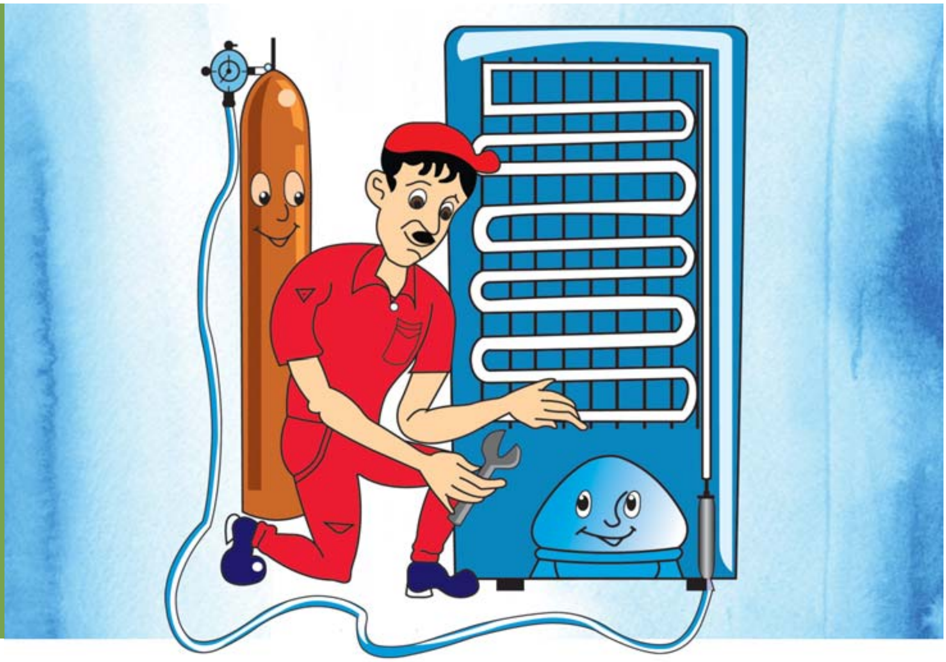
National CTC Phase-out Plan



Selection and safe use of alternatives to CTC

Refrigeration and Air-conditioning

gtz PROKLIMA

On behalf of
Federal Ministry for Economic Cooperation and Development

On behalf of
FFEM

Published by

Deutsche Gesellschaft für Technische
Zusammenarbeit (GTZ) GmbH

(German Technical Cooperation)

GTZ Proklima, A-33 Gulmohar Park
New Delhi – 110 049, India

Edition 1, November 2008

Table of Contents

1. The Phase-out of CTC 2
   1.1 About CTC 2
   1.2 The Montreal Protocol 2
   1.3 Role of GTZ-Proklima 3
2. The Practical dimension 4
   2.1 CTC applications 4
   2.2 Rising cleaning standards 4
   2.3 Formation of sludge 4
   2.4 Servicing practices to avoid 5
   2.5 Good servicing practices 5
3. Alternatives to CTC 7
   3.1 Selection criteria 7
   3.2 Viable alternatives 7
4. Health and safety 9
   4.1 Hazard potential of alternatives 9
   4.2 Controlling the risk of solvent usage 10
   4.3 Preventive measures 10
5. Glossary 13
6. Other publications for you 16

1. The Phase-out of CTC

1.1 About CTC

Carbon tetrachloride (CTC) is a solvent and cleaning agent used widely across many industry segments. Its high solvency power, low cost and the fact that it is non-flammable made it popular in many cleaning applications.

Although CTC is very popular, it is an ozone depleting substance (ODS) like chlorofluorocarbons (CFCs). It destroys the stratospheric ozone layer. The ozone layer protects life on our planet from harmful ultraviolet-B (UV-B) rays. The thinning out of the ozone layer in the stratosphere increases the earth's exposure to UV-B radiation which affects both human and animal life. It increases the incidence of skin cancer, eye cataract, suppresses the human immune system, reduces crop yields and affects aquatic life. Another adverse impact of CTC is its contribution to global warming. The global warming potential (GWP) of CTC is about 1,400 times higher than that of carbon dioxide (CO_2), the main greenhouse gas.

At the workplace CTC is an occupational health hazard. CTC is very toxic and is absorbed in the gastrointestinal, respiratory system and the skin. It is then distributed throughout the entire body. Highest concentrations are accumulated in liver, brain, kidneys, muscles and blood. CTC affects the central nervous system (CNS) severely, causing headache, weakness, lethargy, nausea and vomiting. Inhalation of high levels can damage the liver and kidneys. The severity of the effects depends on the route and frequency of exposure as well as co-exposure to other chemicals. CTC is proven to cause cancer in animals and is a suspected human carcinogen.

1.2 The Montreal Protocol

To protect the ozone layer, India, along with more than 190 countries has signed the Montreal Protocol to phase out production and consumption of CTC and other ozone depleting substances.

Under this agreement India has committed to phase-out the use of CTC as a solvent by 31st December 2009.

As the phase-out is progressing, CTC supplies in the market are dwindling rapidly. Beyond 2009 CTC will not be available for cleaning uses. Given the reduction of supply, the price of CTC has risen substantially. As a consequence CTC is costlier today than most of its alternatives.

1.3 Role of GTZ-Proklima

For enterprises there is an urgent need to substitute CTC now. But finding suitable alternatives, especially safer ones, is not an easy task. Considerable risk lies in the possibility that enterprises may substitute CTC with an even more hazardous substance such as Trichloroethylene or Benzene. Another challenge is that no single alternative can replace CTC in all its applications.

Under the framework of the Multilateral Fund of the Montreal Protocol, the Government of Germany and France have mandated GTZ-Proklima to provide technical assistance to CTC phase out affected small and medium scale industries in India. These activities are being undertaken with consent of the Ozone Cell of the Ministry of Environment and Forests, Government of India.

GTZ-Proklima offers technical assistance to industries currently using up to 10 metric tons or 6,250 litres of CTC per year. In close interaction with industries, GTZ-Proklima identifies viable alternatives for known uses of CTC. GTZ-Proklima's free-of-charge services aim to provide competent guidance in identifying 'safe' CTC substitutes that do not compromise on quality and competitiveness of the industry. GTZ-Proklima maintains strict independence from any brand or product.

As a result of this work, GTZ-Proklima has anaylsed the requirements and options available for RAC enterprises. The results and conclusion of this work are compiled in this booklet.

2. The practical dimension

2.1 CTC applications

A large share of RAC service enterprises use CTC for circuitry cleaning. It produces satisfactory results and is considered workable.

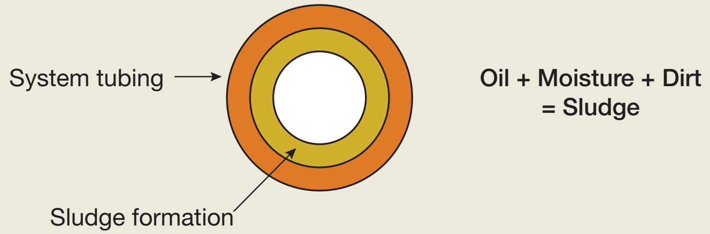
2.2 Rising cleaning standards

CFCs have been successfully substituted with ozone friendly alternatives like Hydrofluorocarbons (HFCs) and Hydrocarbons (HCs). This resulted in another problem: While CFCs have a high tolerance for system contamination, the same is not true for HFC and Polyol ester oil (POE) combinations. During the transition from CFC-12 to HFC-134a many manufacturers encountered the problem of capillary chocking. Most have overcome this through improved system cleanliness and better manufacturing processes. To ensure continued good system performance the service sector also needs to maintain higher system cleanliness standards.

2.3 Formation of sludge

A variety of contaminants accumulate in the circuitry over time. Some of them originate from the system, such as moisture, non-condensable gases, chemical residues, dust, metal particles and organic compounds. Other contaminants are 'imported' from other systems or service equipment in the process of servicing.

Figure 1
Sludge formation



This includes petrol, anti moist, and air from leak testing, self evacuation and filling. Contaminants also enter when the circuitry is kept open for a long time during servicing. Over time, contaminants present in the system get circulated and, under high temperature and pressure, turn gradually to sludge.

Sludge forms a plaque deposit in the capillary and gradually chokes the system. Sludge inside the condenser tubing reduces the heat transfer. This results in an increased condensing temperature and pressure, reducing the system performance and the compressor life.

2.4 Servicing practices to avoid

Some of the common cleaning practices often do not achieve the required cleanliness. This invites embarrassing repeat failures of systems serviced. Practices that should be avoided are:

- Flushing and leak testing with air
- Improper evacuation
- Improper cleaning of circuitry and brazing joints
- Dusty, untidy workplace
- Handling with unclean hands

In order to ensure safety the following practices should be avoided:

- Excessive use of solvents
- Direct exposure to and contact with the solvent
- Eating or smoking with hands soiled with solvents

More over, a casual approach towards occupational health and safety is common among service sector enterprises. This typically leads to unnecessary exposure of technicians to toxic cleaning agents.

2.5 Good servicing practices

Compressed air should never be used for flushing, particularly when a hermetic compressor is used for generation of compressed air. This is because compressed air contains moisture, other gases as well as lubricants from the compressor and thereby contaminates the system. Only dry nitrogen should be used for flushing. It is inert and will also absorb some of the moisture inside the system.

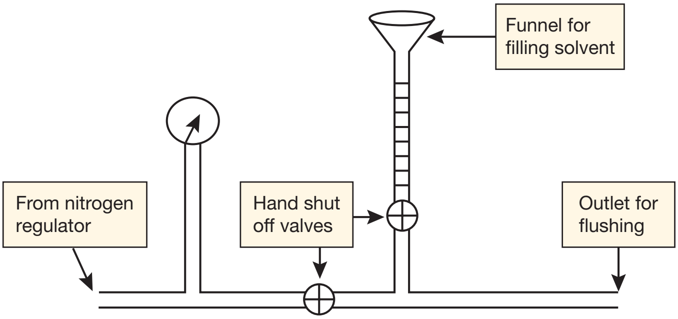
Another reason for avoiding the use of air or oxygen for flushing systems is that the oxygen can react with the compressor oil whilst the moisture in the air is absorbed by the compressor oil. This is particularly critical for compressors running on HFC134a and POE lubricants.

When chemical cleaning is required for contaminated circuitry, choose an alternative to CTC. The next chapter presents viable options. Ensure that all solvent in the liquid phase is vaporised and flushed out of the system with dry nitrogen. Petrol should not be used as a cleaning agent as it contains impurities that will contaminate the system.

Good servicing practices recommended:

- Avoid wasting solvents while filling the circuitry. Use a system of funnel and valves as shown in the diagram for filling a measured quantity of solvent into the system.

Figure 2
Model of solvent filler



- Use dry nitrogen for flushing and leak testing.
- Use a two-stage regulator for nitrogen cylinders.
- Use a two-stage vacuum pump for evacuation of the system.
- Clean and tidy workplace will reduce the possibility of contaminants entering the circuitry when open.

More guidance on good practices with regard to occupational health and safety are presented in the section 4 – 'Health and safety'.

3. Alternatives to CTC

3.1 Selection criteria

No alternative is ideal in all regards and each one has certain advantages and disadvantages. The listing below shows the range of criteria that should be considered for the alternative to CTC for circuitry cleaning.

- Good cleaning efficacy
- Should not tarnish or corrode copper
- Should not leave behind any residues
- Cost lower or equal to CTC
- Locally available
- Low toxicity
- Free from carcinogenic substances
- Free from ozone depleting substances (ODS)

3.2 Viable alternatives

Based on the selection criteria presented above, GTZ-Proklima identified a range of alternatives, some of which are already in common use by RAC enterprises. Their suitability has been evaluated in the laboratory and confirmed in industrial trials. Tried and tested alternatives are:

• Hexane (n-Hexane)
• Methylene Dichloride (MDC)
• Perchloroethylene (PCE)
• Toluene
• White petrol

Trichloroethylene (TCE) has good cleaning properties and is used by some enterprises, its usage is strongly discouraged because of the inherent cancer risk.

In conclusion, no single substance can be suggested as the best. Selection has to be made based on the work environment, the individual cleaning practices and the ambient temperature. For example, Methylene dichloride has good solvency power but has a boiling point of 40^0 C which makes it evaporate very fast and thus may not be an economical option in hotter climates. Hexane, Toluene and White petrol are highly flammable and must be used with due precautions to minimize fire risk. Solvents with Hansen solubility parameter below 19 are especially effective in cleaning mineral oils, lubricants and greases. The following table presents a selection of relevant key parameters.

Table 1
Properties of solvents

Parameters	Methylene Dichloride (MDC)	Perchloroethylene (PCE)	n-Hexane	Toluene	White Petrol	Trichloroethylene (TCE)[1]
Flammability	None	None	Highly flammable	Highly flammable	Highly flammable	None
Flash point	None	None	– 23 ^{0}C	4 - 7 ^{0}C	–18 ^{0}C[2]	None
Boiling point	40 ^{0}C	121 ^{0}C	63 - 70 ^{0}C	111 ^{0}C	50-120 ^{0}C[3]	87 ^{0}C
Specific gravity	1.33 g/cm^3	1.62 g/cm^3	0.69 g/cm^3	0.87 g/cm^3	0.67-0.69 g/cm^3 [2]	1.47 g/cm^3
Vapour pressure	350 mm_{Hg}	14 mm_{Hg}	124 mm_{Hg}	21 mm_{Hg}	180 mm_{Hg}	58 mm_{Hg}
Solvency power	136 KB	90 KB	29 KB	105 KB	32 KB	129 KB

[1] **CAUTION:** Use strongly discouraged! Values for comparison only.
[2]Value approximated

4. Health and safety

4.1 Hazard potential of alternatives

No alternative is perfect. Each substance has specific limitations and is a hazard for health and safety. While all solvents are toxic, the degree varies from one substance to another. Understanding the strengths and weaknesses of alternatives is essential for taking informed decisions. In the context of circuitry cleaning, particularly the risk of inhalation and skin contact needs to be considered. The table below shows the hazard ratings of the alternatives discussed above. Ratings distinguish six grades shown with a corresponding colour shade. The least risk is shown in light blue, followed by shades of yellow and orange. Dark red represents the most severe risk.

Table 2
Hazard rating

	Risk	Inhalation	Skin	Environment	Flammability
E	High	Severely toxic	Severely toxic	Very hazardous	Extremely flammable
D		Very toxic	Very toxic		Highly flammable
C		Toxic	Toxic	Hazardous	Flammable
B		Harmful	Harmful		Combustible
A		Irritant	Irritant		Possibly combustible
-	Low	None	None	Not classified	Non-flammable

The selection of a solvent should be made so as to reduce the hazard as far as feasible. However, as is apparent from the ratings above, for circuitry cleaning there is hardly any choice because all substances are classified as ‘Very toxic’ for ‘Inhalation’ and ‘Toxic’ under ‘Skin’. Safe use can therefore not be ensured by a prudent selection alone. For comparison the risk levels of water, CTC and TCE are also shown.

The following section will guide you on measures to safeguard health and safety.

Table 3
Hazard rating for alternatives to CTC

Viable alternatives	Hazard rating			
	Inhalation	Skin	Environment	Flammability
Methylene Chloride	D	C		
Toluene *aka Methylbenzene*	D	C		D
Perchloroethylene (PCE)	D	C	E	
n-Hexane	D	C	E	D
White Petrol	D	C	E	D
Water				
Carbon Tetrachloride (CTC)	D	C	E	
Trichloroethylene (TCE)	E	E	C	

4.2 Controlling the risk of solvent usage

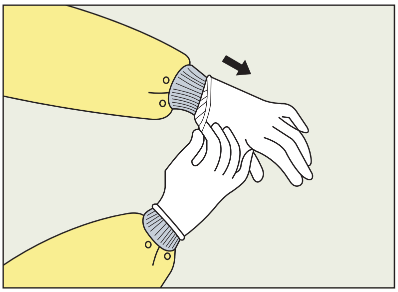
The toxic potential of alternatives combined with typical exposure situations in circuitry cleaning makes safety measures necessary. Risk control follows certain priorities. Substitution is generally accorded the highest. Next in line are engineering controls such as ventilation followed by administrative controls. The use of personal protective equipment should be the last measure in exposure control.

4.3 Preventive measures

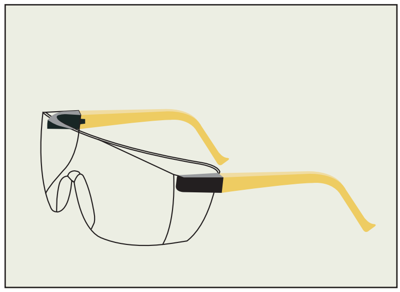
- **Prudent substance selection:** Select the safest possible substance (refer 4.1 – 'Hazardous potential of alternatives').
- **Consult an MSDS:** Demand a material safety data sheet (MSDS) of the solvent from your retailer.
- **Limit the quantity:** You might need less solvent than you think you need. Most technicians overestimate the requirement for circuitry cleaning. Assess the required quantity carefully and use no more. It is believed that solvent exposure can be reduced significantly by this measure alone.
- **Purge with inert gases:** Though some solvents do not have a flash point, all should be considered as flammable. Therefore purging with air could lead to explosions. Use only inert gases like nitrogen.

Face shield

Mask



Gloves



Goggles

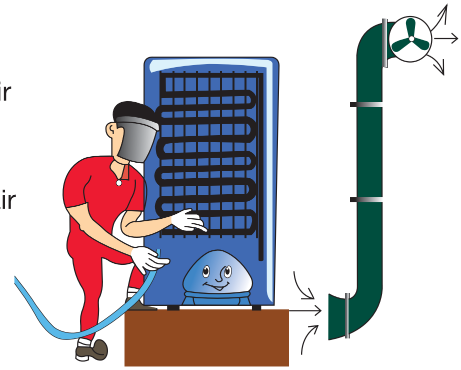
- **Wear goggles:** Flushing leads to a pressure build-up that may result into splashing of both solvent and contaminant. Building the pressure up gradually minimizes the risk. However, protect your eyes with goggles.

- **Wear gloves:** Skin contact with the solvent during flushing occurs regularly. All solvents remove the fat content of the skin. Only gloves can protect your skin adequately.

- **Ensure good ventilation:** All solvents are toxic. While performing the cleaning operation the solvents evaporates into the surroundings. If the person experiences drowsiness or nausea, it is an indication that concentration of solvent vapours is above tolerable limits in the surroundings and there is a need for better ventilation of the cleaning area. The possible options include:

  - Shift cleaning operations to an area with high ceilings and cross-ventilation.

- If there is a perceivable flow of air, clean downwind so that the air first reaches you and then the circuitry being cleaned. That way the air you breathe is cleaner.



- If none of these prove sufficient, consider the installation of local exhaust ventilation (LEV). LEVs capture contaminants before they disperse into the air of the workplace. Such systems consist of a hood, a duct and an air cleaner. LEVs cannot be bought off the shelf and they have to be sized by experts to meet the specific requirements.

- **Training:** Last but not least, training and instructions are the most important part of personal protection. Ensure that the workers involved in cleaning operations are aware of the hazards of substances used.

The recommendations above address a great share of health and safety problems. However, they do not address specific issues of individual enterprises. In order to enhance adequacy of recommendations further GTZ-Proklima has launched into a detailed workplace assessment to investigate exposure situations to define specific control approaches.

5. Glossary

This glossary defines terms you are likely to encounter in material safety data sheets (MSDS)

Acute effect: The effect caused by a single short term exposure to a high amount of concentration of a substance.

Aerosols: Liquid droplets or solid particles dispersed in air that are of fine enough particle size (0.01 to 100 microns) to remain dispersed for a period of time.

Alkali: Any of a class of substances that liberates hydroxide ions in and have a pH of more than 7. Strong alkalis in solution are corrosive to the skin and mucous membranes. They are also called bases and may cause severe burns to the skin.

Anhydrous: Does not contain water (e.g. anhydrous lime)

Asphyxiation: A condition whereby oxygen in the air is replaced by an inert gas such as nitrogen, carbon dioxide, ethane, hydrogen or helium to a level where it cannot sustain life. Normal air contains 21 percent of oxygen. If this concentration falls below about 17 percent, the human body tissue will be deprived of their supply of oxygen, causing dizziness nausea and loss of coordination. This type of situation may occur in confined work places,

Auto-ignition temperature: The minimum temperature at which a material ignites with out application or a flame.

Boiling point: The temperature at which liquid changes to a vapour state at a given pressure (Usually 760 mm of Hg or one atmosphere)

Caustic: The ability of an alkali to cause burns

Chronic health effect: An adverse effect on a human body with symptoms developing slowly over a long period of time.

Chronic toxicity: A chronic effect resulting from repeated doses of or exposure to a substance over a relatively prolonged period of time.

Combustible: A term used to describe and classify substances that burn.

Confined space: Any area that has limited openings for entry or exit that would make escape difficult in an emergency, has a lack of ventilation, contains known and potential hazard, and is not normally intended or designed for continuous human occupancy (e.g. a storage tank, manhole of collection conveyances systems in effluent treatment plants)

Explosion proof-equipment: Apparatus or device enclosed in a case capable of withstanding an explosion of specified gas or vapour and preventing the ignition of specified gas or vapour surrounding the enclosure by sparks, flash or explosion and operating at an external temperature so that surrounding flammable atmosphere will not be ignited.

Flammable: A flammable liquid is defined as a liquid with a flash point between 21 and 55 degrees Celsius. It may catch fire on contact with a source of ignition.

Flammable/explosion limits: Flammable/explosion limits produce a minimum and a maximum concentration of gases/vapours/fumes in air that will support combustion. The lowest concentration is known as the lower flammable/explosion limit (LEL), the highest concentration is known as upper flammable/explosion limit (UFL)

Flash point: Minimum temperature at which, under specific conditions, a liquid gives off sufficient flammable gas/vapour to produce a flash on contact with a source of ignition.

General exhaust/ventilation: A system for exhausting or replacing air containing contaminants from a general work area.

Hansen solubility parameter: A numerical value that indicates the relative solvency behavior of a specific solvent. This number is calculated (based on volume percentage) from the properties like dispersion, polarity and hydrogen bonding of the solvent. Hansen solubility parameter is available for every solvent, any liquid or polymer.

Hazard: A potential to cause danger to life, health, property or the environment.

IDLH (Immediate danger to life and health): The maximum concentration from which one could escape with in 30 minutes with out any escape-impairing symptoms or irreversible health effects. Usually used to describe a condition where self contained breathing apparatus (SCBA) must be used

Incompatible: Condition of materials that could cause dangerous reactions from direct contact with one another. Particularly relevant when storing different substances in the same place.

Local exhaust: A system or device for capturing and exhausting contaminants from the air at the point where the contaminants are produced. (e.g. dust in shaving and buffing)

MSDS (Material safety data sheet): Consolidated information on specific identity of hazardous chemical substances, also including information on health effects, first medical aid, chemical and physical properties, emergency measures etc.

OEL (Occupational exposure limit): An exposure level established by a regulatory authority (e.g. OSHA, NIOSH).

Poisoning: Normally the human body is able to cope with a variety of substances within certain limits. Poisoning occurs when these limits are exceeded and the body is unable to deal with a substance (by digestion, absorption or excretion)

Risk: The measured probability of an event to cause danger to life, health, property or the environment.

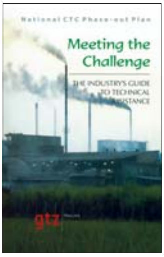
TLV (Threshold limit value): A concentration threshold in the atmosphere which is set specially for each pollutant. It refers to the limit accepted in the atmosphere of working area.

TLV-STEL, TLV short term exposure limit: Concentration threshold in an atmosphere contaminated with a specific type of pollutant for a 15 minute exposure (if not otherwise specified)

TLV-TWA, TLV time weighted average: Concentration threshold in an atmosphere contaminated with a specific type of pollutant, usually for a continuous eight hour exposure

Toxicity: The inherent potential of a chemical substance to cause poisoning.

6. Other publications for you



Meeting the Challenge provides essential information on CTC Phase out and industry sectors most affected by it. The publication also elaborates on 'applications' across sectors affected by CTC phase out as also GTZ-Proklima's mandate, approach and technical assistance provided to affected industries.

Languages: English, Hindi, Gujarati, Kannada and Malayalam

Solvent Alternatives is a compilation of technical information on a variety of CTC alternatives that are in use in industry – across industry sectors and applications. The advisory elaborates on use and potential risks involved therein, with regard to profiled substances

Languages: English

Industry specific guidelines for the substitution of CTC in about 10 sectors are under preparation. Their launch is expected from December 2008. Similar to this guideline for RAC enterprises, other guidelines will inform of alternatives to CTC in other sectors and their safe use.

Languages: English

Printed copies of GTZ-Proklima's publications are available on request, free-of-charge to users of CTC. All publications are also available for free download at our website www.ctc-phaseout.org

Ozone Cell, Ministry of Environment and Forests, Government of India, is the central agency coordinating the phase-out of CTC. The cell has established the regulatory framework and national phase-out plan. It ensures that domestic CTC production and import progressively decrease in compliance with national targets.

The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH is an international cooperation enterprise for sustainable development with worldwide operations. GTZ-Proklima is a sectoral program which implements bilateral and multilateral projects in order to assist partner countries in fulfilling their obligations under the Montreal Protocol. With more than 130 projects, GTZ-Proklima is the largest bilateral partner of the Multilateral Fund of the Montreal Protocol. GTZ-Proklima, on behalf of the Government of Germany and under the overall coordination of Ozone Cell, Ministry of Environment and Forests, provides support to Indian industries for smooth transition to a CTC-free world. In the current project GTZ-Proklima holds an additional mandate on behalf of the Government of France which provides financial support through its French Global Environment Facility (FFEM). GTZ-Proklima does not promote any particular product or brand but provides technical assistance to CTC consuming industries.

On behalf of
Federal Ministry for Economic Cooperation and Development

On behalf of
FFEM

National CTC Phase-out Plan

Project Office:
GTZ-Proklima
A-33 Gulmohar Park, New Delhi - 110 049
Phone : 011-2661 1021
Email : contact@ctc-phaseout.org
Web : www.ctc-phaseout.org

Deutsche Gesellschaft für Technische
Zusammenarbeit (GTZ) GmbH

Dag-Hammarskjöld-Weg 1-5
65760
Eschborn/Deutschland
T +49 61 96 79 - 0
F +49 61 96 79 - 11 15
E info@gtz.de
I www.gtz.de