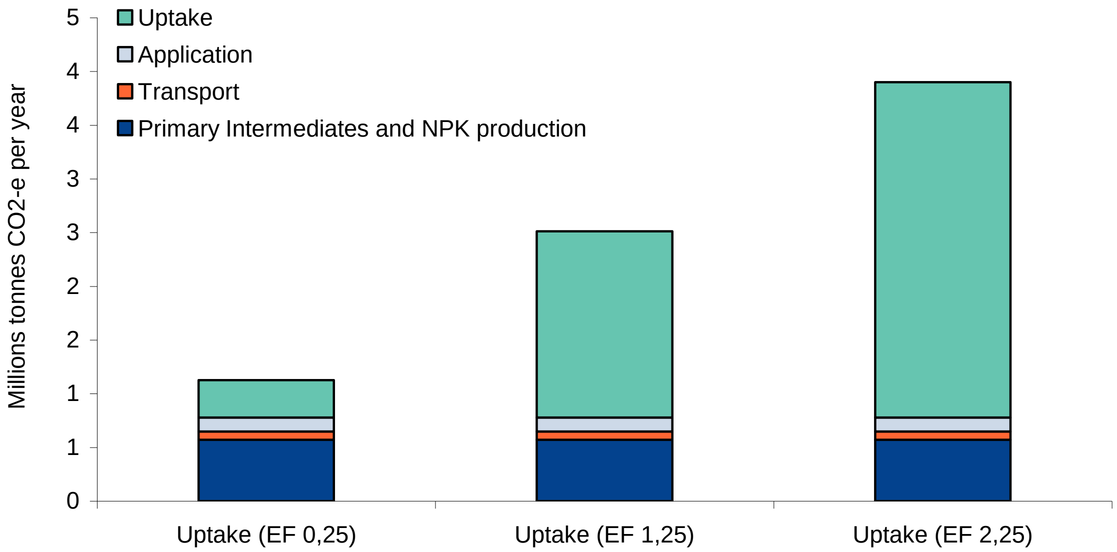
These numbers shows that the application practice is an area that deserves particular attention. If the carbon footprint of fertilizer exports is to be reduced, application practices must be made sustainable to ensure adequate uptake of N_2O.

Figure 0.3 Overview of Carbon Footprint. (Million tonnes CO_2-e per year)



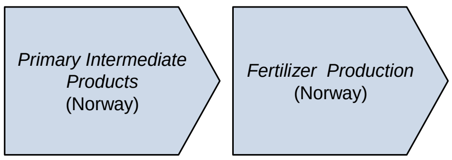
[11] Based on 2007 exports of 465 735 tonnes of NPK fertilizers as stated by Norwegian Statistics (www.ssb.no)

Figure 0.4 *Total Carbon Footprint per uptake Emission Factor (EF). (Million tonnes CO_2-e per year)*

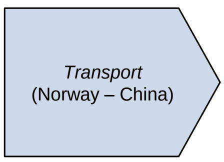


NPK fertilizers: Extended environmental analysis

This section discusses other environmental consequences linked to the production, transportation, application and uptake of NPK fertilizers other than climate impacting GHGs. This is done according to the same stages as the Carbon Footprint to provide a broader assessment of the environmental consequences of a FTA. As the consequences of application and uptake are closely interlinked, these are discussed jointly.



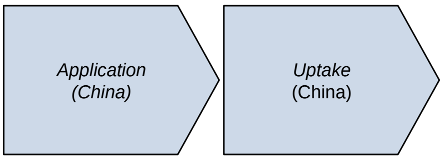
The environmental issues related to the production of the primary intermediate products and the blending of the NPK fertilizers are mostly linked to the GHG emissions covered in Section 0 above. The other main environmental concern relating to this stage is that the depletion of abiotic resources, such as fossil fuels or minerals is their decreasing availability for future generations. For fertilizer production the abiotic resources in question are natural gas used as a fossil fuel in the production and the very depletion of the raw minerals used in the production (Brentrup et al 2004).



Ocean transportation is often considered an environmentally beneficial alternative, taking into consideration its capacity to transport large volumes at a relatively low input of energy. As far as carbon dioxide emissions are concerned, the advantages of sea transportation are undisputable.

There are however other environmental drawbacks related to ocean transportation. These are primarily linked to the impact of maritime transport on the biodiversity of the world seas. Ships do not only emit GHGs but many also accidentally and intentionally release substances such as oil spills, garbage and toxics into the environment. The damage to plants, fisheries, birds, and mammals of these substances can be considerable.

Another common practice that has environmental consequences is when vessels take on and discharge ballast water to insure vessel stability. When vessels take on ballast water, aquatic life indigenous to that region is often found in the water. When the water is discharged in another region, the discharged aquatic life may then thrive and disrupt the local ecological system. When there are no natural predators, the non- indigenous aquatic life will alter or destroy the natural marine ecosystem.



Mineral fertilizers make major contributions to land productivity gains from intensification that reduces the need to convert forest and rangeland to cropland. In addition, fertilizers are an important component in securing food supply by increasing the grain, vegetables and fruits growing in an area. As long as fertilizers are applied to meet crop requirement and in accordance with good farming practice, with locally derived rates and timing, the fertilizer components will be largely taken up by the plant. It is then present in agricultural outputs, grains, fruit, vegetables, milk, meat, and eggs. When used correctly fertilizers also improve and protect the environment by:

- Improved productivity from cropped land avoids the need to destroy further areas of natural forest and grassland
- Sustained green crop growth essential for maintenance of the atmosphere.
- Reduced losses of soil due to wind or water erosion
- Improved crop rooting systems which can make better use of both the soils nutrient supply and applied fertilizers

Without the addition of fertilizers, crop yields world wide would be significantly reduced. The agricultural output in Western Europe would be reduced by 40-50 per cent in the short term and in North America, Eastern Europe, Asia and Australasia by around 30 per cent (Yara Q&A).

However, the need for good quality food at affordable prices should be met with minimum adverse effects on the environment. Excessive rates of fertilizer application are potentially environmentally harmful as well as economically wasteful. Problems can occur when:

- More nutrient is applied than the crop needs
- A deficiency in one nutrient is left uncorrected leading to unbalanced nutrition and poor utilisation of other nutrients
- Nutrients applied in manures are not taken into account when applying fertilizer

When the application rates are too high, as is often the case in China, this is not only economically inefficient to the farmer but there are also large risks of adverse environmental effects. Nitrogen can drift through the environment and potentially cause adverse environmental impacts (Powers, 2005). The critical application rate at which there is a high risk of large leaching and N_2O runoff losses from fertilizer use is at 150-225kg/ha. At these levels, common in China, a high proportion of nitrogen is lost to rivers, lakes and coastal waters. Nitrogen is also lost to the atmosphere and contributes to acid rain, GHGs accumulation and global warming but it also has an indirect effect on rivers and land in the local area (Norse, 2003). At the local level, the main related problems are likely to be:

- **To crops**: lodging, enhanced susceptibility to diseases and quality problems
- **To water:** acidification, aquatic eutrophication and enhanced nitrate concentration. The nitrate concentration poses a risk to humans and is quickly becoming a main concern in parts of China. The situation is particularly serious in the cultivation of vegetables, as these are often grown in or close to urban areas, resulting in fairly direct contamination of the drinking water sources for large numbers of people.
- **To air**: unnecessary emissions of ammonia (contributing to soil acidification and eutrophication) and nitrous oxide (Yara, Fertilizers and the Environment).

Phosphorus does not readily leach, except in exceptional circumstances such as at very high soil phosphorus contents and following heavy rains that cause soil erosion. When this occurs, lakes and rivers can become green and cloudy with enhanced algal growth (eutrophic). This phenomenon causes the ecosystem to deteriorate, and can deleteriously affect fish populations (Norsk Hydro, 2003).

Conclusions

A FTA that brings about increased exports of fertilizers from Norway to China and a higher fertiliser use in China will have both positive and negative impacts on the environment at the global and local level. On the positive side, Norwegian fertilizers of type NPK 15-15-15 are likely to be better balanced for the Chinese soil that many of the unbalanced fertilizers used today. Applied properly, these fertilisers can help to increase crop yield and build up soil organic matter. This is in turn most valuable for a country like China that strives to secure food supply under environmental balance.

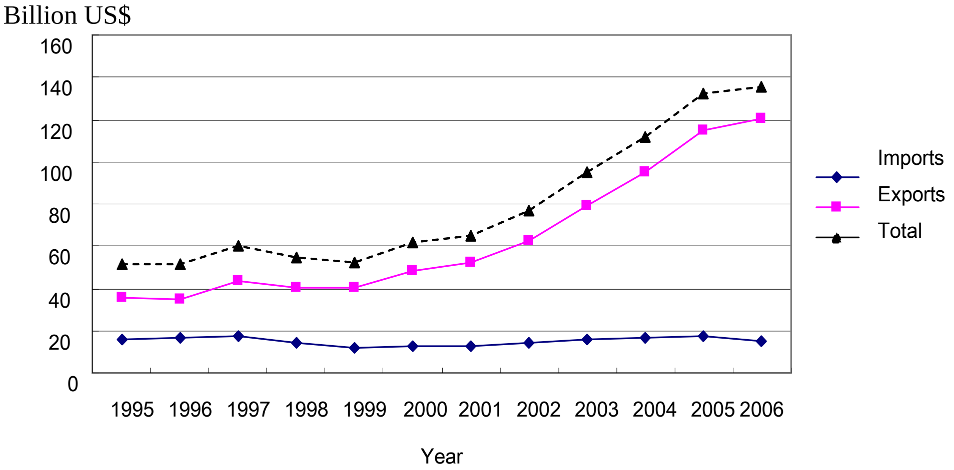
However, if the Chinese farmers do not apply adequate attention when applying the fertilizers the fertilizer can lead to an increased release of N_2O in Chinese soil. This would be detrimental both for the local environment and is of growing importance as a driver for climate change. Higher, unsustainable fertilizer use is likely to cause regional eutrophication of lakes, reservoirs and ponds and lead to fish mortality and algal blooms, soil acidification, and to other environmental stresses such as the accumulation of heavy metals in the soil (Norse, 2003).

In Norway, emissions related to the production of the fertilizers will increase. In spite of the technological development already taken by Norwegian fertilizer producers, additional technical development is needed to further enhance the carbon efficiency related to production of intermediate products.

Cotton Cloth

China is the largest cotton producer and the biggest producer and exporter of cotton textiles and apparel products in the world (UNCTAD, 2008). Moreover, as is shown in Figure 0.5 below, the production and export of textiles and apparel have been on the rise since China joined the WTO in 2001. Since 1997 China's average annual growth rate for apparel exports has been around 14 per cent

Figure 0.5 Foreign Trade Changes of China's textile product



Source: NBS (2008)

The total volume of China's textiles and apparel products exports exceeded US$ 140 billion in 2006[12]. These exports included 17.8 billion apparel items, which is roughly three items for every person on the planet (Cottoninc, 2008).

Cotton textile is estimated to make up around one third of the value of products exported, i.e. US$ 47 billion. The Chinese Association for Textile Industry estimated that China produced 5.5 billion meters of cotton textile cloth in 2005. This was an increase of 0.8 billion meters compared to the previous year (Shen, 2006). Correspondingly, the cotton cloth industry also occupies a crucial position in the national economy and provides the means of livelihood for around 4.5 million Chinese (National Bureau of Statistics, 2008).

Chinese Cotton Cloth Exports to Norway

Textiles and apparel are also the main products exported from China to Norway, accounting for around 45 per cent of China's total exports to Norway. In 2006, China surpassed EU as the largest exporter of textiles and clothing to Norway as the export value increased to US$ 572.4 million, (2004: US$ 501million, 2005: US$ 430.8 million). According to the *Feasibility Study* the most important textile articles exported from China to Norway in 2006 were pullovers/ cardigans, cotton sweaters and women trousers of cotton (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007).

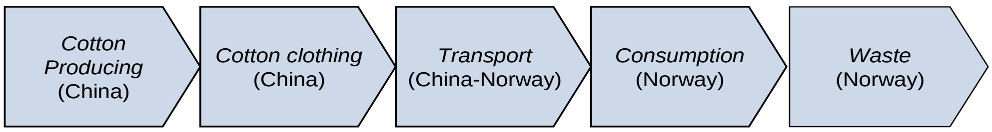
[12] Full list of China's textile products value of Imports and Exports in 2005 and 2006 is found in Appendix C.

As was established in the Feasibility Study, Chinese apparel export to Norway is likely to increase with the introduction of a Sino-Norwegian FTA that removes the current trade barriers. Norway still maintains 299 tariff lines liable to customs duty covering clothing and a number finished textile articles. These tariffs have been maintained in order to protect the few remaining producers in the Norwegian apparel industry. The tariff rates vary from 0 to 13.7 per cent. A majority of China's exports to Norway in this category is subject to a tariff rate of 10.7 per cent (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007).

A more liberalised trade-regime would probably augment the flows of apparel and textiles from China resulting in increased Chinese production and lower apparel costs for Norwegian consumers. This could threaten the remaining Norwegian suppliers but perhaps also entail new opportunities. The Norwegian textile industry has in many ways already switched from the kind of low cost apparel imported from China to high value apparel sectors and relaxed trade barriers could thereby also provide an opportunity for increased two-way trade of textiles and apparel products (Ministry of Trade and Industry, Norway and the Ministry of Commerce, China, 2007).

Chinese Cotton Cloth life cycle

Among the textile products exported from China to Norway, cotton cloth is chosen to calculate its environmental impacts. The life cycle of cotton cloth consists of multiple elements, summarized in the following 5 steps:



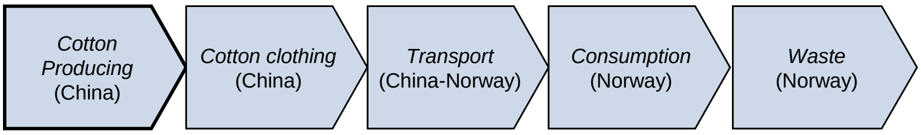
Cotton production is the process of producing cotton from seeds to lint cotton in a season long period. In the growing process, it consumes water, chemicals, electricity and machinery. At the same time, carbon dioxide, ammonia and nitrogen could be released from the application of chemical fertilizers and pesticides as discussed in section 0 above. Cotton clothing is the process of spinning and dying cotton to be cotton cloth, usually with some chemical fibre mixed in. It mainly consumes electricity and water in the process. Transportation is the process of transporting cotton cloth from China to Norway. It consumes oil by shipping. The consumption process of cotton cloth in Norway also consumes little electricity for storage etc. Finally disposal of waste cotton cloth at the end of lifecycle in Norway also consumes some energy for collection and treatment as waste, such as incineration or landfill. Incineration often produces commercial energy, but at the cost of emissions to air.

The Cotton Cloth carbon footprint

Throughout its life cycle, from production of lint cotton to cotton cloth consumption, the emissions of GHGs in the cotton cloth life cycle is successively decreasing through the production chain. The significant GHG emissions are electricity related carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

The carbon footprint analysis below will provide an account of carbon emission related to cotton cloth by focusing at emissions in each element of the life cycle.

Stage 1: Cotton Producing



Cotton production is the process of producing cotton from seeds to lint cotton in a season long period. In the growing process, it consumes water, chemicals, electricity and uses machinery. At the same time, carbon dioxide, ammonia and nitrogen could be released from the application of chemical fertilizers and pesticides.

Cotton productivity increased sharply in China during the period 1961-1966, when seed cotton yields per hectare rose from 620 kg to 1,425 kg (with an increase of about 130 per cent in five years) and fiber output per hectare moved from 259 kg to 345 kg. After 1966, the productivity increase stagnated until the early 1980 when seed cotton yields increased again by more than 5 (reaching 3,197kg per hectare in 2005) and output levels rose by more than 4 for cotton fiber (1,119 kg/ha in 2005).

Today, cotton production in China is carried out in many various ways and production patterns have transformed in recent years. In remote areas, some farmers still use very traditional farming system, using only small quantities of oil and electricity and larger quantities of human and animal labour. In some other areas however, such as in Northern Xinjiang, a more energy intensive farming system has developed and is already widely used.

About one third of Chinese cotton production takes place in the Xinjiang Autonomous Region and the remaining parts take place in central and eastern part of China. Textile factories in coastal areas increasingly use imported cotton instead of domestic produced cotton in their production. Most often the cotton is imported from United States, the Commonwealth of Independent States (Uzbekistan in particular), India and Pakistan and even far from African countries.

Due to the increased import of cotton, there is so far no cotton inventory of LCA in China yet and there are only a few studies on cotton's environmental impacts (Shen, 2006). Therefore, foreign cotton carbon inventory data have to be borrowed. Table 0.1 below shows cotton carbon production inventory data, which reflects the world average of the cotton sector.

Table 0.1 Carbon inventory of Cotton production

Unit: kg cotton	Unit	Polyester	Cotton	Organic cotton
Energy (electricity and fuel) consumption	MJ	97.4	59.8	53.6
CO_2 direct Emission	Kg	2.31	4.265	3.913

Source: Kalliala, (2007)

However, this inventory has to be adapted to China's real situation in the following way:

- About only 2 per cent is organic cotton and 98 per cent is normal cotton
- About 10 per cent polyester is on average mixed with cotton cloth
- The calculation does not differentiate China's cotton production and imported cotton
- One ton of cotton cloth consumes 1.5 – 2.5 ton of lint cotton with mixed fibre
- 1 MJ electricity emits about 0.2 kg CO_2

So, the adjusted inventory for China's cotton production is as below.

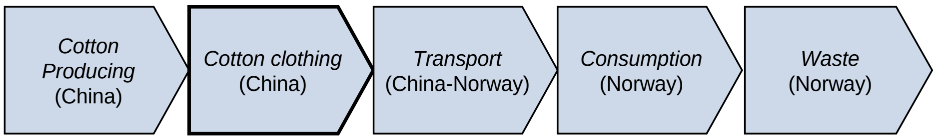
Table 0.2 Adjusted Carbon Inventory of Cotton production in China

	Unit	Polyester	Cotton	Organic cotton
GHGs equivalent of Energy (electricity and fuel) consumption	Kg	19.48	11.84	10.72
CO_2 direct Emission	Kg	2.31	4.265	3.913
Total	Kg	21.79	16.1	14.63

So, the average carbon emission of cotton production in China can be estimated to 16.1 kilo for one kilo cotton.

Life Cycle Unit	Kilo CO2-e/kilo	Source
Cotton production	16.1	Kalliala (2007) Author's calculation

Stage 2: Cotton clothing



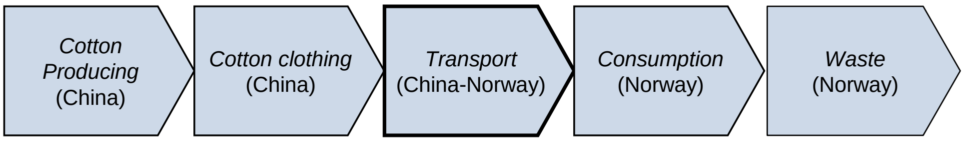
The cotton cloth process of spinning and dying cotton mainly consumes electricity and water. By Chinese technical standards of cotton cloth industry the following estimates have been established (Shen, 2006):

- For 1 ton of cotton yarn production, 2.248 kWh electricity is consumed, which is equivalent to 0.854 tce. This equals 0.000854 tce per kilo.
- For 100 meter cotton cloth, 29.93 kWh electricity is consumed and 2.0 ~ 4.0 m3 water, which is equivalent to 0.0117 tce. By using the parameter of 0.3kg/meter long with 1.6 meter width, 100 meter cotton cloth equals 30 kilo. Hence, 1 kilo cotton cloth consumes 0.00039 tce.

In sum, the production of1 kilo cotton cloth equals 0.001244 tce (0.000854 + 0.00039 tce). By using the Chinese parameter, 1 tce = 2,28 ton CO_2-e, so GHGs emission of 1 kilo cotton clothing is about 2.83632 kilo CO_2-e.

Life Cycle Unit	Kilo CO_2-e/kilo	Source
Cotton clothing	2.83632	Shen, (2006), SEPA report Tang Chuayi (2003), Journal of Shanghai Texile S&T Ma Xiao (2007) , Journal of China's Environmental Industry

Stage 3: Transport



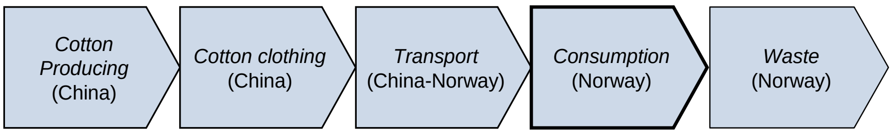
Transportation is the process to transporting cotton cloth from China to Norway. It consumes oil by shipping. A total of 213 tonnes of cotton cloth with the property we investigate (code 52081200) was imported from China to Norway in 2007. The majority of this import was transported via sea freight.

The closest sea distance between the Oslo port and Shanghai port is about 11,030 kilometres via the Suez canal (http://e-ships.net/dist.htm). Using the same estimates as in section 0, we assume that cotton cloth is transported on ships with a dwt over 8,000 that emit 15 grams of CO_2 per tonne and kilometre (IMO, 2008).

This translates to 165,450 grams per tonne and kilometre for the distance of 11,030 kilometres from Shanghai to Oslo. This is 0.16545 kilo CO2 per kilo cotton cloth for the full distance between Oslo and Shanghai.

Life Cycle Unit	Kilo CO_2-e /kilo	Source
Transport	0.16545	Statistics Norway, 2008 IMO, 2008

Stage 4: Consumption

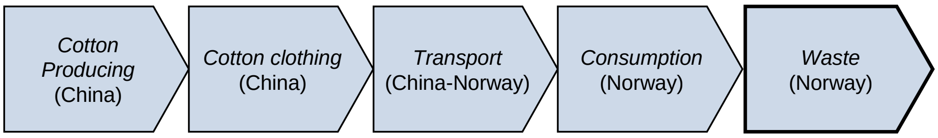


Laundry is the major carbon contributor of cotton cloth consumption. A typical A-class washing machine consumes 1 kwh (3.,6 MJ) per 6 kilo wash. For 1 kg it thus consumes about 0.6 MJ electricity. 1 MJ emits 0.15 kg CO_2 equivalent, based on the Nordic country LCA inventory (Kalliala, 2007).

If we assume that the cotton cloth is not transformed into clothing but stays cloth we can assume that this cloth is washed twice a year on average for 15 years life long use. Hence, the consumption of cotton cloth within 15 years in Norway is as below.

Life Cycle Unit	Kilo CO2-e /kilo	Source
Cotton production	2.7	Kalliala (2007) Author's calculation

Stage 5: Waste



Textile waste in Norway can be handled by either burning of the waste or placing of the waste in deposits. When the waste in burned, the carbon is freed from the products and CO_2 is produced. Most of the transformation occurs during the burning but some of the carbon is preserved in the ashes and transformed only later (ECON, 2000).

Based on an average of several studies calculating the emission factors of burning of textiles, ECON (2000) estimates that 917 kilo CO2, 0.875 kilo SO_2 and 0.29 kilo MH4 are emitted per tonne of textile waste. These emission factors depend however on the composition of the textile material. Burning of biological material is seen to have to have en emission factor of 0 while textiles containing carbon from fossil sources do have a positive emission factor. Whether or not there is energy recovery also matters. Since the product used in this analysis is cotton cloth of 100-200 grams/m^3 mixed with only 10 per cent polyester fibre, emissions are estimated to be insignificant.

Cotton Cloth Carbon Footprint Summary

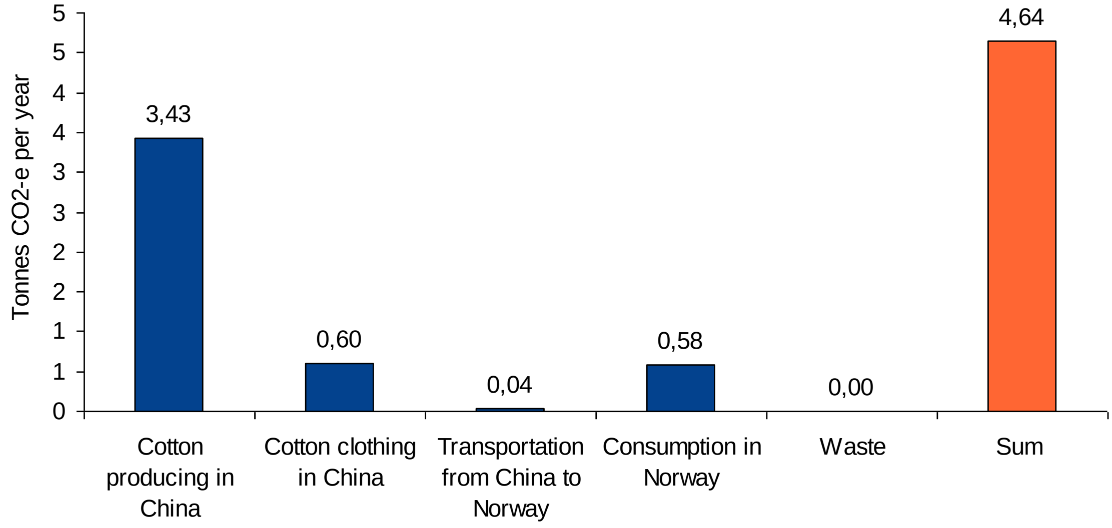
To sum up the above analysis, the carbon footprint in each unit is as below:

Life Cycle Unit	Kilo CO_2-e/kilo	Tonnes CO_2-e per year[13]
Cotton producing in China	16.1	3.429
Cotton clothing in China	2.8	0.604
Transportation from China to Norway	0.2	0.035
Consumption in Norway	2.7	0.575
Waste	0.0	0.000
Sum	21.8	4.644

The main GHG emissions associated with cotton cloth are hence linked to the production of cotton, cotton clothing and consumption. In the first stage, the emissions are related to energy (electricity and fuel) consumption and chemicals applying with direct carbon dioxide and CH4, NO_x emissions. In the consumption stage, it has mainly electricity consumption for launderings.

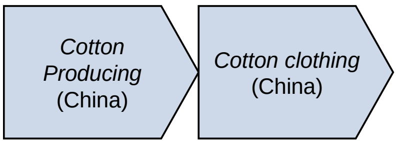
[13] Based on 2007 exports of 213 tonnes of cotton textiles as stated by Norwegian Statistics (www.ssb.no)

Figure 0.6 Overview of Cotton Cloth Carbon Footprint. (Tonnes CO_2-e per year)



Extended environmental analysis

The exports of cotton cloth from China to Norway also have other direct environmental impacts than GHG emissions, especially on water pollution in China. These are accounted for in the extended environmental analysis below.



Beside agriculture, textile industry is one of the most water resource consumption sectors in China. According to Shen (2006) the textile industry discharged 1.72 billion tons of wastewater in 2005 and took up 7 per cent of total industrial effluent which made it the fifth most polluting Chinese industry. .Its COD discharge was the fourth largest in the country and took up 6.05 per cent of total COD emissions.

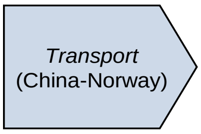
The production related environmental impacts of cotton cloth exports in 2005 are summarized in Table 0.3 below. As is shown, the most significant environmental impact is wastewater effluent. To export 1 meter cotton cloth, 31.4 kilo wastewater is discharged to the water body.

Table 0.3 Cotton cloth exporting and its direct environmental impacts in 2005

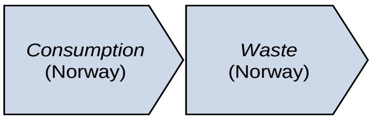
Exporting and Emissions	Production	Increased comparing with last year	Increased %
Exporting amount (million meter)	5,496	795	14.46
Associated amount of COD (thousand ton)	140.4	20,696	14.74
Waster water discharge (million ton)	172.80	25,472	14.74
Water consumption (million ton)	216	27,825	12.88
Coal consumption (tce million ton)	2.43	0,358	14.73

Source: Shen (2006)

The vast water usage and waste water discharge is alarming given China's present water stress. The country's unprecedented economic development has put great strains on the country's natural resources and water is among the scarcest resources. The available resources of water is only 2186m3 per capita, a quarter of the world average and the scarcity is even further advanced in the North. As a result, reports of water related conflicts are emerging. Between 1990 and 2002 there were more than 120,000 water related conflicts reported to the Chinese Ministry of Water Resources (Hildebrandt and Turner 2005).

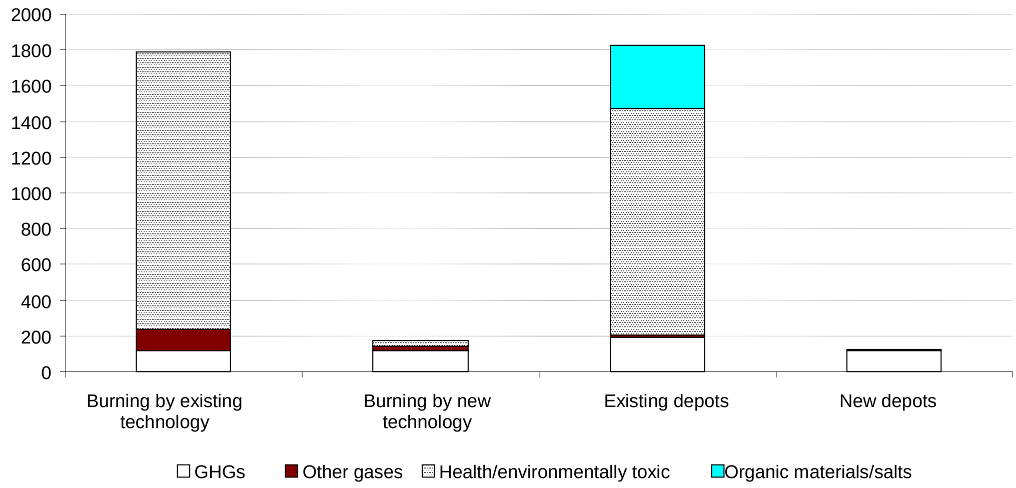


See section 0 above.



The environmental effects of cotton cloth other than GHG emissions are primarily related to the waste treatment of the textiles. The handling of textile waste can incur several environmental challenges including releasing health- and environmentally toxic emissions (Pb+Cr+Cu+Mn+Ni+As) and organic material and salts. The extent of the environmental consequences varies greatly between modern and traditional waste treatment facilities. Figure 0.7 below shows the big differences between existing and modern technology in Norway.

Figure 0.7 Comparison of external effects of waste treatment of textiles. (NOK/tonne waste)



Source: Econ (2000)

The health- and environmentally toxic emissions traditionally imply substantial problems and can have impacts on the health of both people and the environmental surroundings. As an example colour additives in textiles can cause diseases and provoke allergies even at very small quantities, In addition, many of the toxic chemicals decompose slowly and can damage the ecological and biological diversity for generations to come (Econ, 2000)

Conclusions

A Sino-Norwegian FTA would probably bring about increased exports of cotton cloth from China to Norway. Based on our estimates, such a trade increase would increase carbon emission by 16.6 kilo CO_2-e /kg cotton cloth and 31.4 kg wastewater by meter. On the Norwegian side, a higher cotton cloth use in Norway would also have negative impacts on GHG emissions. Higher consumption and more laundering of cotton cloth would increase CO_2-e emissions by 2.7 per kilo cotton cloth. For transportation from China to Norway, it would increase 0.16 kilo CO_2-e /kg cotton cloth.

The Chinese farmers could somewhat decrease the GHG emissions of the cotton production process by shifting to organic cotton farming. Similarly, if the cotton cloth producing would follow cleaner production technology with China's environmental friendly label certification, it also could reduce a certain amount of GHGs emission as well as water pollution. The mitigation measures available in Norway are more environmental friendly laundering processes, for example using detergent-free washer and the use of natural dry-up instead of drier use.

Implications for a FTA

In sum, the two carbon footprints show that the main environmental consequences of trade in fertilizers and cotton textiles are linked to the initial and final stages of the product life cycles. Usually, the most polluting aspect of consumable products is the pollution emitted in production. Interestingly, the case studies show that significant pollution is also linked to the usage of the products. The environmental effect of fertilizer export depends mainly on the carbon efficiency of fertilizer production *and* on a balanced application of fertilizers and for cotton cloth, the equivalent is true for cotton production and washing.

A FTA that brings about increased trade in fertilizers and cotton cloth will hence have a negative environmental effect in both countries. However, as noted earlier, the negative effect related to fertilizer use in China can be mitigated if the fertilizers are applied properly. However, if the Chinese farmers do not apply adequate attention when applying the fertilizers this can lead to an increased release of N_2O in Chinese soil which would be detrimental both to the Chinese soil quality and to global warming. A FTA that eliminates current TRQs should therefore ideally be coupled with measures to capture the environmental costs of increased fertilizer use (Norse, 2003). This would however be particularly challenging for the Chinese authorities that are faced with a delicate trade-off between the environmental stresses from fertilizer use and food security benefits that are impossible to achieve without the use of mineral fertilizers.

Another way of decreasing the emissions related to farming practices in both cases is to spread information regarding sustainable farming practices of cotton, including the use of fertilizers. A well balanced fertilizer application is not only environmentally sustainable but also economically beneficial for the farmers and increased information should therefore be of interest to all parties.

A FTA can also be coupled with consumer communication measures in Norway aimed at limiting emissions related to cotton imports. This communication can be directed at washing practices but also aimed at informing consumers of the environmental sustainability of the cotton cloth that they choose to buy. Through affecting demand, supply practices can also be altered. This kind of information is possible as China has used the textile eco-label The "Environmental Friendly Product Label" since 1996 and has reached an agreement on mutual recognition with White Swan Program products. The authorities are also planning to develop a new label related to low carbon product standards.

Finally, in order to highlight the environmental issues as brought forward in these two examples, China and Norway could also choose to sign an environmental cooperation agreement associated with the FTA. Such an agreement could highlight the areas of concern linked to Norwegian and Chinese trade, such as fertilizer application and initiate collaboration initiatives such as the spreading of information and mutual technology development.

Environmental technology exchange

China's speed and scale of development combined with its severe resource scarcity provides an exceptional opportunity for increased international exchange of sustainable solutions (Reinvang & Peters, 2008). Evenly distributed, the vast Chinese population has access to only 0.1 hectare arable land (45 percent of the world average) and only 2 200 m3 water per person (25 percent of world average). If China is to reach its ambitious goals for economic development, the country must find ways to power the achievement of those goals that are both environmentally and socially sustainable (University of California, 2004). This challenge presents an opportunity for domestic and international companies alike. Ideally, a FTA would enhance mutual environmental technology exchange between Norway and China and provide new opportunities for Norwegian firms wishing to expand operations in, or exports to China.

This section aims to clarify if a FTA would benefit some of the environmental technology firms presently active in China [14]. It also aims to understand which barriers they perceive stand in the way for increased technology exchange. Naturally, the views presented here are not representative for the individual companies, nor for all Norwegian technology firms active in China today. However, the views brought forward by the interviewed firms consistently highlight some issues that should be of interest for Norwegian and Chinese decision makers.

The companies included in the study were chosen in collaboration with Innovation Norway in Beijing and were interviewed during the project team's field visit in Beijing in October 2008.

In sum, the analysis reveals that changes of tariffs and quotas in the current trade regime are unlikely to have any substantial effect on Norwegian firms' potential on the Chinese markets. Instead, a FTA could benefit Norwegian-Chinese environmental technology exchange through: (1) highlighting institutional complications in the Chinese system; (2) through promoting connections between Norwegian firms, Chinese counterparts and Chinese authorities (3) and finally through contributing to awareness of environmental challenges and management thereof.

Norwegian environmental technology firms in China

Several Norwegian environmental technology firms have been active in China since the country opened up to trade in the late 1970s. Most of them exited after the Tiananmen Square incident and re-entered in the mid 1990s.

The scope of services provided by Norwegian firms range from high technology products and services such as Carbon Capture and Storage (CCS) techniques to less advanced products aimed at handling key challenges at hand such as water and air pollution. In our interviews for this analysis, we have spoken to:

[14] The analysis focuses primarily on the potential for Norwegian environmental technology firms and do not place ample focus on the implication for increased Chinese technology transfers to Norway. Although important, this is outside the scope of the analysis.

- *Aker Solutions*; active in China since early 1900. Today, the firm primarily works with introducing foreign engineering technologies into China. Technology portfolio includes primarily upstream technology and Capture and Carbon Storage technology.
- *Elkem*; leading international special metals and materials company producing a wide range of products for steel, iron, foundry, aluminium, smelting, construction, chemicals, electronics, photo voltaic and automobile industries. Elkem produces several products in China and serves both the Chinese domestic market and exports to foreign markets. Elkem has developed technologies for reducing industrial furnace particle emissions, captive renewable energy resources, and comprehensive research & development programs.
- *Green Clean Energy*; a new consultancy firm focusing on trade of climate quotas and on developing projects under the CDM mechanism. The company assist in buying and selling quotas and through developing CDM projects, primarily in biogas and biological fertilizers. Representatives of the firm have been active in China since 1996-1997.
- *Malthe Winje*; active in China since 1996. The company installs transformers and automatic systems for water cleansing and sewage treatment. Malthe Winje has worked under a Norad-contract to deliver their water treatment system to several places in China. Today, China-related activities account for 100 million of the firms 250 million turnover.
- *Pöyry Environment China*; environment consultants focused on engineering and consulting services for the process and energy industries and the architectural and infrastructure sectors in China.
- *StatoilHydro*; active in China since 1978 when Norwegian authorities wished to tie closer ties with the Chinese government. Statoil's first office was established in 1982. During 1985-86 the company trained 10-20 *Sinoc* trainees in offshore technology. Many of these are now in top positions in the Chinese oil industry.
- We also conducted an interview with *Werner Christie, Science and Technology Counsellor of Innovation Norway in Beijing*. Innovation Norway promotes nationwide industrial development profitable to both the business economy and Norway's national economy, and helps release the potential of different districts and regions by contributing towards innovation, internationalisation and promotion.

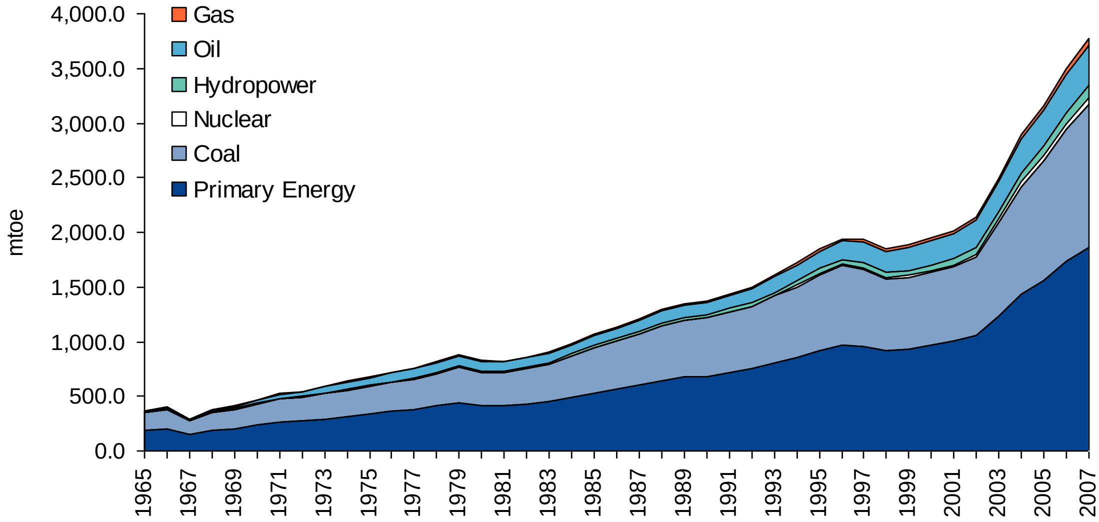
In the text below, statements given by the companies are referred to by way of capital letters, such as AS for Aker Solutions, MW for Malthe Winje etc.

The development of the Chinese market for environmental technology

The Chinese market for environmental technology has developed rapidly over the past decades. A steep demand increase stems from the heightened focus placed on environmental preservation by the Chinese central government and enhanced financial resources.

China's current use of energy is as pollution intensive as it is inefficient. Powering the extraordinary Chinese economic development since 1978 has been coal. This has resulted in the world's largest Sulphur dioxide (SO_2) emissions and a level of Carbon dioxide emissions (CO_2) that is on par with the level in USA. It has also had as a result that deaths from respiratory diseases are 10 times more common than in Europe and USA (WHO, 2008).

Figure 0.1 Energy Consumption in China 1965-2007



Source: BP (2008)

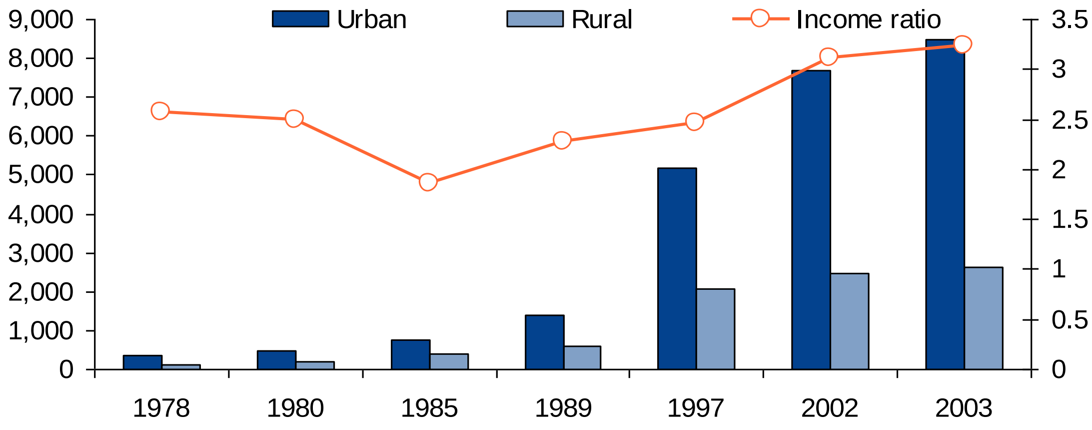
To power continued growth and to prevent pollution related human casualties, more energy efficient and environmentally friendly technologies are required. The Chinese central administration is therefore encouraging more investments in environmentally friendly solutions and is scaling up its own investments (MW). 70 billion RMB has been set aside within the 11th 5 year plan for water treatment and 6.5 billion RMB was invested in 2008 for rural area water safety. Furthermore, the State Administration of Environment was upgraded to Ministry level in March 2008. The central government is also searching for new sources of energy. Statoil Hydro estimates that Chinese demand for natural gas will rise from 70-80 million m3 in 2008 to 150 million m3 before 2020 (SH).

Although demand has increased, there is however still a tendency for the Chinese administration to focus on treating the symptoms at hand instead of preventing the real roots of the problems (AS). The demand is still relatively short sighted and focused around air and water treatment. Increased awareness building is needed to show the need for carbon capture like and energy efficiency promoting technologies.

One country, two markets

Viable technology solutions in China must be cost efficient, especially if solutions are to be financed by local administrative levels in the more rural parts of China. Although the country has experienced unprecedented economic growth and has lifted millions out of poverty, large parts of China are still poor. Over 20 percent of the Chinese population still lives under $2 per day and the average rural income is less than a third of average urban income (Chen & Ravallion, 2008).

Figure 0.2 Income development 1978-2003



Source: World Bank China (2008). Left axis: Yuan per year

An equivalent gap exists between urban and rural regions for infrastructure development, education, FDIs and capital accumulation. Therefore, there are in effect two separate markets for environmental technology: One reasonably modern and well off; the other traditional and poor. We call one urban and the other rural, although some urban areas actually belong in the "traditional and poor" category.

The development gap between the urban and rural markets contributes to a well known discrepancy in priorities between central authorities and rural, poorer administrations that complicates the implementation of centrally coordinated environmental projects at lower administrative levels. Although there is an increasing central political will to implement environmental efficient technologies, it is evident that environment concerns are still second to economic development at lower administrative levels (GCE).

Norwegian companies that wish to increase exports of environmental goods and services must therefore chose strategy according to which market the companies are aiming for. As an example; there is huge demand for water cleansing technologies in China. Only six of the twenty-seven largest cities supply drinking water that meets government standards and over 400 million people in rural areas drink water that is at least partially polluted (China Environment Forum, 2008). Both are problems of water quality but they require different solutions.

In the rural areas, there is little available financing and low awareness of what causes pollution. There is also limited human capital available to implement new technology and provide regular maintenance. Viable solutions must therefore be cost efficient and relatively uncomplicated. As Norwegian certifications often require high technology solutions, the final product is often too sophisticated and too expensive for the rural Chinese market.

Only in the larger cities where there is good access to financing can more expensive Norwegian technologies be sold. In these areas the competition is however fierce. To distinguish themselves from the competitors, Norwegian firms have to find avenues to differentiate their products and services.

According to the companies interviewed for this study, one adequate way of positioning Norwegian technology is to emphasize the Norwegian awareness of environmental management and experience in applying environmental management and safety standards (SH). Another possibility is *innovation*. Although Chinese firms are efficient and good at developing existent technologies, they are often less prominent in Research and Development. New, innovative solutions to China's problems will therefore be more likely to succeed than refinements of previous technologies (Werner Christie).

Could a FTA help increase environmental technology exchange?

The firms included in this study emphasize that a FTA between Norway and China would have greater political use than commercially benefit their businesses. The current challenges for providers of environmental technology firms in China, as described by the firms interviewed in this study, are primarily linked to insufficient awareness, to establishing relationships and to the irregular institutional framework. A FTA is however seen as positive political signal that can be combined with other efforts to enhance exports of Norwegian environmental technology to China.

It should be mentioned that beside the technology itself, Norwegian technological goods, services and investments applying under the present WTO commitments are de facto still subject to trade barriers. As an example, the imported Norwegian equipment for the Three Gorges dam project was eligible for tariffs and there are still human capital barriers since engineers require visas and professional certificates to install the equipments. Such barriers should ideally be overcome after FTA.

What could be done from an official level?

The Norwegian firms brought forward mainly two areas where official actions could complement the introduction of a FTA in order to endorse environmental technology exchange from Norway to China;

1. Firstly, Norwegian officials could help the Norwegian firms with marketing and with establishing the essential contacts, both institutional and with other firms (AS, MW). Official representation is often needed to develop corporate networks and to establish necessary governmental contacts (AS). It is however crucial that these official networking attempts are planned in accordance with Chinese corporate culture and properly followed through (GCE).

2. Norwegian official representatives could during the FTA negotiations also stress the problems caused by the Chinese irregular institutional framework and promote more stringent routines for controls of standards and regulations (SH, MW, GCE, Elkem). This relates to promoting awareness of environmental concerns and capacity building on how to manage them. Rather than lack of financing or lack of technical expertise, awareness and management capacity is often what is missing in the Chinese context. While Chinese firms are already experts within many traditional fields of Norwegian expertise such as hydropower, they often have inadequate routines for managing environmental and social concerns[15].

[15] As an example, China is the largest producer of hydropower in the world and has the technical capacity to manage hydropower plants of larger scale than will ever be developed in Norway. The Three Gorges Hydropower Station in Hubei Province is one example. The station will encompass 26 large generator groups with an expected annual 84.7 Twh electricity supply (http://www.ctgpc.com). The development of the Three Gorges Hydropower Station has however been surrounded by inadequate handling of large resettlements of people and environmental consequences such as erosion and land slides. Awareness of the management of such concerns is, to a great extent, still insufficient in China.

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Appendix A: Interviews

2008-10-14, *Terje Bratlie*, Managing Director & *Georg Finsrud*, Malthe Winje

2008-10-15, *Håvard Nørstebø*, Green Clean Energy

2008-10-16, *Fredrick Støa*, Project manager of StatoilHydro China

2008-10-16, *Helen Yu*, Public Affairs Manager of Aker Solutions Beijing Branch

2008-10-17, *Werner Christie*, Science and Technology Counsellor of the Norwegian Embassy in Beijing

2008-10-17, *Joanna Zhang*, Senior Consultant of Pöyry Environment China

2008-10-22, *Tom Prestulen*, Elkem China

Appendix B: Product Specification NPK 15-15-15

Yara Porsgrunn	PRODUCT SPECIFICATION 15-15-15S (SOP)			PSS.R031
Procedure ref. L-405 **Instr. nr.** L-405/1	**Approved by** Bøyesen, Jan **Date** 19.02.2008	**Prepared by** Åmås, Jon Åsmund **Date** 19.02.2008	**Tolerances** 15 KINA **Market** CHINA	**Product no.** PG765P000
Revision no. 10		**Color**		**Brand**

Chemical composition	**Declared value**	**Min**	**Max**
Total Nitrogen	15,0 %	15,0 %	
Ammonium-N	8,5 %	7,5 %	
Nitrate-N	6,5 %		7,5 %
Citratesoluble P2O5	15,0 %	15,0 %	
Watersoluble P2O5	10,5 %	10,5 %	
Total K2O	15,0 %	15,0 %	

Physical values	**Typical values**	**Min**	**Max**
Bulk density (Loose)	1,13 kg/l	1,08 kg/l	1,18 kg/l

Granolumetry (ISO)	**Typical values**	**Min**	**Max**
+4,0mm	6 %		
-4+2mm	85 %		
-2,0mm	9 %		

Appendix C: China's textile products value of Imports and Exports in 2005 and 2006

Unit: USD 100 million	**2005**		**2006**	
Section & Division by HS code	**Exports**	**Imports**	**Exports**	**Imports**
Textile Materials and Products	1076.61	234.45	1380.94	256.77
Natural Silk	13.36	1.36	14.24	1.27
Wool; Wool Yarn and Woolen Woven Fabrics	18.45	21.47	19.97	21.41
Cotton	74.38	70.78	88.77	91.09
Other Textile Fiber; Yarn and Related				
Woven Fabrics	6.18	4.77	6.61	4.86
Chemical Fiber; Continuous Filament	58.90	37.76	65.99	37.95
Chemical Fiber; Staple Fiber	43.87	32.57	55.33	28.27
Wadding; Felt and Adhesive-Bond Fabrics;				
Special Yarn; Thread; Rope; Cable and Related Products	8.60	7.07	11.00	8.33
Carpets and Related Products	9.32	0.62	10.69	0.76
Special Woven Fabrics; Lace; Embroidery	27.09	8.46	33.67	8.38
Coated Textiles; Textile Products for Industrial Use	17.55	14.50	21.32	15.69
Knitwear and Crocheted Fabrics	36.52	18.78	46.40	21.53
Knitted or Crocheted Garments & Clothing Accessories	308.71	6.95	449.00	7.17
Garments Not Knitted or Crocheted	350.31	8.15	437.20	8.68
Other Textile Products; Secondhand Garments				
Footwear; Headgear; Umbrellas; Canes; Whips;	103.36	1.19	120.76	1.38
Processed Feather; Artificial Flowers; Wigs	227.73	6.71	262.53	7.76
Parts of Footwear; Gaiters	190.52	5.42	218.13	6.08
Headgear And Accessories	14.43	0.13	17.50	0.14
Umbrellas; Canes; Whips and Accessories	9.61	0.09	11.42	0.08
Processed Feathers and Related Products;				
Artificial Flowers; Wigs	13.16	1.07	15.48	1.45

Source: National Bureau of Statistics (2008)