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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Fifty-fifth Meeting
Bangkok, 14-18 July 2008

DRAFT ASSESSMENT REPORT ON THE STUDY FOR THE PHASE-OUT OF CTC IN THE CHLOR-ALKALI SECTOR (DECISION 52/31(B))

1. The Executive Committee, in its decision 52/31, had requested the World Bank to submit a draft of the report "Global assessment of CTC phase-out in the chlor-alkali sector" by the second Meeting of the Executive Committee in 2008. This draft report is attached to this document. Due to the commercial nature of the data presented, the World Bank has requested to keep the document's distribution limited.

2. The Executive Committee might wish to consider the draft report and discuss whether to request any further work from the World Bank, taking also into consideration UNEP/OzL.Pro/ExCom/55/50 and the recommendations contained therein.

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CONFIDENTIAL

- GLOBAL CTC PHASEOUT REPORT - IN THE CHLOR-ALKALI SECTOR

FINAL REPORT
(Report 3 of 3)

Prepared by
Tecnon OrbiChem
in association with Sherry Consulting

WB Ref: PO7145979

Commissioned by:

THE WORLD BANK

June 2008

CONFIDENTIALITY

This Report is for use only by the World Bank and the UN Montreal Protocol and must not be copied or shared either in whole or part outside that community.

The Report refers to various named individuals who have provided information in confidence to our consultants in the course of the research for this Report. The confidentiality of all market respondents, both individuals and companies, must be strictly maintained.

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BACKGROUND

This Final Report is the third Report out of three to be submitted to the World Bank to complete commissioned work on Global CTC Phase in the Chlor-alkali Sector (WorldBank reference 100008069).

The Conception and Interim Reports were duly submitted in February and April 2008 and were discussed and critiqued via conference calls between the interested Parties.

The primary contributors to this Report were:

- **David Sherry** and **John Wilkinson** of **Sherry Consulting**
- **Tecnon OrbiChem -** Chlorine market worldwide and CTC use research in China and Taiwan.

Task 1: Global CTC consumption by chlor-alkali sector

Research and update of existing global information on CTC that is used a process agent for NCl_3 removal by the chlor-alkali sector in both Article 5 and non-Article 5 countries

To accomplish this task: *Tecnon OrbiChem will:*

- *review existing data held on its CTC and chlorine databases*
- *visit selected chlorine plants that consume CTC and comment on them*

Outcome*: Presentation of data in the Report by country and by production facility*

Data presentation*: to be provided for base year 2006 with comments on likely future conversions or shut downs, with dates provided where identified*

Task 2: Review of CTC-free technologies for the chlor-alkali sector

Research and update of existing information to provide the basis for a detailed review of currently existing technologies or processes for the production of chlorine, which ***do not use*** *CTC as a process agent for the removal of NCl_3.*

To accomplish this Task*: Tecnon OrbiChem will specify if and how NCl_3 is removed from the final chlorine stream, whether residual levels of NCl_3 remain in the final product, and whether any ODS are produced as byproducts (e.g. conversion of chloroform into CTC) by:*

- *reviewing the technical process data held on its database*
- *visiting and/or interviewing technology suppliers and other relevant market participants to identify any changes in chlorine production technology that might inform this task*

Outcome*: Presentation of data in the Report by technology and/or process with comment on any likely future developments in the industry*

Data presentation*: to be provided by process technology with individual chlorine producers identified for base year 2006 with comments on likely future changes and/or technology currently being developed and/or tested, but not yet in commercial operation.*

TERMS OF REFERENCE/SCOPE OF WORK

The following is a duplication of the Terms of Reference/Scope of Work provided by The World Bank and agreed with Tecnon OrbiChem and its Associate Sherry Consultancy (*shown in italics* below):

EVALUATION OF ALTERNATIVES FOR THE PHASEOUT OF CARBON TETRACHLORIDE ("CTC") AS PROCESS AGENT IN THE PRODUCTION OF CHLORINE

1. Background

Liquid chlorine is produced by electrolysis of sodium chloride brine. Even after undergoing purification, the natural rock salt used as raw material in the preparation of the brine contains impurities, leaving traces of ammonium and nitrogen in the electrolyte solution. These impurities are entrained by the chlorine gas after the electrolysis process is completed. As chlorine gas is liquefied it may react with these impurities, and the result is Nitrogen Trichloride (NCl_3). NCl_3 is a highly explosive compound when present in concentrations over three percent (3%), and it must therefore be periodically removed from the chlorine production process.

The chlor-alkali industry around the world traditionally used Carbon Tetrachloride (CTC), CCl4, to extract NCl_3 from liquid chlorine.(Tecnon OrbiChem comment: It should be noted that there is no clear evidence that its use is "traditional", although CTC use was more widespread in the 1990s than it is today). The chemical properties of CTC are ideal for this process, since it is both soluble in chlorine and a solvent for NCl_3, and it therefore mixes well with the two compounds. Moreover, the boiling point of CTC is 77 C, which is significantly higher than that of chlorine (-34 C) and similar to that of NCl_3 (71 C). It is therefore possible to keep NCl_3 in solution with CTC, at a range of temperatures where liquid chlorine is no longer present. CTC is inert, non-corrosive, and it is stable in a relatively wide range of temperatures.

CTC is controlled by the "Montreal Protocol on Substances that Deplete the Ozone Layer". It has been recognized as a controlled substance used as process agent by the Meeting of the Parties to the Montreal Protocol (Decision XV/6) when used to eliminate NCl_3 in the production of chlorine. Therefore, as countries phase out their consumption of Ozone Depleting Substances (ODS) in accordance to their commitments to the Montreal Protocol, the use of CTC by the global chlor-alkali sector has decreased, particularly in non-Article 5 countries (UNEP PATF, 1997). The overall consumption of CTC as a process agent in Article 5 countries is not, at present clearly known, but is expected to be relatively small. A report prepared by the Technology & Economic Assessment Panel (TEAP) is expected to be released in June 2007 and should provide insight on this matter.

A few chemicals have been identified that can be used as substitutes for CTC in the production of chlorine for the removal of NCl_3, but none is as versatile or as efficient. Therefore, in spite of having relatively low levels of CTC consumption, in absence of suitable alternatives, Article 5 countries that produce chlorine risk being out of compliance to their Montreal Protocol obligations before 2010. In an effort to identify potential countries that may need additional assistance to meet their target ODS reductions, the Executive Committee of the Montreal Protocol has requested the World Bank to carry out an assessment of the global chlor-alkali sector and to identify technically and economically viable alternatives to the use of CTC in the production of chlorine in Article 5 countries.

2. Project Objective

The main objective of this project is to examine technologies and eventual sectoral plans relevant to the phaseout of CTC in the production of chlorine with a view to identifying more cost-effective alternatives.

3. Project Activities

Activities to be conducted under this project are as follows:

Task 1: Global CTC consumption by chlor-alkali sector

Consultants will establish the current global context of CTC consumption as process agent for chlorine production. Specifically, consultants will determine remaining CTC consumption as a process agent for NCl_3 removal by the chlor-alkali sector in both Article 5 and non-Article 5 countries. Data will be presented in a disaggregated manner, by country and by production facility.

Task 2: Review of CTC-free technologies for the chlor-alkali sector

Consultants will provide a detailed review of currently existing technologies or processes for the production of chlorine, which do not use CTC as a process agent for the removal of NCl_3. Consultants will specify if and how NCl_3 is removed from the final chlorine stream, whether residual levels of NCl_3 remain in the final product, and whether any ODS are produced as byproducts (e.g. conversion of chloroform into CTC).

Task 3: Review of conversion projects

Consultants will review conversion projects that have been carried out over the past 10-15 years, through which chlor-alkali facilities have phased out the use of CTC as process agent in the production of chlorine. The review will include information on conversion projects in both Article 5 and non-Article 5 countries. The evaluation should include, but not be limited to, the following:

i. *Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures*

ii. *Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)*

iii. *Detailed description of methodology or technology used to achieve the phaseout of CTC and of new production processes*

iv. *Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)*

v. *Percent of NCl_3 in final chlorine product and related safety considerations*

vi. *Duration and cost of conversion project (cost effectiveness ratios will be provided)*

vii. *Post conversion issues and solutions*

A minimum of five examples describing different conversion alternatives will be provided. Consultants will also provide contact details of technical personnel who can be approached for additional information at each of the facilities described.

Task 4: Review of alternatives

In its Decision X/14 of 1998, the Meeting of the Parties to the Montreal Protocol noted that process agent used in non-Article 5 countries should not be taken into account in the calculation of a country's consumption or production, if the emissions of controlled substances had been reduced to "insignificant" levels as defined in the text of the Decision, through operating processes and containment technologies.

Consultants will review current CTC emission levels in a sample (at least five) of non-Article 5 chlor-alkali plants where containment approaches have led to acceptable losses of CTC, as per Decision X/14. Consultants will estimate the cost effectiveness of containment alternatives and will make recommendations on the feasibility of adopting them in Article 5 production facilities.

Task 5: Analysis and recommendations

Based on their evaluation of the chlor-alkali sector, of the existing types of production facilities and of the alternatives for NCl_3 removal in the production of chlorine, consultants will propose possible scenarios for CTC phaseout in Article 5 countries (e.g. most suitable types of technical and procedural alternatives depending on the various types of production facilities). Consultants will make recommendations and prepare terms of reference on potential sectoral plans (at the country or at the global level) that can be developed for the complete phaseout of CTC in the production of chlorine.

Recommendations should be made on the basis of the most environmentally sound and cost effective alternatives for conversion or containment, which at the same time ensure the safety of the workers at the production plant and of the chlorine costumers (e.g. level of NCl_3 in final product). Consultants will specify expected cost-effectiveness ranges of each alternative proposed and eventual sectoral plans.

4. Management and Implimentation Arrangements

The World Bank is the implementing agency for this proposed project.

The Montreal Protocol Unit in the Department of Sustainable Development has overseen this work.

A. EXECUTIVE SUMMARY

- The minimum capacity to produce CTC globally from all manufacturing processes stands at 155-183 ktpa. This is based on the default of assuming that CTC is produced as a co-product of chloroform production typically at 10% on chloroform but in some cases higher. There is no real maximum capacity because all plants can be adjusted to make CTC on demand: it may exceed 500-600 ktpa.

- The actual output of CTC in 2006 is assessed at just under 180 kt. This is NOT a statement of emissions: much of this CTC was consumed as a chemical intermediate into perchloroethylene, into fluorocarbons including CFC11/12 and HFC245fa and HFC365mfc, into DV Acid chloride and into other chemical specialities. Much of this production was fatal, but some of it was deliberate.

- In 2006, we estimate that 9 plants globally (of over 1100 chlorine producing units) are using CTC in the manufacture of chlorine to manage nitrogen trichloride emissions. The apparent consumption (as make-up quantities; or as quantities purchased) was nearly 1130 tons, and the emissions are calculated at ~7.5 tons. USA is overwhelmingly the largest consumer (3 users, make-up over 1000 tons, but emissions or "consumption" around 2 tons). Seven (7) of these plants are in Article 2 countries, and two (2) are in Article 5.1 countries

- In addition we estimate that 3 plants are using CTC to manage tailgas emissions: the apparent consumption (make-up) is some 180 tons and the emissions are some 45 tons. Of this consumption, 90 tons are in an Article 5.1 country and 45 tons of emissions are from this plant, which is subject to a conversion project in 2009 that is beyond the scope of the present study.

- The two CTC-consuming plants in Article 5.1 countries (Brazil and Colombia) have both been the subjects of conversion projects. The Colombian plant will convert 2 tons/a of CTC use (and 2 tons/a of CTC emissions) into a chloroform based process by the end of 2009. The Brazilian plant has invested in emission management techniques and its ~50 tons/a apparent consumption resolves into 1-2% emissions (<1 ton/a).

- CTC has not been a widely used chemical in the application of NCl_3 management. Case studies developed under Tasks 3 and 4 demonstrate that a wide variety of techniques are used to prevent NCl_3 build-up. Essentially these resolve into pre-electrolysis measures (good salt, make-up water, and brine management) to avoid or minimise nitrogen content; and post-electrolysis measures that resolve into handling techniques for the liquefaction of chlorine, where this is necessary. Few plants globally use catalytic or UV light treatment. Some plants employ a batch-treatment process to enable heat-treatment of specific high NCl_3 content chlorine, but often this exists as a contingency.

- Because according to the present study there is no large identified global demand for a CTC replacement, and because in any case there is no one single measure or chemical that would replace it, the sectorial plan development has by agreement evolved into a listing of possible decisions and actions, which where possible have been shown with variable and/or fixed cost implications. However since each plant is very specific, and since most NCl_3 management is based on operational techniques, many of the possible actions cannot show economics.

B. OBSERVATIONS ON TERMINOLOGY, ACRONYMS & CONVENTIONS USED

a) Carbon Tetrachloride (CTC)

CTC is a clear liquid with a sweet, ether-like odour, an odour threshold over 10 ppm, and a boiling point of 76.5^{0}C. CTC is regarded as a possible human carcinogen based on evidence of carcinogenic effects in animals. In addition, CTC is a Montreal Protocol-regulated ozone-deleting substance, with an ODP (Ozone Depletion Potential) rated at 1.1 relative to CFC11.

Synonyms for carbon tetrachloride include:

- Tetrachloromethane
- Perchloromethane
- Carbon chloride
- Methane tetrachloride
- Benziform
- “Tet”
- “Carbon tet”
- CTC

In this Report, carbon tetrachloride is referred to either by its full name, or as "CTC".

b) Global Production of CTC

Although it was not specifically requested as part of this report, we have thought it useful to present our findings on the global capacity to produce CTC, and to make some observations on the actual production and disposition of CTC by region, which we have presented for 2006 as being generally harmonious in terms of time frame with the data sets presented elsewhere in the report. This is in part to address one concern which has been voiced as “*Concern needs to include mention of discrepancy between Scientific Assessment Panel measurement based data and reported CTC data is large. There is a discrepancy of about 60,000 -145,000 t/y (average ca 80,000 t/y) CTC in observed and reported data*”. (Feedback to Interim Report). There has been no requirement, in the scope nor the ToR, to comment on Scientific Assessment Panel based data but Tecnon OrbiChem hopes to contextualise the role of CTC as an NCl_3 management agent by presenting the larger picture.

CTC is a member of the higher chloromethanes family of products. The higher chloromethanes are produced either by the chlorination of methane or by the chlorination of methyl chloride (monochloromethane).

In both processes, the ratio of chlorine to the feedstock plays an important role in the ratio of the different products. Apart from CTC, the other chloromethanes are methylene chloride (dichloromethane, CM2), and chloroform (trichloromethane, CM3). It is possible to produce more or less of any individual product, but in general all three products will be co-produced.

Because CTC has had a continually reducing industrial requirement since the years of peak demand as a chemical intermediate in the late 1980s, its co-production is generally minimised.

In one convention, it is assumed that minimum CTC production (that is, the minimum possible amount of CTC that can be inevitably co-produced) represents of the order of 5-6% of the overall chloromethanes capacity. A higher real-time production by individual producers generally would mean either older technology, or more typically that CTC is being deliberately manufactured. However, operators of more modern plants, and notably those operating in China, state ratios of below 5%.

In another convention, the minimum CTC production ratio is assumed at some 10% of the chloroform output or capacity (which are not the same). Again there are exceptions depending on the plant technology and original plant design. Some plants are based on photochemical reactions and some older units, notably in India, which were expressly set-up to produce high CTC levels, exceeded this at up to some 12-15%.

Tecnon OrbiChem's global analysis of these markets is presented below and illustrates the ratios of CTC to the chloromethanes.

Table 1: Global Production Higher Chloromethanes, 2006/2007 (kt)

	CM2	*CM3*	*CTC*	*%CTC total CMs*	*%CTC on CM3*
2006	817	1153	179	8	15
2007	873	1161	175	8	15

Source: Tecnon OrbiChem

Note: the CTC production level indicated is a total number. It does not in any sense represent emissions. Much of it is used as a chemical feedstock to make intermediates for HFCs and CFCs, in the production of perchloroethylene, in the manufacture of agrochemical and pharmaceutical intermediates, or is destroyed by approved processes.

CTC can also be co-produced in the perchlorination processes from hydrocarbons or chlorinated hydrocarbons. "Per" chlorination means total chlorination of the given molecule, with complete substitution. This process is also called "chlorinolysis". Importantly, CTC from chloromethanes units is readily introduced into perchlorination reactors. CTC acts as the reactive diluent and is used to control the reaction temperature, and also itself reacts into perchloroethylene according to reactor conditions and feedstocks. Recycling the product least desired to the reaction zone can control the product distribution between carbon tetrachloride and perchloroethylene. By our analysis, perchlorination plants today generally are used to consume CTC and to produce perchloroethylene excepting in cases where CTC is specifically required as an industrial intermediate.

Another process to CTC, which is today commercially not at all relevant, is the carbon disulphide route. The last such plant was in North Korea, and this closed in early 2005.

For completeness the other chemical intermediate applications have been summarized below (perchloroethylene having been commented already). It is beyond the scope of this study to quantify the use in each individual application.

CFC11 (trichlorofluoromethane, CCl_3F) and CFC12 (dichlorodifluoromethane, CCl_2F_2)

CFC11, slightly the smaller in overall volume terms of the two main CFCs, had an overall volume of production reported by AFEAS of 8.7 million tons in the period 1934-2001, with a peak of 382kt produced in 1987. The largest of all the fluorocarbons, CFC12 had an overall volume of nearly 11.5 million tons reported by AFEAS in the period 1931-2001, with a peak of 424.7 kt in 1987.

In 2006 CFCs were being produced in India, Argentina, Venezuela, USA and Europe but, excepting some small essential use exemptions, it will all be discontinued by 2010. CTC demand to CFC11 and 12 exceeded 1 million tons in 1987.

HFC245fa (Pentafluoropropane, $C_3H_3F_5$)

This product has been commercialised by Honeywell in the USA, and (with some patent discussions) by Central Glass in Japan, as a replacement product for HCFC141b in foam blowing applications. There is also some Chinese capacity, but HCFC141b is a much larger product for foam-blowing in China with considerable capacity and a relatively low price. In the Honeywell process, HFC245fa depends upon pentachloropropane, known as HCC240fa, as feedstock, and this is produced by the reaction of vinyl chloride with CTC.

HFC236fa (Hexafluoropropane, C3H2F6)

This product is a fire fighting material developed and globally patented by DuPont and marketed as FE36. There are thought to be some three Chinese plants capable of manufacture as well as one US plant. We understand that product is presently being sourced from China. The product requires hexachloropropane ($C_3H_2Cl_6$) as feedstock, and this is prepared by the reaction of vinylidene chloride (1,1-dichloroethane, VDC, $C_2H_2Cl_2$) with CTC.

HFC365mfc (Pentafluorobutane, C4H5F5)

This product has been commercialised by Solvay Fluor in Europe as a replacement product for HCFC141b in foam blowing applications. HFC365mfc depends upon pentachlorobutane as feedstock, and this is produced by the reaction of monochloropropene (C_3H_5Cl) with CTC.

DV Acid Chloride

DV acid chloride is also known as cypermethric acid chloride ($C_8H_9Cl_3O$) and is a starting point for the production of synthetic pyrethroid type agrochemicals including cypermethrin and permethrin. It is produced in India and in China. Chemically it is 3-(2, 2-dichlorovinyl)-2, 2-dimethyl cyclopropane-1-carboxylic acid chloride. The starting point in the production routes in India and China is the Kharasch reaction of CTC with acrylonitrile to form tetrachlorobutyronitrile.

Chinese CTC management solutions

These are the options used following the mandate that new chloromethanes plants must arrange to have a guaranteed chemical intermediate route or destruction mechanism in place before chloromethanes manufacturing licences can be granted. None of the Chinese CTC producers has opted for the thermal recycling of CTC with HCl recovery, preferring as they say to create product rather than destroy it. Their solutions include:

- CTC to cinnamic acid (reaction of CTC with styrene as start point)
- CTC to perchloroethylene
- CTC to trifluoropropene (reaction of CTC with ethylene as start point)
- CTC to methyl chloride
- CTC to benzophenone (reaction of CTC with benzene as start point)

The main volumes are represented by the conversions to methyl chloride and to perchloroethylene.

In addition it might be noted that one Japanese company has installed, and uses, capacity for the conversion of CTC back to chloroform, with some methylene chloride co-product.

The capacities and disposition of CTC for 2006 are displayed in the following table. It must be noted that the CTC capacities shown represent a minimum, based on chloromethane production capacity, and that all producers of chloromethanes can readily produce higher volumes.

Using the table, it can be concluded that CTC is being deliberately produced in the USA, Japan and India, and is being inadvertently produced to minimum levels in China, Taiwan, South Korea and Russia. In Europe, some CTC is being made deliberately whilst other producers convert the CTC to HCl by thermal treatment, based on economics or because they have no local market or mechanism to supply CTC.

Table 2: Assessment of 2006 CTC Minimum Capacity and Use

Region	***Countries***	***Type***	***Min Capacity (kt)***	***Production (kt)***	***Use / Destruction (kt)***	***Export (kt)***	***Comment***
EU-27	Czech, France, Germany, Italy, Spain, Romania, UK	9 CM, 4 PCE	45-55	53	44	9	Less 1 CM 2007, less 1 PCE 2007
NAFTA	USA	4 CM, 2 PCE	30-40	50	43	7	
Russia		3 CM, 1 PCE	4-6	5	4	1	
India		3 CM, 1 PCE	13-15	19	25.5	-6.5	new cap 2007, 2010 and 2011
Japan		3 CM	6-10	8	8	0	
China		8 CM, 1 PCE	50-55	41.7	41.7	0	10 CM 2007
SK		1 CM	1	1	0.5	0.5	
Taiwan		1 CM	1	1	1	0	
Total				**178.7**			

Source: Tecnon OrbiChem

In summary, in 2006 there were 32 chloromethanes plants operating in 8 countries or country blocks. Some manufacturers have more than one location. Since then China has added two/three new units, India has added one new unit with further units planned in 2010 (41 ktpa) and 2011 (200 ktpa), and one plant has closed in Europe. We have used trade data from these countries as a verification of CTC movement. The capacities shown are for chloromethanes, not for CTC.

Note 1: there is a PCE/CTC plant in Brazil, but this discontinued CTC production in 2004 although it continues to make PCE and indeed periodically imports CTC from the USA and Europe to contribute to the smooth running of the plant. It has been recommended (in a separate project managed by UNDP) that this process be auditted by a third-party to verify the complete conversion of the CTC. The Romanian PCE plant closed in 2007. The Czech PCE plants produces some CTC but all of this is incinerated on-site. All other PCE plants have been modified and can produce zero CTC

Note 2: The EU has informed that 13kt of CTC were destroyed in 2006 and that 31 kt were used in feedstock, with 45 metric tons going to essential uses. The make-up quantities used in the chlorine industry for both NCl_3 and tail-gas applications in 2006 are 56 tons (emissions are reported at under 1000kg), and one other large use, also with very small emissions (but nothing to do with the chlorine industry and therefore outside the scope), consumes over 300 tons.

Within the feedstock uses, there is ongoing CFC11/12 production in the EU, CTC is used as a feedstock to perchloroethylene, and in addition is used in the manufacture of HFC365mfc. All of this is legal production.

Note 3: In the USA, CTC is used for small ongoing CFC11/12 manufacture, is mainly used in the manufacture of the feedstock to HFC245fa, and is processed in two perchloroethylene plants. Three plants use CTC in chlorine manufacture: we know that the consumption (in the sense of purchases or make-up) at two of them totals around 40 tons/year. Exports have been essentially to feedstock applications in Argentina, Venezuela, Brazil, and India. There has been a historic export of around 1 kt to Canada for use in VCM manufacture, which is now since 2007 classified as PA use, but this stopped in 2005. Exports to Mexico for CFC manufacture stopped in 2005 but there is a small ongoing requirement for up to 100 tpa for use in tail-gas processing. This will stop in 2009.

Note 4: in Japan, the CTC manufacturers association (JAHCS), METI, and the NOU have informed us that all CTC produced in Japan is either converted to chloroform or other products or is destroyed, excepting some very small laboratory and analytical use. Based on our assessment of chloroform manufacture in Japan (around 55 kt in 2006) the theoretical CTC output would be around 5-6 kt. Since METI and industry association data show production of 8.1 kt, we assume this is for chemical intermediate use: into HFC245fa would be a logical conclusion. The gross production of CTC in Japan averaged 3-4 ktpa in the early 2000s and has accelerated to over 9 kt (2005) and 8 kt (2006).

Note 5: in India, no imports may be made for other than chemical intermediate uses, and these are essentially for continuing CFC manufacture as well as DV Acid Chloride production. In China, imports of CTC are not allowed at all. In China, all CTC production must either be chemically converted, or be destroyed, or may only be sold to approved uses on a quota basis. Article 7 data submitted by China for 2006 show 775 ODP tons of production and 774.4 ODP tons of consumption. We understand that in 2006, from a total production of 41.7 kt, over 40 kt were used as chemical intermediates to manufacture CFCs (which are declining sharply in China) and other chemicals (2006 Verification Report).

Note 6: Following the interim report there was a query about the actual reported production in China and the supposed minimum. It must be pointed out that the minimum capacity to produce is exactly that: at capacity operation. Since Chinese chloroform units were running at 65-70% of rated capacity it is credible that the actual CTC output would be inside the rated total.

c) Chemical Trade

For the purpose of import and export control as well as for fiscal monitoring, chemical products are assigned a Harmonised Tariff Code (HTC) which uniquely identifies single products if they are of a certain importance in terms of volume or value, or otherwise identifies families of products. These numbers are largely universal although some countries may have additional coding systems, or slight variants. In some cases, to protect commercial confidentiality, it may be possible for single producers, or importers, of selected chemicals to request that trade data be suppressed.

Carbon tetrachloride has the Harmonised Tariff Code 290314. With caveats that trade from certain producing and exporting countries, such as the UK and France, is suppressed as discussed above, it has been largely possible to track imports and exports of CTC from most of the Parties to the Montreal Protocol. It is not possible to use the HTC to track trade that is internal to a Party, in other words internal supply by a national CTC manufacturer to users within that Party. Additionally, reporting of trade flows may take place in slightly different timeframes from reporting requirements of consumption under the Montreal Protocol. Thus, an 18 ton consignment of product from (for example) Korea in Dec 2004 may track as an arrival in the 2005 fiscal year in the destination country. This may show as all being “consumed” (i.e. purchased) in 2005 for the purposes of Article 7 reporting but the actual physical consumption at the using enterprise may take place during 2005-2007.

We have generally used the trade flows to show the overall demand trend for CTC within a given Party and used comparison with Article 7 data to assess the real consumption pattern.

d) Quantitative Measurements of Traded Volume

It is a recognised convention that, within the institutions of the Montreal Protocol, a “ton” of product is referred to in terms of its ozone depletion potential (ODP), this in relation to the benchmark of CFC-11, which is taken as 1.0. These are called ODP tons and are a multiplier of the assigned ODP of the substance by one ton of the substance. This is especially the case in Article 7 reporting as issued by the Ozone Secretariat, wherein the quantities of ozone depleting substance (ODS) produced and consumed are always referred to as ODP tons. It is also the case in the National Plans submitted by the Parties. Because the ODP of CTC is calculated at 1.1, the use of 1000 metric tons of product by a consumer would calculate as 1100 ODP tons of consumption within the Montreal Protocol conventions.

In this Report, unless specifically otherwise stated, *tons* are metric tons of 1000 kg (2204.6lbs). Annual production or consumption figures are referred to in *kt* (kilotons, thousands of tons), and "capacity to produce" is expressed as *ktpa* (kilotons per year, thousands of tons per year). This is because industry produces and uses quantitative tons, and because trade grids and other tracking devices also count actual product, rather than ODP-related volumes.

Where is it important to use ODP-related calculations, this will be made clear and both metric and ODP tons will be quoted.

TASK 1: GLOBAL CTC CONSUMPTION BY CHLOR-ALKALI SECTOR

The exercise to identify the potential use of CTC as a process agent in the chlorine industry for the specific purpose of controlling the build-up of dangerous nitrogen trichloride is global in nature and requires two key elements:

1. EXISTENCE OF A CHLORINE INDUSTRY

We used the Tecnon OrbiChem global chlorine plant database *"SD/b-Chem"* to identify the specific countries where chlorine is being produced or has been produced. The database contains over 1100 entries, each of these representing a plant where chlorine is or has been produced. In total, chlorine is produced in 87 countries. This is reproduced for capacity by plant worldwide in 2006 in Annex 1.

The EU represents one economic block of 25 countries for historic reporting purposes although today it counts as 27 countries including Bulgaria and Romania. Some 51 of the countries are Article 5.1 countries within the Montreal Protocol, and 36 of the countries (including all of the EU-25) are Article 2 countries.

<u>Please note that countries that do not produce chlorine, whether they consume/import CTC or not, have been fully excluded from this Report.</u>

In 2007, China (Article 5), with in excess of 18 million tons pa of chlorine production capacity, has the largest capacity. The USA and EU-25 plus Switzerland and Norway are broadly equal at around 13 million tons pa each of production capacity. Japan follows with 4.6 million annual tons. India (Article 5) has 2.4 million annual tons.

Neither China, India nor Japan has any identified use of CTC for the removal of NCl_3.

The EU-25 with two CTC-consuming plants (2007 data), the USA with three CTC-consuming plants, and Israel with currently two CTC-consuming plants, have the largest number of such units of any country. <u>Production of chlorine has no direct causal relationship with consumption of CTC,</u> since many diverse technologies may be used to manage eventual NCl_3 build-up in chlorine. This theme will be developed later in the report.

2. ROUTES USED TO ESTABLISH POTENTIAL CONSUMPTION OF CTC AS AN NCL_3 MANAGEMENT AGENT

We used the following avenues to explore and verify CTC consumption patterns in as many of the chlorine producing countries as possible.

2.1. The NOUs of the Parties concerned.

- It has been our experience that NOUs are very well informed about specific CTC consumption patterns in their country. In most cases we addressed specific questions to the NOUs related to available Article 7 data and CTC trading patterns. An example of the type of this communication is provided in Annex 2. Tecnon OrbiChem would like to express its thanks for the responsiveness and openness of the many NOUs that cooperated with us in identifying the use of CTC in the chlorine industry.

- *NOUs contacted:* EU (DG Environment); USA (EPA); Israel; India; Japan; South Korea; Russia; Qatar; Saudi Arabia; Argentina; Venezuela; Czech Republic; Thailand; Indonesia; Switzerland; China; Bangladesh

- *Responses still awaited:* India; Russia; Qatar; Saudi Arabia; Indonesia; Bangladesh

2.2. The lead implementing agencies (IAs) involved with the Parties.

- The IAs have generally been involved in detail with the conversion projects away from CTC, and even where Sector Plans have been implemented there is an overall awareness of the companies and projects that to date have been beneficiaries of available Funding or are still potential recipients. In addition we took advice from the Multilateral Fund Secretariat to discuss the overall inventory of projects in Article 5 countries.

- *IAs contacted:* WB; UNIDO; UNDP; UNEP (Thailand); GTZ

2.3. Chlorine Manufacturers Associations

- In general these associations cannot be expected to know, or share, the specific manufacturing technologies of the individual members but they do have an excellent overview of issues that broadly affect the industry, and this includes the Montreal Protocol. Overall the Associations are believed to represent in excess of 80% of global chlorine manufacture. Some offer specific advice and technologies on manufacturing issues.

- *Associations contacted:* Chlorine Institute (USA); EuroChlor (EU-27, Switzerland, Norway); Indian Alkali Manufacturing Association (India); Ruschlor (Russia); Clorosur (South America); Chinese Chlor-Alkali Association, Taiwanese Chlor-Alkali Association

3. SPECIAL CONCERNS ABOUT CTC USE

Within the Montreal Protocol, CTC as an ODS has been somewhat unique in the sense that both historically and today, most CTC use has not been controlled, since the largest part has been the volume produced and consumed for feedstock applications.

At the peak of CTC demand, in the late 1980s, more than one million tons pa of CTC were being consumed as feedstock, effectively masking the myriad of much smaller solvent, process agent, and laboratory applications. The controlled uses were being constantly redefined as new applications were discovered, submitted and recognized (by decisions X/14, XV/6 and 7, and XVII/7 and 8).

At the same time, it was the sector with the most advanced phase-out schedule for the Article 5 countries, moving from no restrictions – even after the establishment of a consumption and production baseline of 1997-1999 - to a phase-out of 85 % versus this baseline in 2005. The juxtaposition of controlled and uncontrolled uses made accurate reporting difficult. This brought about situations such as in Mexico, where the PA use in chlorine for the treatment of tail gas was mistakenly assumed as a feedstock use, and in the vinyl industry where the same use in facilitating the cracking of EDC to VCM was variously reported as both PA and chemical intermediate, and in any case was not confirmed as a PA use by TEAP until late 2006.

Because of this factor we have paid particular attention, with frequent cross-checking of data received from different stakeholders, to:

- Parties where a former or continuing CFC11/12 manufacturing industry, with consequent large volumes of uncontrolled CTC use, might have disguised smaller pockets of use in the chlorine industry. (Argentina, Venezuela, South Korea, Russia, India, China)

- Parties where indigenous CTC manufacture may have mistakenly been supplied as a chemical intermediate to PA uses (South Korea, China, India, Russia, Taiwan, Czech Republic)

- Parties where Article 7 reporting does not seem to tally with reported trade movements, where there could be a potential for use being mistakenly declared as uncontrolled, and also Parties where no recent Article 7 data or trade data are apparent (Vietnam, Indonesia, Qatar, Saudi Arabia, Thailand)

4. SUMMARY OF DATA RECEIVED TO MID MAY 2008 - CTC USERS IN THE CHLORINE INDUSTRY

Although we have specific data on the limited number of historic and actual production units that consume CTC for the purpose of NCl_3 management, almost without exception the companies have asked not to be specified for reasons of commercial confidentiality. We ask World Bank to respect this fact, recognising that one commentator to the original report has asked that Tecnon OrbiChem should disclose the interviewees.

4.1. EU-25 and other Europe

In its effective capacity as NOU, DG Environment provided details of the consumption of CTC in various industries in the period 2000 to 2006. For the chlorine industry the following pattern emerges:

4.1.1. CTC Use as NCl_3 management agent:

Since 2000, there have historically been 5 consumers of CTC for NCl_3 management in three countries.

The process for the scrubbing of Cl_2 from Tail Gas is shown in Annex 8.

One producer, with two plants, discontinued in 2005, in one case by a plant closure and in the other by process change, which is covered in Task 3. One company effectively converted its process in 2001 but retained CTC back-up, and used it, as an effective means to counteract NCl_3 build-up in times of problems. However this was discontinued in 2005. Therefore only two consumers remain.

The process by which the CTC is used is different in the two cases as will be seen in the descriptions in Task 4. We have some evidence, however, that the amount *in this application* recorded by EU in 2006 may be inaccurate, and perhaps should be closer to 90 tons (make-up quantity: NOT consumption in the sense of the Montreal Protocol). Similarly the emissions (consumption) should be adjusted to around 1000kg. One of the users, with a small make-up quantity of 11 tons/a (5-year average is 9.5 tons/a) and almost zero emissions, is looking at alternative technology for installation in 2009. This is based on NORAM (Canada) technology. We are following this. The company is concerned about a future total ban on CTC use.

DG Environment has reported as follows:

2003:	**157.6 tons as make-up;**	**emission 0.428 tons**
2004:	**167 tons as make-up;**	**emission 1.205 tons**
2005:	**130.34 tons as make-up;**	**emission 0.611 tons**
2006:	**11.06 tons as make-up;**	**emission 0.204 tons**

What we now know (late March 2008), and as we have informed DG Environment, is that these figures are understated. Whilst the 2003-2005 figures should be accurate, those of 2006 are not.

For application #1 (NCl_3) we are aware that only one European company has reported for 2006. This contrasts with 4 users of CTC at five sites in the process in 2005. We are certain beyond any doubt that one company with two sites discontinued use of CTC during 2005, and this will be reported in the case studies, although we must respect the company's desire for confidentiality. The company was a large user (make-up, not emissions) of CTC in volumes approaching 100 tons/year. One company has reported to us that it stopped use in 2001, but nevertheless reported that it maintained the CTC system as a back-up, and has indeed reported use to DG Environment in the region of 7-10 tons/year until 2005, but with no emissions. We are sure that this company has had no use of CTC since 2005 although it maintains a back-up system that could use CTC.

At least one company had continued use of CTC in 2006 at the average level of demand to application #1 of 86 tons/year (make-up). In addition there has been use in the tail-gas application at average 42 tons/year. The company has reported to us that its total use in 2006 was 60 tons. However the company also has ancillary use of CTC in a cooling application. We are sure, based on site logistics, that only minor and permitted amounts of the CTC are emitted. But in this case, neither use as NCl_3 treatment nor in tail-gas treatment was reported to or by the EU. In fact the reported >45tons of use of CTC in tail-gas treatment originated with a further company operating within the new EU, but this is outside the scope of the study and in any event emissions are virtually zero (32 kg reported). This company operates an on-site incinerator which also destroys third-party chlorinated wastes for third-parties. *Hence we might expect that "real" EU make-up quantities were of the order of 100-110 tons in 2006 (and not 11.16 tons) but that emissions are of the same order as reported.*

Similarly, we might expect that "real" tail-gas use for CTC was of the order of 90 tons in 2006, again however with no substantive change to the emissions reported.

As reported, the peak demand for CTC in the application since 2000 was in 2004. Reference has been made, in the initial feedback to this report, to a graphic published by the EU which displays that 21% of the total ODS consumed in Europe as a process agent, was CTC used in the elimination of NCl_3, but this is an average figure for 2000-2006 and in any case refers to make-up quantity and not emissions. This may be verified by the data for chlorine capacity by producer worldwide in 2006 in Annex 1 (together with those companies with no production in 2006 as shown in Annex 1b).

A list of EC companies known as process agent users in 2000 to 2006 is provided in Annex 5.

We would like to acknowledge the role of both DG Environment and the industry association EuroChlor in supporting the role of the present Report and EuroChlor especially for facilitating the necessary contacts.

It might be noted that the emissions are highly specific numbers representing, as they are supposed to, the emissions from one-four chemical units according to year, and it needs to be verified if this number is calculated or based on specific measurements. The evidence suggests that they are calculated numbers based on periodic sampling and extrapolation. We have asked the National Focal Points from each of the three countries concerned but to date (late April 2008) have no feedback. The companies have indicated that the emissions are largely calculated data.

4.1.2. CTC Use in Tail Gas Management

This application is outside the main scope, but Tecnon OrbiChem noted that it could provide quantitative data established during the Report.

In 2006 the data suggest one remaining user of CTC in tail gas management, but this is actually not the case. There are two clear users that we have identified and the make-up quantity should be of the order of 90 tons/year. There is no evidence to suggest that the emissions will be any higher than 1000kg/a.

DG Environment has reported as follows:

2003:	**46.9 tons as make-up;**	**emission 0.1 tons**
2004:	**47 tons as make-up;**	**emission 0.456 tons**
2005:	**90.23 tons as make-up;**	**emission 0.412 tons**
2006:	**45.36 tons as make-up;**	**emission 0.032 tons**

The peak demand for CTC in the application since 2000 has been 2002, with 253.7 tons of make-up and 1.75 tons as emissions.

4.1.3. Special note concerning Sweden (until 1998)

Sweden had virtually eliminated all use of ODS by 1996 but had allowed some temporary derogations to allow the use of CTC in the chlorine industry, to mitigate NCl_3 build-up, whilst alternatives were sought.

Use as make-up between 1996 and 1998 is assessed at no more than 4-5 tons/year a**nd emissions are estimated at well inside 1000kg.**

Three chlorine producers were implicated in this:

- One plant, with a production of some 110 ktpa chlorine, elected to discontinue the chlorine distillation process and to feed dried gaseous chlorine direct to the EDC reactors where the heat of reaction decomposed the dilute NCl_3, with all off-gases being fed to vent incinerators. This plant is quoted as having an allowance for 4 tons/a CTC prior to discontinuation in 1995;

- A second plant, also with some 110 ktpa chlorine production, eliminated the CTC stage completely. It continues to use liquefied chlorine whereby the dried and compressed chlorine from the cell-rooms is washed with liquid chlorine. The liquid chlorine used for washing is then fed to a downstream reactor whereby the contained NCl_3 is destroyed in the process. In this case, process reconfiguration was adequate to eliminate CTC use. This plant is quoted as having an allowance of 2 tons/a CTC prior to discontinuation in 1997;

- The third plant, with some 80 ktpa chlorine production, had significant third-party movements of liquid chlorine, elected to use a substitute solvent (perchloroethylene) to displace CTC. The NCl_3 content of the produced chlorine was relatively low and therefore it was found not necessary to drain liquid from the column under normal circumstances. However, during shut-downs, with risk of chlorine evaporation and hence concentration of the NCl_3 in the column, drainage into the solvent system (where perchloroethylene replaced CTC) was vital. Some of the perchloroethylene was found over time to react to CTC. Again, the allowance was historically for 2 ton per year CTC until the process was switched in 1997, when an allowance of 250kg was requested in case of process emergencies. This may be the case for all plants where chlorine is liquefied but where NCl_3 levels are generally low. The plant has closed in recent years.

4.2. NAFTA

4.2.1. United States of America

We know of three users in USA, one using (make-up) 1 ton/year, another using (make-up) 28-35 tons/year based on 7 ton unit deliveries, and the third unknown. As this report was on the verge of completion, we received information from the USA EPA that the total make-up quantity into the specific NCl_3 sector was just over 850 tons in 2005 and just over 1000 tons in 2006. This tends to define the consumption of the third user, whom we are unable to name on the basis of strict confidentiality. The emissions are reported as 4.6 metric tons (0.5%) in 2005 and just over 2 metric tons (0.2%) in 2006. The TOTAL balance of make-up and emissions in the USA is as in the table below. It is noteworthy that in 2005, when we can compare the data for the overall and the spercific uses of CTC, the NCl_3 use accounts for about 50% of the make-up but only 10% of the reported emissions. The third consumer is also a CTC producer, and has told us that under no circumstances will it reveal its use. USA's EPA has provided overall emissions data as follows:

Table 3: US Demand of CTC total 1999-2006

Year	*Emissions (ODP Tons)*	*Make-up*
1999	189.0	NK
2000	148.3	NK
2001	139.0	NK
2002	50.4	NK
2003	72.6	NK
2004	47.8	NK
2005	46.0	1626
2006	46.5	NK

Source: EPA

We acknowledge the support of the EPA in providing these numbers. An analysis into use in application #1 has been promised but not yet delivered. The Ozone Unit in Nairobi has declined to furnish country specific information and referred us back to the countries concerned.

4.2.2. Canada

Initial comment: One user in Canada has been reported but we have been unable to verify this except as perhaps very old information. We have been in dialogue with the NOU to verify the make-up and emissions. The only reported user of CTC in Canada is clearly for laboratory purposes. The NOU has said that there is now no chlorine production in Canada, but this does not coincide with Tecnon OrbiChem data. We think they mean that there is no chlorine production using CTC, which is possible There is no evidence whatsoever that the extant plants use CTC.

4.2.3. Mexico

UNIDO has confirmed that there is one remaining use for CTC as a process agent in the chlorine industry. This is as follows:

4.2.3.1. *Use in tail-gas Management*

- One current user. The **make-up quantity is 80-85 tons/a,** and the **emissions are estimated at some 40-45 tons/a.**

- Chlorine is dissolved in CTC post-liquefaction and then recovered for sale. The recovered chlorine contains traces of CTC. Some of this is sold directly to a fence-line customer for use in the production of EDC/VCM, where the CTC is assumed to be unreacted through the system and destroyed in the on-site incinerators. The balance, which is calculated as the CTC emission, is partly lost through the recovery units and partly contained in the chlorine which is sold off-site to other users. Although this may in fact be destroyed in downstream reactions, this is not certain so it is counted as an emission. There are also some small vent losses.

- This process is the subject of UN funding and will be replaced by new low pressure/deep chilling equipment which will enable recovery of most of the tail-gas chlorine. The balance will be absorbed into a caustic soda solution and recycled. This use is outside the scope of the project but has been noted because it represents the single largest Article 5.1 country use/emission that we have been able to identify. It is, approximately, the same size of demand as that practised in the two European plants that use similar technology, and that continue to consume on the basis of compliance with CTC emission standards.

4.3. China

Initial comment: There are expected to be no users in China. This is because the quota system for CTC use existing in China requires consumers to register the use. NO such use has been reported. We understand that it is prevalent in China to use a caustic scrubbing system to eliminate nitrogen compounds.

Our routes to access data in China have been somewhat frustrating. Because one of our team members has been directly involved in CTC auditing in China for the last four years (and, incidentally has never been exposed to any use of CTC in the application either on site visits, through CTC producer and commercial records, or by Governmental records) and therefore knows the WB and SEPA officials concerned, we had expected relatively smooth access. However this has not been forthcoming, because the current study has been treated as a commercial exercise and no information has been disclosed. Different contacts within SEPA all referred us instead to the Chinese Chlor-Alkali Association. We did however at the same time start contacting some of the major producers. It will be a matter of no surprise that in organisations with some 10000 employees, the issue of finding the right contact who is willing to disclose company procedures is not easy, and indeed we were unable to verify if there was CTC use at the leading users. It may indeed be the case that if there <u>is</u> no CTC use, then no official in any company would be able to disclose what the use actually is!

We then contacted the Association, who has replied that we would need governmental approval before any information could be provided. Our local team has reported that *"In addition, with both the association and the government, we are coming up against a lack of understanding why we are asking these questions when they are reporting direct to the World Bank on this issue on a twice yearly basis."*

In April, we conducted a survey of twenty leading chlorine producers in China with a slightly different bias, to ascertain how they actually managed the issue of nitrogen trichloride. A list of these producer contact and responses is provided in Annex 6.

We have verified the use of caustic soda as a treatment means and in addition the Chinese Chlor-Alkali Association has told us (translation) *"Some plants in China use* *submerged pump in the process of packaging liquid chlorine and no need to use evaporator any more. The condition in which submerged pump could be used is limited NCL_3 output. He said some plants which produce caustic soda by ion exchange membrane cell electrolysis process has less problems with the build-up of NCL_3 than those producing soda by diaphragm process. Therefore, most of those producers using ion membrane method could directly packaging liquid chlorine with submerged pump."*

Care must be taken by the chlorine consumer to control the amount of NCl_3 in its system. Chlorine suppliers normally give advice on how to manage this.

Care should also be taken by the producer to control the amount of NCl_3 that ends up in its product. If Cl_2 evaportes, NCl_3 could concentrate to potentially explosive concentrations.

Sinopec Qilu has said that they use a "chlorine wash" sysyem which effectively means a chlorine/caustic soda treatment to form the NaOCl which destroys the NCl_3.

Since the World Bank itself has reported that there is no CTC use in China in this application, and since the World Bank (2004) requested a fact-finding mission to China to review the prevalent Chinese technology of caustic-based absorption, we must still conclude that China is not very likely to be a user of CTC in the application. We doubt the value of independent visits to the chlorine sites if these are not backed by governmentally approved sponsorship. We acknowledge the possibility – although it is small, given the strict governmental controls – that perhaps some users of CTC in the application may regard the use as being non-controlled, particularly if perhaps they are or have been CTC producers themselves.

Note: there will be a Chinese study group visiting USA in June 2008 to review CTC options. This is analogous to the tour done in Europe by a Chinese delegation in 2006. Our consultancy team will be part of this programme, but it is beyond the time-based scope of the present study.

4.4. Israel

The NOU in Israel has confirmed the current situation:

4.4.1. Use as NCl_3 management agent

- There are two current users of broadly equal consumption (make-up) and each using technology installed by Krebs Swiss. This consumption in in the range 6-7 tons/year. Most of the CTC is contained in the reboilers and is subsequently destroyed by approved incineration technologies. There is expected to be a small passage of CTC entrained in the chlorine that is used or sold. The limit is expected to be 10 ppm by volume.

- It has been reported that one of these users has currently stopped the use of CTC in the application and is undertaking trials on new, ODS-free technology. This has recently been identified as applying the use of UV post-treatment to the dried gaseous chlorine. In fact CTC use in recent times has anyway been minimal to non-existant because of a low NCl_3 content, but the UV system has been installed and will start to be operated as a trial at end 2008 when a chlorine side-loop has been completed. In fact it is not a chlorine specific system but one that is generally used for water treatment. We will not be able to comment on its overall efficiency during the scope of the study.

- The Israeli NOU has pointed out that it is reporting the project carefully and, if it proves to be economically and ecologically sound, may elect to regulate for further use of alternative technologies. We do gratefully acknowledge the support of the Israeli NOU, which has been especially cooperative.

- The make-up quantity for the two plants is 6.0-7.0 tons/a (at roughly equal distribution) and the emissions are estimated at less than 500kg/a (a quantity that will be halved if the present project is judged to be successful).

4.5. Brazil

The author of this report has worked in Brazil in conjunction with the NOU and UNDP and the current situation is confirmed as:

4.5.1. Use as NCl_3 management agent

- One current user. The **make-up quantity averages just under 50 tons/a** and the **emissions are in the range 1.0-1.9 tons/a**.

- The plant had activated a detailed Report to convert away from CTC on the request of the Brazilian government who wanted to eliminate all imports, and had selected a process to convert to chloroform during 2008 at a total installed cost of around US$3.5 million. During review of the project it became clear that the volume of apparently consumed CTC is largely being destroyed.

- This in part was taking place due to the entrainment of CTC in gaseous chlorine fed to the downstream chlorination reactors, where it emerged unreacted as a part of the by-product stream fed to the on-site incinerators, where it is wholly destroyed.

- The balance of the CTC is the spent, unusable residues in the reboilers, which is sourced to a third-party incineration company that applies approved destruction technologies. Emissions occur only during unexpected downtime of the company's vent stream incinerators.

- The project is currently based on allowing a continuation of this emissions minimisation approach pending the company approval to invest in new chlorine production technology, which will result in the generation of higher-pressure chlorine gas that will not require liquefaction for repressurisation for on-site use. There are no chlorine sales.

- The company Carbocloro used CTC in this application until approximately 2002 when it converted to chloroform. There appear to be no specific records of its consumption, most probably because the company is 50% owned by Occidental (OXY) of the USA and no funding would have been available. The technology used is similar to that used by Oxy at many of its USA plants.

- The company Cenibra, a pulp/paper manufacturer, used CTC in the application until 2002 when it disposed of its stock. The apparent consumption was some 6-10 tons/a. The company discontinued chlorine manufacture so no conversion technology is applicable.

4.6. Colombia

UNDP has confirmed that there is remaining use of CTC as follows:

4.6.1. Use as NCl_3 management agent

One current user.

The **make-up quantity is some 2 tons pa** and the **emissions are also 2 tons** pa.

- The company has a relatively small chlorine output but has limited use for chlorine to internal derivatives and is required to liquefy chlorine for sale. Because there is no approved incineration outlet in Colombia, the spent CTC arising from the reboilers is vented to the atmosphere. (Note, it seems likely that some of the CTC will be entrained into the chlorine that is liquefied for sale, but equally that this is likely to be emitted rather than converted or destroyed in or after use).

- After reporting a number of options, the company has elected to go ahead with a conversion of its process to the use of chloroform, using Eltech (now UhdeNora) as its main technology supplier and contractor.

- It might be noted that we would expect some of the chloroform to be reacted to CTC during operations in the reboilers, and that the venting of the spent chloroform seems likely to continue. However we expect this to be minimal quantities, perhaps 10-15% of the chloroform will convert to CTC based on Eltech's reported experience in the USA.

- It has been suggested that a Mexican chlor-alkali producer may be interested in acquiring this plant.

4.7. Countries with Current CTC Consumption as NCl_3 Management Agent

The Table below is a summary of those countries where CTC is consumed, in 2006, as a NCl_3 Management Agent. It might be noted that the identification of the consuming countries is exactly consistent with the TEAP April 2007 Progress Report (p38) although our work was conducted independently of the TEAP report. Otherwise the TEAP report has no specific information germane to the current study.

Table 4: Countries with Current CTC Use as NCl_3 Management Agent (2006)

Country	*Application*	*Number of Plants*	*Make-Up (tons)*	*Emission (tons)*	*Status*
EU-25	NCl_3	2	60	0.600	Emission management
EU-25	Tail gas	2	90	<1.0	Emission management
USA	NCl_3	3	1009	2	Emission management
Canada	NCl_3	0	0	0	
Mexico	Tail gas	1	90.0	45.0	Converting by 2009
Israel	NCl_3	2	6.0-6.5	0.8-1.0	One plant trialling non-ODS alternative
Brazil	NCl_3	1	50.0	1.0-1.9	Conversion to non-ODS is on hold pending approval for emission management system
Colombia	NCl_3	1	2.0	2.0	Conversion to chloroform by end 2009
Total	**NCl_3**	**9**	**~1127**	**~7.5**	Make-up mainly EU, USA and Brazil
Total	**Tail gas**	**3**	**~180**	**~45**	Mainly Mexico
Total		**12**	**~1200**	**<53**	

Source: Tecnon OrbiChem/Sherry Consulting, support from NOUs

4.8. Countries that have Confirmed no Current CTC Consumption in the Chlorine Industry

4.8.1. Switzerland

- The NOU has actively confirmed that there is no current use of CTC in Switzerland for the chlorine industry: all the use is confirmed for laboratory needs.

4.8.2. South Korea

- The NOU has actively confirmed that the majority of the output of the indigenous CTC producer, Samsung, is currently consumed in the legal manufacture of CFC-11 and CFC-12, and that the balance of the domestic consumption is used for laboratory purposes. There are some continued exports.

4.8.3. Japan

- The NOU, together with MITI, has actively confirmed that none of the CTC production in Japan that arises as a co-product from the continuing chloromethanes operations is used for anything other than laboratory or analytical uses.

- We have had previous confirmation from the solvent manufacturers association JAHCS that, apart from the declared Article 7 volumes, CTC is used for the manufacture of non-controlled substances such as chloroform/methylene chloride, in the manufacture of HFC245fa, or is otherwise destroyed by approved incineration technologies.

4.8.4. India

- The Indian Alkali Association, as well as some individual personal contacts, have all assured that the fact of the virtually 100% use of solar salt in India means that no nitrogen compounds are available in the salt source that could convert to NCl_3 on electrolysis. Therefore we can reliably assume that NO CTC is used in India for the application.

- The Indian Chemical Council also asserted this during a Mission of one of our team-members in 2006.

- There has been no reconfirmation of this from the NOU or the World Bank, both of whom have been contacted and re-contacted, but Mission documents from 2006 also clearly show that none of the highly detailed individual and Sector projects include the conversion of CTC from the application, and indeed the very detailed quota system for CTC trade also reveals no use in the c/a sector.

4.8.5. Vietnam

- The NOU has confirmed that since August 2005, strict import controls on CTC have been in place. Prior to that, we had questioned why apparent trade imports into Vietnam were in clear excess of the reported Article 7 data (2004, 39 metric tons, 2005, 61 metric tons). This is because of some confusion over which substances were controlled and which were non-controlled and this has now been clarified.

- All of the recent historic use of CTC has been for metal cleaning and leather treatment. None of the four chlorine plants is registered as having had use.

4.8.6. Thailand

- Both NOU and World Bank were asked about potential use of CTC in the chlorine industry of Thailand. We are still checking with the industry to see if there was any historic and/or current use and how its use is averted.

- World Bank has commented that the NOU is about to start a survey but that in principle no CTC has been imported into Thailand for some two years and that any remaining use will almost certainly be linked to laboratory or analytical applications.

4.8.7. Czech Republic

- The Czech Republic should normally be covered under EU reporting, but we have requested a clarification from the NOU concerning the present situation.

- There is no current Article 7 reporting but the baseline has been given as over 3000 ODP tons (presumably an error based on some historic use in CFCs?) and most recent inputs give 132 ODP tons in 2002 and 94.6 ODP tons in 2003. Since there are two chlorine producers as well as existing CTC production in the country we have asked for clarification on the disposition of the CTC.

- The CTC itself arises as a co-product of perchloroethylene production and as we understand it is largely (entirely?) incinerated. We also understand that the Czech Republic did not allow CTC exports, although whether this has changed under accession to the EU is not clear.

- We have received a comprehensive answer to our questions from the NOU, to whom we express our thanks for their support. It seems reasonable to provide the full text of the response, which is complete, although the company's name has been suppressed on the request of the NOU. This is provided below:

"CTC is being produced in the company xxxxx as an undesired by-product of the tetrachlorethylene production. The reason for a theoretical amount of CTC which is not destroyed emerges from the system annual reporting that does not actually reflect the way how the production and destruction of substances works in industry. The CTC produced as a by-product is stored in the destruction facility in special tanks before its actual destruction. With the reference to the chemical properties of CTC the incineration of the CTC as a pure chemical is not convenient. Before the actual destruction it is mixed with the waste liquids from the epichlorohydrin production. Therefore the schedule of the destruction of CTC does not follow the CTC production timeframe. The amount contained in the apparatus of the destruction facility was reported as an amount of CTC in storage.

For example the total amount stored in the end of the year 2003 was already incinerated during 2004. The necessary transitory storage in the apparatus keeps being more or less the same, however it is still dependant on the epichlorohydrin production schedule. If you look at our production data, which are presumably known to you, and calculate the overall balance, you can easily verify that the amounts theoretically "produced" are destroyed in following years.

So right now there is a of 41,36 tons on the consumption side. The 184,21 tons is higher as it includes 262 tons exported for BDN use in the year of 2000, so we are actually below zero for the referred period of time. We expect that destruction will exceed production in year 2007, however we don't have the exact data yet.

The company intended to export CTC for the Process Agent use to Venezuela, but as far as we understand it the contract never happened in the end, although xxxx had a EAN number from the Commission and was therefore allowed to export.

So we can conclude with an answer to your question - there is no use of CTC as a Process Agent in CZ and the whole amount of by-produced CTC is destroyed since 2000 in the same company that produces it. The use of CTC is not non-controlled in CZ - it is banned under the Art. 4(1) of the Regulation 2037/2000 on ODSs."

In separate discussion the Czech company XXXXX has confirmed to our complete satisfaction that no CTC is being used as a PA in the company's chlorine production. We have been able to obtain a full breakdown of this company's use and are fully satisfied that any CTC generated is being properly managed and destroyed. The company says that its NCl_3 management is assured as follows:

1. Only vacuum salt from proven suppliers is used

2. There is a very low content of ferrocyanide (5 – 8 ppm) in the NaCl feedstock, and none in the KCl feedstock

3. Condensate from the chlorine cooling is not recycled back to the brine system

4. Chlorine is not vaporised directly from the liquid chlorine storage tanks

5. The chlorine vaporizers are operated at a chlorine temperature above 70deg C

6. The future intended chlorine profile of this company will ensure no risk of NCl_3 generation.

4.8.8. Taiwan

- Taiwan has no visible reporting to the Ozone Secretariat. Tecnon OrbiChem has conducted a detailed geographic review - see research responses in Annex 7.

- In essence, Taiwanese producers have confirmed that there is NO use of CTC in the chlorine industry (either in NCl_3 management application or in tail gas management) mainly due to the fact that the incoming salt quality does not allow for the introduction of ammonium/nitrogen compounds.

4.8.9. Argentina

- UNIDO has asserted that there is no CTC use in the chlorine industry and that all the controlled use is in the solvent sector. However Argentina has a combination of a large chlorine industry as well as a large historical import of CTC for the non-controlled use as a CFC feedstock. Because Argentina may nominally fall into the same category as Mexico, we have requested the NOU to check with the chlorine industry to reaffirm that no mistakenly identified use is possible. <u>We have received a firm confirmation from the NOU that no CTC is used by the Argentinean chlorine industry.</u>

4.8.10. Venezuela

- Similarly to Argentina, we have contacted the NOU to request a confirmation that the CTC imports for CFC production in Venezuela might not also in part have been used at the one, but large, chlorine manufacturer in the country. We have received a specific confirmation that this is NOT the case.

4.8.11. Indonesia

- Records indicate that CTC imports were banned in 1998. Nevertheless **trade flows show 16.5 tons/year being imported in the period 2002-2004**. Subsequent UNIDO records show this as being almost wholly accounted for by specified solvent users with an appropriate phase-out programme. It seems therefore very improbable that there is any CTC use in the sector in Indonesia

4.8.12. Russia

- Russia falls into the complex category of being a large chlorine producer and also having at least three plants that can and do produce CTC as a co-product of chloromethanes manufacture. **Article 7 data shows Russian consumption at –77.9 ODP tons in 2005 and –50.2 ODP tons in 2006. Trade figures indicate 2006 exports of around 1000 metric tons**.

- The nominal production in Russia, based on chloroform output, is around 4000-5000 metric tons per year so we might assume that either this is being chemically transformed or is being destroyed by approved methods.

- We have asked the NOU for **clarification**, since Russia has some 15-18 chlorine manufacturers. There has been no response. However the trade association Ruschlor has provided this statement*: "Let me inform you that all the production of tetrachloromethane has been ceased in the Russian Federation pursuant to the Montreal Protocol. Nevertheless, a negligible quantity of the substance is still being produced in Volgograd at the premises of Open Joint-Stock Company "Khimprom". All that tetrachloromethane is being consumed without any remainder there for the purposes not connected to the removal of the nitrogen trichloride.Tetrachloromethane is definitely not used at Russian chlor-alkali plants in any connection to nitrogen trichloride. In compliance with GOST 6718-93 an acceptably low and therefore safe nitrogen trichloride content of Russian chlorine, namely 0.002% and 0.004% for the premium and first grade chlorine respectively is guaranteed by the technical norms regulating the ammonia ion content of the raw materials used in the production of chlorine such as salt, water, etc. "*

4.9. General

- Feedback from World Bank, UNDP, UNIDO and UN-MFS all suggests that the Implementing Agencies, and the Multilateral Fund Secretariat, are not aware of any current projects or uses of CTC in the chlorine industry in Article 5 countries outside the stated projects in Brazil, Colombia, and Mexico.

- UNIDO is categorical in stating that there is no such use in any country where it is the lead agency with the exception of Mexico (which is a tail-gas use), UNDP takes a similar stance on South American countries excepting Brazil and Colombia, and World Bank states that they are not aware of any other project that has been presented to the Excom that deals with this topic.

- We have had discussions with a number of chlorine technology suppliers and plant construction contractors. These include UhdeNora, Uhde, Ineos Technologies, Asahi Kasei, Simon Carves, Eltech, NORAM (Canada), and Krebs Swiss. With two exception (Krebs and Eltech) the companies are unaware of any plants using CTC-based management technologies and all say they have not been required to install such systems for many years. It has been referred to a "stone-age" technolgy. Most refer to the necessity to manage the nitrogen content of the brine incoming to the electrolysers, whether by the salt itself or by the quality of the process water used.

Eltech (which acquired Oxy's technologies division in the 1990s and is now itself part of DeNora) has quoted for and promoted chloroform as a CTC substitute in Brazil and Colombia but in the USA appears to prefer the use of iodoform (CHI3). However it seems only to have been servicing Oxy chlorine plants. In discussion, Krebs seems still to prefer CTC technology as the simplest and optimal solution, although they built chlorine units to clients' wishes and do not proscribe. Since we were aware that the the two Israeli chlorine plants used Krebs technology, they would not deny this but refused to talk of other installations except agreeing that the global total of such plants using CTC technology does probably not exceed ten. They doubt the effectiveness of on-line analysers as a tool to enable management decisions about chlorine production, and resist the idea of UV technology as dangerous. Krebs has no experience in China or Russia.

Comparison of Reported Trade Data (where available) with Article 7 data in relevant Article 5.1 countries

In one of the critiques to the first part of the report (the Conception Report) the basis for our discounting certain countries as being improbable users of CTC for the processing of NCl_3 in chlorine management was questioned. It was noted that the IA's (Implementing Agencies) do not necessarily have the resource or technical background to be able to research all possible uses and users. It was also noted that the NOU's (National Ozone Units) might equally not have access to each user, although we question that based on the establishment of the necessary quota systems for each individual user as mandated since 2005.

We have therefore, in the table below, set out the recorded IMPORT data for CTC for all of <u>the Article 5</u> countries that are reported in the Comtrade database of the United Nations for 2006 (or for other years if 2006 data are not available), <u>and that have a chlorine industry</u> according to our 2006 database. Then, we have compared this with the reported Article 7 data for the same countries. Then, we have matched the data with the reported comments of the IAs and NOUs, and we have commented on the likelihood of any unreported or questionable volumes being consumed in the chlor-alkali sector, with special reference to the NCl_3 management issue.

Obviously the table only concerns those countries that actually have chlorine production, since this is the scope of the exercise. And some countries do not report. We note the absence of Taiwan in the Comtrade statistics as an example.

We recognise that this is not foolproof. We know that there may be countries where CTC is produced and where trade is not apparent. In other parts of the report we have tried to address these issues. These countries are China, India, Korea, USA, Russia, Japan, Taiwan and the EU. Excepting India, S Korea and China, NONE of the concerned countries are in the Article 5.1 nations that are the express subject of the report, and we have covered these two countries as a special issue. Of these countries, only the EU and USA have continuing use for CTC in the nitrogen trichloride application.

The following table encapsulates CTC imports into Article 5 countries that have a chlorine industry. Article 2 countries are not included since the scope is to identify areas where there may be continuing CTC use in NCl_3 management in Article 5 countries and offer experience gleaned elsewhere. It is NOT an exhaustive list of CTC imports, and it does NOT mean that the CTC import identified is used in the chlorine industry. It has been used as Tecnon OrbiChem's reality check on where to search for enterprises that may be beneficiaries of a CTC replacement programme.

Table 5: CTC Imports into Article 5 Countries with Chlorine Industry

Country	*2006 Comtrade CTC (metric tons)*	*2006 Article 7 (ODP tons converted into metric tons)*	***Comment*** (*see Chlorine Capacity 2006 in Annex 1*)
Algeria	0.133	2.0	Unlikely to support chlorine production
Argentina	1035.7	9.9	NOU and IA have both confirmed no use in chlorine
Armenia (2007)	0.100	0	100 kg too small for Cl2 use
Azerbaijan	0.009	0	90 kg too small for Cl2 use
Bangladesh (2004)	0.129	0.09	129 kg too small for Cl2 use
Bosnia Herzegovina	0.120	0	120 kg too small for Cl2 use
Brazil	804.1	0.09	Country extensively visited and use in CL2 characterised
Bulgaria (now EU)	0.446	0	Too small for Cl2 use
Chile	(0.080)	(0.09)	
China	0	704.0	Country characterised elsewhere in report
Colombia	0.548	0.64	Use of CTC known
Cuba (2003)	0.073	0	Too small for Cl2 use
India	6587.0	1025	Country characterised elsewhere in report
Iran (2003)	54.67	1972 (2003) 10 (2006)	May need more review. Access difficult.
Jordan (2007)	0.065	1.0	Too small for Cl2 use
Kazakhstan	0.120	0	Too small for Cl2 use
Kenya	0.200	0.27	Too small for Cl2 use
Korea (South)	(1640.0)	30	NOU has investigated and assured no Cl2 use
Morocco	0.079	0.09	Too small for Cl2 use
Oman	0.009	0	Too small for Cl2 use
Pakistan	69.90	38	Country specifically visited, no use of CTC in chlorine, all uses identified
Paraguay	0.148	0	Too small for Cl2 use
Peru (2002)	0.136	0	Too small for Cl2 use
Qatar	8623.89	0	From Iran(!) Clear reporting error. No response from NOU. The sole chlorine producer denies CTC use

Country	**2006 Comtrade CTC (metric tons)**	***2006 Article 7 (ODP tons converted into metric tons)***	***Comment*** *(see Chlorine Capacity 2006 in Annex 1)*
Saudi Arabia	22.1	0 (2005)	2003-2005 average 0.085 tons. Use doubtful in Cl2.
Serbia	134.1	1.27	2.0 mt in 2005. Use doubtful in Cl2.
Sri Lanka	3.34	0	Too small for Cl2 use?
Tunisia (2005)	0.010	0	Too small for Cl2 use
Turkey (2005)	1.606	0.82	Too small for Cl2 use
Uruguay (2004)	0.304	0	Too small for Cl2 use
Vietnam	60.80	0	Verified with NOU after specific questions, no use in Cl2

Data sources: Comtrade, Ozone Secretariat website

Countries that have been approached about potential trade data/Article 7 discrepancies (pending response)**:**

Despite all the foregoing, it cannot be excluded that there may be pockets of use in some Parties where a combination of historic stock plus an incomplete understanding of all the elements of controlled and uncontrolled use may lead to new findings. For this reason we have made the following contacts where trade data are in potential conflict with Article 7 declarations.

It should be clearly understood that the contacts taken in this section are exclusively for the purpose of cross-checking. Under no circumstances should it be taken that Tecnon OrbiChem is suggesting that there is any question of deliberate misreporting.

It has already been pointed out that we have used available trade records as directional only. Once a response has been received from these Parties, they will be appropriately re-categorised either as NO use of CTC in the chlorine industry, or with an actual use.

4.9.1. Qatar

- We have asked the NOU to clarify what is clearly a trade misreport: **a volume of 8000 tons of CTC (8000 kg?) in 2006 with an apparent origin in Iran**. This contrasts with the expected, and reported, Article 7 inputs of zero consumption against a zero baseline: since there is a large chlorine manufacturer in Qatar a clarification was sought.

- The technology behind the Qatari chlorine producer is European and from companies that have no CTC consumption domestically, and further the demand for chlorine is in the category of EDC production, where we would expect the direct use of dried chlorine gas with no need for NCl_3 treatment. The producer, in discussion, has denied the use of CTC in the process.

4.9.2. Saudi Arabia

- Article 7 data for Saudi Arabia show zero consumption in 2003 and 2005 but **27.5** ODP **tons in 2004**. **Trade data suggest an import of 22.1 metric tons in 2006**. This is close to the baseline of 259.2 ODP tons (235.6 metric tons) and suggests ongoing use. There is nothing to suggest it is being used in the chlorine industry, but with a number of large plants in Saudi Arabia, we have requested clarification. This has not yet been obtained either from the NOU nor from the main producer.

4.9.3. Bangladesh

- **Reported Article 7 data for Bangladesh** show a baseline of 5.7 ODP tons with recent consumption reported at 5-14 ODP tons/a until 2004**,** then 0.8 ODP tons in 2005 and 0.1 ODP tons in 2006. **This shows good compliance, but trade data for 2003 and 2004 are in some conflict showing respectively 21 metric tons and 129 metric tons (which may be stock building). Since Bangladesh is recorded as having some 3-4 chlorine producers, we have asked the NOU for** clarification**.**

1. PRE-ELECTROLYSIS: ISSUES FOR CONSIDERATION

Note: most interview partners, whether chlorine producers ot technolgy suppliers, have stressed the importance of controlling the nitrogen content of the brine as the most effective way, pre-electrolysis, to eliminate downstream issues with NCl_3. The second most important observation concerns the elimination, if possible at all, of chlorine liquefaction. Processes where EDC or HCl is produced are examples. Clearly though, liquefaction cannot always avoided.

It is also the case that most interviewees have said that no one solution can be visualised. It is a function of plant design, material of construction, brine sourcing, need for chlorine purity, need for liquefaction and each plant is individual and unique.

1.1. Feedstock Brine Purity

The brine feedstock may contain nitrogen compounds that later generate nitrogen trichloride (NCl_3) in the chlorine production. Ammonia (NH_3) is the main source of NCl_3. There are potentially many sources of NH_3 that can contaminate feedstock brine. The following are a few examples:

- brine from wells containing pockets of natural gas;
- water treatment chemicals used for dissolving salt;
- direct contact cooler water for chlorine gas;
- caustic liquor from the ammonia stripper column used to extract salt (NaCl) from caustic product;
- NH_3 by-product from explosives used in salt mining;
- feedstock salt anticaking agents (ferrocyanides) that can form NCl_3 in the chlor-alkali process;
- finished brine picks up NH_3 salts from the direct hydrogen cooler;
- flocculating agents used in brine treatment;
- traces of ammonia/nitrate-based fertilizers in the process water used in brine production;
- and sulfuric acid, contaminated with nitric acid, used to dry chlorine.

Formation of NCl_3 under different pH conditions

➢ pH>9.5

- $NH_3 + NaOCl = NH_2Cl + NaOH$

Ammonia + Sodium Hypochlorite = monochloroamine + sodium hydroxide

- Monochloroamine is volatile and can be removed from the brine by aeration prior to feeding cells

➢ pH 4.5 – 5.0

- $NH_3 + 2HOCl = NHCl_2 + 2H2O$

  Ammonia + hypochlorous acid = Dichloroamine + water

- Dichloroamine is non-volatile and will remain in the brine feedstock until later in the cells it is converted into NCl_3

➢ pH < 4.5

$NH_3 + 3Cl_2 = NCl_3 + 3HCl$

Ammonia + Chlorine Gas = Nitrogen Trichloride + Hydrochloric Acid

- Cell acid conditions favor the formation of NCl_3

- 25% of NCl_3 formed in the cells enters the chlorine process

Nitrogen trichloride accumulation points within the plant process (e.g., reboiler, coolers that use evaporating liquid Cl_2 as a cooling fluid, purge line from vaporizers, storage vessels) should be identified and a monitoring frequency based on variability and nitrogen trichloride should be established.

The use of vacuum salt, especially with low levels of anti-caking agent, or solar salt, can eliminate some of these issues associated with mined rock salt. Vacuum salt or solar salt is anyway the preferred source for modern membrane plants. One company has introduced a source of vacuum salt where the anti-caking agent is not nitrogen containing, although this comes at additional cost. Anti-caking agent decomposition is readily achieved, if necessary, by hypochlorite treatment in the brine circuits.

1.2. Removing Ammonia Compounds from Brine

If ammonia compounds are found in the chlor-alkali process; significant amounts can be removed by reacting the brine with either chlorine (direct chlorination) or through the addition of hypochlorite (bleach). At a pH greater than 9.5 sodium hypochlorite (NaOCl) reacts with NH_3 to form monochloroamine and product sodium hydroxide. Monochloroamine is volatile and can be removed. Under acidic conditions (pH < 4.5) NH_3 reacts with chlorine gas to form NCl_3. 25% of NCl_3 formed in the cells enters the chlorine process. Therefore, pH (acidity) control is very important. Another vessel may be needed to provide chlorine sparging of the brine and the equipment must be protected from corrosion from chlorine or the hypochlorite addition.

Operating to the minimum necessary ferrocyanide content in the incoming vacuum salt is another precaution.

2. POST-ELECTROLYSIS: ISSUES FOR CONSIDERATION

2.1. Analysis of Chlorine for Nitrogen Trichloride

Chemical analysis of chlorine for nitrogen content after the removal of nitrogen compounds has been accomplished should be done. The classic Kjeldahl method used to determine total nitrogen is usually applied. This is a reliable method; however, it measures nitrogen concentrations (total nitrogen) of all compounds including NCl_3 and may over state the NCl_3 content. Another analytical method has been developed ("Nitrogen Trichloride Sampling and Analysis ASTM E 2036-01") that uses a high pressure liquid chromatography (HPLC) method; however, each facility should determine which analytical method to use for its specific site. The elimination of nitrogen containing compounds in the brine before it enters the cell is the best way of preventing NCl_3 formation.

2.2. Methods of Destroying Nitrogen Trichloride

2.2.1. Catalysts

Catalysts should be used with dry chlorine gas or liquid where they will not be deactivated by water or salt. Metal salts can be used with a substrate, such as alumina or carbon. The exhausted catalyst can often be reactivated with hot, dry air. During the initial startup of a catalyst bed care must be taken to prevent overheating from two sources: reaction with small amounts of hydrogen in the chlorine gas and absorbed water on the catalyst reacting with chlorine. Examples of catalysts are:

- activated carbon;
- monel shavings;
- alumina;
- iron and iron compounds;
- silica;
- copper chloride;
- silver chloride and various other metal chlorides.

This said, the Chlorine Institute located in Virginia, USA is not aware of any current commercial applications.

It has been noted during interviews that one plant used activated carbon to destroy NCl_3; however, the activated carbon needs a pre-chlorination stage to avoid excessive carbon-chlorine exotherm and good temperature control. This technology appears to be the subject of a patent

2.2.2. Ultra Violet (UV) Light Radiation

UV radiation will decompose NCl_3 ($2NCl_3 = N_2 + 3Cl_2$) into nitrogen and chlorine. Decomposition will occur in either wet or dry Cl_2. Decomposition of NCl_3 in chlorine gas is preferred due to the absorption of UV by more dense chlorine molecules in the liquid phase that would slow the rate of removal. The required wavelength is 3600 – 4780 angstroms. Usually mercury vapor lamps are used for their intensity and wavelength emissions; however, other lamps emitting the same wavelength can be used.

Typically lamps are arranged in a series for good coverage of the chlorine stream. Distance of the UV light from the chlorine, wall effects, chlorine contact time with the UV light are variables to consider for NCl_3 destruction;(e.g. 1 second UV residence time = 50% reduction NCl_3). The design should consider the size and arrangement of the chlorine piping and the layout of the UV lights as well as the volume of chlorine throughput. It must be noted there always exists a risk of hydrogen gas being present in the cell room. UV radiation could act as a source of ignition. The technology is rarely used.

2.2.3. Chemical Reactions

Chemical reactions with NCl_3 can transform it into other chemical compounds.

The addition of iodide in the reboiler fluid promotes a substitution reaction ($2NCl_3 + 3I_2 = 2NI_3 + 3Cl_2$) to form NI_3. NI_3 decomposes at a lower temperature relative to NCl_3.

Wet chlorine gas can be treated with aqueous hydrochloric acid, which will destroy NCl_3 and will remove some water and other impurities. The acid strength used is between 23 – 30% at a temperature of 10 degrees centigrade.

Liquid chlorine containing NCl_3 that is discharged from the chlorine purification unit can be treated with a caustic soda (NaOH) solution instead of CTC. This technology is used within the Chinese chlor-alkali industry extensively. This is accomplished by replacing the stripper unit with an alkali absorption/neutralization reactor, where NCl_3 is decomposed to nitrogen and chlorine at a controlled rate. Nitrogen is given off as a gas and chlorine reacts with NaOH to form sodium hypochlorite (NaClO). NaClO can be sold as a disinfectant or used in wastewater treatment systems.

2.2.4. Thermal Destruction

Thermal destruction of NCl_3 in the chlorine compressor can be accomplished by compressing chlorine gas before it is cooled. The heat of compression at 40-50 degrees centigrade will destroy NCl_3. However, this destruction removal efficiency (50% - 95%) is both temperature and residence time dependent.

Each site must verify the destruction removal efficiency for its unique system; especially if this system is the primary removal system for NCl_3. At least one interview partner that has installed such a system in a new membrane train has expressed disappointment with the results and continues to operate a UV-based system for safety reasons.

2.2.5. Chloroform Substitution of Carbon Tetrachloride

Chloroform ($CHCl_3$) can be used as a substitute for carbon tetrachloride (CCl_4) as a diluent for NCl_3. Chlorine gas contaminated with NCl_3 and liquid chlorine enter the process purification column together. As the chlorine gas (BP= minus 34 degrees centigrade) is cooled by liquid chlorine; NCl_3 (BP=71 degrees centigrade) cools along with it and becomes a liquid. Liquid NCl_3 becomes separated from chlorine gas and is immediately transferred to the reboiler containing $CHCl_3$. The reboiler contents are partially purged to incineration when the concentration of NCl_3 reaches 0.6% (6,000 ppm) and replaced by fresh $CHCl_3$. (note: diagram) Please note that in one experience, some 11% of the $CHCl_3$ was found to convert to CTC after prolonged exposure to chlorine gas, and this may also require the reboiler contents to be destroyed. Each plant would be expected to have a different rate of conversion to CTC

2.2.6. Tail Gas

$CHCl_3$ can also be used as a substitute for CCl_4 to scrub chlorine gas from the process tail gas. $CHCl_3$ is used in a process scrubber to absorb chlorine gas and then later the chlorine is stripped from the $CHCl_3$ by heating. The chlorine gas is fed back to the plant for liquefaction and the remaining waste gas is incinerated. (note: diagram) $CHCl_3$ is then recycled back to scrubber to begin the process all over again. Of course tail gas can also be processed through caustic soda to create sodium hypochlorite bleach, or be used as a source stream in chlorine feed to synthesis HCl production, these being the most common practices.

TASK 3: REVIEW OF CONVERSION PROJECTS

We were told at the interim report stage that the case studies that we provided on a number of conversion projects were too detailed for the body of the main report, and that it would be more appropriate to provide the detailed write-up material as an annex. Therefore, we have restricted ourselves at this stage to a summary of the main actions taken by companies to eliminate the use of CTC. The detailed write up is provided in Annex 3.

We were also told at at the interim report stage that some more detail on the companies would be desirable. It must be pointed out that the present study is conducted under a purely commercial-technical aegis. There has been no obligation for companies to provide data, since it has not fallen under any kind of governmental requirement. Indeed in many cases we have had to explain exactly what is the Montreal Protocol, what is its role in CTC management, and what role the World Bank plays in the process. In short, the companies concerned have voluntarily provided the information provided in the case studies that follow, and we are obliged to accept their requirements for both confidentiality as well as the broad, rather than detailed, description of process.

It should be noted that a number of plants that technically fall into this category have actually discontinued chlorine production totally.

CASE A:

This company changed both its profile of derivatives and its chlorine manufacturing process in 2005. A older diaphragm process plant was dismantled and a new membrane process plant has been constructed. Since 2003 CTC was not used at all. A high-grade vacuum salt is used, make-up water is purified and the brine treatment circuit includes an NaOCl loop essentially for decomposition of the ferrocyanide anti-caking agent, which is specified at very low levels in the starting salt. There is no need to pre-cool the chlorine and no NCl_3 collection, although there is a back-up batch-process chlorine heating circuit in case of NCl_3 spikes. The cost to construct a chlorine heating vessel, with associated evaporation and collection equipment, is estimated at some €200-400k(this is subject to plant size).

CASE B

This company stopped CTC use in 2005 by a combination of switching to a purer grade of salt (low-no ferrocyanide) and by using high quality make-up water. The emissions previously were virtually zero, with CTC residues being incinerated on site. The NCl_3 content of the chlorine is said to be around 1 ppm. There is a combination of on-line and back-up laboratory analysis. The brine processing uses an NaOCl loop. If analysis proves the need to remove NCl_3, this is done by a batch process by charging of the chlorine liquid to a heating vessel. The cost to construct a chlorine heating vessel, with associated evaporation and collection equipment, is estimated at some €400-600k.

CASE C

This company, which has now discontinued chlorine production completely, used CTC until around 1997 at a level of maximum 2 tpa (make-up). In 1998 the company switched from the use of 250 kg/a CTC to using perchloroethylene as the solvent medium to manage NCl_3 in the precoolers. Perchloroethylene (PCE) is not an ODS. This product was used in the same process at approximately the same volumes and with approximately the same unit purchase cost until 2005, when the plant was closed.

CASE D

This plant converted from CTC use in 1995-6, with make-up in the range of 2.5 tons/year. Emissions were not specifically measured. The phase-out was due to national legislation, which banned the use of ozone depleting substances. The plant process of scrubbing chlorine gas (4 – 5 ppm NCl_3) with liquid chlorine in a column up stream of the compressor was changed to a co-flow mixing tube desuperheater purchased from Sulzer Chemtec. The desuperheater avoids the collection of liquid chlorine and hence, no accumulation of NCl_3 is possible. Cost for conversion to the non-CTC technology was 3.5 million SEK or approximately $585,000 (in today US$) or $320,000 (historic). The instillation of the desuperheater unit did not increase the price of chlorine.

CASE E

This plant, which is in an Article 5 country, continues to use CTC at the rate of 2 tons/year. All the CTC is said to be emitted (although it seems possible that some is contained in the produced chlorine). The conversion project will be completed in 2009 and is fully described in Annex 3: the company will convert from CTC to chloroform. The overall cost should be $510,740. Once production with chloroform is underway, the operational costs to *Prodesal S.A.* plant would not be significantly affected form the change in process agents, as the price of CTC and that of chloroform are comparable.

CASE F

This plant, which is in an Article 5 country, continues to use CTC. There has been a project to convert the process from CTC to the alternative of chloroform, for which the full economics had been developed, but at present this is on hold pending approval for the company to continue using CTC on the basis of minimal emissions (2% of total make-up). The continuing use is not expected to be for the long-term, since an expected conversion by the company to membrane-process technology would deliver the chlorine at a pressure sufficiently high that it could be used directly in its gaseous state, with the NCl_3 being destroyed in the downstream reactions.

Therefore, the description below represents the nominal process to convert from CTC to chloroform in the application: the conversion has NOT been effected.

Since 1999, the average annual use of CTC (make-up) into this process has been just over 48 metric tons per year, and the peak year occurred in 2003 (just under 65 metric tons). The chlorine production has been in the range 300-360 ktpa. Purchase of CTC is somewhat linked to chlorine production, but “consumption” in the Montreal Protocol sense is more linked to incineration operations. Some of the CTC is carried by the chlorine stream to downstream reactions, where it remains largely unreacted and forms part of the liquid and gaseous waste streams from ethylene dichloride production. Both of these streams are incinerated on the company’s incineration unit which operates in compliance with approved ODS destruction technologies. However in periods of incinerator downtime, the gaseous streams are released to the atmosphere (with the understanding of local authorities) and accounting for the only known losses of CTC from the application. Spent CTC from the reboilers is disposed of by approved incineration methods at a third-party incineration company. The consumption of CTC in recent years has been in the order of 1-2 tons/a.

The company had elected to convert its use of CTC to chloroform. This package in total requires an investment which equated to US$3.65 million at the exchange rate current in 2006. The company’s board has approved the project but because of confidentiality agreements with the technology supplier there is limited access to the full design details. There is predicted to be a price differential of the order of US$150/ton between chloroform and CTC. This is because CTC is becoming globally in surplus and companies producing it are more likely to be willing to offer low prices (versus the alternative of destroying it). By contrast chloroform typically sells in the price range US$600-800/ton (drums). The difference is predicted to be some US$150/ton which would add an average of US$ (48 tons*US$150) or US$7200 to annual operating costs. Since the process is not actually being used no results can be given.

CASE G (This case is written up in entirety in this section: there is no more detailed information to report in the annexes)

This company, based in Europe, switched from an older mercury process to a membrane technology in 1999. Their combination of low nitrogen content brine, and this company's brine treatment plants required anyway for the membrane process, lead to a very low potential for NCl_3 build-up in the liquefied chlorine. Some chlorine gas is also used for synthesis HCl manufacture. The liquid chlorine used for washing the chlorine gas is drained on a daily basis and used together with the main site supply of liquid chlorine in the manufacture of derivatives whereby the NCl_3 contant is wholly destroyed. Until 1996 this liquid was sent to aaa separate vessel containing CTC. The equipment now used for collecting washing liquid consists of a 0,7 m3 vessel, piping and a DCS system.

The investment cost for the installation was approximately €55,000 when realized in 1996.

CASE H (RESULTS OF DISCUSSIONS WITH TECHNOLOGY PROVIDERS)

Two leading technology providers have already told us that they cannot, except in the broadest sense, provide details of what they have provided to chlor-alkali producers. These are Uhde, and Foster Wheeler. Another two, Simon-Carves and Fluor, have told us that they are bound by a licence contract with a chlor-alkali producer. Technology poviders such as Ineos Technologies, UhdeNora, and Ashai Kasei did not recognise the issue except in the broadest terms of brine, water and eventually chlorine management, and argued that it was all site-specific. In general the technology is about nitrogen avoidance in the brine. Uhde has told us that they recommend a specification of <1ppm NH4 equivalents in the brine for the new membrane plants that they construct.

The company NORAM provides deep-chilling technology of produced chlorine followed by batch treatment of eventual NCl_3 build-up by heat processing of the chlorine. This is written up in Annex 3 and illustrated in Annex 10. The company Eltech proposes a chloroform or iodoform substitution of CTC.

TASK 4: REVIEW OF ALTERNATIVES

In Task 4 actions we summarise the data obtained from those chlorine plants that continue to use CTC, on the understanding that the emissions from the process are managed to the point of acceptably minimal emissions by local authorities. As in the case of Task3, we have presented the detailed discussions with operators in Annex 4 and below we have presented summaries.

CASE I

This plant, which is in an Article 5 country, continues to use CTC. There has been a project to convert the process from CTC to chloroform, for which the full economics had been developed, but at present this is on hold pending approval for the company to continue using CTC on the basis of minimal emissions. The emissions as recorded by the company are apparently in line with the levels acceptable to authorities in Article 2 countries, representing as they do some 1-2% of the total make-up quantity of CTC, and we understand that this project has been supported by a recent decision of the Executive Committee.

The CTC used in NCl_3 treatment is eliminated, by destruction, in two separate directions. The largest part – around 85% - is carried by the gaseous chlorine recovered from the (CTC using) reboilers to the site use system, which is 100% linked to the direct chlorination of ethylene to make EDC for domestic and export use. The CTC carried in the chlorine is inert in the EDC reaction and is emitted unchanged in the EDC vent gas system. Until 1997 this was simply purged to the atmosphere. In 1997 the company installed an on-site Sulzer incinerator with gas and liquids treatment capability for chlorinated by-products, thereby ensuring that all light-end chlorinated by-products from their site process were virtually wholly eliminated. This also destroys, therefore, the CTC carried by chlorine from the NCl_3 treatment.

CTC losses occur only when the site incineration is idled for planned or unplanned maintenance shutdowns. When the incinerator is not operating, the EDC vent gases are released to the atmosphere instead of being incinerated. This procedure is within the local operating permit for the plant and local authorities are formally notified when incinerator operations are to be interrupted. The liquid streams can be captured and stored during such periods but the volume of vent gas makes storage impossible. This venting is the only source of plant emissions of CTC excepting some potential minimal fugitive emissions on charging and discharging the reboilers.

The smaller part of the CTC – the heavily contaminated CTC in the reboilers – was until 1997 vented to the atmosphere. Since 1997, as part of the environmental improvement programme, the CTC has been filled into 200 litre plastic drums and periodically sent to a third-party incineration company. In August 2007 a UN team visited the incineration site. It was established that the unit operates an 8 ktpa capacity rotary kiln (with capacity therefore to receive solid wastes) with the potential for liquid injection of chlorinated wastes. The incineration company appears to be operating its incineration equipment within the approved destruction parameters of the Montreal Protocol.

<u>On-site incinerator</u>

The installed cost of this incinerator was US$6.97 million in 2007 money. The capacity to treat chlorinated waste is 300 lit/hour of liquids and 800Nm3/hour of gaseous vent streams. As is typical of site incineration units, the capacity is over-designed for site needs to allow for periods of off-specification production. According to the company, the content of CTC averages +/- 1% of the total waste stream.

The variable cost of the total incineration unit is US$568,000 year and is very constant since incineration must be kept running continuously even when the input rates are low (and occasionally the vent gases must have nitrogen added to assure adequate flow). In this case the incremental cost to manage the CTC component of the feed is therefore 1% of US$568,000/year or US$5,600/year. It is regarded as representing destruction technology as approved by the Montreal Protocol.

CASE J

This plant continues to use CTC in its chlorine processing on the basis of minimal emissions, which are within permitted levels. The make-up quantity has averaged just below 10 tons/year, and the emissions are reported in the range of 200kg/year. However it is concerned that CTC may be non-available longer term either by legislation or by cessation of supply. The spent CTC is incinerated off-site: it is not known at the time of writing where this is done or if it meets the requirements of destruction under the Montreal Protocol. However this CTC is not reported as emissions. There is a present exercise to investigate process change, which is focussed on post-electrolysis treatment, and is being conducted with the Canadian company NORAM. As we understand it, this company will investigate a deep-cooling system that will enable the recovery of pure chlorine. The concentrated NCl_3/chlorine residues will be periodically batch-treated through a heater system. This heater system will replace the CTC/chlorine/NCl_3 system that is currently operated on a virtually continuous basis. The investment is expected to be in the region of €500k. However other technologies are presently being exploring including a simpler batch treatment system for the bottom chlorine liquid containing NCl_3. This might bring the costs to below €400k.

The company comments that this will *"decrease the amount of NCl_3 but don't suspend the use of CTC. We have to continue to use CTC because our process has a scrubber that cools down and purifies the chlorine feed to the compression that is volumetric, so we always have some NCl_3 in the scrubber that must be purged."*

On this site, the liquefaction process is a vital part of the chlorine purification, which must be oxygenate-free for use in the profile of derivatives.

CASE K

<u>Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures</u>

This plant, which is based in Europe, actually has three uses for CTC in the chlorine production process. Apart from the use that is the subject of this report, CTC is also used in a chlorine cooling process, and is used in tail gas recovery. The major use is in the capture and processing of NCl_3. The nominal capacity to produce chlorine is in excess of 200 ktpa and this uses diaphragm technology of the company's own design. The plant has existed since the 1960s although the specific technology to produce chlorine was modified in 2000. Historically the plant consumed chlorine for internal derivatives and also exported by pipeline and by railcar to third parties, including to export destinations. Nowadays the use is essentially captive. All consumption and emissions are recorded as part of the EU submission to the Ozone Secretariat.

The consumption of CTC (in the sense of purchases) was some 60 tons in 2006 but has at some periods of higher chlorine output exceeded 100 tons/a. However the emissions (="consumption") from all processes have been calculated to barely exceed 1 ton/a.

CASE L

This plant has a 72 ktpa mercury based chlorine plant linked to potassium hydroxide production. The production of chlorine has been in the range 50-55 ktpa. It is used for the production of HCl, liquid Cl2 and sodium hypochlorite, as well as in some specialities, but it is also pipelined to the adjacent titanium dioxide site where it is used to make titanium tetrachloride, the starting point of the process. The company has stated in written correspondence that it shifted from CTC use in 2001 and started using a distillation process to manage the NCl_3. It also has said that it “keeps the CTC process as a spare process”. The company, until 2005, has continued to report CTC consumption, that we assess at 9-11 tons/year (as make-up).

The process changed from CTC use into one where a new distillation column, with additional refrigeration and thermal fluid charges, was used to concentrate the impurities and purge them to reboiling with nitrogen trichloride destruction and chlorine gas recovery. The process was nominally changed in 2001 but the CTC system was kept open as a back-up and in fact was used 3-4 times per year from 2001-2005 as problems arose in the new system. Since 2005 this has not been necessary and from 2006 CTC use has not been reported to the EU, although one reboiler still exists as a back-up. Until 2005, the company’s usage of CTC as make-up, and its emissions, was reported to the EU and the figures are included in the EU summary.

Bromine content has been an issue in the changed process. Historically all bromine was retained in the processed chlorine which was not an issue for the downstream uses but inhibited chlrine sales to some users. With the new system, the heating process separates out the bromine, and this is captured. The site uses bromine as a feedstock so this is revalorized.

The level of investment has not been disclosed for confidentiality reasons. A cautionary estimate from the consultants is around €2-2.5 million including a fixed cost of $0-500k.

CASE T

This company operates a number of chlorine plants in Europe. The technology is mixed between diaphragm, mercury and membrane. Overall capacity is in the range 700-800 ktpa. CTC has been used in two processes, in one plant in chlorine liquefaction processing (but not to eliminate NCl_3) and in a second plant, now closed, to eliminate NCl_3. This process however was discontinued in 2000, and the overall production was closed in 2006. Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

The company has, according to site, operated at 75-85% of effective capacity. Consumption of CTC ceased overall in 2001 and the company has no enduring records of actual use.

In one of this company’s plants, partially-liquefied chlorine was run into a CTC bath as means of eliminating the hydrogen content (and has nothing therefore to do with NCl_3) prior to total liquefaction. Chlorine desorption as gas was effected by reheating, and the hydrogen, being insoluble in the CTC bath, was run off as a side-stream. The CTC was incinerated in the company’s own incineration complex when spent. The process was also used to absorb oxygenates, which were not acceptable either in the then sales of the product nor in local processing to derivatives. In 2002 the company moved to a complete use of partially liquefied chlorine and had no need to use CTC. The applications for the company’s chlorine enabled a combination of gaseous and partially liquefied use.

At the second plant (mercury-based) where CTC was used (until 2000) the need to use liquefied chlorine was questioned and eliminated, and chlorine gas was used direct to the end-applications.

The brine sources at the company's existing plants are scrutinised, as is the potential for NCl_3 build-up. A third plant requires a particularly purified chlorine source requiring liquefaction: if the NCl_3 levels build up in the chlorine the overall production procedures are modified so that the derivatives that can support a higher nitrogen content are favoured and overall NCl_3 levels in the liquefied chlorine are reduced: this in general involves higher feed rates to ethylene dichloride and lower to chloromethanes.

One of the company's plants uses vacuum salt, with no/ minimal ferrocyanate content and in any event the liquefied chlorine portion is minimal: the adjacent customer that uses the chlorine to process ores uses gaseous chlorine, so does the on-site EDC plant, so the demand for liquefied chlorine in minimal and can be adjusted by flow-rate. This illustrates how judicious management of the chlorine flow can be used to avoid NCl_3 build-up.

TASK 5: ANALYSIS AND RECOMMENDATIONS

In this section we have been requested to provide a sectoral plan covering the scenarios for phase-out of CTC in the chlorine sector (NCl_3 specific) in Article 5 countries. We were told that may be approached on a volume of use basis, or perhaps a geographic basis, or perhaps a technology basis.

At the outset we should say, as might have been concluded from the earlier sections, that there is *no one single* technology that is used to manage NCl_3 build-up in chlorine. The use of CTC has not been widespread and indeed Article 2 developed economies have used it more far extensively than Article 5.1 countries – and continue to. This may be because the chlorine industry was initially developed in the industrialised nations, and the developing economies were able to select other management methods. The main management techniques are about judicious brine management and skilful downstream production techniques to enable any NCl_3 build-up to be managed without resort to additional investment costs. This means that in essence there is no one drop-in solution to replace CTC, and that each production plant will have its own individual set of parameters that will require it to develop its own management techniques.

Our **initial and interim findings** suggested that the use of CTC as a PA in this sector in Article 5 countries is far less prevalent than might have been assumed. It appears to be the case that use in the Article 2 countries – with some current 7 practitioners of the CTC process (3 USA, 2 Israel, 2 EU) – is far more widespread than in the Article 5 countries. Indeed that it is possible that both existing users of CTC in Article 5 countries in the process have been identified, with a **total emission identified so far of around 3.5 metric tons**. Plans are in place for one of these consumers to convert to a non-ODS alternative by 2009, and this will eliminate 2.0 tons of emissions. The other CTC consumer has recently (April 2008) been approved as having adequate destruction technology in place, and in any case will in the longer term displace the present CTC system for one that will not require any chlorine liquefaction.

We do not lay claim to having covered every single chlorine plant in the world: there are more than 1,100 and no one plant is under any kind of obligation to explain its processes to us.

However, what has become apparent during the development of this study is that, whilst CTC is a one-chemical approach to manage the issue of NCl_3 build-up, it is not at all the case that this simple chemical can be replaced by any other one-chemical approach with the possible exceptions of chloroform ($CHCl3$) or iodoform ($CHI3$), and that these too have issues. Neither has CTC been universally used; in fact its use is rare, and seems to be at least in part linked to the original licensing process of Hooker/Diamond Shamrock plants in the 1960s and 1970s. We have traced some 9 plants out of 1,100 chlorine plants that currently use CTC, and of these three are on conversion projects. One is in an Article 5 country and is being funded; the other two are concerned about long-term availability of CTC (which actually will not be an issue, it will always be available as a co-product) and in any case have minimum emissions.

Nowadays, and also perhaps historically, it is in general the case that NCl_3 is managed by a systematic approach to containment. This begins with good salt management (so that specifications are set on the nitrogen content, both fatal and deliberate) and continues with good water management. The diluent water whereby the salt is diluted to the brine feedstock is a critical issue. In membrane chlorine technology, water treatment plants can be and often are adopted to use chemicals (such as NaOCl) that will purge the nitrogen compounds. Conversely, if river or aquifer water is used as the medium, and if it is not treated, it can be the case that nitrate-based fertilisers may have seeped into the water and will present the source of nitrogen that can influence the electrolysis. In this case, post-electrolysis measures may be necessary.

This has in the past involved the use of CTC in the case of a limited number of companies, but other solutions have perennially existed. The simplest is just not to liquefy the chlorine. The NCl_3 passes directly, in dried and compressed chlorine gas, to the derivative reaction where it is generally destroyed in the heat of reaction. In many cases the simple process of gas compression creates the heat required to destroy the NCl_3. If some liquefaction is required, this can be balanced to NCl_3 build-up and more vaporised chlorine can be used (consuming the NCl_3 content) until levels are secure again.

Another simple method is to assure that there is adequate agitation in the liquefaction and storage vessels such that no local build-up of NCl_3 is possible.

For what it is worth, we should note that on-line analysis of the NCl3 content of chlorine seems now to be readily achievable. At the 7th EuroChlor Technical Conference in Lyon, France (April 2008) the company AppliTek made known its gas-phase on-line analysers; these come at an installed cost of €100-150k. Similarly, the company offers on-line analysis of the nitrogen content of the brine, so that NCl_3 formation can be predicted. Details are available at www.applitek.com. This is not a promotion… there is no doubt that other companies will offer a competitive service. In the 6th Technical Conference in 2005, the chlorine-producing company Solvay had made known its efforts to develop and use such a technology but with inconsistent results. We know of a number of companies that use such on-line analysers. Many say that the NCl_3 content of the detection stream is so low that the results are variable, and in general for now companies support on-line analysis with periodic laboratory testing.

Therefore, since there is no geographic concentration, nor indeed any supposition of CTC usage linked to chlorine production volume, what we have elected to present is a “technology tree”. This is with the understanding of the World Bank, with whom we discussed our interim findings in a conference call on April 30th 2008. This represents all of the stages at which chlorine producers might find ways to eliminate, or diminish, the nitrogenous elements in the brine feed that might engender NCl_3 production in the eventual chlorine.

We also suggested that the concept of a cost-effectiveness factor may not be especially relevant. Since the volumes emitted (as opposed to “consumption” meaning as make-up) are so slight, the ratios concerned would typically be in the region of US$5000/kg, which would be an unreasonable distortion of the reality of investments and management decisions, that, if required, would rarely exceed a capital cost of US$1-3 million.

If NCl_3 is nevertheless created during the electrolysis process, the “technology tree” also attempts to show potential solutions. It must be noted that whilst some of these solutions depend upon techniques to physically destroy the NCl_3, most of them depend on “producer art” to minimise it to the point where it is not an issue, that is, the specific techniques by which plant managers in any given site configuration are able to firstly manage the salt input to the brine and the brine input to the electrolysers, and secondly to adjust the balance between evaporated and liquefied chlorine so that there is never a danger of NCl_3 build-up to dangerous levels. These are not investment decisions, but trained techniques whereby plant safety is assured.

Our technology tree is presented below. It is as comprehensive as we can make it, but it will never be complete because individual chlorine plants will have additional and unique solutions to the NCl_3 issue. Nevertheless we hope it will provide some guidance as to the steps that might be considered.

Table 6: Technology Decision Tree

Item	***Description***	***Variable Cost***	***Fixed Cost***	***Comment*** *(extent to which used etc.)*
Salt Quality	1.) NH3 by-product from explosives used in salt mining 2.) Feedstock salt anticaking agents that contain compounds that form NCl_3 3.) Organic waste in solar salt (guano)	Cost of switching to no/low nitrogen containing salt. Cost delta per ton may be US$5-10/ton salt. At a unit ratio of 1.7 units salt per unit of the ECU (1 ton chlorine plus 1.1 tons caustic soda) the variable cost can be increased by US$8.5-17/ton of the ECU or around US$4-8/ton of produced chlorine. However there may be compensating benefits in terms of sludge reduction: overall virtual equivalence.		Extensive, and in any case usually vital for new membrane cell plants.
Water Quality	1.) NH3 in water from water treatment chemicals used in dissolving salt 2.) Water used for brine make-up may be river water or aquifer water that contains fertilizer	Cost of water without nitrogen containing compounds: water treatment plant	$100 - 500k	Common
		Minor costs by using tail gas as a source of chlorine	$100 - 500k	
Brine Treatment	1.)NH3 in caustic liquor from ammonia stripper column used to strip NaCl product caustic 2.) Finished brine picks up NH3 salts from the direct hydrogen cooler 3.) Flocculating agent in the brine treatment 4.) Sulphuric acid, containing nitric acid contamination, used to dry chlorine			Common
(Membrane)	2.) Use of solar or vacuum salt with low potential of containing nitrogen compounds	As discussed, variable cost		Common

Item	*Description*	*Variable Cost*	*Fixed Cost*	*Comment* (*extent to which used etc.*)
(Mercury & Diaphragm	3.) Use of NaOCl to treat brine before it enters the cell		$100 - 500k	
	4.) Treat the brine with chlorine to form chloramines; aeration of the brine to remove chloramines, excess chlorine and adjust the pH	$2 - $5/ton	$100 - 500k	Common
	5.) High nitrogen brines are treated by adjusting the pH ~10 & treatment with NaOCl	$2 - $5/ton	Dedicated packed tower $ 200 - $750k	
Chlorine Analysis	Chlorine should be analyzed for NCl_3 content periodically by the kjeldahl or HPLC methods	$2,000 - $25,000	On line analyzers would be justified for large chlorine producers having a medium to high probability of the presence of NCl_3. Anticipate $150k	Common
Operational	The use of additional evaporation applied in the pre-cooling or liquefaction stages	None, operational training		Frequent.
	Process reconfiguration to use chlorine (with NCl_3) in downstream operations	Operational training, maybe some investment in range $0.2-1.5 million		Frequent
	Avoid chlorine liquefaction entirely	Operational training and possible investment ~$0.5 million		Frequent.

Item	*Description*	*Variable Cost*	*Fixed Cost*	*Comment* (extent to which used etc.)
UV Treatment	1.) UV radiation of NCl_3 will decompose it to nitrogen and chlorine gases 2.) UV lights would be arranged in a series in a header system so the gas will irradiated by each light as the gas passes through the header 3.) The wavelength of light emitted should be in a range of 3600 - 4785 angstroms 4.) Care should be taken that chlorine gas goes through the header and not liquid 5.) UV mercury lamps are used for their intensity 6.) Variables such as; distance of the UV lamp from the chlorine gas; wall effects; and contact time (1 second UV residence time = 50% reduction NCl_3) should be monitored 7.) Care should be taken for a constant air purge surrounding the lamps so as not to cool or over heat the lamps 8.) Inspection of the lights for damage and intensity should be once per year Note: one plant in the USA uses the UV light system as a back-up for their brine pre-treatment, one European plant uses it systematically, one Israeli plant is testing the system	$ 321/light/year (each light around US$200, use "several thousand hours). Power rating per light 4-5kW	Hanovia 4500-watt, high pressure mercury arc, quartz lamps. Potential investment cost of $0.5-1.5 million	Three identified companies, one as back-up only, one in process of change. Potentially dangerous.
Use of NaOH	Chlorine passes through a stripping unit containing caustic soda whereby NCl_3 is decomposed to nitrogen and chlorine, which reacts with the caustic soda to form useful NaOCl	Subject to internal ECU values (depends on internal caustic value versus chlorine and sales value of NaOCl). Costly at times of high caustic soda values.	$0.5-1.5 million	Normal in China, seldom elsewhere
Thermal Treatment	Several ways exist to destroy NCl_3 through thermal treatment		$1 to 2 million	

Item	***Description***	***Variable Cost***	***Fixed Cost***	***Comment*** *(extent to which used etc.)*
	1.) Chlorine gas that passes through the compressor reaches a temperature of 40 - 60 degrees centigrade. NCl_3 will be reduced by more 90%; this destruction efficiency is both temperature and residence time dependent <u>and is plant specific</u>			Frequent
	2.) NCl_3 that collects at the bottom of the pre-cooler and is purged into a reboiler tank containing an organic solvent that can be heated to 40 degrees centigrade to destroy NCl_3			This is the CTC (or chloroform) process. Apart from the 9 plants that use CTC we have identified around 9-10 that use chloroform
	3.) Pass the liquid chlorine containing NCl_3 through a heating column and strip off nitrogen gas			Often a batch process. Also helps eliminate bromine. Frequently used.
Containment of NCl_3 by Chemical means (CTC, CHCl3, PCE)	1.) Chloroform (CHCl3) can be used as a substitute for carbon tetrachloride (CCl4) as a diluent for NCl_3. Chlorine gas contaminated with NCl_3 and liquid chlorine enter the process purification column together. As the chlorine gas (BP= minus 34 degrees centigrade) is cooled by liquid chlorine; NCl_3 (BP=71 degrees centigrade) cools along with it and becomes a liquid. Liquid NCl_3 becomes separated from chlorine gas and is immediately transferred to the reboiler containing CHCl3. The reboiler contents are purged to incineration when the concentration of NCl_3 reaches 6% (6,000 ppm). (Note: diagram) Please note that 11% CHCl3 converts to CTC after exposure to chlorine gas which would require the reboiler contents to be destroyed. Chloroform (CHCl3) can be used as a substitute for CTC.	None, virtually same cost as CTC	$1 to 2 million	Maybe 9-10 plants globally use or will use chloroform

Item	***Description***	***Variable Cost***	***Fixed Cost***	***Comment*** *(extent to which used etc.)*
	2.) Perchloroethylene (PCE) has been used as a substitute for CTC as a diluent, however, corrosion problems need to be overcome.			
	3.) Caustic soda.			
	note: Sodium Iodide (NaI) addition (2-20 ppm) has been used successfully to control the corrosion of the reboiler if heat is used to destroy NCl_3 in a solution with the above chemicals.			

ANNEXES TO THE REPORT

ANNEX 1 - CHLORINE CAPACITY BY PRODUCER 2006

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Canada, Alberta	Dow Chemical	Fort Saskatchewan	D	460		Closed end 2006
Canada, British Colombia	Canexus	Vancouver	D	140		
Canada, New Brunswick	Pioneer	Dalhousie	MER	33	Possible CTC user	Now Olin
Canada, New Brunswick	St Anne Chemical	Nackawic	MEM	9		Closed 2006
Canada, Quebec	Pioneer	Becancour	D	254	Possible CTC user	Now Olin
Canada, Quebec	Pioneer	Becancour	MEM	63		Now Olin
Canada, Quebec	PPG Canada	Beauharnois	MEM	100		Membrane, ICI FM2I.
Canada, Saskatchewan	Erco Worldwide	Saskatoon	MEM	31		
Mexico	Industia Quim. del Istmo SA de CB	Pajaritos	MER	120		---
Mexico	Industia Quim. del Istmo SA de CB	Monterrey	MER	20		---
Mexico	Mexichem	Santa Clara, Mexico	MER	34	CTC 100 tpa tail gas	---
Mexico	Mexichem	Santa Clara, Mexico	MEM	-	CTC 100 tpa tail gas	Conversion Uhdenora 2007
Mexico	Mexichem	Guadalajara	D	35	CTC 100 tpa tail gas	---
Mexico	Mexichem	Coatzacoalcos, Veracruz	D	255	CTC 100 tpa tail gas	---
Mexico	ROT Chimica	Monterrey	KOH (MEM)	8		
USA, Alabama	GE Plastics	Burkville	D	26		
USA, Alabama	Olin Corporation	McIntosh	D	366		---
USA, Alabama	Oxychem	Muscle Shoals	KOH (MER)	141	Switched CTC to CM3	Plant closing by 2008
USA, Alabama	Oxychem	Mobile	KOH (MEM)	42	Switched CTC to CM3	
USA, Alabama	Sunbelt	McIntosh	MEM	227		50:50 Olin:Polyone
USA, Georgia	Geogia Pacific	Savannah	MEM	6		---
USA, Georgia	Olin Corporation	Augusta	MER	110		---
USA, Indiana	GE Plastics	Mt Vernon	D	66		
USA, Kansas	Oxychem	Wichita	D	170	Switched CTC to CM3	Vulcan 2005
USA, Kansas	Oxychem	Wichita	MEM	75	Switched CTC to CM3	Vulcan 2005
USA, Kentucky	Westlake	Calvert City	MEM	190	Using CTC	Start up 2002.
USA, Louisiana	Dow Chemical	Plaquemine	D	860	Using CTC	340 ktpa closed in 2002.
USA, Louisiana	Georgia Gulf Corporation	Plaquemine	D	410		---
USA, Louisiana	Olin Corporation	St Gabriel	MEM	156		Formerly Pioneer
USA, Louisiana	Oxychem	Taft	D	488	Switched CTC to CM3	---
USA, Louisiana	Oxychem	Taft	MEM	195	Switched CTC to CM3	---
USA, Louisiana	Oxychem	Geismar	D	245	Switched CTC to CM3	Formerly Vulcan
USA, Louisiana	Oxychem	Geismar	MEM	205	Switched CTC to CM3	Formerly Vulcan
USA, Louisiana	Oxychem	Convent	D	354	Switched CTC to CM3	---
USA, Louisiana	PPG Industries	Lake Charles	D	1,000		---
USA, Louisiana	PPG Industries	Lake Charles	MER	250		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
USA, Nevada	Olin Corporation	Henderson	D	110		Formerly Pioneer
USA, New York	DuPont	Niagara Falls	Sodium	80		---
USA, New York	Olin Corporation	Niagara Falls (2)	MEM	250		---
USA, New York	Oxychem	Niagara Falls	D	306		
USA, Ohio	Ashta Chemical	Ashtabula	KOH (MER)	32		
USA, Oklahoma	Fort Howard Paper	Muskogee	MEM	8		
USA, Tennessee	Olin Corporation	Charleston	MER	170		
USA, Tennessee	Olin Corporation	Charleston	KOH (MER)	100		
USA, Texas	Bayer	Baytown	MEM	272		
USA, Texas	Bayer	Baytown	HCl	100		---
USA, Texas	Dow Chemical	Freeport	D	2,750		---
USA, Texas	Dow Chemical	Freeport	MEM	500		---
USA, Texas	Formosa Plastics Corporation	Point Comfort	MEM	811		---
USA, Texas	Oxychem	Corpus Christi	D	549		---
USA, Texas	OxyVinyl	La Porte	D	495		---
USA, Utah	US Magnesium	Rowley	Magnesium	116		
USA, Washington	Equapac	Longview	MEM	75		---
USA, West Virginia	PPG Industries	Natrium	D & MER	245		55ktpa shut 2001.
USA, Wisconsin	Erco Worldwide	Port Edwards	KOH (MER)	46	Using CTC	From Vulcan 2005
USA, Wisconsin	Erco Worldwide	Port Edwards	MER	27	Using CTC	From Vulcan 2005
USA, Wisconsin	Georgia Pacific	Green Bay	D	7		---
Argentina	Atanor	Río Tercero	MEM	27	Checked with NOU and UNIDO, no CTC	Membrane conversion 2005
Argentina	Clorox	Pilar (Buenos Aires)	MEM	14		
Argentina	Keghart	Chacras de Coria (Mendoza)	MER	7		---
Argentina	Ledesma SAAI	Pueblo Ledesma (Jujuy)	MEM	12		
Argentina	Pamcor	Rio Tercero (Cordoba)	---	9		---
Argentina	Papelera Tucuman	Tucuman Campana	MEM	8		---
Argentina	Petroquimica Bermudez	Gral Bermudez (Sante Fe)	D	26		
Argentina	Petroquimica Rio Tercero S.A.	Rio Tercero (Cordoba)	D	20		---
Argentina	Petroquimica Rio Tercero S.A.	Rio Tercero (Cordoba)	MEM	9		
Argentina	Solvay - Indupa	Bahía Blanca	MER & MEM	180		---
Argentina	Transclor	Pilar (Buenos Aires)	MER	43		
Argentina	Transclor	Pilar (Buenos Aires)	MEM	6		Start up Q1 2004
Brazil	(Companhia Agro Industrial) Igarassu	Recife	MER	28		---
Brazil	Braskem	Maceio	D	410	Currently using CTC	Braskem 2002
Brazil	Canexus	Vitoria	MEM	43		
Brazil	Carbocloro SA Industrias Quimicas	Cubatao	D	151		---

Country	***Chlorine Producers with Capacity in 2006***	***Site***	***Technology***	***Capacity 2006 (kt)***	***CTC use***	***Operational Remarks***
Brazil	Carbocloro SA Industrias Quimicas	Cubatao	MER	113	Used CTC until 2003: converted to chloroform	---
Brazil	Dow Quimica	Aratu	D	415		---
Brazil	Guangming Group	Honorio Gurgel	KOH (MER)	18		KOH Production.
Brazil	Guangming Group	Honorio Gurgel	MER	14		Including some KOH.
Brazil	Klabin Riocell	Rio Grande do Sul	MEM	20		Uhde contractor.
Brazil	Solvay - Indupa	Santo Andre	MER	110		
Brazil	Suzhou	Belo Horizonte	D	17		---
Brazil	Trikem	Camacari	MER	68		Braskem 2002 onwards
Chile	Manufactuera de Papelas Y Carlores	Laja	MEM	14	None per UNDP	---
Chile	Occidental Chemical-Chile	Talcahuano	MEM	61	None per UNDP	
Colombia	Mexichem Colombia	---	MEM	2	None per UNDP	---
Colombia	Prodesal	Cali, Cartagena	MEM	23	Has been using CTC; converting to chloroform	
Colombia	Refisal	Betania	MER	16		
Colombia	Refisal	Betania	MEM	5	None per UNDP, Brinsa reconfirms	New MEM line 2005/2006
Cuba	State Authority	Sagua la Grande	D	8		
Cuba	State Authority	Sagua la Grande	KOH	8		
Peru	Quimpac	Paramonga	MER	46	None per UNDP	
Peru	Quimpac	Callao	MER	53	None per UNDP	
Trinidad & Tobago	Ansa McAL	Savonetta	MEM	4	No Art 7 CTC imports since 2000, no baseline use	
Uruguay	EFICE	Montevideo	MER	12	None per UNDP	---
Venezuela	Pequiven	El Tablazo	MEM	135	Checking WB and UNIDO and NOU, no CTC use confirmed	
Austria	Donau Chemie AG	Bruckl	MEM	61		---
Belgium	SolVin	Jemeppe	MEM	175		---
Belgium	SolVin	Antwerp (2)	MER	230		Previously Solvay
Belgium	SolVin	Antwerp (2)	MEM	145		Previously Solvay.
Belgium	SolVin	Antwerp (1)	MER	100		Previously BASF
Belgium	Tessenderlo Chemie SA	Tessenderlo	MEM	200		new plant 2006
Belgium	Tessenderlo Chemie SA	Tessenderlo	KOH (MER)	105		
Belgium	Tessenderlo Chemie SA	Tessenderlo	KOH (MER)	23		
Bulgaria	Polymeri	Devnia	D	124		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Czech Republic	Spolana	Neratovice	MER	136	No article 7 data since 2003 (94 tons), baseline 3077 tons. Checking, should be none as reported within EU-25. No CTC confirmed.	
Czech Republic	Spolchemie	Usti nad Labem	MER	30		
Czech Republic	Spolchemie	Usti nad Labem	KOH (MER)	20	Company confirms no CTC	KOH production.
Eire	Micro-Bio Ltd	Fermoy (Co Cork)	MEM	8		
Finland	Eka Chemicals	Oulu	MER	40		
Finland	Kemira	Joutseno	MEM	75		
France	Arkema	Lavera (2)	D	170		---
France	Arkema	Lavera (2)	MER	166		---
France	Arkema	Jarrie	MER	170		---
France	Arkema	Fos sur Mer	D	160	Used CTC tail gas until 2002	
France	Arkema	Fos sur Mer	MEM	120	Used CTC tail gas until 2002	
France	Metaux Special	St. Marcell	Sodium	42		---
France	PPC	Thann	KOH (MER)	50	Used CTC for NCl_3, stopped 2005	
France	PPC	Thann	MER	20	Used CTC for NCl_3	
France	Rhodia (ChlorAlp)	Pont De Claix	D	245	Using CTC for NCl_3 and tail gas	
France	Soc des Produits Chimiques d'Harbonnieres	Harbonnieres	KOH (MER)	23		
France	Solvay France	Tavaux	MER	255		---
France	Solvay France	Tavaux	MEM	132		---
France	Tessenderlo Chemie SA	Lille	KOH (MER)	33		
Germany	Akzo Nobel	Ibbenburen-Uffeln	MER	120		
Germany	Akzo Nobel	Bitterfeld	MEM	75		
Germany	BASF	Ludwigshafen	MEM	225		---
Germany	BASF	Ludwigshafen	MER	160		---
Germany	Bayer	Uerdingen	MEM	110		Expansion likely.
Germany	Bayer	Uerdingen	MER	110		---
Germany	Bayer	Leverkusen	MEM	300		
Germany	Bayer	Leverkusen	HCl	30		---
Germany	Bayer	Dormagen	MEM	370		---
Germany	Bayer	Dormagen	HCl	80		---
Germany	Bayer	Brunsbuttel	HCl	170		---
Germany	Clariant	Gersthofen	MEM	40		
Germany	Degussa AG	Lulsdorf	KOH (MER)	86		

Country	***Chlorine Producers with Capacity in 2006***	***Site***	***Technology***	***Capacity 2006 (kt)***	***CTC use***	***Operational Remarks***
Germany	Degussa AG	Lulsdorf	MER	54		
Germany	Dow Chemical	Stade	D	1,036	Tail gas reinjection	---
Germany	Dow Chemical	Stade	MEM	500		---
Germany	Dow Chemical	Schkopau	MEM	220		---
Germany	Hoffman La Roche	Grenzach	MER	10		---
Germany	Ineos Chlor	Wilhelmshaven	MER	130		
Germany	LII Europe	Frankfurt	MER	167		Converted to MEM 2004.
Germany	Solvay	Rheinberg	D	115		---
Germany	Solvay	Rheinberg	MEM	85		---
Germany	Vestolit	Marl	MER	180		---
Germany	Vestolit	Marl	MEM	30		---
Germany	Vinnolit	Knapsack	MER	150		
Germany	Vinnolit	Knapsack	MEM	100		---
Germany	Vinnolit	Gendorf	MER	90		New membrane 2009
Germany	Wacker-Chemie GmbH	Burghausen	MEM	50		
Greece	Hellenic Petroleum	Thessaloniki	MER	40		
Greece	Unilever Hellas	Athens	MEM	3		
Hungary	Borsodchem RT	Kazincbarcika	MER	125		
Hungary	Borsodchem RT	Kazincbarcika	MEM	70		
Hungary	Budapesti Vegyim	Budapest	MER	7		---
Hungary	Nitrokemid	Balanlonfuzro	MER	11		---
Italy	Altair	Saline di Volterra	KOH (MER)	27		
Italy	Caffaro SpA	Torviscosa	MER	69		---
Italy	Eredi Zarelli	Picinisco	MER	6		---
Italy	Solvay	Rosignano	MER	120		
Italy	Solvay Ausimont	Bussi sul Tirino	MER	90		---
Italy	Syndial SpA	Porto Marghera	MER	200		---
Italy	Syndial SpA	Assemini	MEM	170		
Italy	Tessenderlo Chemie SA	Pieve Vergonia	MER	40		
Netherlands	Akzo Nobel	Delfzijl	MEM	45		---
Netherlands	Akzo Nobel	Botlek	MEM	600	Used CTC until 2005	
Netherlands	GE Plastics	Bergen-op-Zoom	MEM	87		
Norway	Borregaard Industries Ltd	Sarpsborg	MEM	45		---
Norway	Elkem Bremanger Smelteverk	Bremanger	MEM	11		---
Norway	Norsk Hydro AS	Rafnes	D	136	Vapour only to vinyls	
Norway	Norsk Hydro AS	Rafnes	MEM	130		New 130 ktpa MEM
Poland	Anwil	Wloclawek	MEM	195	Using CTC for tail gas	
Poland	Dwory	Oswiecim	MER	25		Plant closed May 2006
Poland	PCC Rokita	Brzeg Dolny	MER	120		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Poland	ZA Tarnow	Tarnow	MER	60		---
Poland	ZA Zachem (Ciech)	Bydgoszcz	D	70		
Portugal	CUF Químicos Industriais	Estarreja	MER & MEM	61	Using CTC for NCl_3	Mercury 48ktpa Membrane 13ktpa
Portugal	Solvay	Povoa	MEM	29		---
Romania	Chimcomplex	Onesti	MEM	125	None per UNIDO	---
Romania	Complex	Turda	KOH (MER)	16	None per UNIDO	---
Romania	Complex	Tirnaveni	MER	45	None per UNIDO	---
Romania	Oltchim	Rimnicu Vilcea	MER	186	None per UNIDO	---
Romania	Oltchim	Rimnicu Vilcea	MEM	106	None per UNIDO	---
Slovakia	Novacke Chemicke Zavody	Novaky	MER	76	Minor article 7 imports consistent with lab use	---
Slovenia	Tovarna Kemicnih Izdelkov	Hrastnik	MEM	12		Converted to MEM 1994.
Spain	CUF Químicos Industriais	Pontevedra (Lourizan)	MER	32	None per DG Env	
Spain	Electroquímica de Hernani SA	Hernani (Guipúzcoa)	MEM	15		---
Spain	Ercros	Vilaseca (Tarragona)	MER	135		
Spain	Ercros	Vilaseca (Tarragona)	MEM	40		
Spain	Ercros	Sabiñánigo	KOH (MER)	25		
Spain	Ercros	Palos de la Frontera, Huelva	MER	100		
Spain	Ercros	Flix - Tarragona	MER	150		---
Spain	Química del Cinca	Monzón del Rio Cinca (Huesca)	MER	30		
Spain	Solvay	Torrelavega	MER	65		---
Spain	Solvay España	Martorell (Barcelona)	MER	225		---
Sweden	Akzo Nobel	Skoghall	MEM	85		---
Sweden	Norsk Hydro AS (Ineos)	Stenungsund	MER	120	Gaseous to EDC	
Switzerland	Borregard	Attisholz	MEM	9	None in CH per BUPAL	
Switzerland	Saurefabrik Schweizerhall AG	Schweizerhalle	MER	25	None in CH per BUPAL	---
United Kingdom	Ineos Chlor	Runcorn	MEM	400	UV light plus thermal, not v happy	
United Kingdom	Ineos Chlor	Runcorn	MER	338	UV light	convert to MEM
United Kingdom	Ineos Chlor	Runcorn	KOH (MEM)	25		Closed end 2006
Armenia	State (NPO Nairit)	Yerevan	---	50	No article 7 since 2000, trade 50-150 kg/a	---
Azerbaijan	State (Azerkhimia)	Sumgait	MER	185	No Article 7 imports	Potential MEM (Eltech 2001)
Bosnia & Herzegovina	Elektrobosna	Jajce	MER	17	No Article 7 imports, no baseline, minimum 50-80 kg trade	---
Bosnia & Herzegovina	Incel Fabrika Celuloze	Banja Luka	MER	40		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Bosnia & Herzegovina	Sodaso	Tuzla	MER	37		---
Kazakhstan	State	Pavlodar	MER	100	No Article 7 import since 2000, trade <70 kg/a	may not be operating
Kazakhstan	Ust-Kamenogorsk	Ust-Kam	Sodium	30		---
Macedonia	Organsko Hemijska Industrija Skopje (Ohis)	Skopje	MER	10	Trade <20 kg/a	---
Russia	Avisma	Berezniki	Sodium	60	Enquiry to NOU	---
Russia	Bereznikisoda	Berezniki	D	20		---
Russia	Bratskkomplex	Bratsk	MER	106		Unlikely operational.
Russia	Kaprolactam	Dzerzhinsk	MEM	140		To membrane tech. in 1990.
Russia	Kaustik	Volgograd	MEM	100		---
Russia	Kaustik	Volgograd	MER	100		---
Russia	Kaustik	Sterlitamak	MER	162		
Russia	Khimprom	Volgograd	MER	130		---
Russia	Khimprom	Novocheboksarsk (1)	MER	80		Produce around 52ktpa.
Russia	Khimprom	Kemerovo	D	75		---
Russia	Kirvo-crepetzk	---	MER	118		---
Russia	Norilisk	Krasnoyarsk	MER	20		---
Russia	NPO Sintez	Moscow	D	14		---
Russia	Sayanskkhimprom	Zima	MER	226		---
Russia	Solikamsk Magnesium	---	Sodium	3		---
Russia	State	Novomoskovsk	D	90		---
Russia	Ufakhimprom	Ufa	D	36		---
Russia	Usolyekhimprom	Usolye, Sibirsk	MER	250		
Russia	Usolyekhimprom	Usolye, Sibirsk	Sodium	5		
Russia	Volgokhimprom	Chapayevsk	D	50		
Serbia & Montenegro, Serbia	FSC	Ivangrad	MER	5	Minor imports Article 7 2004-2005, but trade shows 134mt in 2006:	---
Serbia & Montenegro, Serbia	Matroz Fabrika Celuloze i Papira	Sremska Mitrovica	MER	10		---
Serbia & Montenegro, Serbia	Zupa	Krusevac	MER	4		---
Tajikistan	Tadjikkimesanoat	Yavan	MER	18	No article 7 imports or baseline	---
Ukraine	DniproAZOT	---	D	48	No article 7 imports or baseline	---
Ukraine	GP Khimprom	Pervomaisk	D	154		---

Country	***Chlorine Producers with Capacity in 2006***	***Site***	***Technology***	***Capacity 2006 (kt)***	***CTC use***	***Operational Remarks***
Ukraine	Karpatneftokhim	Kalush	MER	70		MER closed 2006. New plant 2008
Ukraine	Zaporozhye TP	Zaporozhye	Sodium	15		---
Uzbekistan	JSC Elektrokemprom	Chirchik	Sodium	16	No Art 7 imports since 2002, baseline 75 ODPt	---
Uzbekistan	Uzbek Chemical Combine Navoi Azot	Navoi	MEM	23		---
Algeria	ENIP	Skikda	MEM	38	Trade shows <350 kg/a but Article 7~20 tons to 2003, 2.2t/a 2004-6. Suggests solvent/lab.	KruppUdhe.
Algeria	Soc Nat des Ind de la Cellulose (SONIC)	Mostaganem	MER	22		---
Angola	Soda Luanda	Luanda	MER	10	No article 7 imports or baseline	
Egypt	Alexandria Oil & Soap Co	Kafr El Zayat	MER & MEM	8	No apparent use (UNIDO)	
Egypt	Egyptian Petrochemical Co	Alexandria	MEM	64	No apparent use (UNIDO)	
Egypt	El Nasr Co for Intermediate Chemicals (NCIC)	Abou-Rawash, Giza	MEM	18	No apparent use (UNIDO)	Oxy Tech. to 18kt from 2006.
Egypt	El Nasr Co for Intermediate Chemicals (NCIC)	Abou-Rawash, Giza	MER	5	No apparent use (UNIDO)	Oxy Tech.
Egypt	Misr Chemicals	El Mex, Alexandria	MEM	56	No apparent use (UNIDO)	Conversion from MER. Uhde.
Egypt	Rakta (General Co of Paper Ind.)	Alexandria	MEM	3	No apparent use (UNIDO)	---
Egypt	Trust Chemical Industries	Port Said	---	100	No apparent use (UNIDO)	
Iran	Abadan Petrochemical	Abadan	MER	21	UNIDO plan (UNEP/OzL.Pro/ExCom/50/35 and UNIDO IRA/SOL/50/INV/180) identifies 4 enterprises and some SMEs using CTC as solvent, 2005 consumption 11 ODP tons. No PA use, current or historic, has been identified. Terminal phase-out planned.	
Iran	Al Tariq - Fallujah II	---	---	18		---
Iran	Bandar Imam Petrochemical	Bandar Imam	MER	230		possible increase to 250kt.
Iran	Chlor Pars Co	Tabriz	MEM	10		Plant start-up in 1996.
Iran	Chloran Chemical Production Co.	Semnan	MEM	4		
Iran	Isfahan Water Board	unknown	---	2		not operating as at 2004
Iran	Kimya Bon	Gasvin	MER	2		---
Iran	Nirou Chlor	Isfahan	MEM	8		
Iran	Pazagad Chemical	Abadan	MER	4		---
Iran	Ravand Mashhad	Shiraz	MEM	4		
Iran	Shiraz Petrochemical (SPC)	Shiraz	MER	21		NPC Subsidiary.

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Iran	Teheran Water Board	Teheran	MER	2		Plans to expand plant.
Iraq	Basra complex	Khor al Zubair	MER	54		May not be operating.
Iraq	Rayon State	Sadath Al-Hindiyah	MER	14		May not be operating.
Israel	Dead Sea Bromine	Beer Sheva	Magnesium	70	Used 3.5 tons/a, changing away from CTC	---
Israel	Dead Sea Bromine	Beer Sheva	MEM	60		
Israel	Dead Sea Bromine	Beer Sheva	D	37		May close 2005/6.
Israel	Electrochemical Industries	Acre	MER	36		
Israel	Makhteshim Chemical Works	Ramat Hovav	MER	35	Uses 3.5 tons/a, emissions minimal	
Jordan	Jordan Bromine Co	Safi	KOH	25	None per WB	Start up January 2005
Jordan	National Chlorine Industries	Amman	MEM	24	None per WB	---
Kenya	Panafrican Paper Mill	Webuye	D	4	Article 7 use 200-300 kg (ODP)/a	---
Kuwait	Ahlia Industrial Projects	Shuaiba	MEM	36		---
Libya	Libya General Co	Abu Kammash	MER	70	No article 7 imports or baseline	---
Morocco	Coelma	Tetouan	MER	8	None per UNIDO	---
Morocco	Soc Nat d'Electrolyse et de Petro (SNEP)	Mohammedia	MEM	22	None per UNIDO	
Oman	Oman Chlorine Company	Sohar	MEM	13	<10 kg 2003-2006	---
Qatar	Qatar Vinyl Co	Messaieed	MEM	263	No article 7 imports or baseline, but some trade imports ~40-80 tons? Needs check, use possible (Arkema) but likely to be gas phase chlorine	
Saudi Arabia	Arabian Chemical Co	Yanbu	MEM	20		
Saudi Arabia	Basic Chemical Ind. (BCI)	Dammam	MEM	33		
Saudi Arabia	RC Jubail & Yanbu	Al-Jubail	MEM	8		---
Saudi Arabia	Sadaf	Al Jubail	D	410		
Saudi Arabia	Sadaf	Al Jubail	MEM	235		
Saudi Arabia	Saudi Water Co.	---	MEM	8		---
South Africa	Mondi Paper	Richards Bay	MEM	18	No article 7, no imports, no issue	
South Africa	National Chemical Products (NCP)	Chloorkop	MEM	90		
South Africa	Sasol	Sasolburg (2)	D	87		
South Africa	Sasol	Sasolburg (2)	MEM	56		
Syria	Syria General Establishment for Chem Ind	Der El Zar	MER	14		May noy be operating.
Tanzania	Techimont	Moshi	MEM	1		
Tunisia	Societe Nationale Tunisienne de	Kasserine	MEM	7	None per UNIDO	

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
	Cellulose					
Turkey	Ak-Kim	Yalova	MEM	32	None per UNIDO	
Turkey	Kemisan Elektrokimya Sanayii ve Ticaret	Istanbul	D	2	None per UNIDO	---
Turkey	Klor Alkali Sanayi Urenleri	Izmit	MEM	51	None per UNIDO	
Turkey	Petkim	Aliaga	MEM	100	None per UNIDO	---
Turkey	Turkish Cellulose & Paper Corp.	Dalaman	MER	12	None per UNIDO	Could be idle.
UAE	Emirates Chemicals	Ajman	MER	5		---
UAE	Safewater Chemicals	Mussafair	MEM	7		---
Australia	Australian Magnesium Corporation	Stanwell, QLD	MEM	8		
Australia	CSBP	Kwinana, WA	MEM	5		
Australia	Elite Chemicals	Brisbane, QLD	MEM	7		
Australia	Nufarm-Coogee	Melbourne, VIC	MEM	6		Hypochlorite.
Australia	Nufarm-Coogee	Kwinana, WA	MEM	17		
Australia	Nufarm-Coogee	Kemerton, WA	MEM	17		
Australia	Orica	Laverton	MEM	35		---
Australia	Orica	Gladstone, QLD	MEM	9		
Australia	Orica	Botany, NSW	MEM	35		---
Bangladesh	Chittagong Chemicals	---	D	6	Trade shows 21 tons 2204, 129 tons 2005. Article 7 shows 5.7 ODPt deadline, consumption 5-14 ODPt to 2004 then 0.5t.	
Bangladesh	Global Heavy Chemicals	---	MEM	14		BiChlor Ineos 2002.
Bangladesh	Karnufuli Paper	Chittagong	D	6		---
India	Aditya Burla Navo	Veraval, Gujarat	MEM	63	Regarding India, we were specifically told on the last evaluation Mission that NO CTC is used in the application. This has been reconfirmed by a key producer.	
India	Andhra Sugars Ltd	Tanuku, AP	KOH (MEM)	10		New plant 2006
India	Andhra Sugars Ltd	Saggonda	MEM	105		
India	Atul Products Ltd	Atul, GUJ	MEM	10		---
India	Atul Products Ltd	Atul, GUJ	MER	10		Lurgi conversion.
India	Ballarpur Industries Ltd	Ballarshah, MAH	MEM	12		
India	Bihar Caustic & Chemicals	Palamu, BIHAR	MEM	67		New MEM plant
India	Century Rayon	Kalyan, MAH	MEM	17		---
India	Chemfab Alkalis Ltd	Kalapet, Pondicherry	MEM	35		---
India	Chemplast Sanmar	Mettur	MER	42		---
India	Chemplast Sanmar	Karaikal, POND	MEM	28		Uhde.
India	DCW Ltd	Sahupuram, TN	MER	56		---
India	Durgapur Chemicals Ltd	Durgapur, W BENG	MER	10		---
India	Grasim Industries	Nagda, MP	MEM	90		---

Country	Chlorine Producers with Capacity in 2006	Site	Technology	Capacity 2006 (kt)	CTC use	Operational Remarks
India	Grasim Industries	Nagda, MP	MER	75		---
India	Gujarat Alkalies	Vadodara	MEM	115		
India	Gujarat Alkalies	Vadodara	KOH (MEM)	12		
India	Gujarat Alkalies	Dahej	MEM	100		---
India	Gujarat Flouro Chemical Ltd	---	MEM	35		
India	Hindustan Heavy Chemicals	Calcutta, BENG	MER	12		---
India	Hindustan Paper Corp Ltd	Nuagon, ASSAM	MER	19		---
India	Hindustan Paper Corp Ltd	Cachar, ASSAM	---	15		---
India	Hukumchand Jute & Ind. Ltd	Shahabad, MP	MER	34		---
India	Hukumchand Jute & Ind. Ltd	Shahabad, MP	MEM	14		---
India	Indian Petrochemicals Corporation	Gandhar, Gujarat	MEM	163		
India	Jayshree Chemicals	Gunjam, ORISSA	MER	20		---
India	Kanoria Chemicals & Ind.	Renukoot, UP	MER	47		MEM to replace MER
India	Kanoria Chemicals & Ind.	Renukoot, UP	MEM	35		MEM to replace MER
India	Lords Chloro Alkali	---	MEM	23		---
India	Modi Alkali Chemical	Asahi	MEM	25		May expand by 12ktpa.
India	Modi Alkali Chemical	Alwar, RAJ	MER	58		---
India	National Rayon Corp	Kalyan, MAH	MEM	52		Conversion 1994.
India	Punjab Alkalies & Chem. Ltd	Nangal, PUNJ	MEM	100		Membrane start-up 1998.
India	Saurashtra Chemicals (SCL)	Porbandar, GUJ	CHEM	19		---
India	Search Chemicals	Unknown	MEM	64		---
India	Shree Gopal Paper Mills	Jamunager, PUNJAB	MEM	12		---
India	Shriram Alkali DCM Chemicals Works	Kota, RAJ	MEM	66		
India	Shriram Alkali DCM Chemicals Works	Bharuch, GUJ	MEM	56		
India	Siel	Rajpura	MEM	83		Refit of Tacoma plant, 1997.
India	Sirpur Paper Mills	Sirpur, AP	D	6		---
India	Solaris Chemtech Ltd	Karwal, MYS	MER	54		
India	Sree Rayalaseema (SRACL)	Kurnool	MEM	63		---
India	Standard Industries	Thana-Balapur, MAH	MEM	72		---
India	Tamilnadu PetroProducts Ltd	Manali, Chennai	MEM	60		
India	Tata Chemicals	Mithapur, GUJ	MEM	32		May merge with Hind Lever.
India	Travancore Cochin Chemicals	Alwaye, KERALA	MEM	57		
India	United Phosphorus	Baroda, GUJ	MEM	60		May not be operating?
Indonesia	Asahimas Chemical	Cilegon	MEM	336	Nothing apparent from UNIDO reporting. CTC nominally banned from 1998 but 16.5 ODPt reported 2002/3/4. IDS/SOL/44/INV/162 reports thatequipment for the CTC user has been ordered, demand 16.5 ODP tons. Assumed no chlorine use.	

Country	Chlorine Producers with Capacity in 2006	Site	Technology	Capacity 2006 (kt)	CTC use	Operational Remarks
Indonesia	Fabrik Kertas Tjiwi Kimia	Mojokerto Jawa Timur	MEM	50		---
Indonesia	IKPP	Perawang	MEM	100		Oxy Tech. / Expanded 1996.
Indonesia	IKPP	Jambi	MEM	39		Oxy Tech.
Indonesia	Inti Indorayon	Utama	MEM	17		---
Indonesia	Kertah Letjes PM	Probolinggo	MEM	9		---
Indonesia	Leces	Surabaya	D	8		---
Indonesia	Lontar Papyrus	Jambi	---	35		---
Indonesia	Miwon	Surabaya	D	6		---
Indonesia	Musi Pulpmill	Prabumulin	MEM	13		---
Indonesia	PT Kiani Kertas	Berau Kalimantan Timur	MEM	12		---
Indonesia	PT Pakerin	Surabaya	MEM	13		Oxytech.
Indonesia	PT Pindo Deli Pulp & Paper Mills	Pindo Deli	MEM	43		---
Indonesia	PT Soda Industries	Surabaya, Java	MEM	24		---
Indonesia	Riau Andaran	unknown	MEM	36		---
Indonesia	SASA	Surabaya, Java	MEM	9		
Indonesia	Soda Sumatera	Medan	MER	4		---
Indonesia	Sulfindo	Cilegon	MEM	195		
Indonesia	Suparma	Surabaya	D	2		---
Indonesia	Tanjung Enim Lestari	Palembang	MEM	14		---
Malaysia	CCM	Pasir Gudang	MEM	80	None per WB	
Malaysia	Malay Sino Chem Ind	Kemaman	MEM	22	None per WB	---
Malaysia	Malay Sino Chem Ind	Ipoh	MEM	36	None per WB	
Malaysia	Sabah Forest Industries	Sipitang, SABAH	MEM	10	None per WB	
Myanmar	Pupei Company	Rangoon	MER	3		
New Zealand	Carter Holt Harvey (CHH)	Kinleith	MEM	8		Replaces a MER cell unit.
New Zealand	Carter Holt Harvey (CHH)	Kaweru	MEM	10	3.3 ODPt baseline bit 0 tons Article 7 since 2000	
Pakistan	Chasada Chemicals	Chasada	MER	3		---
Pakistan	Ittehad Chemicals	Kala-Shah-Kaku	MER	150		---
Pakistan	Ravi Chemicals	Sheikhupura	MEM	9		---
Pakistan	Sitara Chemical Inds. Ltd	Faisalabad	MEM	107		
Pakistan	Sitara Chemical Inds. Ltd	Faisalabad	MER	11		
Philippines	APC Manila	Manila	MEM	4	No article 7 baseline or imports	
Philippines	Inchem	Balagtas	---	2		---
Philippines	Mabuhay Vinyl	Iligan, Mindanao	D	18		---
Philippines	Mabuhay Vinyl	Iligan, Mindanao	MEM	8		New membrane end 2003.
Philippines	PICOP	Bislig	MEM	4		
Philippines	Superior Gas & Eq	Mandaluyons	MER	3		---
Philippines	UAI	Manila	---	4		---
Singapore	Chemical Industries Far East (CIFE)	Pulau Sakra	MEM	89		

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Singapore	ISK	Singapore	MEM	7		
Thailand	Aditja Birla Chemicals (Thailand) Ltd	Rayong	MEM	45	Checking NOU, WB, WB says none	
Thailand	Chemex	Phrapradeang	D	10		---
Thailand	Chemex	Phrapradeang	MEM	10		---
Thailand	Phoenix Pulp & Paper	Khon Kaen	MEM	10		
Thailand	Siam Occidental	Samut Prakan	MEM	44		
Thailand	Thai Asahi Caustic Soda	Samut Prakan	MEM	90		---
Thailand	Thai Asahi Caustic Soda	Rayong	MEM	218		Expanded 2004 by 11kt
Thailand	Thai Asahi Caustic Soda	Rayong	KOH	20		
Thailand	Thai Fermentation	Bangkok	MEM	10		
Thailand	Thai Fermentation	Bangkok	D	8		
Thailand	Thai Plastic and Chem. Co	Rayong	MEM	25		
Thailand	Vinythai	Map Ta Phut	MEM	240		---
Vietnam	Bai Bang Paper Company	Bai Bang	D	4	1.6 ODPt baseline, <1.0 reported in some years, trade stats show 39 tons 2004, 60 tons 2005. Check. NOU says all solvent/lab, imports now banned	
Vietnam	South Vietnam Basic Chemical Co	Bien Hoa	MEM	18		
Vietnam	Vedan Vietnam EC	Phvoc Thail	MEM	55		---
Vietnam	Viet Tri Chemicals	Viet Tri	D	6		---
Japan	Asahi Glass	Kitakyushu, Fukuoka	MEM	14		---
Japan	Asahi Glass	Kashima	MEM	272		Conversion to MEM mid 98.
Japan	Asahi Glass	Chiba	MEM	151		
Japan	Asahi Glass	Chiba	KOH (MEM)	50		KOH production
Japan	Asahi Kasei Corp	Nobeoka	MEM	141		---
Japan	Central Chemical	Kawasaki	MEM	30		Closed June 2006
Japan	Daiso (Osaka Soda)	Matsuyama	MEM	45		Diaphragm closed.
Japan	Daiso (Osaka Soda)	Kokura	MEM	28		Converted to MEM cells.
Japan	Daiso (Osaka Soda)	Amagasaki	MEM	85		
Japan	Denki Kagaku Kogyo	Ohme	MEM	57		
Japan	Kaneka	Takasago	MEM	285		---
Japan	Kanto Denka Kogyo	Shibukawa	MEM	50		---
Japan	Kanto Denka Kogyo	Mizushima	MEM	64		---
Japan	Kashima Denkai	Kashima	MEM	378		
Japan	Kokkaido Soda	Tomakomai	MEM	140		---
Japan	Kureha Chemical	Nishiki	MEM	120		
Japan	Mitsubishi Chemical	Kurosaki	MEM	35		---
Japan	Mitsui Chemicals Inc	Omuta	MEM	54		
Japan	Mitsui Chemicals Inc	Omuta	MT-Chlor	50		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Japan	Mitsui Chemicals Inc	Omuta	KOH (MEM)	14		
Japan	Nankai Chemical	Wakayama	MEM	29		---
Japan	Nihon Keikinzoku Co. Ltd.	Kanbara	MEM	47		
Japan	Nihon Seishi	Iwakuni	MEM	20		---
Japan	Nippon Soda	Takaoka	MEM	50		
Japan	Nippon Soda	Takaoka	KOH (MEM)	12		KOH production.
Japan	Nippon Soda	Nihonski	Sodium	16		---
Japan	Okayama Butadiene	Mizushima	MEM	120		---
Japan	Shin-Etsu Chemical	Naoetsu	MEM	44		
Japan	Showa Denko	Kawasaki	MEM	93		---
Japan	Showa Enso	Okinawa	MEM	3		
Japan	Sumitomo Chemical	Niihama	MEM	151		---
Japan	Toagosei Chemical Industry	Tokushima	MEM	143		
Japan	Toagosei Chemical Industry	Tokushima	KOH (MEM)	20		
Japan	Toagosei Chemical Industry	Nagoya	MEM	71		DCM electrolysers.
Japan	Tohoku Tosoh Chemical	Sakata	MEM	45		---
Japan	Tokuyama Corporation	Tokuyama	MEM	370		
Japan	Tosoh Corporation	Yokkaichi	MEM	177		---
Japan	Tosoh Corporation	Nanyo	MEM	850		
Japan	Tsurumi Soda	Tsurumi	MEM	73		---
Japan	V-Tech	Mizushima	MEM	164		
North Korea	State	Pyonyang	---	50	Personal Sherry visit	---
South Korea	DC Chemical	Kunsan	MEM	50	None per NOU	
South Korea	Dong Jin	Ansan	MEM	8		
South Korea	Hanwha Chemical Corporation	Yeosu	MEM	500		
South Korea	Hanwha Chemical Corporation	Ulsan	MEM	220		
South Korea	Kokuto Chemical	Seoul	MER	4		---
South Korea	Korea Otsuka	Ulsan	---	19		
South Korea	Korea Otsuka Chemical	Onsan	MEM	19		---
South Korea	Korea Potassium Chemical Co	Incheon	MEM	22		
South Korea	Korea Potassium Chemical Co	Incheon	KOH (MEM)	18		
South Korea	LG Chem	Yeosu	MEM	181		
South Korea	Paik Kwang Pharmaceutical Company	Seoul	MEM	31		
South Korea	Paik Kwang Pharmaceutical Company	Kunsan	MEM	50		
South Korea	Samsung	Ulsan	MEM	175		
South Korea	Unid	Incheon	MEM	75		---
Taiwan	Cheng Tai	Taipei	MEM	16	TO checking, no CTC use	
Taiwan	Chia Hsin	Taichung	D	7		---
Taiwan	China Gulf Plastics	Toufen	MEM	32		

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
Taiwan	Chung/HWA Pulp Corp	Hualien	MEM	27		
Taiwan	Formosa Plastics Corporation	Mailiao	MEM	1,085		
Taiwan	Formosa Plastics Corporation	Kaohsiung	MEM	325		---
Taiwan	Taiwan Chlorine Industries (TCI)	Lin Yuan, Kaohsiung	MEM	125		---
Taiwan	Taiwan Pulp & Paper Corp	Hsinying	KOH (MEM)	12		
Taiwan	Taiwan Pulp & Paper Corp	Hsinying	MEM	11		
Taiwan	Yee Fong Chemical	Taipei	MEM	24		
Taiwan	Yee Fong Chemical	Taipei	KOH (MEM)	16		KOH production.
China, Anhui	Anhui Bayi Chemical Industrial Group	Bangbu	D & MEM	55	During a late 2006 Monitoring Mission in China, all of the evidence provided by SEPA suggests there is no use of CTC in the application. This includes the specific evidence of the approved use listing in China, the strict controls on the CTC producers, who must account for all product moved, and a strict quota system for each process chemical user	
China, Anhui	Anhui Chlor-Alkali Chemical Industrial	Hefei	D & MEM	91		
China, Anhui	Wuhu Ronghui Chemical	Wuhu	D & MEM	55		
China, Beijing	Beijing Huaer (Beijing No.2 Chemical)	Beijing	D & MEM	146		MEM 10. To be moved to Tongzhou by end 2007
China, Chongqing	Chongqing Changshou Chemical Industrial	Chonqging	D	32		---
China, Chongqing	Chongqing Jialing Chemicals	Chongqing	---	5		---
China, Chongqing	Chongqing Sanyang Chemical	Chongqing	MEM	20		---
China, Chongqing	Chongqing Tianyuan Chemical	Chongqing	MEM	18		Replacing old D line.
China, Fujian	Fujian Longyan Chlor-Alkali Chemical	Longyan	D	46		---
China, Fujian	Fujian Nanping Rongchang Chemical	Nanping	---	55		
China, Fujian	Fujian Sannong Chemicals	Sanming	D	16		---
China, Fujian	Fujian Southeast Electrochemical	Fuzhou	D	91		
China, Fujian	Fujian Xialu Electrochemical	Zhangzhou	D	32		---
China, Fujian	Meizhou Gulf Chloride-Alkali Industrial	Quanzhou	MEM	72		---
China, Fujian	Xiamen Deli Group Ganzhou Chlor-Alali	Ganzhou	D	11		
China, Gansu	Gansu Rare Earth Group	Baiyin	D	18		---
China, Gansu	Jinchuan Group	Jinchang	D	32		---
China, Gansu	Jinchuan Group	Jinchang	D	23		---
China, Gansu	Lingtai Chemical Industrial	Lingtai	D	2		---
China, Gansu	Yanguoxia Chemical Industrial	Yanguoxia	MEM	18		YaSheng Group.
China, Gansu	Yanguoxia Chemical Industrial	Yanguoxia	D	8		YaSheng Group.
China, Guangdong	Foshan Huahao Chemical	Foshan	D	27		---
China, Guangdong	Guangzhou Jiangmen Guangyue	Jiangmen	D & MEM	68		

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
	Electrochem					
China, Guangdong	Guangzhou Shaoguan Electrochemical	Shaoguan	D	7		Possibly idled from 2002.
China, Guangdong	Haotian Chemical Group	Guangzhou	D & MEM	91		---
China, Guangdong	Meizhou Jinjiang Chemical Industrial	Meizhou	D	4		Possibly idled from 2002.
China, Guangdong	Shantou Electrochemical	Shantou	D	5		---
China, Guangdong	Zhanjiang Elecrochemical Industrial	Zhanjiang	D	4		Possibly idled from 2001.
China, Guangxi Zhuang	Baise Electrochemical	Baise	D & MEM	9		---
China, Guangxi Zhuang	Guangxi Guofa Forestry & Paper Manufacturing	Luzhai	---	18		---
China, Guangxi Zhuang	Guangxi Wuzhou Lianyi Chemical	Wuzhou	D	11		
China, Guangxi Zhuang	Liuzhou Dongfeng Chemical	Liuzhou	D	27		
China, Guangxi Zhuang	Nanning Chemical Industrial	Nanning	D & MEM	200		---
China, Guizhou	Guizhou An'long Jinhong Chemical	Qian Xi Nan Zhou	MEM	46		---
China, Guizhou	Guizhou Zunyi Alkali	Zunyi	D	55		---
China, Guizhou	Guizhou Zunyi Alkali	Zunyi	MEM	37		---
China, Guizhou	Kaili Paper Manufacturing	Kaili	D	2		---
China, Hebei	Hebei Baoshuo Group	Baoding	D & MEM	91		---
China, Hebei	Hebei Cangzhou Chemical	Cangzhou	D & MEM	73		---
China, Hebei	Hebei Jiheng Group	Hengshui	D	50		---
China, Hebei	Hebei Jiheng Group	Hengshui	MEM	46		---
China, Hebei	Hebei Shenghua Chemical	Zhangjiakou	D & MEM	46		---
China, Hebei	Hebei Shenghua Chemical	Zhangjiakou	MEM	46		
China, Hebei	Hebei Xinfeng Agrochemical	Handan	D	64		
China, Hebei	Hebei Xingtai Mining Group	Xingtai	KOH	19		---
China, Hebei	Hebei Xinxing Chemical	Zhuozhou	KOH (MEM)	11		
China, Hebei	Huanghua Chlor-Alkali	Huanghua	D	73		---
China, Hebei	Jinhua Chemical Industrial	Huanghua	D	27		---
China, Hebei	Shijiazhuang Shuanglian Chemical	Shijiazhuang	D	46		---
China, Hebei	Tangshan Jidong Chlor-Alkali	Tangshan	D & MEM	46		
China, Hebei	Tangshan Sanyou Chemical	Tangshan Sanyou	MEM	91		---
China, Heilongjiang	Daqing Oilfield Company of Fine Chemicals	Daqing	---	14		Possibly idled from 2002.
China, Heilongjiang	Harbin Huaer Chemical Industrial	Harbin	D	32		
China, Heilongjiang	Jiamusi Heilong Agrochemical Industrial	Jiamusi	D	27		---
China, Heilongjiang	Jiamusi Paper Maufacturing	Jiamusi	D	46		---
China, Heilongjiang	Mudanjiang Xinli Chemical	Mudanjiang	D	30		---
China, Heilongjiang	Qihua Chemical Industrial	Qiqihar	---	55		---
China, Heilongjiang	Qiqihar Checheng Chemical Industrial	Qihua	---	1		---
China, Henan	Henan Chemical Industrial	Zhenghou	D	64		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Henan	Henan Haohua Yuhang Chemical	Jiaozuo	MEM	163	Checking	
China, Henan	Henan Haohua Yuhang Chemical	Jiaozuo	D	73		
China, Henan	Henan Hengtong Chemical	Jiyuan	D	50		
China, Henan	Henan Jiyuan Fangsheng Chemical	Jiyuan	MEM	41		
China, Henan	Henan Kaifeng Dongda	Kaifeng	D & MEM	45		---
China, Henan	Henan kaipu Chemical	Gongyi	D	90		Former Henan Chemical
China, Henan	Henan Lianchuang Chemical	Jiyuan	MEM	23		---
China, Henan	Henan Shenma Chlor-Alkali	Pingdingshan	D	27		---
China, Henan	Henan Shenma Chlor-Alkali	Pingdingshan	MEM	18		---
China, Henan	Henan Shenma Chlor-Alkali	Pingdingshan	MEM	15		On stream mid 2006
China, Henan	Henan Xinyang Fubang Chemical Industrial	Xinyang	D	32		---
China, Henan	Henan Zhechuan Fengyuan Chemical Ind	Zhechuan	---	11		---
China, Henan	Hongjin Chemical Industrial	Jiaozuo	---	9		---
China, Henan	Jiaozuo Coal Industrial	Jiaozuo	---	23		
China, Henan	Nanyang Xinwang Chlor-Alkali	Nanyang	D	41		
China, Henan	Puyang Chlor-Alkali	Puyang	D	32		---
China, Henan	Sanmenxia Jinyou Chemical	Shanxian	---	32		
China, Henan	Sanonda Zhengzhou Pesticide	Zhengzhou	D	14		---
China, Henan	Xinxiang Shenma Zhenghua Chemical	Xinxiang	D	26		
China, Henan	Zhengzhou Haihua Chlor-Alkali	Zhengzhou	D	23		
China, Hong Kong	TCVT	Hong Kong	MEM	3		
China, Hubei	Hubei Jingzhou Chemical Industrial	Jingzhou	---	11		---
China, Hubei	Hubei Shuanghuan Chemical Industrial	Yingcheng	D	32		---
China, Hubei	Hubei Yihau Chemical	Yichang	MEM	110		---
China, Hubei	Jianghan Salt & Chemical Complex	Qianjiang	MEM	64		
China, Hubei	Qianjiang Xianqiao Chemical Product	Qianjiang	MEM	45		---
China, Hubei	Sanonda Group	Jingzhou	D	72		---
China, Hubei	Wuhan Gehua Group	Wuhan	D	91		---
China, Hubei	Yichang Changlong Chlor-Alkali	Yichang	D	14		
China, Hunan	Baling Petrochemical	Yueyang	D & MEM	118		---
China, Hunan	Chenzhou Hauxiang Chemical	Chenzhou	D	32		
China, Hunan	Chenzhou Hauxiang Chemical	Chenzhou	MEM	32		
China, Hunan	Hunan Haili Zhuzhou Fine Chemical Industrial	Zhuzhou	D	7		Possibly idled from 2001. Captive
China, Hunan	Hunan Hengyang Jiantao Chemical	Hengyang	D	82		
China, Hunan	Hunan Hengyang Sente Chemical Industrial	Hengyang	---	10		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Hunan	Hunan Hongjiang Hengguang Chemical Ind	Hongjiang	D	50		---
China, Hunan	Hunan Nantian Enterprise	Changsha	D	15		---
China, Hunan	Hunan Zhuzhou Chemical Industrial	Zhuzhou	MEM	128		---
China, Hunan	Hunan Zhuzhou Chemical Industrial	Zhuzhou	D & MEM	91		---
China, Hunan	Hunan Zijiang Agrochemical	Zijiang	D	2		Possibly idled from 2000.
China, Hunan	Seventy-One Chemical Industrial	Hunan	D & MEM	2		
China, Hunan	Shaoyang Chemical Industrial	Shaoyang	KOH (MEM)	5		
China, Hunan	Xikuangshan Shanxin Diye	Xikuangshan	D	18		---
China, Jiangsu	Changzhou Chemical Industies	Jiangdong	D	118		
China, Jiangsu	Jiangsu Anbang Electrochemical	Huaian	Sodium	150		
China, Jiangsu	Jiangsu Chemical Industrial & Agrochem	Suzhou	D	55		---
China, Jiangsu	Jiangsu Chemical Industrial & Agrochem	Suzhou	MEM	45		---
China, Jiangsu	Jiangsu Chemical Industrial & Agrochem	Donghsa, Zhangjiagang	MEM	55		
China, Jiangsu	Jiangsu Guangming Chemical Co Ltd	Taixing	KOH (MEM)	22		---
China, Jiangsu	Jiangsu Guangming Chemical Co Ltd	Taixing	KOH	16		---
China, Jiangsu	Jiangsu Haoshoucheng	Qidong	D	1		Possibly idled from 2000.
China, Jiangsu	Jiangsu Jinpu Beifang Chlor-Alkali Chemical	Xuzhou	MEM	91		
China, Jiangsu	Jiangsu Jinyi Group	Jiangsu	D	18		
China, Jiangsu	Jiangsu Kuaida Agrochemical	Rudong	---	15		
China, Jiangsu	Jiangsu Meilan Electrochemical Group	Taizhou	MEM	136	Use CTC for perchloroethylene products, not NCl_3 eradi cation. No external sales	
China, Jiangsu	Jiangsu Meilan Electrochemical	Taizhou	D	90		
China, Jiangsu	Jiangsu Shuangling Chemical Industrial	Lianyungang	D	27		
China, Jiangsu	Jiangsu Sopo	Zhenjiang	D	73		
China, Jiangsu	Jiangsu Xuanli Fine Chemical	Changshu	KOH	6		---
China, Jiangsu	Jiangsu Yinka Chemical Industrial	Wuxi	D	18		---
China, Jiangsu	Nanjing Alkali	Nanjing	---	3		---
China, Jiangsu	Nantong Jiangshan Agrochemical	Nantong	D	82		---
China, Jiangsu	Nantong Jiangshan Agrochemical	Nantong	MEM	55		---
China, Jiangsu	Shuangshi (Zhangjiagang) Fine Chemical	Zhangjiagang	D & MEM	109		---
China, Jiangsu	Sinopec Nanjing Chemical	Nanjing	D	55		
China, Jiangsu	SP Chemicals	Taixing	MEM	132	No CTC	---
China, Jiangsu	SP Chemicals	Taixing	MEM	132		

Country	***Chlorine Producers with Capacity in 2006***	***Site***	***Technology***	***Capacity 2006 (kt)***	***CTC use***	***Operational Remarks***
China, Jiangsu	Taicang Jintai Chemical Industrial	Taicang	---	3		---
China, Jiangsu	Wuxi Greenapple Chemical Industry Co Ltd	Wuxi	D & MEM	132		---
China, Jiangsu	Xinyi Jiaytai Chemical	Xinyi	D	41		
China, Jiangsu	Yancheng Electrochemical	Yancheng	D	46		---
China, Jiangsu	Yangnong Chemical	Yangzhou	D	91		---
China, Jiangsu	Yangnong Chemical	Yangzhou	---	63		---
China, Jiangsu	Zhenjiang Lixin Chemical Industrial	Zhenjiang	---	1		---
China, Jiangxi	Bule Star New Chem Mat Jiangxi Organic Silicone	Yongxiu	MEM	45		---
China, Jiangxi	Bule Star New Chem Mat Jiangxi Organic Silicone	Yongxiu	D	18		---
China, Jiangxi	Ganzhou Chlor-Alkali Company	Ganzhou	D	9		
China, Jiangxi	Hukou Xinkangda Chemical	Jinshawan, Hukou	MEM	2		
China, Jiangxi	Jiangxi Electrochemical	Leping	D	82		---
China, Jiangxi	Jiangxi Ganzhong Chlor-Alkali	Zhangshu	D	45		---
China, Jiangxi	Jiangxi Ganzhong Xuefeng Chemical	Xingan	D	27		
China, Jiangxi	Jiujiang Hengyu Chemical	Jiujiang	D	27		---
China, Jiangxi	Jiujiang Xinkangda Chemical	Jiujiang	D & MEM	55		
China, Jiangxi	Nanchang Chlor-Alkali	Nanchang	---	27		
China, Jilin	Jilin Petrochemical	Jilin	MEM	46		---
China, Jilin	Siping Haohua Chemical	Siping	D & MEM	41		
China, Liaoning	Benxi Dongfang Chlor-Alkali	Benxi	MEM	54		
China, Liaoning	Dahua Group	Dalian	---	5		---
China, Liaoning	Dalian Dyechem	Dalian	D & MEM	18		---
China, Liaoning	Dalian Potassium Chlorate Plant	Dalian	D	3		---
China, Liaoning	Jincheng Paper & Pulp	Yingkou	MER	9		---
China, Liaoning	Liaoning Jin Hua Chemical	Huludao	MEM	272	No CTC	Former Jinxi Chemical
China, Liaoning	Shenyang Chemical	Shenyang	D	118		---
China, Liaoning	Shenyang Chemical	Shenyang	MEM	64	Allegedly 1.25 tpa CTC exploded 2004	
China, Nei Mongol	Baotou Beida Tomorrow Technology	Baotou	MEM	86		---
China, Nei Mongol	Baotou Beida Tomorrow Technology	Baotou	D	18		---
China, Nei Mongol	Etuokeqi Baiyanzhuo Chemical	Etuokeqi	---	7		---
China, Nei Mongol	Etuokeqi Shuangxin Chemical	Etuokeqi	---	6		
China, Nei Mongol	Haiji Chemical	Wuhai	MEM	55		---
China, Nei Mongol	Haishi Chlor-Alkali	Haishi	---	9		---
China, Nei Mongol	Neimeng Huanghe Chemical	Wuhai	D & MEM	36		---
China, Nei Mongol	Neimeng Lasengmiao Company	Wuhai	---	18		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Nei Mongol	Neimeng Sanlain Chemical	Hohhot	D & MEM	73		---
China, Nei Mongol	Wuhai Chlor-Alkali Industrial	Wuhai	MEM	100		---
China, Nei Mongol	Wulateqianqi Linhai Chemical	Wulateqianqi	D	55		
China, Nei Mongol	Xilinguole Sunite Alkali	Xilinguole	D	36		---
China, Nei Mongol	Zhonghua Sanlian Chemical	Hohhot	D	73		---
China, Ningxia	Ningxia Dayuan Chemical Co	Yinchuan	KOH	13		---
China, Ningxia	Ningxia Jinyuyuan Chlor-Alkali	Qingtongxia	D	72		
China, Ningxia	Ningxia Jinyuyuan Chlor-Alkali	Qingtongxia	MEM	36		
China, Ningxia	Ningxia Risheng Industrial	Shizuishan	D	64		---
China, Ningxia	Ningxia Western PVC	Yichuan	MEM	90		
China, Ningxia	Ningxia Yinglite	Shizuishan	D	23		---
China, Shaanxi	Beiyuan Chemical	Shenmu	MEM	56		---
China, Shaanxi	Shaanxi Chemical Industrial	Shaanxi	---	23		---
China, Shaanxi	Shaanxi Jintai Chlor-Alkali Chemical	Yulin	MEM	91		---
China, Shaanxi	Xihua Thermopower	Xian	MEM	64		---
China, Shandong	China Aluminum Shandong	Zibo	MEM	55		---
China, Shandong	Dongying Hi-Tech Shengli Electrochemical	Dongying	MEM	82		---
China, Shandong	Dongying Huatai Chemical Group	Dongying	MEM	109		---
China, Shandong	Dongying Huatai Chemical Group	Dongying	MEM	27		---
China, Shandong	Shandong/DongYing JinLing Chemical Industry	Dongying	MEM	127	No CTC at present	
China, Shandong	Dongyue Chemical Industrial	Zibo	MEM	286	Produce CTC but not for NCl_3 eradication (mostly for methane chloride and some external sales)	
China, Shandong	Huantai Bohui Group	Qingdao	MEM	110	No CTC	---
China, Shandong	Huantai Bohui Group	Qingdao	D	73		---
China, Shandong	Jinan Runyuan Chemical	Jinan	D	90		---
China, Shandong	Jinan Sipu Chemicals	Jinan	---	4		---
China, Shandong	Jining Jinwei Coal & Electricity	Jining	MEM	55		---
China, Shandong	Jining Zhongyin Electrochemical	Jining	MEM	90		---
China, Shandong	Jining Zhongyin Electrochemical	Jining	D	45		---
China, Shandong	Linzi Futai Chemical Industrial	Zibo	---	6		Possibly idled from 2001.
China, Shandong	Mouping Dongfang Chemical Industrial	Yantai	D	14		---
China, Shandong	Qingdao Haijing Chemical Industrial Group	Qingdao	D & MEM	109		---
China, Shandong	Qingdao Tianyuan Chemical	Qingdao	D	36		---
China, Shandong	Shandong Binhua Group	Binzhou	MEM	109		
China, Shandong	Shandong Binhua Group	Binzhou	D	45		
China, Shandong	Shandong Dacheng Agrochemical	Zibo	D & MEM	109		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Shandong	Shandong Dezhou Petrochemical	Dezhou	---	136		---
China, Shandong	Shandong Haihua Chemical	Weifang	---	91		---
China, Shandong	Shandong Hangtian Foaming Agent	Wendeng	D	27		---
China, Shandong	Shandong Hauyang Pesticide Chemical Ind	Ningyang	D	91		---
China, Shandong	Shandong Hengtong Chemical Ind	Yancheng	D	227	No CTC	---
China, Shandong	Shandong Liaocheng Luxi Chemical Ind	Liaocheng	D	36		Thermopower Plant
China, Shandong	Shandong Linyi Paper Manufacturing	Linyi	---	55		---
China, Shandong	Shandong Longkou Keda Chemical Industrial	Longkou	D	9		---
China, Shandong	Shandong Lubei Group	Binzhou	D	60		---
China, Shandong	Shandong Lubei Group	Binzhou	MEM	55		---
China, Shandong	Shandong Plastics Experimental Plant	Jinan	D	55		---
China, Shandong	Shandong Shouguang Xinlong Electrochem	Shouguang	D	91		---
China, Shandong	Shandong Yizhou Cement Group	Yizhou	D	73		---
China, Shandong	Shandong Zhucheng Taisheng Chemical Ind	Zhucheng	D	55		---
China, Shandong	Sinopec Qilu Petrochemical	Zibo	D	227	No CTC	---
China, Shandong	Sinopec Qilu Petrochemical	Zibo	MEM	182	No CTC	---
China, Shandong	Weifang Yaxing Group	Weifang	MEM	109		---
China, Shandong	Weifang Yaxing Group	Weifang	D	55		---
China, Shandong	Xintai Dongdu Chlor-Alkali	Xintai	D	18		Possibly idled from 2002.
China, Shandong	Yantai Chlor-Alkali	Yantai	D	46		---
China, Shandong	Yantai Chlor-Alkali	Yantai	MEM	27		---
China, Shandong	Zhoucun Guangming Chemical Industrial	Zibo	---	1		Possibly idled from 2002.
China, Shandong	Zoucheng Kailai Chemical Industrial	Zoucheng	---	4		---
China, Shanghai	Shanghai Chlor-Alkali Chemical (SCAC)	Shanghai	MEM	273	No CTC	---
China, Shanghai	Shanghai Chlor-Alkali Chemical (SCAC)	Shanghai	D	91		---
China, Shanghai	Shanghai Taopu Chemical Industrial	Taopu	---	3		---
China, Shanghai	Shanghai Tianyuan Huasheng Chemical	Caojin	MEM	164		---
China, Shanghai	State Authority	Shanghai (Tianyuan)	MER & MEM	262		---
China, Shanxi	Datong Huachang Chemical Industrial	Datong	---	23		---
China, Shanxi	Datong Plastics & Chemical Industrial	Datong	---	7		---
China, Shanxi	Huojia Industry	Changzhi	MEM	145		---
China, Shanxi	Shanxi Jinjia Chemical Industrial	Taiyuan	---	18		---
China, Shanxi	Shanxi Synthetic Rubber Group	Datong	MEM	18		---
China, Shanxi	Shanxi Wentong Sylvite Group	Wentong	---	31		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Shanxi	Taiyuan Chemical Group	Taiyuan	D	73		---
China, Shanxi	Taiyuan Chemical Group	Taiyuan	MEM	45		---
China, Shanxi	Yangquan Coal Industry Group	Yangquan	---	91		---
China, Shanxi	Yanquan Chlor-Alkali Company	Yanquan	---	21		---
China, Shanxi	Yongji Chemical Industrial	Taiyuan	---	9		---
China, Shanxi	Yushe Chemical Industrial	Yushe	---	136	No CTC	
China, Sichuan	Baqu Alkali	Qu	---	5		---
China, Sichuan	Chengdu Chemical	Chengdu	---	6		
China, Sichuan	Chengdu Huarong Chemical	Chengdu	KOH (MEM)	25		
China, Sichuan	Chengdu Huarong Chemical	Chengdu	D	18		---
China, Sichuan	Jiangyou Qimingxing Chlor-Alkali Chemical	Jiangyou	---	18		
China, Sichuan	Leshan Wutongqiao Electrochemical	Leshan	D	10		---
China, Sichuan	Leshan Yongxiang Resins	Lashan	MEM	180	No CTC	
China, Sichuan	Luzhou Chemical Industrial	Luzhou	---	11		---
China, Sichuan	Luzhou Xinfu Chemical Industrial	Luzhou	---	46	Produce CTC for internal use, but not NCl_3 eradication	
China, Sichuan	Nanchuan Hongyuan Chemical Industrial	Nanchuan	---	14		---
China, Sichuan	Pangang Gangcheng Enterprises	Panzhihua	D	3		Possibly idled from 2002.
China, Sichuan	Sichuan Jinlu Chemical	Deyang	MEM	135		---
China, Sichuan	Sichuan Jinlu Chemical	Deyang	D	64		---
China, Sichuan	Sichuan Jiuda Salt Group	Zigong	D	5		---
China, Sichuan	Sichuan Juxing Agrochem & Livestock Group	Chongzhou	---	14		---
China, Sichuan	Sichuan Luzhou Xinfu Chemical	Luzhou	---	32		
China, Sichuan	Wutingqiao Caustic Soda	Leshan	---	10		---
China, Sichuan	Xichang Wangfa Rare Earth	Xichang	---	3		---
China, Sichuan	Yibin Tianyuan Chemical	Yibin	D & MEM	272	Small use CTC internal only	
China, Sichuan	Zigong Honghe Chemical	Sichuan	D & MEM	137	Use CTC to produce tetrachloroethylene, but not for eradication of NCl_3.	
China, Sichuan	Zigong Zhangjiaba Salt Chemical	Zigong	---	23		
China, Tianjin	Tianjin Beifang Chemical Industrial	Hangu	---	9		---
China, Tianjin	Tianjin Binhai Cable & Wire	Tanggu	---	11		---
China, Tianjin	Tianjin Botian Chemical	Tianjin	D & MEM	291	No CTC (stopped)	
China, Tianjin	Tianjin Caibao Chemical Industrial	Hangu	---	2		Possibly idled from 2001.
China, Tianjin	Tianjin Dagu Chemical	Tianjin	D	218	No CTC	---
China, Tianjin	Tianjin Dagu Chemical	Tianjin	MEM	200		---
China, Tianjin	Tianjin Dagu Chemical Industrial Service Co.	Tianjin	---	9		---

Country	*Chlorine Producers with Capacity in 2006*	*Site*	*Technology*	*Capacity 2006 (kt)*	*CTC use*	*Operational Remarks*
China, Tianjin	Tianjin Dongsheng Chemical Industrial	Jinnan	---	3		Possibly idled from 2001.
China, Tianjin	Tianjin Haizhong Alkali	Hangu	---	27		---
China, Tianjin	Tianjin Hejia Chemical Industrial	Hangu	---	9		---
China, Tianjin	Tianjin Hongsanhuan Alkali	Hangu	---	27		---
China, Tianjin	Tianjin Jianhua Chemical Industrial	Hangu	---	9		Possibly idled from 2001.
China, Tianjin	Tianjin Jinda Alkali	Hangu	---	2		Possibly idled from 2001.
China, Tianjin	Tianjin Jinhua Chemical Industrial	Hangu	---	14		---
China, Tianjin	Tianjin Juyuan Chemical Industrial	Tanggu	---	2		Possibly idled from 2002.
China, Tianjin	Tianjin Kaiwei Chemical Industrial	Tianjin	---	46		---
China, Tianjin	Tianjin Kaiyi Chemical Industrial	Tianjin	---	14		---
China, Tianjin	Tianjin Lida Chemical Industrial	Jinnan	---	1		---
China, Tianjin	Tianjin Ruitian Chemical Industrial	Jinnan	---	3		---
China, Tianjin	Tianjin Tianhong Chemical Industrial	Tianjin	---	12		Possibly idled from 2002.
China, Tianjin	Tianjin Tianshun Alkali	Hangu	---	18		---
China, Tianjin	Tianjin Xingwu Chemical Industrial	Jinnan	---	1		Possibly idled from 2001.
China, Tianjin	Tianjin Yuanlong Chemical Industrial	Tianjin	---	9		---
China, Tianjin	Tianjin Zhonghua Enterprises	Tanggu	---	9		Possibly idled from 2003.
China, Xinjiang	Hefang Lianda Electrochemical	Hefang	D	4		Possibly idled from 2002.
China, Xinjiang	Qingsong Building Material & Chemical Ind	Akesu	D	2		---
China, Xinjiang	Xinjiang Bositenghu Weiye	Bositenghu	---	4		---
China, Xinjiang	Xinjiang Tianye Chemical	Shihezi	MEM	236	No CTC	---
China, Xinjiang	Xinjiang Zhongtai Chemical	Dongshan	MEM	249	No CTC	
China, Yunnan	Baoshan Chemical Industrial	Baoshan	D	3		Possibly idled from 2000.
China, Yunnan	Kunming Electrochemical	Kunming	D	14		---
China, Yunnan	Yunnan Hongyun Chlor-Alkali	Anning	MEM	23		---
China, Yunnan	Yunnan Kaiyuan Chlor-Alkali Chemical	Kaiyuan	---	14		---
China, Yunnan	Yunnan Luliang Yinhe Paper Manufacturing	Luliang	D	2		---
China, Yunnan	Yunnan Phosphorus Group	Xundian	---	91		
China, Yunnan	Yunnan Salt & Chemical	Yunnan	---	118		
China, Zhejiang	Hangzhou Electrochemical	Hangzhou	D	64		---
China, Zhejiang	Hangzhou Electrochemical	Hangzhou	MEM	36		---
China, Zhejiang	Jiahua Chemicals Co.	Jiaxing	MEM	50		---
China, Zhejiang	Jiahua Chemicals Co.	Jiaxing	D	46		---
China, Zhejiang	Ningbo Donggang Electrochemical	Ningbo	MEM	110		
China, Zhejiang	Ningbo Donggang Electrochemical	Ningbo	D	36		
China, Zhejiang	Wenzhou Tiansheng Chemical	Wenzhou	D	91		---
China, Zhejiang	Xiaoshan Lianfa Electrochemical	Xiaoshan	D	45		---

Country	Chlorine Producers with Capacity in 2006	Site	Technology	Capacity 2006 (kt)	CTC use	Operational Remarks
China, Zhejiang	Zhejiang Gala Chemical Corp	Ningbo	MEM	110	No CTC	
China, Zhejiang	Zhejiang Linghua Chemicals Group	Huzhou	D	27		---
China, Zhejiang	Zhejiang Quhua Fluor-Chemistry Co	Quzhou	D & MEM	300	CTC for tetrachloroethylene/ cinnamic acid only	
China, Zhejiang	Zhejiang Shangao Chemicals	Ningbo	MEM	73		---
China, Zhejiang	Zhejiang Taizhou Caustic Soda	Taizhou	D	5		---
	TOTAL WORLD CHLORINE CAPACITY (kt)			**63,497**		

ANNEX 1A PLANTS WITH NO CHLORINE CAPACITY IN 2006

Country	***Chlorine Producers with no Capacity in 2006*** *(shut down, or future projects announced)*	***Site***	***Technology***	***CTC use***	***Operational Remarks***
Canada, Alberta	Dow Chemical	Fort Saskatchewan	MEM		Closed end 2002
Canada, British Colombia	Canexus	Vancouver	MEM		
Canada, British Colombia	CXY	Nanaimo	D		Closed end 1990.
Canada, British Colombia	CXY	Squamish	MER		Closed 1991.
Canada, Nova Scotia	Canso Chemicals	Abercrombie	Sodium		Closed September 1992.
Canada, Ontario	Dow Chemical	Sarnia	D		Closed
Canada, Ontario	Great Lakes Forest Products	Dryden	MEM		Closed 2000.
Canada, Ontario	ICI Canada	Cornwall	MER		Closed October 1994.
Canada, Quebec	Domtar Pulp Ltd	Lebel-sur-Quévillon	MER		Small plant.
Mexico	Celulosa el Pilar SA	Ayotla	D		Closed 1993.
Mexico	DuPont	Altamira	MEM		Possible
Mexico	Guanos y Fertilizantes de Mex SA	Salamanca	MER		Closed 1993.
United States, Alabama	Akzo Nobel	Le Moyne	MER		Closed 1988
United States, California	Dow Chemical	Pittsburg	D		Closed 2000.
United States, Delaware	Oxychem	Delaware City	KOH (MER)	Switched CTC to CM3	Closed 2006
United States, Delaware	Oxychem	Delaware City	MER	Switched CTC to CM3	Closed 2003
United States, Georgia	Georgia Pacific	Brunswick	MEM		Closed 1980s
United States, Georgia	LCP Chemical (Hanlin)	Brunswick	MER		Closed 1990s
United States, Kentucky	Westlake	Calvert City	MER		Closed 2002.
United States, Louisiana	Formosa Plastics Corporation	Baton Rouge	D		Closed in 2003
United States, Louisiana	La Roche	Grammercy	D		Closed end 2000.
United States, Louisiana	Olin Corporation	St Gabriel	MEM		Formerly Pioneer
United States, Louisiana	Oxychem	Taft	KOH (MEM)	Switched CTC to CM3	---
United States, Louisiana	PPG Industries	Lake Charles	MEM	Believed UV light	---
United States, Louisiana	Shintech	Plaquemine	MEM		Expansion end 2007
United States, Massachusetts	Holtrachem Manufacturing	Orrington	MER		---
United States, Massachusetts	LCP Chemical (Hanlin)	Orrington	MER		Closed 1980s
United States, New York	E I Du Pont de Nemours & Co.	Niagara Falls	D		---
United States, New York	LCP Chemical (Hanlin)	Syracuse	D & MER		Closed 1980s
United States, New York	Olin Corporation	Niagara Falls (1)	MER		Closed.
United States, North Carolina	Holtrachem Manufacturing	Acme	MEM		Operated Nov 99 - Oct 00.
United States, North Carolina	Holtrachem Manufacturing	Acme	MER		Closed Oct 99.
United States, North Carolina	LCP Chemical (Hanlin)	Acme	MER		Closed 1980s
United States, North Carolina	Weyerhaeuser	Plymouth	---		Closed 1975.
United States, Ohio	Ashta Chemical	Ashtabula	KOH (MEM)		

Country	*Chlorine Producers with no Capacity in 2006* *(shut down, or future projects announced)*	*Site*	*Technology*	*CTC use*	*Operational Remarks*
United States, Oregon	Arkema	Portland	D & MEM		Shut end Q1 2001.
United States, Texas	E I Du Pont de Nemours & Co.	Corpus Christi	D		Shut down 1986
United States, Texas	OxyVinyl	Deer Park	D & MER		MER 93ktpa shut 2001. MEM 252ktpa idled 2001.
United States, Washington	Elf-Atochem	Tacoma	MEM		Closed 1994.
United States, Washington	Georgia Pacific	Bellingham	MER		Shut end 1999.
United States, Washington	Olin Corporation	Tacoma	D		Formerly Pioneer
United States, Washington	Olin Corporation	Tacoma	MEM		Formerly Pioneer
United States, Washington	Weyerhaeuser	Longview	D		---
United States, West Virginia	LCP Chemical (Hanlin)	Moundsville	MER		
United States, Wisconsin	Procter & Gamble Paper Products	Green Bay	MEM		Shut down 1987
Argentina	Atanor	Río Tercero	MER		
Argentina	Compania Quimica SA	Buenos Aires	MER		Not operating.
Argentina	Inchlor	unknown	MEM		Not operating.
Argentina	Indupa (Solvay)	Cinco Saltos (Rio Negro)	MER		Closed.
Argentina	Ledesma SAAI	Pueblo Ledesma (Jujuy)	MER		Closed 2005
Argentina	Progar (Agrocom)	Aldo Bonzi (Buenos Aires)	MER		Not operating.
Argentina	Viplastic SACI	Chacras de Coria (Mendoza)	---		Not operating.
Brazil	Carbocloro SA Industrias Quimicas	Cubatao	MEM		Due on stream 2008
Brazil	Champion Papel e Cellulose SA	Mogi Guacu	MER		Not operating.
Brazil	Guangming Group	Honorio Gurgel	MEM		---
Brazil	Hoechst AG	Suzano	MER		Closed September 1995.
Brazil	Industrias Anhembi SA	Sao Caecano do Sul	D		Not operating.
Brazil	Jari Cellulose	Jari	D		Not operating.
Brazil	Matarazzo	Cataguases	MER		Not operating.
Brazil	Morro Verde	Parana	---		Not operating.
Brazil	Solvay - Indupa	Santo Andre	MEM		---
Chile	Manufacturera de Papelese y Cartones (CMPC)	Laja, San Vincente	MEM	None per UNDP	Closed in 1998.
Chile	Manufacturera de Papelese y Cartones (CMPC)	Laja, San Vincente	MER	None per UNDP	---
Colombia	Alcalis de Colombia Ltda	Betania	MER	None per UNDP	Shut down, sold to Refisal.
Colombia	Planta Colombiana De Soda	Mamonal	---	None per UNDP	51ktpa plant shut down.
Paraguay	Inquipa	---	MEM	None per UNDP	Small plant - capacity unknown.
Trinidad & Tobago	CariSal	Point Lisas Industrial	---		---

Country	***Chlorine Producers with no Capacity in 2006*** *(shut down, or future projects announced)*	***Site***	***Technology***	***CTC use***	***Operational Remarks***
		Estate			
Austria	Biochemie	Kufstein	---		Not operating.
Austria	Donau Chemie AG	Bruckl	MER		Converted to MEM in 2000.
Austria	Polser Zellulose und Papierfabrik	Pols	MEM		Not operating.
Austria	Solvay Oesterreich	Hallein	MER		Closed October 1997
Austria	Zellstoff Fabrik	Gratkorn	D		Not operating.
Belgium	Bayer Shell Isocyanates	Antwerp (2)	HCl		Closed end 2003
Belgium	SolVin	Jemeppe	MER		Closed 2002.
Belgium	Tessenderlo Chemie SA	Tessenderlo	MER		
Bulgaria	Chimkomplekt Engineering	Devnia	MEM	No use reported since 1997. Why baseline 275 ODPt? Trade imports show 300-500kg/a consistent with lab use.	117ktpa conversion stalled
Bulgaria	Polymeri	Devnia	MER		---
Denmark	Dansk Sojakagefabrik Aps	Copenhagen	MER		Closed end 1991.
Finland	Erikem	Aetsa	MER		---
Finland	Erikem	Kuusankoski	MER		Closed 1994.
France	Arkema	St. Auban	MEM		Due on stream end 2008
France	Arkema	St. Auban	MER	Used CTC NCl_3 to 2000	Closed in 2006
France	Rhodia	Lille	HCl		Closed 1997.
France	Solvay France	Dombasle sur Meurthe	D		Closed end 1990.
Germany	Akzo Nobel	Bitterfeld	D		
Germany	Bayer	Brunsbuttel	HCl to Chlorine		
Germany	Bayer	Leverkusen	MER & MEM		---
Germany	Degussa AG	Hurth	Downs		---
Germany	Dow Chemical	Schkopau	D & MER		---
Germany	Farben Fabrik	Wolfen	D		Closed.
Germany	Huels-Troisdorf	Rheinfelden	D & MER		Closed 1995.
Germany	Vestolit	Marl	MEM		---
Germany	Vinnolit	Gendorf	MEM		---
Germany	Wacker-Chemie GmbH	Burghausen	MER		
Hungary	BVM	Budapest	MER		Closed.
Hungary	Nitrokemia 2000	Balatonfuzfo	MER		Closed.
Italy	Altair	Saline di Volterra	KOH (MEM)		Adding 30%
Italy	EniChem	Gela	MER		---

Country	*Chlorine Producers with no Capacity in 2006* (shut down, or future projects announced)	*Site*	*Technology*	*CTC use*	*Operational Remarks*
Italy	EniChem	Mantua	MER		
Italy	Others	unknown	---		---
Italy	Solvay	Rosignano	D		Closed 1993.
Italy	Solvay	Rosignano	MEM		---
Italy	Solvay	Tavazzano	MER		Closed 1993
Italy	Syndial SpA	Porto Torres (1)	MER		Closed in 2002.
Italy	Syndial SpA	Priolo	KOH (MER)		Closed in 2005
Italy	Syndial SpA	Priolo	MER		---
Netherlands	Akzo Nobel	Delfzijl	D	Used CTC until 2005	Closed 2006
Netherlands	Akzo Nobel	Hengelo	MER	NCl_3 destroyed in compressor	Closed 2006
Netherlands	Solvay	Linne Herten	MER		Closed end 1999
Norway	Norsk Hydro AS	Porsgrunn	MER	Vapour only to vinyls	---
Norway	Tofte Industrier A/S	Tofte	MEM		Closed 1992.
Poland	Anwil	Wloclawek	D		---
Portugal	Solvay	Povoa	MER & MEM		Mercury Plant closed.
Romania	Chimcomplex	Onesti	D	None per UNIDO	---
Romania	Complex	Giurgiu	---	None per UNIDO	Closed.
Romania	Oltchim	Rimnicu Vilcea	D	None per UNIDO	---
Slovakia	Duslo Sala SP	Sala	MER	No Article 7 imports, minor trade <200 kg imports	Closed.
Spain	Electroquímica Andaluza SA	Ubeda (Jaén)	MER		Closed 1990
Sweden	Akzo Nobel	Surte (Bohus)	MER		Closed 2006
Sweden	Billerud Uddeholm AB	Skoghall	MER	Converted to MEM	
Sweden	Diacell AB	Gavle	D		Now Westlake
Sweden	Domsjo Klor AB	Domsjo	MER		Closed July 1991.
Sweden	Norrlands Skogsagares Cellulosa AB	Koepmanholmen	MER		Closed 1993.
Sweden	Norsk Hydro AS (Ineos)	Stenungsund	MEM		Closing mercury plant 2010
Switzerland	Solvay	Zurzach	MER	None in CH per BUPAL	Closed 2005
Switzerland	Syngenta	Monthey	MER	None in CH per BUPAL	Closed Q1 2005
United Kingdom	Albion Chemicals	Sandbach	MER		
United Kingdom	Hoffman La Roche	Dalry	MEM		Closed in 2002
United Kingdom	ICI	Hillhouse	MER		---
United Kingdom	Ineos Chlor	Lostock	D		Closed 2001.

Country	***Chlorine Producers with no Capacity in 2006*** *(shut down, or future projects announced)*	***Site***	***Technology***	***CTC use***	***Operational Remarks***
United Kingdom	Ineos Chlor	Lostock	MEM		Closed 2001.
United Kingdom	Ineos Chlor	Wilton	D		Closed June 2002.
United Kingdom	Rhodia	Chesterfield	MER		
United Kingdom	The Associated Octel Co Ltd	Ellesmere Port	Downs		Closed 1998.
United Kingdom	The Associated Octel Co Ltd	Ellesmere Port	MEM		Closed end 2002.
Albania	Makina Import	Vlore	MER		Closed in 1992.
Azerbaijan	State	Baku	---		---
Bosnia & Herzegovina	Elektrobosna	Jajce	MER		Closed.
Bosnia & Herzegovina	Incel Fabrika Celuloze	Banja Luka	MER		Closed.
Croatia	Fabrika Sulfate Cellulose	Ivangrad	MER		Closed.
Croatia	Jugovinil	Split	MER		Closed.
Russia	Kaprolactam	Dzerzhinsk	D		Closed.
Russia	Kaustik	Sterlitamak	MEM		
Russia	Others	Unknown	HCl		not operating.
Russia	Others	Unknown	---		Not operating.
Russia	Rus Vinyl	Kstovo	---		On stream 2010
Russia	Sayanskkhimprom	Zima	MEM		Conversion from mercury.
Russia	State	Angarsk	MER		Not operating.
Russia	State	Bazernik	---		Not operating.
Russia	State	Komsomolsk	MER		Not operating.
Russia	State	Kotlas	MER		Not operating.
Russia	State	Ozczhimsk	---		Not operating.
Russia	Tajikkhimprom	Yavan	---		2003 - may not be operating.
Serbia & Montenegro, Serbia	Hemijska Industrija Pancevo Petrohemija	Pancevo	MER		---
Ukraine	DniproAZOT	---	MEM		---
Ukraine	Karpatneftokhim	Kalush	MEM		---
Ukraine	State	Lisichansk	---		Not operating.
Uzbekistan	Kungrad Soda Co	Kungrad	---		---
Uzbekistan	Navoi - Plast	Navoi	---		---
Algeria	ENIP	Skikda	MER		To MEM in 2004.
Egypt	Misr Chemicals	El Mex, Alexandria	MER	No apparent use (UNIDO)	Converted to membrane.
Iran	Arak Petrochemical Co.	Arak	MEM		100ktpa now cancelled.
Iran	Arvand Petrochemical	Bandar Imam	MEM		
Iran	Chemiabone Company	unknown	MEM		1,000 tpa not yet started.
Iran	Energy Ministry, BIM, SIPFO	Isfahan	---		Plans for 20ktpa
Iran	Energy Ministry, BIM, SIPFO	Tabriz or Qazuin	---		---
Iran	Others (private)	Khorrassan	---		Plan 2 x 3ktpa chlorine

Country	Chlorine Producers with no Capacity in 2006 (shut down, or future projects announced)	Site	Technology	CTC use	Operational Remarks
Jordan	Al-Baha Company of Caustic Chlorine Industry	Al-zarqa	---		Ineos Chlor plant due 2007
Jordan	National Chlorine Industries	Amman	MER	None per WB	MER to membrane.
Morocco	Soc Nat d'Electrolyse et de Petro (SNEP)	Mohammedia	MER	None per UNIDO	MEM to replace MER
Saudi Arabia	Basic Chemical Ind. (BCI)	Dammam	MER		MER replaced by MEM
Saudi Arabia	Jubai Chemical Industries Co (JANA)	Al-Jubail	MEM		New 2007
Saudi Arabia	National Titanium Dioxide Co. (Cristal)	Yanbu	MEM		New 2007
South Africa	National Chemical Products (NCP)	Enstra	MER		Closed 1990s
South Africa	Sasol	Umbogintwini	MEM		Closed March 2001
South Africa	Sasol	Umbogintwini	MER		
Syria	Lead Contracting & Trading	Unknown	MEM	No article 7 imports or baseline	Never built.
Tanzania	Southern Paper Mills	Mufindi	MEM	No article 7 imports, 0.1 ton baseline, minor trade lab use	
Tunisia	Ind Electrochimigue	Dima	D	None per UNIDO	Capacity unknown.
Tunisia	Societe Nationale Tunisienne de Cellulose	Kasserine	MER	None per UNIDO	Closed.
Turkey	Merkim	Izmit	MER	None per UNIDO	
Turkey	Petkim	Aliaga	MER	None per UNIDO	---
Turkey	Tupras	Yarimca-Izmut	MER	None per UNIDO	
UAE	Abu Dhabi National Oil Company - ADNOC	Ruwais, Abu Dhabi	MEM	No article 7 imports or baseline	Project cancelled.
UAE	Abu Dhabi National Oil Company - ADNOC	Umm Al Nar	MER		Closed 2003/4.
Zimbabwe	---	unknown	MEM		
Zimbabwe	BCG	unknown	MEM		Never happened.
Australia	Associated Pulp & Paper	Burnie, TAS	MER & MEM	No Article 7 imports since 2000	Closed October 1998
Australia	Associated Pulp & Paper	Wesley Vale, TAS	MER		Closed.
Australia	Australian Newsprint Mills	Boyer, TAS	MER		Closed
Australia	Australian Paper Mills	Marysvale, VIC	MER		Closed
Australia	Orica	Botany, NSW	MER		Closed 2002
Australia	Orica	Yaraville, VIC	MER		Closed 2002
Australia	Pilbara Project	Pilbara, WA	MEM		750ktpa project - uncertain.
India	Ahmedabad Mfg & Calico Printing	Bombay, MAH	MER		Not operating.
India	Aminex	Khurkumb	MEM		Not operational.
India	Andhra Pradesh Ind. Dev. Corp. Ltd.	---	MEM		31ktpa plant - not built.
India	Andhra Pradesh Ind. Dev. Corp. Ltd.	Nanpada, AP	---		31ktpa - not yet built.
India	Andhra Pradesh Ind. Dev. Corp. Ltd.	Visakhapatnam, AP	---		62ktpa not built.

Country	*Chlorine Producers with no Capacity in 2006 (shut down, or future projects announced)*	*Site*	*Technology*	*CTC use*	*Operational Remarks*
India	Andhra Sugars Ltd	Tanuku, AP	MER		MEM to replace MER
India	Ashok Organic Industries	Bharuch, GUJ	MEM		Not operational.
India	Bihar Caustic & Chemicals	Palamu, BIHAR	MER		---
India	Calico Mills	Ahmedabad, GUY	D		Not operating.
India	Calico Mills	Bombay, MAH	MER		Not operating.
India	Century Rayon	Unknown	MER		Closed.
India	Chemplast Sanmar	Mettur	MEM		---
India	DCW Ltd	Sahupuram, TN	MEM		expansion due 2007/2008
India	Finolex	Ratnagiri	MEM		---
India	G Kumar Lamba	Bharuch, Gujarat	---		31ktpa approved - not built.
India	Haryana Alkalis & Chemicals	Daruchena, HARYANA	---		8ktpa approved - not built.
India	Hindustan Organic Chemicals	Rasayani, MAH	MEM		Closed 2002, re-opened 2007
India	Industrial Prom. Invt. Corp	Gunjam, ORISSA	---		31ktpa approved - not built.
India	Jayshree Chemicals	Gunjam, ORISSA	MEM		---
India	JN Jaju Premier Alkalis	Darubera, HARYANA	---		8ktpa approved - not built.
India	Kadakia Alkalis	Unknown	MEM		Closed.
India	Kothari (Madras) Ltd	Madras, TN	MER		Mercury closed.
India	Mardia Chemicals	Gujarat	MEM		plant closure in June 2004.
India	Narendra Ibhuva	Jafarabad, GUJ	---		31ktpa - not built.
India	Natl. Newsprint Paper Mills	Madhya Pradesh	MER		Not operating.
India	Nepa Mills	Unknown	MER		Not operating.
India	Nirma Limited	Bhavnagar, Gujarat	---		---
India	Orient Paper Mills Ltd	Bajrajnagar, ORISSA	MER		Not operating.
India	Reliance Industries	Hazira	MEM		---
India	Sambhar Salts Ltd	Sambhar, Rajasthan	---		31ktpa approved - not built.
India	Shriram Alkali DCM Chemicals Works	Kota, RAJ	MER		MEM replaced MER 2006
India	Siel	Delhi	D		---
India	Standard Industries	Thana-Balapur, MAH	KOH (MER)		
India	Standard Industries	Thana-Balapur, MAH	MER		
India	Tata Chemicals	Mithapur, GUJ	D		Closed.
India	Travancore Cochin Chemicals	Alwaye, KERALA	MER		---
India	UB Petrochemicals	Visakhapatnam, AP	MEM		Not operational.
India	Vinod Enterprises	Chindwara, MP	---		31ktpa approved - not built.
India	West Bengal Industrial Dev.	Haldia, BENG	---		75ktpa planned - not built.
Indonesia	Basuki Rachmat Perum Kertas	Banyuwangi, Java	MER		Not operating.
Indonesia	Blabak	Yogyakarta	D		Was 1ktpa, not operating
Indonesia	PT Inti Indorayon Utama	Porsea	MEM		Was 34ktpa not operating
Indonesia	PT Perusaan Negra Kertas Letjes	Probolinggo, JAVA	MEM		Not operating.

Country	*Chlorine Producers with no Capacity in 2006 (shut down, or future projects announced)*	*Site*	*Technology*	*CTC use*	*Operational Remarks*
Indonesia	PT Perusaan Negra Kertas Letjes	unknown	D		Not operating.
Indonesia	PT Soda Industries	Surabaya, Java	MER		---
Indonesia	Sulfindo	Cilegon	MER		Converted mid-1998.
Malaysia	Chemical Co of Malaysia Berhad	Selangor, JAYA	MEM	None per WB	Closed 1987.
Malaysia	Petronas / CCM	Kerteh	MEM	None per WB	Project cancelled.
Myanmar	Myanmar Paper & Chemical Industries	Sittoung	---	No CTC use since 2000, no baseline	
Pakistan	Adamjee Paper Board Mills	Nowshera	D	During 2006 evaluation Mission Pakistan, contact with some chlorine producers and evidence of quota certificates for approved users. We are quite confident no CTC use in this application. Closed.	
Pakistan	Bela Chemicals	Bela	MEM		Closed.
Pakistan	Engro Polymer Chemicals	Port Qasim, Karachi	---		Project planned for 2010
Pakistan	Pakistan PVC	Gharo	MER		Closed.
Pakistan	Ravi Alkali	Lahore	MEM		Closed.
Philippines	Superior Gas & Equipment	Manila	MER		Closed.
Sri Lanka	Paranthan Chem Corp	Paranthan	MER		Closed 1984
Thailand	Ajinimoto	Phrapradeang	D		Not operating - mothballed.
Thailand	Thai Asahi Caustic Soda	Samut Prakan	MER		---
Thailand	TPI	Unknown	MEM		Never happened.
Japan	Ajinimoto	Kawasaki	D	NOU (METI) confirms NO use of CTC in this industry in Japan.	Closed mid-1996.
Japan	Ajinimoto	Kawasaki	MEM		Closed mid-1996.
Japan	Asahi Glass	Kansai	MEM		Closed 2000.
Japan	Asahi Glass	Kashima	D		Conversion to MEM mid 98.
Japan	Asahi Glass	Kitakyushu, Fukuoka	D		Closed.
Japan	Chiba Denkai	Chiba	MEM		Closed 1998.
Japan	Chiba Enso	Chiba	D		Closed.
Japan	Daiso (Osaka Soda)	Amagasaki	D & MEM		---
Japan	Daiso (Osaka Soda)	Amagasaki	KOH (MEM)		
Japan	Daiso (Osaka Soda)	Matsuyama	D & MEM		---
Japan	Hodogaya Chemical	Kohriyama	MEM		Closed 1998.
Japan	Hokkaido Soda	Hokkaido	D & MEM		Closed 1994.
Japan	Hokkaido Soda	Hokkaido	MEM		Closed 1994.
Japan	Kansai Kuroru Arukari	Osaka	MEM		May be closed.
Japan	Kureha Chemical	Nishiki	D		Closed 1998
Japan	Mitsui Chemicals Inc	Nagoya	D & MEM		Moved to Omuta 1999.

Country	***Chlorine Producers with no Capacity in 2006*** *(shut down, or future projects announced)*	***Site***	***Technology***	***CTC use***	***Operational Remarks***
Japan	Mitsui Chemicals Inc	Omuta	D & MEM		---
Japan	Nankai Chemical	Tosa	D		Closed 1994.
Japan	Nippon Carbide	Oozu	MEM		May be closed.
Japan	Nippon Soda	Nihongi	D		Diaphragm closed.
Japan	Sanyo-Kokusaku Pulp	Iwakuni	D		Diaphragm closed.
Japan	Showa Denko	Yokohama	D		Diaphragm closed.
Japan	Sumitomo Chemical	Kikumoto	D		Diaphragm closed.
Japan	Sumitomo Chemical	Ohita	MEM		---
Japan	Tosoh Corporation	Nanyo	D		---
Japan	Tosoh Corporation	Yokkaichi	D		Diaphragm closed.
Japan	Tsurumi Soda	Tsurumi	D		Diaphragm closed.
South Korea	Hanwha Chemical Corporation	Yeosu	D		Closed - converted to MEM.
South Korea	Kokudo Chemical Industry	Seoul	MEM		Closed
South Korea	Kumho Petrochemical	unknown	---		34ktpa - never happened.
South Korea	Paik Kwang Pharmaceutical Company	Seoul	MER		---
Taiwan	Cheng Tai	Taipei	MER		---
Taiwan	China Gulf Plastics	Toufen	MER		
Taiwan	Chinese Petrochemical Development Corp.	Chien-Chen	MEM		Scrapped April/May 1988.
Taiwan	Chinese Petrochemical Development Corp.	Lin Yuan, Kaohsiung	MEM		---
Taiwan	Formosa Plastics Corporation	Kaohsiung	MER		---
Taiwan	Hong Chang	Yunlin	D		Strong possibility to close.
China	Nanchang Pesticide Plant	Unknown	---		---
China, Fujian	Xiamen Electrochemical	Xiamen	D		
China, Gansu	Blue Star Cleaning Co Ltd	Lanzhou	MEM		---
China, Hainan	Haikou no. 2 Chemical Plant	Haikou	---		Scrapped in 1994.
China, Hebei	Shijiazhuang Light Industries	Hebei	MEM		50 ktpa plan shelved
China, Hebei	Tangshan Sanyou Chemical	Tangshan Sanyou	MEM		---
China, Hebei	Xingtai No.1 Chemical Industrial	Xingtai	---		Possibly shutdown from 2001
China, Henan	Henan Shenma Chlor-Alkali	Pingdingshan	MEM		On stream mid 2007
China, Henan	Pingdingshan Huiyuan Chlor-alkali	Pingdingshan	MEM		On stream 2007
China, Hubei	Hubei Chuxing Chemical Industrial	Yidu	---		Idled.
China, Hubei	Wuhan Chemning Hanyang Paper & Pulp	Wuhan	---		Possibly idled from 2001.
China, Hubei	Xiangfan Oil	Xiangfan	---		Idled before 1999.
China, Hubei	Xiangfan Xinli Chlor-Alkali	Xiangfan	D		
China, Jiangsu	Jiangsu Sopo	Zhenjiang	MEM		
China, Jiangsu	Jurong Baohua Fine Chemical	Jurong	---		Possibly idled from 2002.
China, Jiangsu	Nanjing Electrochemical	Nanjing	D		Possibly idled from 2002.
China, Jiangsu	Nanjing Electrochemical No.3	Nanjing	D		Possibly idled from 2002.

Country	Chlorine Producers with no Capacity in 2006 (shut down, or future projects announced)	Site	Technology	CTC use	Operational Remarks
China, Jiangsu	Nanjing Jinyan Chemical	Nanjing	---		Possibly idled from 2001.
China, Jiangsu	Nantong Resin	Jiangshan	---		Possibly idled from 2000.
China, Jiangsu	Shuangshi (Zhangjiagang) Fine Chemical	Zhangjiagang	MEM		---
China, Jiangxi	Xinghuo Chemical	Nanchang	D		Possibly idled form 2001.
China, Jilin	Siping Haohua Chemical	Siping	MEM		
China, Liaoning	Liaoning Tieling	Tieling	---		Possibly idled from 2000.
China, Liaoning	Shenyang Yong Xin	Shenyang	MEM		---
China, Nei Mongol	Chenhongli Group Hongli Chemical	Wusitai	---		
China, Nei Mongol	China Salt Jilantai Salt & Chemical	Wusitai	MEM		---
China, Nei Mongol	Neimeng Li'er Chemical	Wuhai	---		---
China, Nei Mongol	Wulateqianqi Linhai Chemical	Wulateqianqi	MEM		---
China, Nei Mongol	Yili Chemistry	Erdos	---		
China, Nei Mongol	Zhonghua Sanlian Chemical	Hohhot	MEM		80kt late 2007, +40kt soon
China, Ningxia	Ningxia Baota Petrochemical	Lingwu	MEM		---
China, Ningxia	Ningxia Meili Paper Industry	Ningxia	MEM		---
China, Ningxia	Ningxia Yinglite	Shizuishan	MEM		---
China, Ningxia	Ningxia Yinglite	Shizuishan	MEM		---
China, Ningxia	Ningxia Yinglite	Shizuishan	MEM		
China, Shaanxi	Dow/Shenshua JV	Shaanxi	---		---
China, Shaanxi	Shaanxi Tianqiao Huanbohai Chemical Ind	Yulin	MEM		---
China, Shandong	Binzhou Ocean Chemical	Binzhou	MEM		
China, Shandong	Dongming Wanhai Chlor-alkali	Dongming, Heze	MEM		---
China, Shandong	Dongying Huatai Chemical Group	Dongying	MEM		Add 500ktpa 2009
China, Shandong	Shandong Hengtong Chemical Industrial	Yancheng	MEM		---
China, Shandong	Shandong Luneng Group	Ningxia	---		---
China, Shandong	Shandong Shen Chemical Industrial	Zibo	Sodium		---
China, Shandong	Shandong Yizhou Cement Group	Yizhou	MEM		---
China, Shanghai	Bayer	Caojing	HCl to Chlorine		
China, Shanghai	Shanghai Tianyuan Chemical	Shanghai	D & MEM	No CTC (stopped)	Moved to SCAC before 2001
China, Shanxi	Lu'an Mining	Changzhi	MEM		---
China, Sichuan	---	Suining	MEM		
China, Sichuan	Sichuan Guifeng Organic Silicon Materials	Luzhou	---		---
China, Sichuan	Sichuan Shengda Chemicals	Leshan	MEM		---
China, Tianjin	LG Bohai Chemical	Tianjin	MEM		---

ANNEX 2 - CTC PHASE OUT QUESTIONNAIRE SAMPLE

EXAMPLE OF LETTER AND QUESTIONNAIRE SENT TO RESPONDENTS

petrochemicals marketing and planning consulting services

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CONFIDENTIAL

Dear Industry Colleague

Carbon Tetrachloride (CTC) use in the Chlor-Alkali Industry -
Management of Potential Nitrogen Trichloride (NCl_3) Build-up

REQUEST FOR INFORMATION - WORLD BANK COMMISSIONED STUDY

Tecnon OrbiChem, an independent global chemicals consultancy, has been engaged by the World Bank to conduct a world study into the chlor-alkali industry's use of carbon tetrachloride. The Study, supported by funding granted by the Executive Committee to the Montreal Protocol, has the objective of identifying various economic means to eliminate, or control the use of, CTC in the chlor-alkali industry. Your assistance in this process is kindly requested, and the background is set out below.

Carbon tetrachloride – CTC -- has been, and to some extent remains, a very useful industrial solvent and process aid, especially in the manufacture of chlorine and chlorinated compounds. However, in the context of the Montreal Protocol on Substances that Deplete the Ozone Layer, CTC is regarded as having a high Ozone Depletion Potential (ODP =1.1) and has therefore been subject to phase-down and phase-out schedules in both developed and developing countries. It should be noted that the Montreal Protocol does not regulate CTC's use as a chemical intermediate, whereby the CTC is transformed into another chemical compound.

In the *Developed Economies* – the Article 2 nations in the Montreal Protocol – the final phase-out date for CTC as an emissive product was 1996. However, there are certain exemptions, either where substitution of CTC would create a greater danger than retaining its use, or where the emissions of CTC to the atmosphere can be demonstrated to be at minimal levels, generally regarded as meaning that more than 98-99% of the input is being contained and destroyed. It is believed that some chlorine-manufacturing companies both in the USA and in Europe continue to use CTC in chlor-alkali production under these derogations.

In the *Developing Economies* – the Article 5 nations in the Montreal Protocol – the final phase-out date will be 2010, with an 85% phase-down stage having been reached in 2005. The baseline for this was taken as average consumption in the period 1997-1999. However some confusion over which are the permitted and which are the controlled uses for CTC have led to a potential inconsistency in the application of local regulations.

The World Bank has been requested by the Executive Committee to the Montreal Protocol to commission a Study that identifies both the extent of CTC's use in the chlorine industry and, notably, the management and control of explosive nitrogen trichloride build-up. Ammonium ions or organic nitrogen potentially contained in the brine are converted into NCl_3 during electrolysis. If liquid NCl_3 then concentrates in downstream processes, it may explode. CTC, used as a diluent for NCl_3, has been one of the control methods incorporated to eliminate this build-up.

This Study also seeks to establish what technologies chlor-alkali companies have used to substitute CTC or to reduce its emissions, and to provide details of the investments and operating costs that are incurred by product or technology substitution.

Tecnon OrbiChem was selected by the World Bank as the consultancy to conduct this Study. Our lead consultants for this study are **David Sherry and John Wilkinson**, who have each worked extensively both in the chlorine industry and as consultants to the Montreal Protocol process, and **Janet Wright**, who is Business Manager, Chlor-Alkali, at Tecnon OrbiChem.

The global chlorine industry is known both for its willingness to provide relevant data as well as for its whole-hearted support for environmental improvement. We therefore cordially request your support, whether as an industry association, an individual company, a technology supplier, or a Montreal Protocol Implementing Agency, to assist us in quantifying the overall extent of CTC use in the chlor-alkali industry. Your active support will also help us develop the alternative products and processes to CTC, with their associated economics, so that CTC's use can be eliminated, or at least that its emissions are dramatically reduced, according to the Schedules of the Montreal Protocol.

Some of our basic questions are provided in Annex 2.

If you require further confirmation or have any questions, please contact David Sherry at dsherry@wanadoo.fr, or John Wilkinson at wilkinsonj@cox.net. You are also welcome to contact World Bank directly for confirmation of the content and purpose of the Study, and the role of Tecnon OrbiChem.

In the meantime thank you in advance for your assistance and support for this important Study.

Yours sincerely,

David Sherry (Project Leader)

Direct Tel: +33 494 19 89 66

Questionnaire Enclosure:

Questions re CTC use in the Chlorine Industry - World Bank Study

In all cases, if you would prefer to discuss this directly rather than respond by a hard copy of the questionnaire, we will be happy to receive your contact details and discuss by personal visit, or by teleconference.

Chlorine producers, via Industry Associations and direct

It should be noted that chlorine-producing companies that are operating in Article 5 countries and that are still using CTC may be entitled to receive Montreal Protocol funding to assist in its substitution or the containment of its emissions. This cannot be guaranteed within the context of this Study, and each case would have to be individually evaluated. Funding may also be possible for retroactive conversions that have taken place since 2000.

Since 1987 **do you currently, or have you used, CTC in the production of chlorine as a means of eliminating NCl_3 build-up**?

Do you/have you used CTC to manage NCl_3? Yes / No (*delete as required)*

Please state if this is current, or the year the use of CTC was stopped ______

Note: CTC is also used as a means of absorbing chlorine from tail gas streams: we would be interested in this too, but only quantitatively.

Yes, we use/have used, CTC to absorb chlorine from tail gas streams________ Yes

Amount of CTC used per year ________________ (Tonnes)

If "yes", please **state the name of your company and the plant location where CTC is**/was used, together with the nameplate chlorine capacity. Would you agree to allow us to refer to your company by name?

Company Name ____

Plant Location:

Plant Site ____

County/District ____

Country ____

Nameplate Chlorine Capacity_________________________(Tonnes)

Authorisation to refer to our Company by Name: Yes / No (*delete as required)*

Do you continue to use (purchase) CTC? Yes / No (*delete as required)*

If yes, how much is used on an annual basis? _______________ (Tonnes)

Who is your current supplier? ____________________ (Supplier or country)

If you continue to use (purchase) **CTC how do you dispose of the used product**?

We dispose of CTC by____

____

____

____

If you continue to use CTC on the basis of virtually zero emissions, would you be willing to discuss the means and the costs of containment? (*We would then contact you)*

Yes / No (*delete as required)*

What **alternatives to CTC** have you considered? Please advise the basis on which you have rejected the alternatives? Will you at some stage revisit this?

CTC Alternatives we have considered

____

Why were alternatives rejected?

____

Will you review the situation again?Yes / No (*delete as required)*

If yes, what will trigger this review?

____

If, since 1987, you have **discontinued the use of CTC for NCl_3 management**, or have invested in **tight emission controls** and/or **CTC destruction technology**, please advise the alternatives that you selected (and those that you rejected). What were the capital and operating costs of conversion away from CTC?

NCl_3 management alternatives now used

1. ____

2. ____

Emission controls and/or CTC destruction technology reviewed________________

____

____

____

Capital costs of conversion away from CTC:

Currency ______________________

Total Capital/Investment Cost ____________________________

Operating costs of conversion away from CTC:

Total Operating Cost __________________________________

In order to build up a complete picture of the technology options and costs, it is possible that we may have some supplementary questions to ask. Thank you for your understanding.

CTC Producers, via Industry Associations and direct

As a CTC producer, **are you aware of any of your customers in domestic or export markets that use CTC as a process agent in the manufacture of chlorine?**

(Note: as Montreal Protocol signatories generally are required to operate a licence system to enable users to import and use Ozone Depleting Substances, this is not normally confidential information. Are you able to say categorically that no such use exists in your domestic market?

Customers that use CTC for chlorine ______________________________________

Location (plant/town/country) ______________________

Or, confirm there is no such CTC use in my domestic market ______________(Yes)

TASK 3: REVIEW OF CONVERSION PROJECTS

We received comments at the interim report stage that some more detail on the companies would be desirable. It must be pointed out that the present study is conducted under a purely commercial-technical aegis. There has been no obligation for companies to provide data, since it has not fallen under any kind of governmental requirement. Indeed in many cases we have had to explain exactly what is the Montreal Protocol, what is its role in CTC management, and what role the World Bank plays in the process. In short, the companies concerned have voluntarily provided the information provided in the case studies that follow, and we are obliged to accept their requirements for both confidentiality as well as the broad, rather than detailed, description of process.

It should be noted that a number of plants that technically fall into this category have actually discontinued chlorine production totally.

CASE A:

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

This chlorine plant was established in the 1960s and had approximately 120 ktpa diaphragm based chlorine nameplate capacity feeding associated captive derivative units as well as fenceline customers. The quality of chlorine required for the downstream operations required a purification process linked to liquefaction.

The company was a producer of chloromethanes and therefore had captive CTC. The compressor type has not been disclosed. After the compression (at around 3.5 bar) the total chlorine stream was absorbed in CTC. Only the chlorine was absorbed. The inerts, such as nitrogen, oxygen, hydrogen, and CO2 were only very marginally absorbed. The CTC-Cl2 mixture was distilled and the purge chlorine gas was condensed and delivered to customers. Gaseous CTC was incinerated in the incinerator of the chloromethanes unit. The incineration unit of the chloromethanes plant was kept running after the CM plant closure. The HCL from the incinerator was reworked to sales specification.

Before the compression step, the chlorine gas was cooled in the pre-cooler with liquid chlorine in a distillation column. This was done to remove impurities such as NCl_3. The top of this distillation was pure chlorine gas with the inerts, which went to the compression and absorption in CTC as described above. The bottom of the distillation contained Cl2 and the impurities, diluted with CTC to reach a low NCl_3 concentration. This liquid was thermally treated to destroy the NCl_3 and to evaporate other impurities and chlorine. The NCl_3 destruction is a closed system with off gas to the chlorine destruction. Possible incidental emissions from (de)coupling of the tetra destruction vessels are not known. The liquid CTC residue was incinerated by approved destruction methods off-site.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

Chlorine production is rated at close to capacity at around 110 ktpa for the old plant. The plant was closed because the main consuming unit, a chloromethanes plant that required pure chlorine delivery, was closed in 2003/4. In 2005, a new membrane-based plant was opened on the site to feed a new monochloroacetic acid palnt. Since 2003 CTC has not been used at all. Diffusive emissions were estimated, not measured, from chloromethanes production, and the compression liquefaction plant of the previous diaphragm unit, and other emissions were done by mass balance based on the fact that the incinerator was on-stream for 96-98% of available time. The emissions from this plant form part of the overall European mass balance.

Detailed description of methodology or technology used to achieve the phaseout of CTC and of new production processes

The change of technology at this site, from diaphragm to membrane, in 2005, as well as the changed profile of derivatives, has meant that there is no need to pre-cool the chlorine and that therefore there is no NCl_3 collection.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

Not relevant

Percent of NCl_3 in final chlorine product and related safety considerations

Within all acceptable limits.

Duration and cost of conversion project (cost effectiveness ratios will be provided)

Not relevant. The technology of the chlorine plant was changed for diverse reasons including a change in the profile of the site derivatives and some governmental directives on chlorine production and transport: some European subsidies were also part of the equation. Asbestos-based diaphragm technology has been challenged in Europe and is due for phase-out except under mitigating circumstances. The use of CTC in chlorine production was not in any way a factor in the technology switch.

Post Conversion Issues And Solutions

None. (This is not a conversion: the technology of the chlorine production was changed and the new derivative profile means that NCl_3 is not an issue)

CASE B

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

The site on which the chlorine plant is located started chlorine production in 1960 but in 1983 a new membrane-based unit was constructed and in 1984 the old plant was dismantled. The nameplate capacity of the membrane plant has been progressively expanded, presently standing in excess of 600 ktpa. The chlorine is all used by pipeline to feed on- and off-site consumers. There is an on-site incinerator to destroy all liquid and gaseous vent streams that originate from site and off-site operations. The compressor type has not been disclosed.

The use of CTC at this plant was to dilute the chlorine-NCl_3 mixture in the bottom of the pre-cooler. The NCl_3 could come from all kind of sources, such as NH3/NH4 in water (steam), nitrogen components in salt etc. It should be noted that as a membrane-technology plant, vacuum quality salt is generally preferred and that this must in any event be pre-treated to eliminate various impurities: this is standard to all membrane plants. The anti-caking agent on the salt was only one of the possible sources, and was not the most likely source because the anti-caking agent was already destroyed in the special treatment in the brine loop. This plant seems to be unique in employing an NaOcl treatment loop as part of the brine processing. In any case, the ferrocyanide anti-caking agent is no longer contained in the quality of salt used at this plant. The CTC residues from the NCl_3 decomposition was treated in the on site incinerator. The NCl_3 destruction unit was closed, with off gas being sent to the incinerator. Possible emissions linked to operations around the destruction unit were not measured specifically.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

This plant, which began operations with around 250 ktpa nameplate capacity in 1984, has been progressively expanded and was operating at just over 500 ktpa of production in the period 2000-2004, and has been subsequently increased to a capacity that would suggest some 600 ktpa annual output since 2005. The make-up quantities of CTC to this plant, and the eventual emissions, are reported as part of the overall European volumes. Since 2005 there has been zero consumption of CTC.

Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes

The company has thus far commented that it still operates an NCl_3 collection system at the bottom of the pre-cooler. It is less than previously because they removed several trays in the pre-cooler with a result that the up-concentration takes place less. The NCl_3 is removed from the bottom of the pre-cooler on a regular basis by dissolving it in chlorine and heating the liquid chlorine to the point of destruction. For this process step a change in the process was necessary. This is now a batch process whereby periodic charging of the chlorine liquid to a heating vessel is required.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

The main changes were associated with additional capacity being brought on-stream.

Percent of NCl_3 in final chlorine product and related safety considerations

Within all required limits.

Duration and cost of conversion project

This is not really a conversion project. However the cost to construct a chlorine heating vessel, with associated evaporation and collection equipment, is estimated at some €400-600k.

Post conversion issues and solutions

None

CASE C

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

Chlorine has been produced at this site since 1925. A new plant was constructed in 1970. Vacuum salt was used as the feedstock to the plant. The plant was equipped with a pre-cooler with 2 functions:

a) Between 1970 and 1975 the plant used graphite anodes, which produced small amounts of carbon tetrachloride (CTC) along with the chlorine. CTC was washed out in the pre-cooler into a reboiler for disposal. Produced chlorine was sold as product. In 1975 the plant installed titanium anodes, which eliminated any further co-production of CTC. The awareness of NCl_3 was not high at that time and very few analyses were taken.

b) The plant was equipped with a three stage turbo compressor. There was no cooling between the first and the second stage. In order to prevent a potential chlorine–iron fire out from the second stage the temperature in to the first stage was held low to approximately –30 degrees centigrade. This low temp was achieved when the produced chlorine gas was washed with liquid chlorine in the pre-cooler

The pre-cooler was a tower with 4 bubble cap trays, the inlet of the produced chlorine entered under the 4 trays and the outlet of chlorine gas entered above the 4 trays. (a diagram is provided)

The bottom of the tower was a sump for liquid chlorine. In this sump there was a coil, which acted as a reboiler. Liquid chlorine was lead through this coil and up to the tray at the top.

The produced chlorine gas had a low NCl_3 concentration (1 to 4 ppm). In the pre-cooler there was equilibrium so the NCl_3 concentration dissolved in the liquid chlorine in the sump was approx 1000 times higher. No NCl_3 was eliminated so the NCl_3 concentration out from the pre-cooler was also 1 to 4 ppm. The product liquid chlorine was sold with an NCl_3 concentration of approximately 5 ppm.

At the maintenance shops (once or twice a year) the pre-cooler sump contents were dumped into two tanks underneath the pre-cooler containing CTC. The contents of the tanks were drummed and transported to an authorized company for destruction. The total consumption of CTC was <0.5 ton/year.

Perchloroethylene (PCE) was used in place of CTC after the phase-out of CTC in 1998 (note: the plant had a derogation to use CTC for two years after the 1996 phase-out). Plant practices remained the same regarding the disposal of the mixture of PCE and NCl_3. The total consumption of PCE was <0.5 ton/year.

The plant shut down production in September 2005.

<u>Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)</u>

This plant had been operating in the range of 70-90ktpa chlorine output prior to and post conversion to non-CTC technology. The demand of CTC (make-up) was stated by the Naturvardsverket (Environmental Agency) in communication to the UNEP at Nairobi (August 2001) to be some 2000kg/a of CTC which already by 1997 had decreased to some 250 kg/a. The consumption of CTC post conversion to an alternative solvent was zero.

<u>Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes</u>

In 1998 the company switched from the use of 250 kg/a CTC to using perchloroethylene as the solvent medium to manage NCl_3 in the precoolers. Perchloroethylene (PCE) is not an ODS. This product was used in the same process at approximately the same volumes and with approximately the same unit purchase cost until 2005, when the plant was closed.

<u>Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)</u>

Around 50% of one man-year (engineering)

<u>Percent of NCl_3 in final chlorine product and related safety considerations</u>

Around 5 ppm

Duration and cost of conversion project

None, change of solvent only

Post conversion issues and solutions

None

CASE D

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

The chlor-alkali plant was constructed in 1969. Vacuum salt is used as the feedstock to the plant. The plant contains 64 mercury cells producing 13.55 MT/hour or 115,000 MT/year and in addition chlorine was purchased from outside to meet overall EDC production needs.. The plant nameplate capacity is 120,000 MT/year. Produced chlorine is transferred directly to the ethylene dichloride unit as a feedstock to make ethylene dichloride (EDC). This company used a cooling and washing tower where liquid chlorine was fed to the top of the tower and liquid chlorine at the bottom. The tower had 5 or 6 bubble cap trays. Chlorine gas along with other impurities such as NCl_3 entered the bottom of the tower. The NCl_3, dissolved in liquid chlorine, was purged into a tank underneath the tower containing CTC. Also, CTC was periodically pumped into the tower to clean any remaining NCl_3. The total consumption of CTC was 2-3 ton/year. The solution of CTC/NCl_3 was incinerated on site in the VCM plant.

85% of the chlorine gas was transferred directly to the ChlorVinyl plant and 15% of the chlorine produced was liquefied and pumped via a storage tank to the VCM plant.

This plant converted from CTC use in 1995-6. Emissions were not specifically measured.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

The plant produces 13.55 MT/hour or 115,000 MT/year. The amount of CTC use phased out was as mentioned around 2500kg/a. The phase-out was due to national legislation, which banned the use of ozone depleting substances.

Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes

With the phase-out of CTC as a solvent for the extraction of NCl_3 from liquid chlorine required the application of new technology to deal with NCl_3. Since NCl_3 has an explosive potential, care had to be taken to install new technology that would be dependable. The plant process of scrubbing chlorine gas (4 – 5 ppm NCl_3) with liquid chlorine in a column up stream of the compressor was changed to a co-flow mixing tube desuperheater purchased from Sulzer Chemtec. The desuperheater avoids the collection of liquid chlorine and hence, no accumulation of NCl_3 is possible.

Traces of NCl_3 are detected in the liquid chlorine that goes as feedstock to the DCM plant and is consumed.

A schema is provided in Annex 9 below.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

Cost for conversion to the non-CTC technology was 3.5 million SEK or approximately $585,000 (today US$). The instillation of the desuperheater unit did not increase the price of chlorine.

Percent of NCl_3 in final chlorine product and related safety considerations

4-5 ppm NCl_3

Duration and cost of conversion project

Duration not known. The cost at the time was reported at around US$320k converting the local currency to historic dollars.

Post conversion issues and solutions

None

CASE E (THE COMPANY CAN BE IDENTIFIED AS PRODESAL, COLOMBIA)

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

The information in this review is essentially based on a document kindly provided by UNDP, and used with their permission, entitled "47th Meeting of the ExCom of the Multilateral Fund for the Implementation of the Montreal Protocol".

Prodesal S.A. began production in 1989. It is one of two chlorine producers in Colombia. The other, Refisal was formerly state-owned. Refisal does not operate its plants using CTC. Prodesal also produces caustic soda, sodium hypochlorite, hydrochloric acid and salt. The capacity is currently some 23 ktpa using ICI's (now Ineos) FM21 membrane technology. The plant is currently equipped with 3 reciprocating (piston) compressors.

After cooling, filtration and drying, chlorine gas is chilled to minus 35 degrees centigrade. In the process of cooling the gas, liquid chlorine condenses trace amounts of other compounds, among which are NCl_3. Most of the liquid chlorine is evaporated in the chilling process. However; the remaining liquid, entraining condensed NCl_3, flows into the stripping section. CTC is added to the stripper and a mixture of liquid chlorine, CTC and NCl_3 subsequently flows into the reboiler. NCl_3 is destroyed at a controlled rate in the reboiler, where temperature ranges from 40 to 60 degrees centigrade. Approximately 99.9% of NCl_3 present in the chlorine stream is destroyed in the reboiler, after scrubbing. The remaining NCl_3 is removed during liquefaction as temperature increases caused by compression of chlorine gas lead to thermal decomposition of NCl_3 at temperatures between 95 – 100 degrees centigrade. The produced chlorine is NCl_3 free at this point.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

The annual consumption of CTC at Prodesal has trended down from 12.77 ODP tons in 1994 (the peak year in the period) to 2.05 ODP tons in 2004. In 1995 Prodesal S.A. had an NCl_3 explosion in their plant. Following this NCl_3 management practices were rigorously reviewed and the CTC consumption fell to a range over just over 3 ODP tons to just under 1 ODP ton. The chlorine output is not known but there was a small capacity expansion in 2005/6 indicating a high level of capacity utilisation. The CTC utilisation reflects the drainage and replacement of CTC in the system. This CTC, in the absence of on-site or indeed national incineration capacity, was simply vented to the atmosphere, so that consumption (make-up) and emissions are virtually equivalent.

<u>Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes</u>

Prodesal S.A. considered three non-CTC alternative technologies. None of these has been implemented as yet, the plan is to achieve transformation to chloroform by 2009. The overview of the options is as follows:

1.) Equipment replacement of the three reciprocating compressors with centrifugal compressors. This influences the pressure and temperature of the liquefaction. The cost would be $2,453,740 (2005).
2.) Substitute CTC with chloroform in the stripping NCl_3 from chlorine gas. It is expected that some of the chloroform would be converted to CTC. Therefore, the reboiler solution would need to be destroyed via incineration. The overall cost would be $510,740.
3.) Substituting CTC by an alkali (NaOH) solution. An alkali absorption/neutralisation reactor would replace the current stripping unit, where NCl_3 is decomposed to nitrogen and chlorine at a controlled rate. Chlorine reacts with NaOH to form sodium hypochlorite (NaClO). The cost would be $422,400.

The more detailed review, as presented by World Bank in 2005, is as follows: there has been some marginal editing

Alternative 1 – Equipment replacement

1. The first alternative to eliminating the use of CTC by *Prodesal S.A.* involves replacing the compressors that control both the pressure and temperature of chlorine gas during the liquefaction process. The plant is currently equipped with three reciprocating (piston) compressors. The range of pressures and resulting temperatures obtained by using this type of compressors (e.g. 95 to 100°C) ensure that any traces of NCl_3 remaining after the scrubbing process are removed from the final liquid chlorine produced.

2. Centrifugal compressors could be used instead of reciprocating compressors. The former operate at lower pressures, and therefore do not require a pre-cooling process. The scrubbing step would therefore be omitted from the chlorine purification process, and CTC would no longer be used. Instead, cooled chlorine gas would be fed directly into the centrifuge compressors for liquefaction, together with NCl_3. However, since discharging temperatures from centrifugal compressors would only reach approximately 60°C, only a fraction of the NCl_3 would decompose during compression.

3. Given the changes in operating temperatures and pressures resulting from a change to centrifuge compressor technology, extensive modifications to the existing equipment of the plant would also be required. Changes would not only involve the purchase of new compressors, but would also require changes in electronic control systems, as well as new liquefaction system and a new filling system that can operated under the new range of pressures.

Alternative 2 – Conversion to chloroform

1. The second alternative to eliminate the use of CTC by Prodesal S.A. involves the use of chloroform as a substitute to CTC in the stripping of NCl_3 from chlorine gas. Chloroform has been singled out by the 2001 TEAP Process Agent Task Force report as the only non-ODS compound with similar properties to those of CTC. However, chloroform may react with chlorine during the removal of NCl_3 to be ultimately converted to CTC. Few plants have made this transition but the technology provider associated with the change

informed that in specific operating conditions, an 11% conversion had been noted. It is not known if this is typical, high or low.

2. Operating conditions must therefore be carefully monitored to reduce, as much as possible, the conversion from chloroform to CTC. In order for this conversion to actually result in the phaseout of CTC use by *Prodesal S.A.*, all the CTC that is generated as by-product of the extraction of NCl_3 with chloroform must be collected and destroyed. Since there are no destruction facilities that can handle chlorinated compounds in Colombia, all CTC produced must be packaged and exported to a waste disposal facility abroad.

3. The specific conditions for conversion from chloroform to CTC (i.e. temperature, pressure, concentration, etc.) are currently not known. A detailed analysis of the plant operating conditions and some lab tests needs to be conducted in order to determine the conditions under which the conversion from chloroform to CTC would be effectively restrained. Significant changes of equipment will probably not be required, but can only be determined by the analysis. It is known, however, that the use of chloroform significantly increases both the pressure of operation and the potential corrosivity of the equipment used. Therefore the specific technology provider recommends the use of Hastelloy steel.

4. The compressors currently being used at *Prodesal S.A.* are less than 15 years old, and have not yet reached half of their expected operating lifetime. (2005 statement) Therefore, if alternative 2 is selected, disposal of CTC generated from the use of chloroform would need to be carried out for at least 15 years after conversion of the plant takes place. The maximum annual volume of CTC that would need to be disposed is equal to 1.5 tons, using historical CTC consumption figures for the plant and assuming that all chloroform converts to CTC, which has not been demonstrated.

Alternative 3 – Substituting CTC by alkali solution

1. The third option to eliminate the use of CTC for removal of nitrogen trichloride from chlorine production at *Prodesal S.A.* involves the thermal decomposition and chemical destruction of NCl_3 by using caustic soda solution. This alternative can be linked to the commercial hypochlorite production system at *Prodesal S.A*.

2. This alternative applies caustic soda (NaOH) solution instead of CTC to treat the remaining chlorine liquid, entraining condensed NCl_3 discharged from the purification unit. An alkali absorption/neutralisation reactor, where NCl_3 is decomposed to nitrogen and chlorine at a controlled rate, and chlorine reacts with NaOH to form sodium hypochlorite, would replace the stripping section. The disposed alkali solution containing by-product NaOCl would be further sent to a hypochlorite system for commercial product of sodium hypochlorite, or discharged into the plant wastewater treatment system for safety disposal.

3. This non-ODS technology of using alkali solution to eliminate NCl_3 in manufacture of chlorine has been commercialised in China chlor-alkali industry for more than 30 years and, therefore, is a technically mature and reliable alternative. As *Prodesal S.A.* already has a hypochlorite production system that receives chlorine gas from filtration and liquefaction operations (tail gas) to produce sodium hypochlorite, this alternative provides additional benefits. In fact, the process of removing NCl_3 can be linked with the existing hypochlorite system to treat waste alkali solution for sodium hypochlorite production, thereby reducing the amount of effluent treatment required.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

Alternative 1. (Equipment change)

1. A change of compressors will result in considerable incremental operational costs relative to the technology currently in use. First of all, installation of the new equipment would require a halt in production for an estimated period of three months. Limited production capacity would be expected for two months after start-up of the new compressors, while staff is trained and while all pertinent quality controls are performed.

2. With new compressors, *Prodesal S.A.* would need to make additional arrangements to dispose of NCl_3-enriched chlorine residue that will accumulate in the system during plant operations. All equipment will need to be washed periodically with caustic soda solution in order to remove any residual NCl_3 that may cause explosions. Accordingly, strict monitoring during plant operations will need to be enhanced to ensure that the concentration of NCl_3 in any part of the system, especially liquefaction and storage assemblies, remains within the safety limit.

Finally, *Prodesal S.A.* will be required to collect and dispose of the potentially explosive chlorine residues that accumulate in client cylinders and containers. The same procedure of washing cylinders with caustic soda solution will need to be followed[1].

Alternative 2. (Change to chloroform)

The conversion from CTC to chloroform will involve changes in operational procedures, and therefore training of personnel. A limited production capacity of the plant for an estimated period of two months after start-up of the new facilities should be expected while all staff is trained and quality control checks are performed. Once production with chloroform is underway, the operational costs to *Prodesal S.A.* plant would not be significantly affected form the change in process agents, as the price of CTC and that of chloroform are comparable.

Alternative 3. (Change to caustic soda)

1. Similar to alternative 1, the equipment substitution component of this proposed activity would involve a halt in production for an estimated period of two months while installing the new facility. Additionally, a limited production capacity of two months would be expected for starting up the new facility while staff is trained and related quality controls are performed.

2. On the basis of estimations, under standard conditions of operation, the required amount of alkali solution needed for removal of NCl_3 would be 18-20 times higher than that of CTC. However, the disposed caustic soda solution can be recovered for commercial production of sodium hypochlorite. Therefore, once the substitute technology is put in place, operation costs would be still comparable to those of the CTC-based process. Converting to the alkali technology would therefore generate no significant impact on operation costs.

Percent of NCl_3 in final chlorine product and related safety considerations

Alternative 1. (Change of equipment)

1. In this alternative process of compressor replacement, most of the NCl_3 generated from chlorine purification is neither destroyed nor removed from the chlorine stream. Nitrogen trichloride instead accumulates in the plant's storage installations and is

[1] According to prevention measures outlined in Pamphlet 21 of the "Nitrogen trichloride, a collection of reports and papers", by the Chlorine Institute.

further transferred to clients' systems. Even though *Prodesal S.A.* can put in place measures to ensure that concentrations of NCl_3 in any part of the plant are below safety limits during normal operations and shut downs[2], the issue of client safety (during transport and use of chlorine cylinders) remains a major concern. A formal chlorine stewardship program would need to be put in place for chlorine clients, to ensure that: i) they are aware of the risks of explosion from the use of liquid chlorine and accumulation of NCl_3; and ii) they take all necessary precautions to minimize the danger. These programs are costly and require continuous monitoring and feedback.

2. Given that the level of risk of explosion at *Prodesal S.A.* or at a client facility remains considerably high, and given the commitment to safety made by the company after their accident in 1995, the option of equipment replacement is not favoured by the management of *Prodesal S.A*, and it is not a recommended methodology for the industry in general.

Alternative 2. (Change to chloroform)

No additional safety issues are associated with the technological conversion. Chloroform would be expected to perform as CTC.

Alternative 3. (Change to caustic soda)

No specific safety issue is associated with the third technical option.

Duration and cost of conversion project

The following figures are provided as a summary from the document kindly provided by UNDP. An annex to this document, providing the detailed cost breakdown, is available on request if the specific cost breakdown is required.

Costs of suggested conversion alternatives

Item	**Alternative 1 – Equipment replacement (US$)**	**Alternative 2 – Switch to chloroform (US$)**	**Alternative 3 – Switch to caustic soda (US$)**
Incremental Capital Costs	1,838,400	373,400	384,000
Contingency (10%)	183,840	37,340	38,400
Incremental Operation Costs	431,500	100,000	0
Total Project Costs	**2,453,740**	**510,740**	**422,400**

Document from 47th Meeting of ExCom of Multilateral Fund for the Implementation of the Montreal Protocol

[2] Euro Chlor Publication, "Maximun levels of Nitrogen Trichloride in Liquid chlorine", GEST 76/55, 9th Edition, September 1990.

Cost-effectiveness of suggested replacement technologies

	Alternative 1 – Equipment replacement (US$)	**Alternative 2 – Switch to chloroform (US$)**	**Alternative 3 – Switch to caustic soda (US$)**
Cost effectiveness (US$/Kg ODP)	1196.9	249.1	206.0

Document from 47th Meeting of ExCom of Multilateral Fund for the Implementation of the Montreal Protocol

Post conversion issues and solutions

None. The technology has not yet been implemented.

Case F

It should be noted that this plant, which is in an Article 5 country, continues to use CTC. There has been a project to convert the process from CTC to an alternative chemical for which the full economics had been developed, but at present this is on hold pending approval for the company to continue using CTC on the basis of minimal emissions. The continuing use is not expected to be for the long-term, since an expected conversion by the company to membrane-process technology would deliver the chlorine at a pressure sufficiently high that it could be used directly in its gaseous state, with the NCl_3 being destroyed in the downstream reactions.

Therefore, the description below represents the nominal economics to convert from CTC to chloroform in the application: the conversion has NOT been effected.

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

This plant consists of two equivalent diaphragm technology chlorine trains each capable of producing some 190 ktpa chlorine per year. The plants originate in 1971 and have a probable useful further life of around 20-25 years although there may be economic grounds to switch to alternative chlorine production techniques (membrane technology) earlier than this. Although the use of diaphragms utilizing asbestos (chrysotile) is subject to a progressive phase-down in the EU, provided safe alternatives exist, and in Saudi Arabia, no such restrictions apply in Brazil or are known to apply elsewhere globally, although NEW chlorine capacity in Brazil must be constructed using membrane technology. The chlorine is all used captively in the production of EDC (ethylene dichloride), which is used in the company's vinyl chain business.

The salt source for the chlorine unit is solution mined brine from the company's own adjacent mine. The company's approach to manage the NCl_3 build-up is to add CTC to the chlorine purification train (the "precooler") to dissolve NCl_3 and carry it down the column into the reboiler. This solvent is indirectly heated to 50-60°C by using steam, which is circulating through a heating jacket of the decomposer. With the feed of cold liquid chlorine (-30 to -38°C) into the warm CCl4 solution, the liquid chlorine vaporizes and NCl_3 is decomposed to its elements. The diagram below (Empromer, "Thermal Degradation of Nitrogen Trichloride in Electrolytic Production of Chlorine" 2nd Mercosur Congress on Chemical Engineering) shows the flow.

Figure 1: Process Flow Diagram for the thermal decomposition of NCl_3

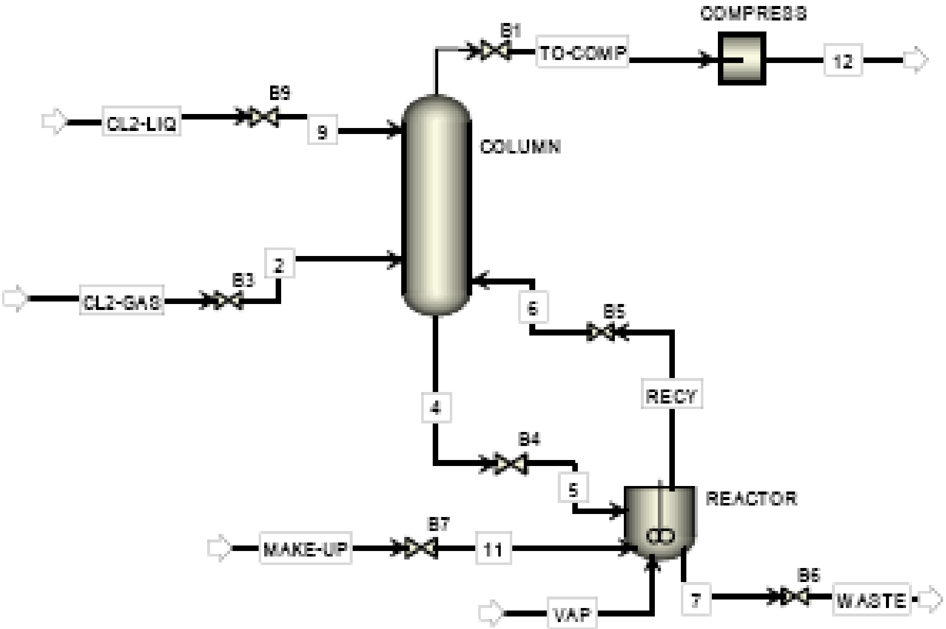


Fig. 1. Process flow diagram (PFD) for the thermal decomposition of NCl_3.

The compressor types are not known.

<u>Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)</u>

Since 1999, the average annual use of CTC (make-up) into this process has been just over 48 metric tons per year, and the peak year occurred in 2003 (just under 65 metric tons). The chlorine production has been in the range 300-360 ktpa. Purchase of CTC is somewhat linked to chlorine production, but “consumption” in the Montreal Protocol sense is more linked to incineration operations. Some of the CTC is carried by the chlorine stream to downstream reactions, where it remains largely unreacted and forms part of the liquid and gaseous waste streams from ethylene dichloride production. Both of these streams are incinerated on the company’s incineration unit which operates in compliance with approved ODS destruction technologies. However in periods of incinerator downtime, the gaseous streams are released to the atmosphere (with the understanding of local authorities) and accounting for the only known losses of CTC from the application. Spent CTC from the reboilers is disposed of by approved incineration methods at a third-party incineration company. The consumption of CTC in recent years has been in the order of 1-2 tons/a.

<u>Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes</u>

The company had elected to convert its use of CTC to chloroform. There is a national precedent for this choice since one partly US-owned company had made the switch in 2003. Because of the US ownership, no funding was supportable, and the company has refused to meet with the current Implementing Agency and discuss its process.

The company used the engineering firm Eltech Systems Corp of the USA to design an appropriate package for them. This package in total requires an investment which equated to US$3.65 million at the exchange rate current in 2006. The company’s board has approved the project but because of confidentiality agreements with the technology supplier there is limited access to the full design details. The capital package consists in summary of:

- increasing the number of plates in the precoolers from 22 to 23, and changing the material of construction of the lower "stripping" part (the bottom five plates) from carbon steel to higher specification steel. Eltech comments that the stripper is normally specified as ASTM A-333 low carbon steel as the temperature can reach -30 ^{O}C on occasions. ASTM A-333 is rated for a lower temperature than plain carbon steel as it contains a small percentage of nickel. However the stripper can be also be constructed out of stainless steel or other special grades of carbon steel. Because ASTM A-333 is not available in Brazil Eltech proposed the use of ASTM 516-grade 70, normalized, as an acceptable substitute for the ASTM A-333.
- The additional plate is to reflect the lower boiling point of chloroform (61.2^{O}C, versus 70.3^{O}C for NCl_3 and 76.7^{O}C for CTC) and therefore to avoid the carry over of chloroform in chlorine, and the change in material is to reflect the greater potential corrosiveness of chloroform.
- increasing the number of reboilers from two as at present to three, changing the design geometry from vertical to horizontal, and using Hastelloy-C as the material of construction. The increased number of reboilers (Eltech recommended four but the company considers that only one additional is sufficient) is to reflect the greater downtime required for reboiler maintenance due to the increased corrosion as well as potential degradation of chloroform, and will enable continuous operations which are essential to chlor-alkali plants. The change in design geometry plays no especial capital role but reflects, according to Eltech, current best practice. The use of Hastelloy rather than carbon steel reflects the increased corrosiveness of chloroform. It should be noted that to support the initial conversion case, the company has provided third-party documentation demonstrating the considerably increased corrosion of chloroform versus CTC under identical plant operating conditions.
- Driers to reduce the potential moisture content of chloroform, and analysers to check the moisture of each incoming drum, are part of the design package. Eltech comments that any upsets in the Cl_2 drying system will add unwanted moisture to the system and accelerate any corrosion. If the reboiler is constructed of carbon steel, the corrosion causes more sludge to accumulate in the reboiler and also greatly reduces its life. The use of Hastelloy C enables a much longer life of the reboiler.
- Additional temperature indicators within the precoolers, effectively moving from five per reboiler today (to be confirmed) to one sensor per tray, and additional monitoring equipment including temperature sensitive controls and gas chromatography for improved testing.

Table 6: Incremental Capital Costs

Item	***Cost (US$)***
Total project Costs (ICC)	3,665,900

It might be noted that we do have access to all the factors that resolve to a US$3.66 million project cost. We have been bound by confidentiality not to reveal these, and in any event the project is on hold pending resolution as to whether the emission management measures are adequate. These will be discussed in Task 4.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

There is predicted to be a price differential of the order of US$150/ton between chloroform and CTC. This is because CTC is becoming globally in surplus and companies producing it are more likely to be willing to offer low prices (versus the alternative of destroying it). By contrast chloroform typically sells in the price range US$600-800/ton (drums). The difference is predicted to be some US$150/ton which would add an average of US$ (48 tons*US$150) or US$7200 to annual operating costs.

The operating temperature range of the precoolers and reboilers is expected to be the same and no incremental energy cost is foreseen.

Since the purged material will consist of a mixture of CTC (formed from chloroform in the process) and chloroform, no increase in destruction costs is foreseen, since all of the CTC is presently being similarly treated. It is possible that there may be an additional quantity but this is difficult to predict. Eltech has reported that its experience at a major US chlorine producer, based in Louisiana, is that approximately 11% of the chloroform is converted to CTC. The conversion from CHCl3 to CCl4 is a slow process partly due to the low temperatures in the reboiler, at around 48-50^{O}C. However the existing presence of ferric chloride in the precoolers/reboiler feed may accelerate the rate of conversion. This can only be determined by use practice.

Since the process is not actually being used no results can be given.

Percent of NCl_3 in final chlorine product and related safety considerations

Not relevant

Duration and cost of conversion project

The following table is based on the publicly available document originated by UNDP that presented the initial case for elimination of CTC use at the company's plant by a process of substitution to chloroform. It displays a cost-effectiveness of US$76.17 per ODP kilogram of CTC phased out and substituted by chloroform. We must again emphasise that this project was not put into place and has been replaced by an emission-control project. In the table below, the average of just over 48 tpa metric tons CTC use are shown as ODP tons.

Table 7: Cost Effectiveness of of CTC Phased Out by Chloroform

COST EFFECTIVENESS CALCULATION FOR xxx Plant

Total ODP Phased Out = 53.15 annual ODP tons

Cost of the project = US$4,048,390

Item	**Cost (US$)**
Incremental Capital Costs	3,665,900
Contingency (10%)	366,590
Incremental Operational Costs	15,900
Total Project Costs	**4,048,390**
Cost Effectiveness (US$/Kg ODP) xxx Plant	**76.17**

Source: UNDP

Post conversion issues and solutions

None, project not implemented.

Case H NORAM Technology, Vancouver, Canada

<u>Overall plant technology characteristics and pre-conversion production procedures for removing both bromine and nitrogen trichloride from the chlor-alkali process.</u>

Bromine can be present in raw salt as NaBr which typically ranges from 10 to 75 ppm. Ionic bromine can be oxidized either in the electrochemical cell or by chlorine to bromine gas (Br_2). In either case Br_2 can be picked up into product chlorine.

In mercury and membrane plants almost all the bromide in the brine ends up as bromine in the chlorine gas. In diaphragm plants only approximately 25% ends up in the chlorine and 75% enters the caustic (NaOH).

The presence of bromine in chlorine can affect product quality problems including exchanger fouling and product discoloration (e.g. in vinyl and isocyanates production)

NCl_3 is an unstable and detonable compound and is produced by the reaction of chlorine with ammonia and amine impurities in the feed brine. NCl_3 can accumulate to dangerous amounts during chlorine purification (washing column) and dispensing liquid chlorine as gas. (Diagram no. 1)

Ideally both bromine and ammonia species could be removed in a single step process to lower their impact on downstream production processes. NORAM has developed an energy integrated low pressure (LP) distillation technology which does remove both bromine and NCl_3.

The pre-cooler is modified and converted into a true distillation column. The technology uses liquid chlorine as a column reflux to reduce bromine levels in the chlorine gas. The top of the column will contain pure chlorine gas and the bottom will contain liquid chlorine with both Br_2 and NCl_3.

The distillation column bottoms will be purged at a rate to ensure that NCl_3 concentrations are less than 5 ppm. NORAM has a vaporiser design to safely vaporise the distillation column bottoms. The bromine can be further concentrated or sent to an HCl synthesis process to make HBr. The system can be designed to remove NCl_3 only with minimal bromine removal. This requires less reflux. (Diagrams No. 2 &3)

TASK 4: REVIEW OF ALTERNATIVES: EMISSION MANAGEMENT

In Task 4 actions we summarise the data obtained from those chlorine plants that continue to use CTC, on the understanding that the emissions from the process are managed to the point of acceptably minimal emissions by local authorities.

CASE I

It should be noted that this plant, which is in an Article 5 country, continues to use CTC. There has been a project to convert the process from CTC to an alternative chemical for which the full economics had been developed, but at present this is on hold pending approval for the company to continue using CTC on the basis of minimal emissions. The continuing use is not expected to be for the long-term, since an expected conversion by the company to membrane-process technology would deliver the chlorine at a pressure sufficiently high that it could be used directly in its gaseous state, with the NCl_3 being destroyed in the downstream reactions.

However the emissions as recorded by the company are apparently in line with the levels acceptable to authorities in Article 2 countries, representing as they do some 1-2% of the total make-up quantity of CTC.

<u>Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures</u>

This has been written up as Case F in the task 3 section and does not need to be repeated.

<u>Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)</u>

This has been written up as Case F in the task 3 section and does not need to be repeated.

<u>Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes</u>

The CTC used in NCl_3 treatment is eliminated, by destruction, in two separate directions. The largest part – around 85% - is carried by the gaseous chlorine recovered from the (CTC using) reboilers to the site use system, which is 100% linked to the direct chlorination of ethylene to make EDC for domestic and export use. The CTC carried in the chlorine is inert in the EDC reaction and is emitted unchanged in the EDC vent gas system.

Until 1997 this was simply purged to the atmosphere. In 1997 the company installed an on-site Sulzer incinerator with gas and liquids treatment capability for chlorinated by-products, thereby ensuring that all light-end chlorinated by-products from their site process were virtually wholly eliminated. This also destroys, therefore, the CTC carried by chlorine from the NCl_3 treatment. CTC losses occur only when the site incineration is idled for planned or unplanned maintenance shutdowns. When the incinerator is not operating, the EDC vent gases are released to the atmosphere instead of being incinerated. This procedure is within the local operating permit for the plant and local authorities are formally notified when incinerator operations are to be interrupted. The liquid streams can be captured and stored during such periods but the volume of vent gas makes storage impossible. This venting is the only source of plant emissions of CTC excepting some potential minimal fugitive emissions on charging and discharging the reboilers.

The smaller part of the CTC – the heavily contaminated CTC in the reboilers – was until 1997 vented to the atmosphere. Since 1997, as part of the environmental improvement programme, the CTC has been filled into 200 litre plastic drums and periodically sent to a third-party incineration company.

The on-site incinerator at the site is not equipped to deal with other than vent gases and light-end chlorinated hydrocarbons. The quantity of spent CTC sent to external incineration is around 10 tons/year. The company states that this consists of ~98% CTC. While there is not a firm confirmation of this fact from the receiving incineration company, there is written assurance that the mean chlorine content of all of the chlorine waste streams sent from the site is around 64%. This would broadly correspond to the average of vinyl chain wastes and is credible.

<u>External Incineration</u>

The company has provided details of annual movements of contaminated CTC to the incineration company as follows

Table 8: Annual Movements of Contaminated CTC for Incineration 2002-09

	2002	**2003**	**2004**	**2005**	**2006**	**2007-9**
Quantity kg	9,889	10,250	9,360	9,380	14,990*	
Average annual quantity kg					**10,774**	
Annual IOC (US$)	8,939	9,265	8,532	9,266	13,664	10,642
Total incremental cost since 2002(US$)					***49,666***	
Predicted three year IOC for project lifetime 2007-2009 (average annual use and current cost)						***31,926***
Total incremental cost for project lifetime 2002-2009						***81,592***

Source: XXX Company Case I

In August 2007 a UN team visited the incineration site. It was established that the unit operates an 8 ktpa capacity rotary kiln (with capacity therefore to receive solid wastes) with the potential for liquid injection of chlorinated wastes.

The kiln operates at over 1000 degC and the afterburner at around 1150-1200degC with a residence time in excess of 3 seconds. Primary and secondary quenches cool the exit gases to an initial 350-400degC and then to below 100degC. Dioxins are specifically measured and meet national requirements.

On-line measurements for CO and O2 are made in the stack and particulates are systematically measured. The incineration company appears to be operating its incineration equipment within the approved destruction parameters of the Montreal Protocol.

On-site incinerator

The installed cost of this incinerator was US$6.97 million in 2007 money. The capacity to treat chlorinated waste is 300 lit/hour of liquids and 800Nm3/hour of gaseous vent streams.

As is typical of site incineration units, the capacity is over-designed for site needs to allow for periods of off-specification production. The proportion of CTC in the overall treatment mix is variable since it depends on the mix of domestic EDC (lower specification therefore less waste stream) and higher specification EDC with more distillation, whereby in the latter case the proportion overall of CTC is less, since more overall waste streams are processed. According to the company, the content of CTC averages +/- 1% of the total waste stream.

The variable cost of the total incineration unit is US$568,000 year and is very constant since incineration must be kept running continuously even when the input rates are low (and occasionally the vent gases must have nitrogen added to assure adequate flow). In this case the incremental cost to manage the CTC component of the feed is therefore 1% of US$568,000/year or US$5600/year.

In 2002, recognising that there was more than usual (predicted at 5-7 days per year) downtime, the incinerator was overhauled, new monitoring equipment was installed, and the performance in terms of atmospheric losses was significantly reduced. The cost of this overhaul was US$800,000 with a CTC incremental investment cost impact therefore of US$8000. Because it was this investment that brought the losses of CTC down to below 2% (and generally just over 1%) the period for funding has been counted as starting from 2002.

The incinerator works in the range 1130degC (below which it shuts down) to 1200 degC and has a minimum residence time of 2 seconds, with an instantaneous quench to below 200 degC. Local government regulations require dioxin emission limits of 0.5ngTEQ/M3 for such units and this plant respects the operating conditions necessary to achieve this. It is regarded as representing destruction technology as approved by the Montreal Protocol.

CTC Site losses at the site (Consumption of CTC)

CTC losses from the on-site system are represented in the following table.

Table 9: CTC Losses from Onsite System 2000-2006

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Days in operation	360	360	360	360	360	360	360
Utilization rate (97%)	349	349	349	349	349	349	349
Maintenance days	16	17	16	9	7	6	6
Non-planned maintenance	30	28	27	20	18	17	17
CTC use	36.390	37.915	34.609	64.740	56.880	35.850	49.510
CTC losses (kg)	1.240	1.149	1.108	818	736	694	694
CTC % losses	**3.4**	**3.0**	**3.2**	**1.3**	**1.3**	**1.9**	**1.4**

Source: XXX Company Case I

Table 10: Incremental CTC Incineration Operating Costs Summary 2002-09

US $	2002	2003	2004	2005	2006	2007-09
Investment on-site	8,000					
On-site incineration	5,600	5,600	5,600	5,600	5,600	16,800
Off-site incineration	8,939	9,265	8,532	9,266	13,664	31,926
Annual Total	22,539	14,865	14,132	14,866	19,264	48,726
Total					**85,666**	**134,392**

Source: XXX Company Case I

The company has taken considerable trouble and incurred significant expense to eliminate the environmental impact of CTC from their site operations, and in fact had been willing to make the significant investment of some US$3.6 million to eliminate CTC use even though they were aware that the emissions were close to zero.

This investment would have a limited lifetime since there is a possibility that the company consider investment in membrane technology to replace the existing diaphragm process. It is likely that this would happen within 5-6 years and as such would represent the maximum lifetime of the CTC replacement investment. This is because membrane technology delivers chlorine at higher pressures and, on this site, would eliminate the requirement for chlorine liquefaction.

Continued use of CTC at levels has been argued for, in recognition of the fact that the apparent consumption of (average) 48 metric tons (52.8 ODP tons) of CTC is being almost wholly managed by emission controls, in this case the destruction of the used product.

This follows the formula that

Production = Amount produced, minus the amount destroyed by technologies approved by the Parties, minus the amount entirely used as Feedstock.

Consumption = production + import – export

In the case of this company therefore, and using average values so as to discount annual stock movements

Production (metric tons) = 0 – 47.5- 0 = -47.5

Consumption (metric tons) = -47.5 +48 -0 = 0.5 (~99% destruction)

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

Minimal, since downtime associated with incinerator modifications was associated with routine overall of the upstream and downstream operations.

Percent of NCl_3 in final chlorine product and related safety considerations

Within safe operational limits

Duration and cost of conversion project

This is not a conversion project

Post conversion issues and solutions

None

CASE J

This plant continues to use CTC in its chlorine processing on the basis of minimal emissions, which are within permitted levels. However it is concerned that CTC may be non-available longer term either by legislation or by cessation of supply.

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

The plant originated in the 1960s with mercury based chlorine technology and has been expanded with a membrane unit in the 1990s. The technology was and remains that of processing chlorine gas in liquid chlorine/CTC, and running the chlorine/NCl_3 liquid through a reboiler to eliminate the NCl_3 content. Contaminated CTC is partly drained periodically and replenished by fresh CTC. The system actually comprises two decomposers, each with a content of some 800 kg CTC. The spent CTC is incinerated off-site: it is not known at the time of writing where this is done or if it meets the requirements of destruction under the Montreal Protocol. However this CTC is not reported as emissions.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)

The plant operates a current 65 ktpa chlorine plant with a small membrane facility of 13 ktpa and the balance based on older mercury technology. The demand for CTC fluctuates but is in the range 8-11 tons per year as the make-up quantity. The emissions are **reported in the range of 200kg/year**.

Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes

The present exercise to investigate process change is focussed on post-electrolysis treatment, and is being conducted with the Canadian company NORAM.

The company comments that this will *"decrease the amount of NCl_3 but don't suspend the use of CTC. We have to continue to use CTC because our process has a scrubber that cools down and purifies the chlorine feed to the compression that is volumetric, so we always have some NCl_3 in the scrubber that must be purged."*

As we understand it, this company will investigate a deep-cooling system that will enable the recovery of pure chlorine. The concentrated NCl_3/chlorine residues will be periodically batch-treated through a heater system. This heater system will replace the CTC/chlorine/NCl_3 system that is currently operated on a virtually continuous basis. The investment is expected to be in the region of €500k. However other technologies are presently being exploring including a simpler batch treatment system for the bottom chlorine liquid containing NCl_3. This might bring the costs to below €400k.

On this site, the liquefaction process is a vital part of the chlorine purification, that must be oxygenate-free for use in the profile of derivatives.

Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)

Not yet known

Percent of NCl_3 in final chlorine product and related safety considerations

Not yet known, but must be small for the application.

Duration and cost of conversion project

Not yet known.

Post conversion issues and solutions

Not yet known

CASE K

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

This plant, which is based in Europe, actually has three uses for CTC in the chlorine production process. Apart from the use that is the subject of this report, CTC is also used in a chlorine cooling process, and is used in tail gas recovery. The major use is in the capture and processing of NCl_3. The nominal capacity to produce chlorine is in excess of 200 ktpa and this uses diaphragm technology of the company's own design. The plant has existed since the 1960s although the specific technology to produce chlorine was modified in 2000. Historically the plant consumed chlorine for internal derivatives and also exported by pipeline and by railcar to third parties, including to export destinations. Nowadays the use is essentially captive. All consumption and emissions are recorded as part of the EU submission to the Ozone Secretariat although it should be noted that there is a discrepancy in apparent 2006 "consumption" (actually make-up) quantity. The brine is captive to the company and although the source of the NH3/NH4 is not known (and we have asked for more detail) it is suspected to come from nitrate fertiliser run-off in the water-table that acts as the dissolving medium for the solution mining.

A schema of this plant is provided in Annex 11 of this Report.

Annual level of production of chlorine and consumption of CTC

The company today produces in the range of 135 ktpa chlorine. This is essentially captive and is used in the production of specialised derivatives. The company has specifically requested us not to indicate additional details. The consumption of CTC (in the sense of purchases) was some 60 tons in 2006 but has at some periods of higher chlorine output exceeded 100 tons/a. It should be noted that this consumption does NOT correspond to the level noted by the EU in its report for 2006 make-up to the Ozone Secretariat, which barely exceeded 11 tons. However the emissions (="consumption") from all processes have been calculated to barely exceed 1 ton/a.

Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes

Concerning the application whereby CTC is used to manage NCl_3, the process involves treating the chlorine gas emerging from the electrolysis by a water wash. The waste water emerging from this wash is run through a CTC tank and the dissolved impurities, including NCl_3, are periodically sampled. When the NCl_3 level approaches 3% part of the contaminated CTC is drawn off for delivery to the on-site incinerator and is replaced by fresh CTC. If the incinerator is down, however, the contaminated CTC may be vented to the atmosphere if the risk of NCl_3 build-up is unacceptably high. Down-time of the incinerator might amount to some 20-25 days/year. It is now planned to add a carbon absorption column to contain the used and contaminated CTC over such periods, and the investment is given at some €300-350k. Most of the CTC used by the company in this application is incinerated.

CTC is also used in the chlorine cooling circuit as part of the condensation process. The CTC used in the cooling loop passes through chilled water. Losses as minor leaks here have been measured at 1.2kg/day (~350kg/year) and the company has been requested by local authorities to improve the containment. This will be effected by a secondary cooling circuit with an investment of some €200k. It is not entirely clear why CTC specifically needs to be used in this application.

The third use of CTC is in tail-gas management, whereby inerts and dilute chlorine gas in the post-compression gases are dissolved in CTC and chlorine gas is recovered for recycling back to the system. Spent CTC from this process is periodically sent to the on-site incinerator. Fugitive losses of CTC, when opening equipment for routine and unplanned maintenance are not measured but are calculated at some 400-500 kg/a.

<u>Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)</u>

No phase-out

CASE L

<u>Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures</u>

The plant has a 72 ktpa mercury based chlorine plant linked to potassium hydroxide production. The compressors are piston-type.

<u>Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion)</u>

The production of chlorine has been in the range 50-55 ktpa. It is used for the production of HCl, liquid Cl2 and sodium hypochlorite, as well as in some specialities, but it is also pipelined to the adjacent titanium dioxide site where it is used to make titanium tetrachloride, the starting point of the process. The titanium dioxide plant also uses sulphate process technology. The company has stated in written correspondence that it shifted from CTC use in 2001 and started using a distillation process to manage the NCl_3. It also has said that it "keeps the CTC process as a spare process". The company, until 2005, has continued to report CTC consumption, which we assess at 9-11 tons/year.

<u>Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes</u>

The process changed from one in which the bottoms from the chlorine gas stream that was passed through liquefied chlorine was passed into a CTC system (with a number of boilers and continuous heat) into one where a new distillation column, with additional refrigeration and thermal fluid charges, was used to concentrate the impurities and purge them to reboiling with nitrogen trichloride destruction and chlorine gas recovery. The process was nominally changed in 2001 but the CTC system was kept open as a back-up and in fact was used 3-4 times per year from 2001-2005 as problems arose in the new system. Since 2005 this has not been necessary and from 2006 CTC use has not been reported to the EU, although one reboiler still exists as a back-up. Until 2005, the company's usage of CTC as make-up, and its emissions, was reported to the EU and the figures are included in the EU summary. The main reason for the change was debromination, which the CTC process did not enable.

<u>Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)</u>

Bromine content has been an issue in the changed process. Historically all bromine was retained in the processed chlorine which was not an issue for the downstream uses. With the new system the heating process separates out the bromine, and this is captured. The site uses bromine as a feedstock so this is revalorized.

Percent of NCl_3 in final chlorine product and related safety considerations

None, no issue. (But the bromine content is still too high for some consumers)

Duration and cost of conversion project

The level of investment has not been disclosed for confidentiality reasons. A cautionary estimate from the consultants is around €2-2.5 million.

Post conversion issues and solutions

None

CASE T

Overall plant characteristics (e.g. age of relevant equipment at the time of conversion, type of electrolytic cell, compressor types) and pre-conversion production procedures

The company operates a number of chlorine plants in Europe. The technology is mixed between diaphragm, mercury and membrane. Overall capacity is in the range 700-800 ktpa. CTC has been used in two processes, in one plant in chlorine liquefaction processing (but not to eliminate NCl_3) and in a second plant, now closed, to eliminate NCl_3. This process however was discontinued in 2000, and the overall production was closed in 2006. The compressor types are not disclosed.

Annual level of production of chlorine (pre and post-conversion) and consumption of CTC (pre and post-conversion).

The company has, according to site, operated at 75-85% of effective capacity. Consumption of CTC ceased overall in 2001 and the company has no enduring records of actual use.

Detailed description of methodology or technology used to achieve the phase-out of CTC and of new production processes

This company has a number of chlorine plants in Europe and has historically used CTC at two of them, in two distinct applications.

In one plant, partially-liquefied chlorine was run into a CTC bath as means of eliminating the hydrogen content (and has nothing therefore to do with NCl_3) prior to total liquefaction. Chlorine desorption as gas was effected by reheating, and the hydrogen, being insoluble in the CTC bath, was run off as a side-stream. The CTC was incinerated in the company's own incineration complex when spent. The process was also used to absorb oxygenates, which were not acceptable either in the then sales of the product nor in local processing to derivatives. In 2002 the company moved to a complete use of partially liquefied chlorine and had no need to use CTC. The applications for the company's chlorine enabled a combination of gaseous and partially liquefied use.

At the second plant (mercury-based) where CTC was used (until 2000) the need to use liquefied chlorine was questioned and eliminated, and chlorine gas was used direct to the end-applications.

The brine sources at the company's existing plants are scrutinised, as is the potential for NCl_3 build-up. A third plant requires a particularly purified chlorine source requiring liquefaction: if the NCl_3 levels build up in the chlorine the overall production procedures are modified so that the derivatives that can support a higher nitrogen content are favoured and overall NCl_3 levels in the liquefied chlorine are reduced: this in general involves higher feed rates to ethylene dichloride and lower to chloromethanes.

One of the company's plants uses vacuum salt, with no/ minimal ferrocyanate content and in any event the liquefied chlorine portion is minimal: the adjacent customer that uses the chlorine to process ore to precious metals uses gaseous chlorine, so does the on-site EDC plant, so the demand for liquefied chlorine in minimal and can be adjusted by flow-rate.

<u>Operational considerations associated with phaseout (e.g. down time of plant, required training of personnel, maintenance, safety issues)</u>

None

<u>Percent of NCl_3 in final chlorine product and related safety considerations</u>

Within acceptable limits: operational procedures enable run-off of chlorine containing higher levels of NCl_3.

<u>Duration and cost of conversion project</u>

Not relevant

<u>Post conversion issues and solutions</u>

None

ANNEX 5 - CTC PROCESS AGENT USE AND USERS

EC Companies known as process agent users in 2000-2006

Company	Street	City	Country	Phone	Substance
Albemarle	Etang de la Gaffette, Boulevard Maritime, B.P. 28	13521 Port-de-Bouc, Cedex	France	001-225-388-8111	CTC
Akzo Nobel Base Chemicals BV	PO box 247	3800 AE Amersfoort	Netherlands	+31 33 467 6865	CTC
Anwil SA *	Torunska 222	87-805 Wloclawek	Poland	+48 54 237 22 71	CTC
Arkema SA* (ex: Atofina)	4-8 cours Michelet – La Défense 10	92091 Paris La defense, Cedex	France	+33 1 49 00 72 33	CTC
Aventis			France		
Bayer Material Science*	CAS-PR-CKD, Gebäude B669	41538 Dormhagen	Germany	+49 2133 - 51-5502	CTC
Caffaro s.p.a	via F. Nullo, 8	25126 Brescia	Italy	030 31921	CTC
CUF Quimicos Industriais SA*	Quinta da Industria Beduidu	3860-680 Estarreja	Portugal	+351 234 810-300	CTC
PPC SAS	95 rue du General de Gaulle	68802 Thann Cedex	France	+33 389 384-600	CTC
Rhodia Organics (ex Chlor Alp)	Rue Lavoisier BP 21	38801 Le pont de claix	France	+33 4 76 69 50 29 or 52 38	CTC
Rhodia Organics (ex Chlor Alp)	Rue Lavoisier BP 21	38801 Le pont de claix	France	+33 4 76 69 50 29 or 52 38	CTC
Solvay Solexis SpA* (ex Ausimont)	Viale Lombardia 20	20021 Bollate MI	Italy	+39 238356614	CFC-12
Solvay Solexis SpA*	Viale Lombardia 20	20021 Bollate MI	Italy	+39 238356614	CFC-113
Teijin Twaron BV (site Delfzijl)	Oosterhorn 6	9936 AD Farmsum	Netherlands	+31 596 648414	CTC

* indicates companies that reported process agent use in 2006 (last report available)

EC Process Agent Use of ODS

allowed uses in the EC

MP Code	Process Description (Montreal Protocoll Dec XIX/15)	Reg Code	Process Description (Regulation (EC) No 2037/2000 Annex VI	ODS
1	Elimination of NCl_3 in chlor-alkali production	(a)	use of carbon tetrachloride for the elimination of nitrogene trichloride in the production of chlorine and caustic soda;	CTC
2	Chlorine recovery by tail gas absorbtion in chlor-alkali production	(b)	use of carbon tetrachloride in the recovery of chlorine in tail gas from production of chlorine;	CTC
3	Production of chlorinated rubber	(c)	use of carbon tetrachloride in the manufacture of chlorinated rubber;	CTC
5	Production of ibuprofen	(d)	use of carbon tetrachloride in the manufacture of isobutyl acetophenone (ibruprofen-analgesic);	CTC
8	Production of aramid polymer (PPTA)	(e)	use of carbon tetrachloride in the manufacture of poly-phenylene-terephtalamide;	CTC
28	Production of radio-labelled cyanocobalamin	(f)	use of carbon tetrachloride for the production of radio-labelled cyanocobalamin;	CTC
9	Production of synthetic fibre sheet	(g)	use of CFC-11 in manufacture of fine synthetic polyolefin fibre sheet;	CFC-11
11	Photochemical synthesis of perfluoropolyetherpolyperoxide precursors of Z-perfluoropolyethers and difunctional derivatives	(h)	use of CFC-12 in the photochemical synthesis of perfluoropolyetherpolyperoxide precursors of Z-perfluoropolyethers and difunctional derivatives;	CFC-12
12	Reduction of perfluoropolyetherpolyperoxide intermediate for production of perfluoropolyether diesters	(i)	use of CFC-113 in the reduction of perfluoropolyetherpolyperoxide intermediate for production of perfluoropolyether diesters;	CFC-113
13	Preparation of perfluoropolyether diols with high functionality	(j)	use of CFC-113 in the preparation of perfluoropolyether diols with high functionality;	CFC-113
14	Production of Cyclodime	(k)	use of carbon tetrachloride in production of Cyclodime;	CTC
		(l)	use of HCFCs in the processes set out in points (a) to (k) when used to replace CFC or carbon tetrachloride.	HCFC

ANNEX 6 - RESPONSES FROM TELEPHONE INTERVIEWS - CHINA

China Chlor-Alkali Industrial Association http://world.ccaon.com/

Mr Zhang Wenlei 张文雷 - Vice General Secretary
Tel: 13502009623

Interviewer: Tecnon OrbChem

He said there are some Chlorine producers continue using CTC in small quantity. China has banned imports of CTC and regulate/control domestic CTC production.

As information related to CTC is very sensitive and Association has very close cooperation with environment ministry, he needs approval from:

Mr Zhang Peichao, General Manager, China Chlor-Alkali Association www.ccaon.com

email: zpc@ccaon.com Tel 010-64384108 13693022122.

(Assistant Yang Sen, peteryang@ccaon.com)

When we telephoned, Mr Zhang Peichao said also it is not easy to tell about volumes of CTC and asked us to send the details to him. We sent him our questionnaire. He said he would need approval from the Chinese Government to give us answers, and that the Association would expect to charge us for this.

Foreign Economy Cooperation Office, Ministry of Enviroment Protection ("MEP") (formerly Sepa, State Environment Protection Agency) http://english.sepa.gov.cn/

Mr. Yang Lirong (Division 3 Leader - division resposible for the project about ODS) email: yang.lirong@mepfeco.org.cnTel: 01088577266

Interviewer: Tecnon OrbChem

He said he cannot authorise a response to the questionnaire for CTC producers or users as the MEP reports to World Bank every six months after the CTC producers have reported to them.

The MEP does not understand why the World Bank has asked us to do this research because the World Bank knows everything from the regular information they send them. The questionnaire also contains a lot of technology questions they don't know the answer to.

He advised us to contact:

Mr Liu Dongsheng, Vice-General Secretary, China Chlor-Alkali Industrial Association: email: Ldsh950@vip.sina.com
Tel: 13312133737 or 022-27428220/27428231

We sent him the questionnaire by email, but he was travelling. We then spoke to him but he declined to help, and referred us back to his colleague **Mr Zhang Peichao** at the **Chlor-Alkali Association**, who we spoke to before.

Chlor-alkali Company/Institution: Tianjin Dagu Chemical, Tianjin, China
http://daguchem.com

Mr Zhang Zhihua 张志华 - Information Department

Tel: 022-25393414, 25387817

Mr Han in the Purchasing Department 022-25393966-2588 said he never heard of CTC and advised us to contact their General Manager at Head Office.

Mr.Liu from the Production Department said that they don't need to worry about the build-up of NCl_3 as they use an advanced production technique.

Mr Liu confirmed that they do not produce or use CTC.

Chlor-alkali Company/Institution: Sinopec Qilu Petrochemical, Zibo, Shandong, China
www.sinopec.com

Mr Yu Guoliang 于国良 - Planning Department

Tel: 0533-7581346, 13589486816

Mr.Yu referred us to the Technical Management Department

Tel: 0533-7523132/7523477 (Mr.Han); Tel: 0533-7580628 (Mr.Zhang Jingyou, Vice General Manager); and Tel: 0533-7522280 (Mr.Zhaomin, Technical Director).

They treat brine with caustic soda, not CTC.

They do not produce or use CTC.

Chlor-alkali Company/Institution: Shanghai Chlor-Alkali Chemical (SCAC), Shanghai, China
www.scacc.com

Mr Jerry Guo 郭肖俊 - Business Division Manager

Tel: 021-58874213

A respondent thought that the company used to produce tetrachloroethylene, but that this unit had been shut down.

Production Department said that they use caustic soda to manage the build-up of NCl_3.

The CTC units stopped production in October 2007. They don't supply the market with CTC any more.

Chlor-alkali Company/Institution: Yibin Tianyuan Chemical, Yibin, Sichuan, China
www.ybty.com

Ms Xiao Chiquan 肖池权 - Director

Tel: 0831-3608888

Mr Zheng, Purchasing Department Tel 0831-3607091

They use CTC in a very small quantity and they did not purchase any recently.

The Sales Department confirmed that **they never sell CTC.**

Chlor-alkali Company/Institution: Shanghai Tianyuan Huasheng Chemical Co Ltd, Jinshan, Shanghai, China

Jerry Guo 郭肖俊, Plant Manager of SCAC

Tel: 86 (21) 62745100

Production Manager said they use caustic soda to deal with NCl_3 and do not use CTC.

They used to produce CTC but they have now stopped.

Chlor-alkali Company/Institution: Shandong Hengtong Chemical Engineering Co, Ltd, Yancheng, Shandong, China

Mr Wang Yongli 王永立 - Director

Tel: 0539-6139001, 13705394008

Factory Tel: 0539-6138384

Mr.Liu said they get rid of NCl_3 with caustic soda.

They do not use or produce CTC.

Chlor-alkali Company/Institution: Zhejiang Quhua Fluor-Chemistry Co Ltd, Quzhou, Zhejiang, China

referred to **Zhejiang Juhua, Quzhou,** Zhejiang, China www.jhgf.cn

Mr Ling Haiping 凌海平 - Manager, Chlor-alkali Department Tel: 13905707415

Mr.Lujia陆嘉(Manager of Sals Dept.) Tel: 13705707203.

They use CTC to produce tetrachloroethylene and cinnamic acid.

Chlor-alkali Company / Institution: Xinjiang Zhongtai Chemical, Dongshan, Xinjiang, China
www.zthx.com

Ms Yang Jianghong 杨江红 - 部长 Tel: 13809959988

Ms Yang said they do not produce or use CTC.

Chlor-alkali Company / Institution: Huantai Bohui Social Welfare Chemical Factory, Qingdao, Shandong, China

Mr Zheng Zhaolu 郑召禄 - Vice Sales General Manager Tel: 13506438158

Ms Zong de – Sales Manager Tel: 13869305111

Mr.Zhang - Manager, Production Tel: 13864302119

Mr.Zhang said they use caustic soda to absorb NCl_3.

They do not produce or use CTC.

Chlor-alkali Company / Institution: Tianjin Botian Chemical, Tianjin, China

Mr Liu Peiqing 刘培清 - 副部长 Tel: 13602198061

Production Department Tel: 022-67992609 Mr.Hu (General Manager - 部长)

Chlor-Alkali Production Manager, Mr.Wang Tel: 022-67992764/67992362

They stopped CTC production many years ago.

Chlor-alkali Company / Institution: Dongyue Chemical Company Ltd, Zibo, Shandong, China
www.dongyuechem.com

Tel: 0533-8520353

Mr.Yu or Mr.Wei (General Manager部长) Tel: 0533-8520361

Mr. Wei said they use caustic soda to get rid of NCl_3.

They produce thousands of metric tons of CTC per year, but <u>not</u> for NCl_3 eradication.

There use CTC to produce methane chloride, and some CTC is sold in the market.

Chlor-alkali Company/Institution: Liaoning Jin Hua Chemical, Huludao, Liaoning, China
www.jinhuagroup.com

Ms Zhang Yujing 张玉静 - Manager Tel: 0429-2900982, 13942990929

Never heard of NCl_3. **They do not produce or use CTC.**

Chlor-alkali Company/Institution: Leshan Yongxiang Resins, Lashan, Sichuan, China

Mr Yi Chengbi 易成碧 - Manager Tel: 13700937586

They do not produce or use CTC.

Chlor-alkali Company/Institution: SP Chemicals, Taixing, Jiangsu, China
www.spchemicals.com

Mr Sun Liang 孙良 Tel: 13901434695

They do not produce or use CTC.

Chlor-alkali Company/Institution: Zhejiang Gala Chemical Corp, Ningbo, Zhejiang, China

Mr Wang Xiaobo 王晓波 - Sales Supervisor Tel: 0574-86182026

Production Dept Tel: 0574-86182071

They use Caustic soda to get rid of NCl_3. **They do not produce or use CTC.**

Chlor-alkali Company/Institution: Xinjiang Tianye Chemical, Shihezi, Xinjiang, China

Mr Mu Jianmin 穆建民 - Vice General Manager Tel: 0991-4542977, 13999336986

Miss Song (General Manager) Tel: 0991-2551189

They use Caustic soda to get rid of NCl_3.

They do not produce or use CTC.

Chlor-alkali Company / Institution: Henan Haohua Yuhang Chemical, Jiaozuo, Henan, China

Mr Zhang Hui 张辉 - 主任 Tel: 13839113866 email: zhanghui3866@sina.com

A questionnaire was sent on the request of Mr Zhang. Mr Zhang will check with relevant Department. This matter is outstanding.

Chlor-alkali Company / Institution: Yushe Chemical Industrial, Yushe, Shanxi, China
www.sxyh.com.cn

Tel: 0354-6633016

Mr Zhang Jianping 张建平 - Vice General Manager Tel: 13509740531

They do not produce or use CTC

Chlor-alkali Company / Institution: Jiangsu Meilan Electro Chemical Group, Taizhou, Jiangsu, China

Mr Li Shoupeng 李寿彭 - Vice General Manager Tel: 0523-6343198, 13901433961

Ms Sun Shuping 孙淑萍 - Deputy Manager Tel: 0523-6574948, 13505262822

Mr.Li Tao - Sales Manager Tel: 13952615881

They use CTC to produce perchloroethylene products (TFP (trifluoperazine), trichloroethylene and tetrachloroethylene.

They do not sell CTC on the open market

Chlor-alkali Company / Institution: Tangshan Sanyou Trading, Tangshan, Hebei, China
(Direct Sales of Tangshan Sanyou)

Mr Han Jia 韩佳 - Sales Manager Tel: 0315-7729203

No contact.

Chlor-alkali Company / Institution: Zigong Honghe Chemical, Zigong, Sichuan, China

Ms Song Zhiqun 宋志群 - Information Supervisor

Tel: 0813-4662905

They use CTC to produce tetrachloroethylene.

Wuhan Hezhong Biochemical Manufacture Company Ltd, Wuhan, Hubei, China
www.hezhongchem.com

Tel: 27-68886688

They produce cinnamic acid and TFP.

Shandong Jinling Chemical Company Ltd, Dongying, Shandong, China
www.shandongjinling.cn

Zhao Yueling, General Manager Tel: 86-0546-688 1718 or 86-0546-688 1881
Apparently they are planning to use CTC for the production of methane chloride.
[this quote is not from the Company]

Luzhou Xin Fu Chemical Industry Co. Ltd, LuZhou City, Sichuan, China
www.xfchemical.com

Mr Ning Tel: 0830 2730004

They do produce CTC, but not any downstream products.
They do not sell CTC into the open market.

He was not willing to comment on how to deal with CTC.

Quote from website:

> *"The company is adopting the patent technique of "ACF" absorption and separation. The new technique is an advantage item for replacing Carbon Tetrachloride."*

ANNEX 7 - RESPONSES FROM TELEPHONE INTERVIEWS - TAIWAN

Chlor-alkali Company / Institution / Institution: Formosa Plastics Corporation

Location: Taiwan

Person interview: Mr. Lin Feng –Plastics Division production & sale

Tel: 886-2-27122211 ext 8123

Interviewers: Tecnon OrbiChem

FPC said they have never used CTC, since they started producing Chlorine. They don't use rock salt producing Chlorine, so they don't have this kind of problem. The key point is the quality of salt used to produce Chlorine.

FPC uses solar salt as a feedstock mainly importing from Australia. Solar salt does not contain nitrogen compound inside. It does not need to purify before using it, and also will not cause the formation of NCl_3 during the process.

Rock salt will be contaminated while mining with explosive, and that's why the producers using rock salt as feedstock while producing chlorine will face the danger of NCl_3 build-up.

Salt is a low-price feedstock. The most important issue Chlorine producers are considered while purchasing or importing salts, is the transportation charges.

Main export countries for rock salt are in South America. It is not economic to import from such a long distance compared with importing from Australia. The main two importing countries for industrial salt in Taiwan are Australia and Mexico. Both of them produce solar salt.

Total capacity of FPC for Chlorine in Taiwan now is 1800ktpa. FPC has two production lines, are 370ktpa and 1430ktpa, respectively.

Their technologies are from three companies, such as Japanese company and German company.

He has never heard of Taiwanese Chlorine producers using rock salt as a feedstock, or using CTC to absorb tail gas stream.

Chlor-alkali Company / Institution: Taiwan Acid and Alkali Industry Association

Location: Taiwan

Person interview: Mr. Yang Jin Bo – Executive Manager

Tel: 886-2-27023910

Interviewers: Tecnon OrbiChem

I talked with the executive manager of association. He suggests us to write a formal letter to the Environmental Protection Administration of Taiwan and Industrial Development Bureau, Ministry of Economic Affairs, to ask some information about CTC. Association is subordinated to government. He has no right to disclose the information except he gets the permission.

He said there are 5 Chlorine producers the belong to the Association. They are FPC, Taiwan Chlorine Industries Ltd., Chung Hwa Pulp Corp, Taiwan Pulp & Paper Corp, and Yee Fong Chemical. Another company, Taiwan VCM Corp (TVCM- belongs to CGPC), also produces Chlorine.

Note: Ms Zheng of association said there is no chlorine producer that uses CTC during production.

Chlor-alkali Company/Institution: Yee Fong Chemical

Location: Taiwan

Person interview: Mr. Chen

Tel: 886-3-3541944

Interviewers: Tecnon OrbiChem

Yee Fong never uses CTC in chlorine production, even the tail gas stream gathering.

The tail gas stream is covered to hydrochloric acid.

Capacity for chlorine now is about 26 ton/per day, and is came to 8.84ktpa. (26*340).

Yee Fong doesn't run at full rate.

Chlor-alkali Company/Institution: Taiwan Chlorine Industries (TCI)

Location: Taiwan

Person interview: Mr. Victor Chang – Director Sales & Marketing

Tel: 886-7-8715171 Ext 219

Interviewers: Tecnon OrbiChem

TCI never uses CTC in production, or for gathering tail gas stream. Nor do the other Taiwanese producers, as far as he knows.

He suggests us to ask FPC, the only one carbon chloride producer in Taiwan, FPC may know which companies are using CTC now.

Mr. Chang said there are only six chlorine producers in Taiwan. They are FPC, Taiwan Chlorine Industries Ltd., Chung Hwa Pulp Corp, Taiwan Pulp & Paper Corp, Yee Fong Chemical, and Taiwan VCM Corp (TVCM- belongs to CGPC).

Capacities for Chung Hwa Pulp Corp and Taiwan Pulp & Paper Corp are 13.2ktpa and 9.9ktpa, respectively.

Other producers, such as Chia Hsin and Cheng Tai, have been closed for ten years.

Chlor-alkali Company/Institution: Taiwan VCM Corp (TVCM) - China Gulf Plastics Group (CGPC)

Location: Taiwan

Person interview: Mr. Xu Zheng Yi– Spokesperson of CGPC

Tel: 886- 37-623391 ext 291

Interviewers: Tecnon OrbiChem

Taiwan VCM Corp (TVCM) belongs to China Gulf Plastics Group (CGPC).

TVCM never uses CTC in their production, or for gathering tail gas stream.

Capacity for chlorine now is 300ktpa (about 30ktons/ per month).

Chlor-alkali Company/Institution: Taiwan Pulp & Paper Corp

Location: Taiwan

Person interview: Ms Yu– Chemicals Division

Tel: 886- 6-6563811

Interviewers: Tecnon OrbiChem

Taiwan Pulp & Paper Corp said CTC neither be used in producing, nor for gathering tail gas stream.

Chlor-alkali Company/Institution: Environmental Protection Administration in Taiwan

Location: Taiwan

Person interview: Mr Chen –Toxic Chemical Substances Control

Tel: 886- 2-23117722 ext 2874

Interviewers: Tecnon OrbiChem

While asking for the information about which companies using CTC/ or producing CTC, he said Environmental Protection Administration do has these data, but he can not tell us. That is because it would involve in commercial secrets and he is not authorized to disclose the names or relative information.

If we want to get this information, we have to write a formal document to Environmental Protection Administration for asking for assistance.

CTC is one restricted toxic chemical substances and is only allowed to be used for the purposes below:

1. Research, experimentation, education

2. Manufacture of dry cleaning agent used for washing and dyeing

3. Semiconductor manufacturing, metal surface degreasing, manufacture of adhesives (solvent) for rubber

4. Manufacture of solvents used for washing electronics and machinery parts

5. Manufacture of grease remover

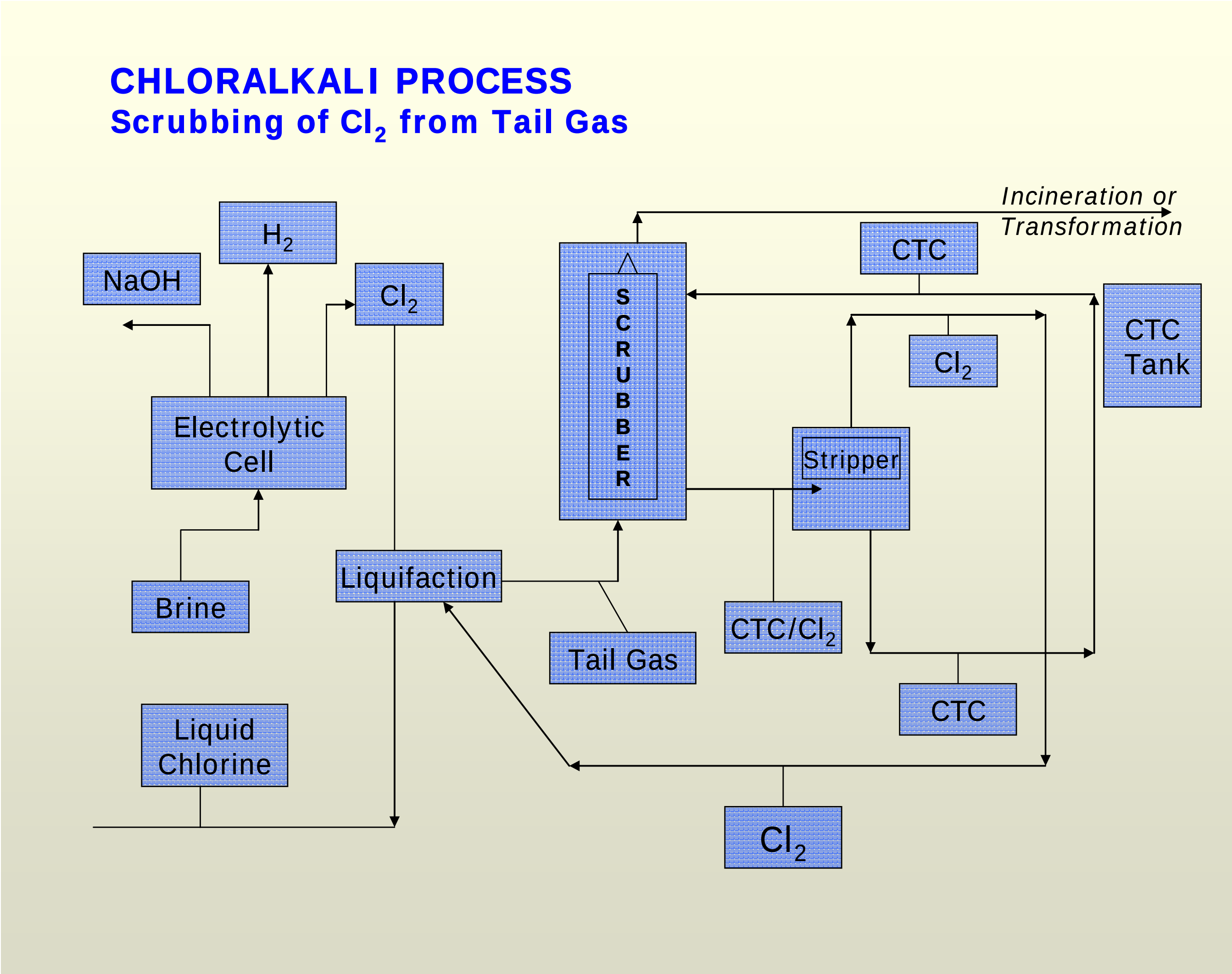
6. Gunpowder curing agent

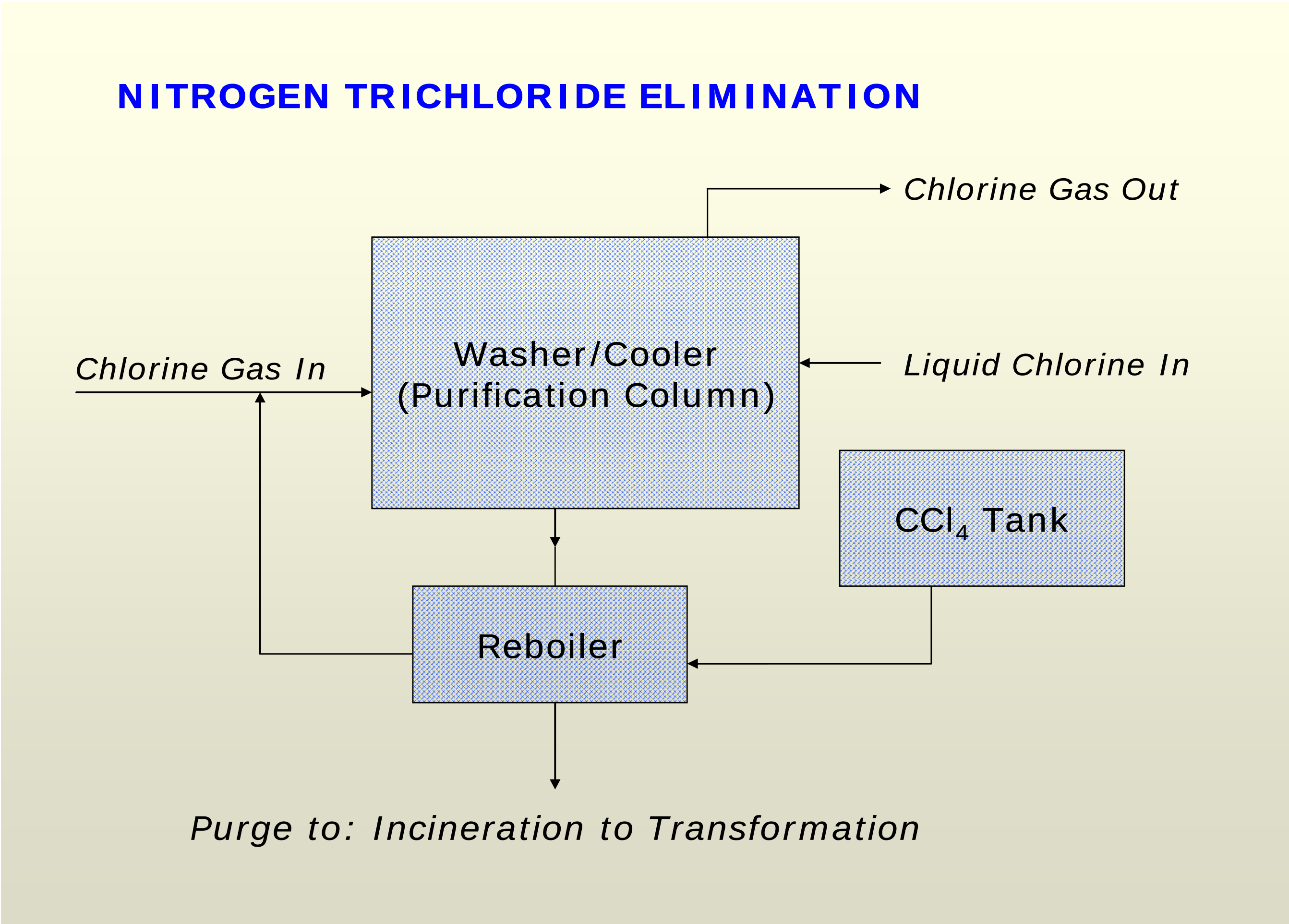
7. Steel refining

8. Manufacture of pharmaceuticals and ethylene dichloride

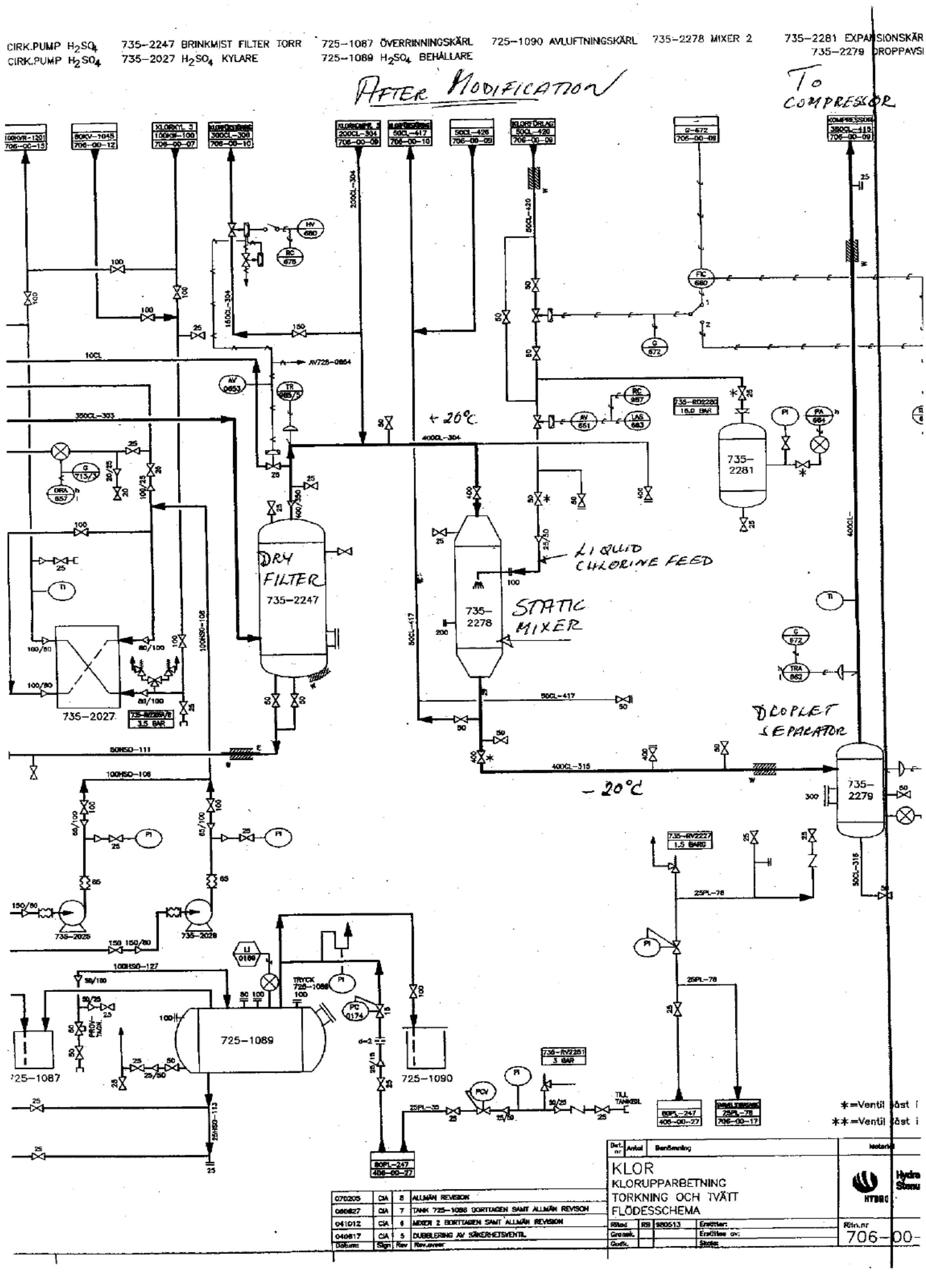
If any companies or institutions want to produce or purchase CTC, they have to register and get a permit.

ANNEX 8 - CHLOR-ALKALI PROCESS WITH CTC - FLOW DIAGRAMS

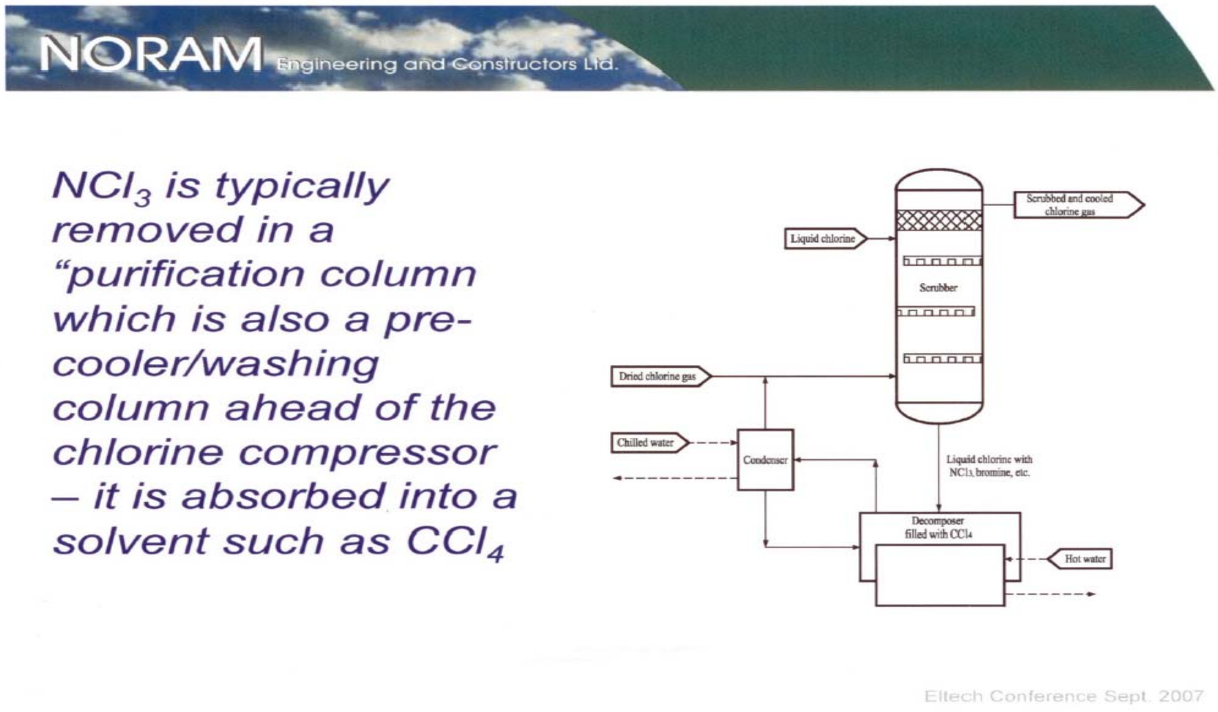


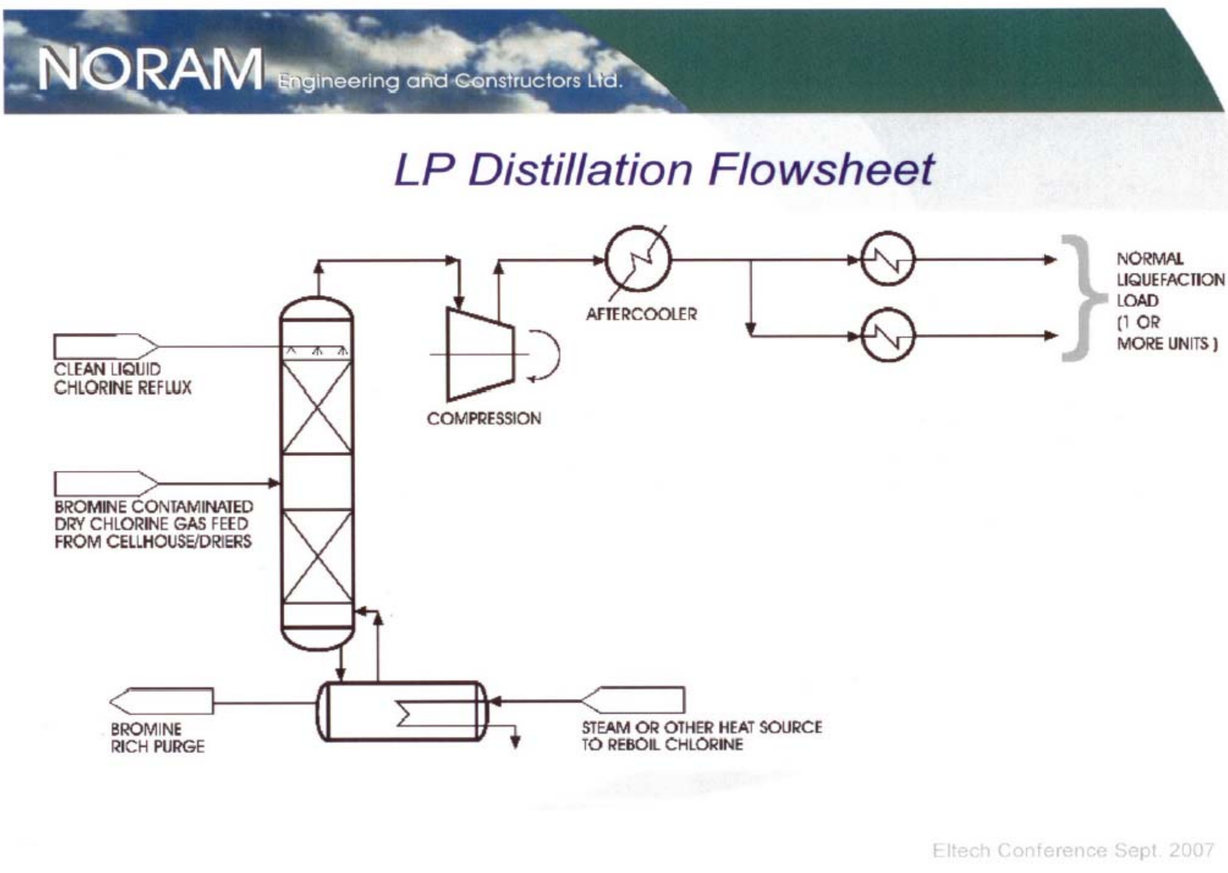

NITROGEN TRICHLORIDE ELIMINATION
Chlorine Gas Out
Washer/Cooler
(Purification Column)
Chlorine Gas In
Liquid Chlorine In
CCl4 Tank
Reboiler
Purge to: Incineration to Transformation

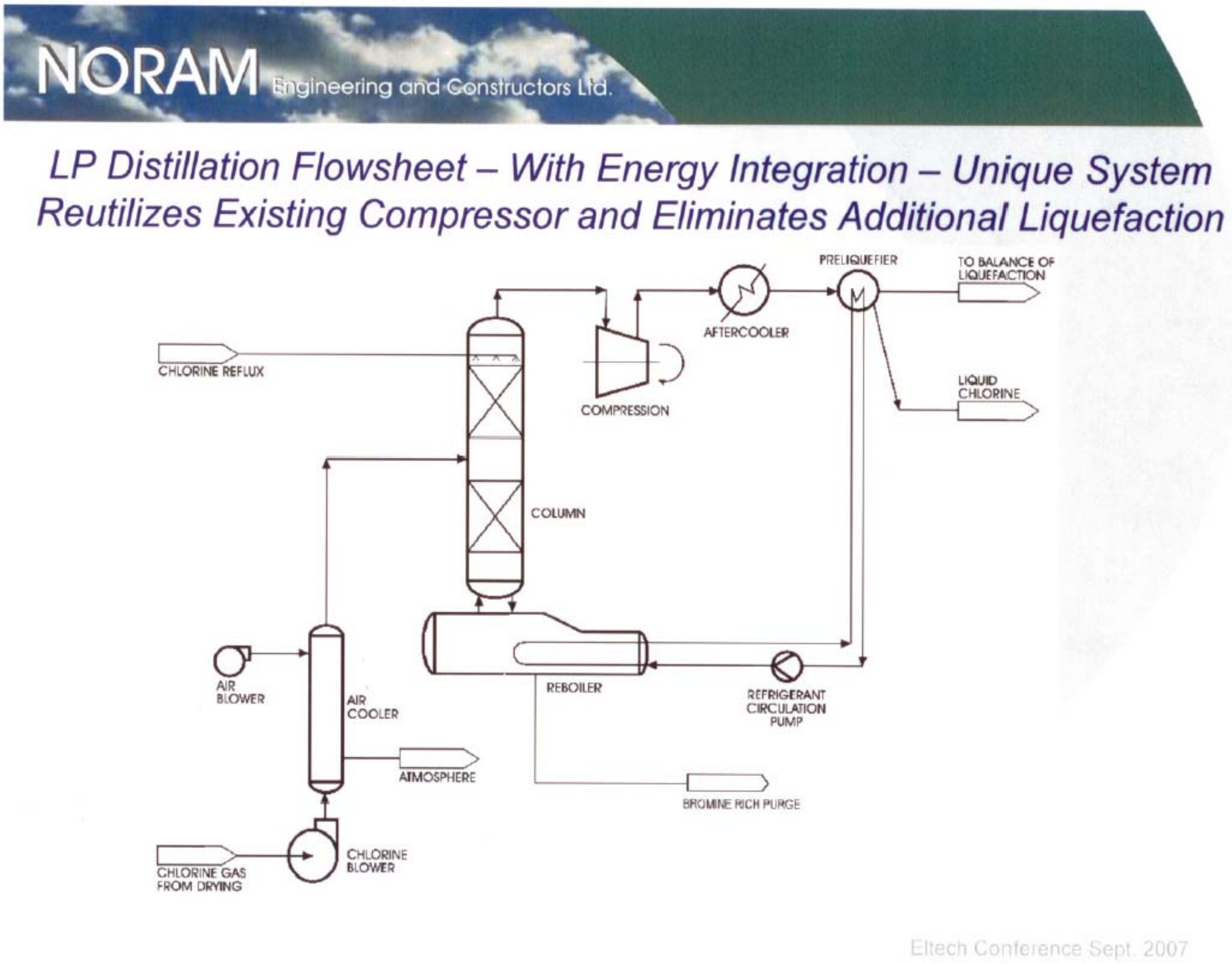
ANNEX 9 – SCHEMA CASE D



ANNEX 10 – CASE H - NORAM






NORAM Engineering and Constructors Ltd.
LP Distillation Flowsheet – With Energy Integration – Unique System Reutilizes Existing Compressor and Eliminates Additional Liquefaction
PRELIQUEFIER
TO BALANCE OF LIQUEFACTION
AFTERCOOLER
CHLORINE REFLUX
COMPRESSION
LIQUID CHLORINE
COLUMN
AIR BLOWER
AIR COOLER
REBOILER
REFRIGERANT CIRCULATION PUMP
ATMOSPHERE
BROMINE RICH PURGE
CHLORINE GAS FROM DRYING
CHLORINE BLOWER
Eltech Conference Sept. 2007

ANNEX 11 – SCHEMA CASE K