Special Edition

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Working with gtz

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Editoral

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and used to be German Federal Minister for Environmental Affairs.

Dear Readers,

Since the drastic thinning of the stratospheric ozone layer was scientifically proved over the Antarctic and, in the last few years, over the Northern Hemisphere, the withdrawal from the production and use of ozone-depleting substances like CFCs has been playing a growing role. This withdrawal has made great progress internationally. In the Federal Republic of Germany very considerable steps toward reduction - beyond international and EU obligations - have been possible.

World-wide we are well on our way to developing replacement materials and technologies. I am glad that we in Germany can already demonstrate a significant success: all German manufacturers of home refrigerators have abandoned CFCs. Most of them have changed over to hydrocarbons, which neither attack the ozone layer nor contribute to the greenhouse effect.

I think that this example shows clearly that ecology and economics need not be contradictory: the market has fully and completely accepted the environmentally-friendly refrigerator. Within the framework of international environmental responsibility we can surely accomplish a total withdrawal from ozone-depleting materials as quickly as possible. This is why I welcome the initiative of the Deutsche Gesellschaft für technische Zusammenarbeit, GmbH (GTZ) to transfer the know-how of the German refrigerator industry to non-industrialised countries.

In this special issue of Akzente are reports on, among other subjects, the cooperation of the Federal Republic of Germany with India and China. I am confident that the friendly cooperation between industrialised and non-industrialised countries will result in successes for the environment in the very near future.

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Essay: Efforts to Phase Out CFCs Are Making Progress

Essay by Mary D.Nichols assistant Administrator for Air and Radiation, US EPA

Destruction of the life-protecting ozone layer by chlorofluorocarhons (CFCs)is one of the most serious global environmental problems. Ozone in the stratosphere absorbs dangerous ultraviolet radiation from the sun, protecting humans from the risk of skin cancer. Ultraviolet light also harms food crops and natural ecosystems. CFCs released into the atmosphere damage the ozone layer, threatening global sustainability through the spread of disease, and dwindling of harvests.

Although we now understand the threat of CFCs, they were once thought of as an ideal compound for many purposes. Invented in the late 1920s,CFCs are nontoxic, noncorrosive, nonflammable, and nonreactive with most other substances. They have been widely used in refrigerators and air conditioners, as a blowing agent for foam products, as aerosol propellants in spray cans, and as solvents.

Lacking understanding of the threat posed by CFCs to the ozone layer, they remained a popular industrial substance that improved the comfort and ease of life. Before the 1970s, scientists had not worried about how CFCs would affect the atmosphere.

However, in 1974, Mario Molina and Sherwood Rowland began considering the ultimate fate of these wonder chemicals. They found that because CFCs were extremely stable in the lower atmosphere, they could drift up into the stratosphere where they wc)tlld break apart when bombarded by the sun s radiation. They suspected that the millions of tons of chlorine atoms released into the stratosphere could severely damage the ozone layer.

Since the invention of CFCs, we have developed methods to assess the impacts of lnaterials and technology. Although we cannot foresee every consequence of each action, it is important to continue to question and take action when necessary.

The Montreal Protocol on Substances that Deplete the Ozone Layer is the international response to the dangers posed by CFCs. As a result of this agreement, CFCs are being replaced by HFCs and HCs. While this replacement begins, we must assure that the substitutes are environmentally acceptable. Although HCs and HFCs have no ozone depleting characteristics, HFCs have a relatively high global warming potential and HCs are flammable. Therefore, the risk balance is to select refrigerants that have high energy efficiency that can he safely used and that are contained and recycled. In Europe, HCs are increasingly replacing CFCs. Small amounts of HCs are used in refrigerators.

The U.S. EPA has sponsored a wide range of projects to investigate these tradeoffs and has helped facilitate the safe use of flammable refrigerants in refrigerators. However, it is European and Japanese companies that have pioneered the commercial introduction of these products. The papers presented in this book describe some of the challenges and triumphs of introducing these flammable HC refrigerants.

The final commercial success of refrigerants that replace CFCs will depend on the right balance between a wide range of environmental factors. The Unites States Environmental Protection Agency will continue to cooperate globally in helping make the right choices as worldwide efforts to phase out CFCs march forward.

The China Project: Haier Converts

Qiu Chengzhong

In China, where the market for household refrigerators is thriving, the first steps have been taken to get away from CFCs and HFCs. GTZ and its German business partner Liebherr are helping the firm Haier, one of the best known and largest Chinese producers of refrigerators, convert a production line to hydrocarbon technology. This pilot project in Qingdao is meant as a paradigm to show other producers how they could make the switch to environmentally friendly products with expertise and financial support. The journalist Qiu Chengzhong describes developments in Qingdao from the Chinese point of view.

In June 1994, only 75.1 out of 100 urban households and 11.4 out of 100 rural households had refrigerators. But since Chinese incomes are growing continually, and economic growth holds year after year, it is safe to predict that many people - especially city-dwellers - who have no refrigerator today will be getting one soon. Thus 75 million refrigerators - a number nearly as large as the total population of Germany - are to be produced for this group of customers alone. So far all Chinese refrigerators have contained CFCs.

"Starting production of CFC-free refrigerators in China is of global significance in the effort to save the ozone layer from destruction," says Wu Kesong, President of Haier Refrigerator, Ltd., in Qingdao, an industrial city on the Yellow Sea. "As a leading refrigerator firm in China we feel the obligation to change our production facilities quickly to environmentally supportable products."

President Wu describes the circumstances for Haier's rejection of CFCs. "Our Chinese customers have been waiting for a new generation of refrigerators without CFCs yet energy-efficient. And we want to think of exports, too." According to the Montreal Protocol for the Protection of the Ozone Layer, China is an "Article 5 country", and therefore has until 2010 to switch to the new technology. But industrialised countries must stop selling refrigerators with CFCs by 1996. "That's why," explains Wu Kesong, "we must do some intensive research now if we don't want to be left behind." And since China is a non-industrialised country, ill-prepared to manufacture CFC-free products immediately without foreign aid, Haier started working with the German firm Liebherr in 1990.

Haier wants to replace CFC 11, the traditional foaming agent for polyurethane insulation, with cyclopentane, and the coolant CFC 12 with isobutane. Both cyclopentane and isobutane are hydrocarbons and contain neither chlorine nor fluorine. They do not damage the ozone layer. Nor do they contribute to earth warming, unlike the hydrofluorocarbon (HFC) 134a, which still serves as a replacement for CFCs in countries like Japan and the USA.

In 1992 Haier developed a CFC- and HFC-free refrigerator, the first of its kind in China. It is still only an experiment: there is as yet no such refrigerator in China, according to Wu. There are still hitches with sensors and supervisory facilities. Hydrocarbons are environmentally friendly but flammable, and as yet there is no state authority to monitor safety. Haier is gathering experience, the sine qua non for a safe changeover to hydrocarbon technology. The extra costs that the changeover will bring are yet another large problem.

In the spirit of the Montreal Protocol, Germany is helping China both financially and technologically in its efforts to get out of CFCs and HFCs. GTZ has been active in China since 1994. Haier was chosen for the pilot project, for which plans were worked out jointly. Wu says: "With the help of the GTZ technicians we will be ready to switch the production facility to hydrocarbon technology within the first six months of 1995. We will have to raise some of the money for this change on our own, too, and arrange for credit."

Ge Fengyu, Technical Equipment Department Head at Haier, explains to us: "We'll finish building all the tanks for the hydrocarbons by the end of 1994. The assembly line in our Number 2 factory is to be converted without a break in normal production. We'll use the holidays for the changeover." In the company's display rooms the engineer Qu Guangming, Production Department Head, points to two test samples of polyurethane to be used for the insulation of the refrigerators: "Foamed with cyclopentane," he says. Then he leads us to a small refrigerator of which he seems to be particularly proud: "This is the prototype of our first-generation CFC- and HFC-free refrigerators!"

The know-how of Liebherr, the German partner, made the technical conversion simpler. "Thanks to the GTZ project we could apply Liebherr's experience directly to our production facilities, because our machines and our technology were imported from Liebherr in the first place. Our production norms conform to the German industry standard DIN [Deutsche Industrie Norm]." In converting to hydrocarbons at Haier the experts could more or less just repeat the procedure that Liebherr had mastered at its own production facility in Germany.

In 1985, when Haier was still a washing machine factory with 700 employees, it introduced the Liebherr production process for household refrigerators and the equipment that went with it. A seven-year cooperation agreement was signed. Then came the second, present phase of the cooperation. The erstwhile washing machine factory has evolved into the Haier group with 5000 employees.

Each year 600,000 household refrigerators are produced, 150,000 for export to over 30 countries, including Germany. In 1994 production is to be increased by about 50,000 units. Of all the Chinese refrigerator manufacturers Haier is the only one to receive the ISO 9001 certificate. Haier was the first firm to build refrigerators with 50% less CFCs.

Even though Chinese industry has an annual production capacity of 15 million household refrigerators and cooling units - and Haier refrigerators sell at prices around 20% higher than other brands - since 1986 Haier production can hardly keep pace with demand. A consumer survey of refrigerators placed Haier third.

The cooperation with Liebherr, says President Wu, should be cultivated and extended beyond the mere transfer of technology and equipment. "We will send more technicians to Liebherr for further training, and more German business partners will come to us to solve problems that arise in production and development," he says. "We will also continue to buy top technology and equipment from Liebherr."

He takes a look at the past. "Through Liebherr's know-how and equipment we could adopt progressive technology and modern management methods. We have given considerable thought to what we have learned, and we have adapted what we learned to the conditions of our own country. And even if on the whole we have learned more from Liebherr than vice-versa, our German partners have learned something in our country, too, that they can take home with them."

At a time when large state enterprises in China are booking losses, Haier's upswing has held for the last ten years. The firm is full of vitality. Its governing body managed to exploit know-how from all over the world during the government push for reform and openness. It managed adroitly to merge staff interests with those of the firm so that Haier could keep up with the development trends in refrigeration technology of the rest of the world.

The firm's motto is felt everywhere on the Haier premises: "Total dedication to the effort for top performance!" Every employee is expected to play a part in producing the best possible product. An example of this determination is the direct conversion of the production system to hydrocarbons, which means more work for everybody at the start. In every workshop a square is drawn on the floor with the inscription: Please present yourself here before quitting time! Those who have met their work assignments may go. In a word, every day every person must answer for what he has accomplished.

Every effort and every initiative is rewarded with honourable mention or a bonus. Haier employees identify their own futures with the future of their firm. And they are turning their energies to the task of a new era: building environmentally-friendly refrigerators for the world

Qingdao-Liebherr Co-operation

Jürgen Melzer

The story of the successfull cooperation between the former Qingdao General Refrigerator Factory, now a member of the Haier Group, and Liebherr started in Och senhausen, Germany, in July1984, when the first co-operation contract was signed.

The contract comprised the transfer of know-how and the delivery of equipment and tools for the manufacture of domestic/household refrigerators and freezers. The initial capacity was 100,000 units per year in two shifts per day.

The essential elements of the contract were the transfer of know-how for three models, the delivery of key production equipment, training in Germany and China, and installation and commissioning in existing buildings (Qingdao I) at Qingdao.

Production started in 1986, and the products were introduced to the Chinese market under the trademark "Qingdao-Liebherr".

In the following years, other models were introduced under licence from Liebherr.

In 1987, cooperation was extended by an additional seven years, and further key production equipment was delivered. After its installation in a new three-storey production building (Qingdao II), production capacity was almost doubled. The foaming equipment installed at the time was the same as the type used by Liebherr in Germany, and it already incorporated sub-floor foaming into the centre at the rear.

Other, new models were introduced that were based mainly on modifications carried out by Qingdao themselves. By the end of the eighties, Liebherr were introducing 50 percent CFC reduced foam within their own production facilities, and Qingdao followed this step within a short time, being the first Chinese manufacturers to do so.

The quality of the Qingdao products was excellent, so that between 1991 and 1993, a considerable number were sold to the German market, having being certifies to DIN and VDE standards. The current production programme comprises more that 20 different models, some of which are pure Liebherr licence products and others are models changed and modified by Qingdao. Through cooperating with Liebherr, Qingdao have always had access to the latest developments and technologies of the German company, and are informed in detail during an annual technical exchange meeting in Germany. Consequently, Qingdao have constantly been aware of the latest developments in refrigeration industry and its current chief issue, CFC and HFC phase- out.

In April 1993, as the first manufacturers worldwide, Liebherr changed their entire production (two factories) from CFC 11 to cyclopentane in the polyurethan foam, and from CFC 12 to CFC free HFC 134a in the cooling circuit.

Meanwhile, HFC 134a is gradually being phased out by the hydrocarbon isobutane (HC 600a), a process that should be completed by end of 1995.

Being aware of these environmentally friendly improvements, and facing the same problems with CFC in China, Qingdao showed serious interest in following suit. By the end of 1993, joint debates were already taking place on how to achieve conversion at Qingdao. Two problems that quickly became apparent were financing this costly investment and applying a technology with the highest safety standards.

It was at this stage that overall contacts between Qingdao, Liebherr, Greenpeace Germany and the GTZ opened the door for a bilateral project aimed at phasing out CFC and HFC at the Qingdao II factory.

While the GTZ is ready to provide the hard currency required for the machines and equipment and installation, Qingdao will cover all local contributions, such as constructional modifications, local assistance, etc., and Liebherr are going to supply technical skill and engineering capabilities to evaluate and lay out technical safety conversion for Qingdao. The total technical concept is to be checked and approved by the German technical inspection association TÜV, and will be installed in the coming four to eight months (the foaming system first, and later on equipment for the new refrigerant). Naturally, all the experience Liebherr have gained over the past 20 months is being integrated in this project. Thus, as. has already sometimes been the case in the past, QingdaoLiebherr co-operation is once again going to perform a pilot function in China's refrigerator industry, and it may mark the start of national CFC phase out in the People's Republic of China.

Liebherr are proud of contributing to this important step for China, and look forward to continuing to cooperate with Qingdao.

GTZ: A Hand for the Phase-Outout of CFCs

Peter Baz

It really all started with Foron's Greenfreeze.

Didn't the CFC and HFC free refrigerator mean that an environmental technology was suddenly available that could make an important contribution to solving the global problem of protecting the ozone layer? And isn't this technology also suitable for developing countries? Doesn't it present a good opportunity for a development and environment policy technology and know-how transfer? Doesn't it create a chance to open up to a greater degree or maintain for the future the ecotechnology potentials of our country - and in particular the new eastern states of the Federal Republic?

These are some of a number of exciting questions that posed themselves. Answers had to be found, and a concept needed to be developed.

In the autumn of 1993, we commissioned a study to the IFEU Institute in Heidelberg on "CFC Substitution in the Third World The State of the Art and Perspectives". With this study, We intended to gain an overview over

- the principal areas in which ozone depleting substances (ODS) were being employed in the Third World,

- the state of the art regarding substitution technologies for ODS in Gemany.

Early in February 1994, we invited 30 persons from companies, consultancy agencies, research institutes, ministries and authorities as well as a representative of the Montreal Protocol secretariat to expert talks. The aim of the talks was to discuss with as many parties as possible project proposals and concepts to reduce CFC/HFC. This was in order to ensure that the proposals would meet the requirements of the developing countries. Issues regarding technology transfer to the various developing countries and the technological lead of German companies were of
The talks provided important ideas and impetus for the development of a concept and the planning of bilateral projects.

Thanks to the readiness of the German firms and important institutes, we were in the fortunate position of having access to the most advanced substitution technologies in the field of hydrocarbon technology.

Our concept regarding support for countries attempting to switch to CFC and HFC free refrigerator production is at once simple and complicated.

The concept comprises four elements:

1st element: The rapid conversion of a company's production plant to facilitate the manufacture of eco-refrigerators is the most important element. This can be best achieved by bringing two cooperation partners together. A lot can be done with the aid of such a demonstration plant". Politicians and decision makers can make up their own minds as to whether the new technology is useful and sensible. Imparting technical, organisational and economic know-how and abilities in joint activities relates closely to practical issues and is efficient. Self-initiative and selfhelp are mobilised.

What the GTZ does is:

- initially providing support for one com-pany in planning conversion through making technological, organisational and economic know-how available;

- finding a German company as a cooperation partner;

- concluding a factory contract of supply on the procurement and delivery of the necessary apparatus and plant.

2nd element: we offer support in the compilation of Conversion planning for other firms that are willing to convert. Arranging cooperation partner firms and assistance in filing applications to the Montreal Protocol are services that belong to the second v nnfLnt of the ranrfznt
The services of the GTZ are:

- sending short-term advisers;

- arranging cooperation partners (German companies);

- assistance in filing applications to the Montreal Protocol.

3rd element: It is important to qualify handicraft businesses for the repair and recycling of eco-refrigerators. This is to start on a pilot basis with a selection of handicraft businesses.

The services of the GTZ are:

- equipping and qualifying a selection of handicraft businesses;

- assisting associations in the establishment and running of training courses for Craftsmen also in the informal sector.

4th element: The establishment and operation of an information and advisory service for hydrocarbon technology enables qualified processing of the increasing number of inquiries.

The services of the GTZ are:

- processmg inquiries and applications for support;

- the establishment of a network of experts in hydrocarbon technology (a pool of firms and advisers)

- preparing publications, such as, for example, a white paper.

The prime task of the GTZ is to put the target groups in the developing countries in a position to improve their living standards by themselves with the aid of non-material ancl material support. We employ various instruments in order to fulfil this task in an efficient way. Selection is aRvays adaptecl or tailor-made regarding a given situation.

Services in this context may be:

- consultancy for organisations and persons through short-term and long-term advisers

- preparing appraisal reports/feasibility studies;

- assistance in the preparation of project planning, in our case conversion planning;

- the procurement and delivery of materials.

What is this like in practical termsv

What is the GTZ actively involved in currently?

GTZ in China

The conversion of one factory line at Haier Quingdao (250 - 300,000 Units) to cyclopentane foaming and isobutane refrigerant with the help of the German market leader, Liebherr, was agreed in principle with the Chinese ministries, MOFTEC, NEPA and CHEAA in June '94; the project agreement is in preparation. Liebherr, Haier and GTZ have concluded the technical conversion plans, and the equipment is in the process of being ordered. GTZ and USEPA will submit a joint bilateral for the spring meeting 1995 of the Executive Committee Meeting of the Multilateral Fund. This factory conversion project and the necessary adaptation of the models and the training of the factory workers amounts to roughly 5.6 mio. DM (3.5 mio. US$) to be funded from German and US bilateral funds; the Haier company will bear the local costs of factory conversion, and China will further contribute by funding institutional adaptation work.

As follow-ups of this one full conversion BMZ/ GTZ would like to support a further 3 - 5 bilateral projects in the planning stage. This is intended to make know-how partners available to interested Chinese manufacturers. The GTZ also wants to finance technical expertise, testing, and planning for factory conversions up to the stage where the Chinese manufacturers will be in a position to apply directly to the Multilateral Fund for funds through one of the implementing agencies. It is likely that these technical support proposals avid also be submitted to an Executive Committee Meeting in early 1995.

The offer to train Chinese service centres in this new- technology is already in discussion with the Chinese authorities but has not yet been worked out in detail. Here too, Germany has established institutions, like the Bundesfachschule fur Kaltetechnik and the Steinbeis-Know-How Transfer Centre in Karlsruhe, who could make this know-how available. This phase will also start in 1995.

GTZ in India

Whereas in China we are going towards straight factory line conversions, the situation in India needs a pilot phase prior to the final decision for the industry and the government to find the appropriate solutions, due to the fact that in India compressor manufacturing is closely interwoven with the refrigerator industry, which means quite severe market and investment decisions. So in August '94,
the German GTZ project joined the efforts of the Swiss SDC ECOFRIG project which had been launched in 1992 with funds additional to the Montreal contributions. This project is now going into its 4th phase after the institutional build up of bringing together the industry, the ministries and research institutions like the Indian Institute of Technology (IIT) and the National Chemical Laboratory (NCL) in a joint approach to the problems. On the formal request of the Goverment of India Germany is also willing to donate funds into this next phase outside the Montreal Protocol. Through the installation of two cyclopentane foaming pilot plants at two of the leading manufacturers, industry and the research institutes will be able to join forces for an in depth investigation of the choice of refrigerants, isobutane and the propane/ butane blends. Know-how will come from the east German pioneer company, FORON. The bilateral contributions of about 3.55 mio. DM will come in equal parts from Switzerland and Germany, with an additional local contribution by Indian industry of about the same amount.

The Foron Story

Marion Kälke

The push for the first CFC- and HFC-free refrigerator came from the industry itself - and an East German firm had the spunk to try something new. At a time when the whole world - ministries, trade associations, research institutes - accepted HFC 134a as the replacement of choice for CFCs, the Saxon firm "Foron Appliances" outdid them all with simple hydrocarbons. Refrigerator production in Germany hasn't been the same since.

Doesn't it sound almost like a fairy tale? At least that's how the German press told the Foron story. The dwarf among giants: a tiny refrigerator manufacturer in Saxony in former East Germany takes the industry by storm with the fridge of the future! Greenpeace plays the good fairy. There are dangers, close calls, dragons to face down. But there is a happy ending - for the little company and for the environment.

"You run faster if you run for your life," says Siegfried Schlottig, head of PR at Foron since reunification. "In the fat years, when everything's fine, no one wants to risk trying something new. But in the lean years..." His firm seemed doomed, so it had nothing to lose. It was easy to take the chance and go off on its own.

The Foron assembly plant is on a narrow country road that winds through the starkly beautiful Erz mountains down to the Czech border. Here in Niederschmiedeberg men and women put together the white boxes dubbed "Greenfreeze" or "Clean Cooler" as the first refrigerators ever to be truly harmless to both the ozone layer and the atmosphere.

Outside the building you can still read "DKK Scharfenstein", the abbreviation for Deutsche Kühl- und Kraftmaschinen. Foron's old name recalls old times. In DDR times the company produced a million refrigerators and freezers and 2.4 million compressors a year - with CFCs, like all other manufacturers. They were sold in Eastern Europe in addition to the DDR, and at dumping rates in the West.

Then came reunification and changed everything. Eastern European markets collapsed. No one in the West wanted East German refrigerators at the new adjusted prices. In the former East German states customers wanted the Western products that had so long been beyond their reach. The "people's firm" DKK Scharfenstein fell to the Federal Republic's government trust company, the Treuhand, formed to integrate erstwhile DDR companies into the free market. Three hundred kilometres away, in Berlin, the fate of the "people's firm" was decided: sell, don't rehabilitate.

But at the same time everyone was trying to get out of CFCs. The favourite alternative at the time was the hydrofluorocarbon 134a, which didn't destroy the ozone layer. The refrigerator establishment felt it could live with the fact that 134a contributed to global warming. No one saw the hydrocarbon alternative, even though hydrocarbons neither heat up the earth nor destroy stratospheric ozone.

"Engineers think in straight lines, like railroad tracks, and they know when the track leads to a barrier," ruminates Schlottig, who is an engineer himself. "And here was a buffer: you can't use hydrocarbons! They're flammable. Right after World War II CFCs replaced them for just this reason. No one considered that the flammability problem might have been solved since then."

It was just the same at DKK Scharfenstein. Even before reunification the factory had begun to shift its entire range of appliances to the hydrofluorocarbon 134a. However, in 1989 the company was not yet allowed to import the material from what was still the West, so it had to bring it from the USSR over vast distances on miserable roads.

So things were not going very well in April 1992, when Wolfgang Lohbeck knocked on the door.

Lohbeck, responsible for the Atmosphere Campaign at Greenpeace Germany, had long been occupied with the problem of getting out of CFCs. Then he heard from two Dortmund medical doctors, Professor Harry Rosin and Dr. Hans Preisendanz, who, needing a new cooling section for their Institute for Hygiene, had stumbled upon an old but environmentally friendly technology: they tried the hydrocarbons propane and butane as coolants and it worked!

Greenpeace activist Lohbeck tried for months to interest the large German refrigerator manufacturers in the old-fashioned technology - no luck! Then he remembered the little East German company that had caught his eye at Domotechnica - the household appliance fair in Cologne in 1991. Their refrigerators were insulated with pentane- and steam-foamed polystyrol -

without CFCs and without HFCs. Maybe they would team up to take on the Dortmund idea? He packed his bags for the Erz mountains.

"There are seven large refrigerator manufacturers," considers Schlottig, thinking about the laws of the market. "And then comes an eighth - from Eastern Germany of all places! This one builds refrigerators that look just like all the others. So this refrigerator has to have something very special if it wants to get hold of some share of the market." For the very first time the East German company was under pressure to innovate. "We have the free market to thank for making the hydrocarbon idea a reality," Schlottig says today.

The engineers in Niederschmiedeberg welcomed Lohbeck's proposal. "Why didn't we think of it ourselves?" they pondered. Hydrocarbons were nothing new, after all; they'd only been forgotten. The engineers were sure they could solve problems like high energy use and safety. The decision was taken: hydrocarbons were their chance to elbow their way into the market. Greenpeace placed an order for 10 prototypes to be completed by autumn.

But then the drama really began. The potential buyer of DKK, the West German firm Bosch/Siemens Household Appliances, Ltd., withdrew its offer. The Treuhand decided to dissolve DKK. "We realised too late that no one would help us - neither the Treuhand government trust nor the competition," remembers Schlottig. "We had to take things into our own hands." Necessity is the mother of invention: Greenpeace and DKK organised a press conference in the Erz mountains at which the first model of the new refrigerator, produced almost overnight, was to have its début.

On the evening before, Managing Director Eberhard Günther's telephone rang: it was Treuhand Director for Termination Ludwig Tränker. He forbad the press conference.

People who work at DKK consider Eberhard Günther tough. Günther didn't mince words with Ludwig Tränker. He threatened to disinvite the journalists by announcing his resignation and told Tränker outright: "I won't play this game any more!" The result was almost a miracle. Tränkner flew to the press conference by helicopter and gave way: production would continue and the DKK would be privatised. The East German fridge with the sober name KT 135 R had won the first round.

"We wouldn't exist anymore without Greenpeace," says Schlottig, thinking back. "Their energy helped us checkmate the Treuhand." The environmentalists from Hamburg had not only made their point at the stormy press conference: they had started an advertising campaign for the eco-refrigerator at a time when the Treuhand had forbidden all publicity. It was the first time that Greenpeace had gone out on a limb for a product or a technology. Within a month thousands of orders had come in - from the mail-order company Neckermann among others. Neckermann was thinking about German consumers, who are particularly environmentally aware.

The competition had already pricked up its ears, however. Under ZVEI, the Central Association of the Electrical and Electronics industry, all refrigerator-producers except Scharfenstein had committed themselves to 134a. No one believed that a David from East Germany could beat the savvy Western Goliaths with a better refrigerator. They got together and declared war on the ever-more-popular upstart from Saxony.

They were so sure that hydrocarbons were worthless that they did something that embarrasses them to this day: they wrote a letter to thousands of dealers, painting the eco-refrigerator in dismal colours. The flammable mixture of propane and butane was hazardous, they claimed, during production and transport, in use and during servicing. The insulating material was inefficient: the fridge used too much energy.

The notice turned into a boomerang. "Negative advertising is the second best advertising there is," Siegfried Schlottig grins. "That notice introduced us to many dealers for the first time." Above all, though, the arguments of the seven competitors could be proved wrong.

There can be no such thing as a "bomb in the kitchen" where, as in this case, only 20 grams of propane/butane are present in the cooling circuit: the tinkerers in Saxony had tested it themselves. "One evening we took a refrigerator into the factory yard and built a lot of concrete around it. Then, with an open flame, we tried to set the mixture alight. Nothing exploded and nothing caught fire!" Of course, the German technical safety inspectorate TÜV (Technischer Überwachungsverein) of Bavaria and Saxony conducted an official test, too, and certified the refrigerator with the "GS" seal for geprüfte Sicherheit - demonstrated safety. The south-western branch of TÜV also examined the larger problem - safety during production - and came to the same conclusion: no danger.

Schlottig stops for a minute, then says, "The real evil for the ozone layer is the foam." While the cooling circuit has only 50 to 250 grams of CFCs, 300 to 600 grams are needed for the usual polyurethane (PUR) insulation. "And since no refrigerator can be perfectly sealed, the stuff is sure to get into the atmosphere!" Air gradually replaces the CFCs in the foam, and so after four or five years the insulation deteriorates and electricity use increases.

The refrigerator producers from DKK used traditional polystyrol for insulation - prefoamed with the hydrocarbon pentane and filled out with steam. The advantage was that polystyrol is an excellent recycling material. The disadvantage was that in fact it doesn't insulate as well as PUR foam. That's why the Saxons build the refrigerator's covering several millimetres thicker than is usual - a flaw that an environmentally-conscious consumer may be ready to accept. But the refrigerator factory in the Erz mountains has had to adapt. Now it too uses polyurethane, PUR, foamed with cyclopentane. "This is not the future, though," Schlottig thinks. "We're working on better solutions."

The Achilles heel of the propane/butane-cooled Saxon refrigerator was that it used too much energy and thus contributed to global warming. An energy-efficiency test by a refrigeration expert at the university of Paderborn - made at ZVEI's request - showed that the new refrigerator used 40% more electricity. "It was a bad test, because they hadn't perfected the cooling system," Schlottig explains. The CFCs had simply been removed from an ordinary refrigerator and replaced with hydrocarbons. "Nowadays the data are not even comparable," says Schlottig. "The compressor, the liquefier, the vaporiser, the ventilator system - everything has to be adapted to hydrocarbons." In Niederschmiedeberg the optimal design was soon reached: by autumn the eco-refrigerators used 10% less energy than those with CFCs or the HFC 134a.

But more than good arguments were needed to mass-produce the "clean cooler" and compete on the open market. Fortune lent a hand and the Niederschmiedebergers seized their chance. When Environment Minister Töpfer happened to turn up right there in Saxony, for completely unrelated reasons, they presented him with a prototype of the eco-box. The Minister didn't particularly want the gift; however, he did send experts to the Niederschmiedeberg to examine it. When they turned in a positive report the dam broke. Töpfer asked the Treuhand to maintain the firm, and as a result it granted the firm DM 5 million to develop the refrigerator.

From that point on things got better and better. In January 1993 Foron Household Appliances, as DKK was now called, was privatised. The East German Investment Trust, London, got the lion's share of the common stock and the rest was divided between Berlin Capital Management GmbH and the Foron Management. In February the "clean cooler" won the Blue Angel award at the Domotechnica trade fair from the Environment Ministry. In March mass production began. In June the German Federal Environmental Foundation honoured the firm with the first German Environmental Prize. This was followed in the autumn by the Prize for Innovation of the State of Saxony and the Alternative Marketing Prize, which Managing Director Günther shared with Greenpeace's Wolfgang Lohbeck.

"Just imagine. If there had been no reunification, no Treuhand, no refusal by Bosch/Siemens to take us on..." Siegfried Schlottig speculates. Then HFC 134a would be the uncontested victor and the environment would bear the cost. Now even the Western competition backs the clean alternative.

Foron employees and Greenpeace were not greatly surprised at the Domotechnica fair of 1993 when the West German firms Bosch, Siemens and Liebherr presented prototypes with hydrocarbon cooling. Although all refrigerator producers had geared their 1993/1994 production to the HFC 134a, little by little they followed suit: first in the insulation, then in the cooling circuit as well. The switch to hydrocarbons is sure to come.

Good for the earth. For Foron, however, which is still in the red, the competition's change of heart means that its market share is shrinking: its "clean cooler" won't be anything special anymore. So the Saxons will have to struggle for their happy ending. "We want to make a place for ourselves with intelligent, innovative and above all ecological appliances," says Eberhard Günther. Schlottig adds, "Our strategy is to find market slots. As a small firm we can react quickly and take advantage of innovations." At present this means above all energy-efficiency. The latest development of the engineers from Niederschmiedeberg is a cylindrical refrigerator: the smaller ratio between volume and surface makes the round refrigerator a real energy-saver. The firm has put its environmental prize money into a foundation. They arranged a 14-day workshop for students to look for new, ecologically interesting possibilities. "Students haven't

had their wits dulled by routine, as have some of the experts," says Schlottig. "They can still think unconventionally."
Cooperation has begun with firms in Eastern Europe. The Saxons want to install their technology in factories already there. They have started a similar project in India supported by GTZ and the Swiss Firm Infras (Infrastruktur-, Umwelt- und Wirtschaftsberatung). In non-industrialised countries hydrocarbons have an especially good chance: unlike HFCs, they are readily available and cheap. "It makes more sense to export our know-how for production there than to export refrigerators to India. That simply wouldn't work," says Schlottig and calls on his experience in marketing to make a point: "If you help these firms, you do a lot for your image." In Foron's experience a good image seems to pay off just fine.

The Greenfreeze Campaign

Dieter Beste

How could the international environmental organisation Greenpeace - famous for its spectacular protest actions - succeed in the crucial but unglamorous task of transforming the German refrigeration industry? All German firms have now changed over to environmentally friendly hydrocarbons as the basic coolant and as foaming agent for insulation. A talk with the head of the Greenfreeze Campaign, Wolfgang Lohbeck.
The German national office of Greenpeace is located in a turn-of-the-century building on the Hamburg harbour front - strategically near great publishing houses like Gruner+Jahr and Der Spiegel. The office location is in tune with Greenpeace awareness of the importance of publicity to attain its goals. The success of the "Greenfreeze" campaign is living proof: a campaign whose goal is to eliminate CFCs and HFCs from home refrigerators - both as coolants and as propellants for insulating foam - and to replace them with environmentally friendly hydrocarbons like propane or butane and cyclopentane. In almost no time at all the environmental organisation won over the entire German refrigeration industry.
"The campaign went off in an entirely new direction," muses head campaigner Wolfgang Lohbeck. "For the first time Greenpeace attained its goals through technological discussion. We didn't limit ourselves this time to just saying no or to pointing out weaknesses." Lohbeck joined Greenpeace's full-time team more than ten years ago, quitting his job as department head in the Ministry of Science of the State of Lower Saxony to fight for the environment full-time. "I had no ties and nothing to lose - leaving my life as a civil servant was no sacrifice."
Wolfgang Lohbeck has helped change the face of Greenpeace Germany in the last two or three years. In fact, he accomplished what has always been unthinkable: that captains of industry and Greenpeace comfortably discuss company strategy together, make agreements, and even form friendships across the gulf between business and ecology. This is the heart of Lohbeck's achievement. How did the environmental revolution in German refrigeration technology come about and lead to such a radical transformation of relations between industry and environmental protection?
July 1990: without a lot of fanfare scientists Harry Rosin and Hans Preisendanz from the Institute for Hygiene in Dortmund publish their findings on a mixture of propane and butane as a coolant in laboratory refrigerators, a discovery that goes almost entirely unnoticed in the trade. It has been known for years that CFCs actively deplete ozone in the earth's upper atmosphere. With the signing of the Montreal Protocol on September 16, 1987, the international rejection of CFC technology is sealed. Greenpeace goes on pillorying CFC producers with protest actions in fine style.
"My contact with the Dortmund Institute for Hygiene happened through pure chance," Wolfgang Lohbeck recalls. Preisendanz and Rosin stumbled across hydrocarbons as a tried and tested coolant while trying to equip a laboratory with a deep freeze section that was both energy-efficient and economically realistic. They quickly noticed that HFC 134a - the alternative of choice to CFCs at the beginning of the 90s - displayed unfavourable thermodynamic properties. Both scientists chose propane and butane because hydrocarbons were known to be good coolants even at low temperatures.
Lohbeck was electrified by the Dortmund findings. He suspected that hydrocarbons might serve to replace the coolant or foam substance CFC with its deadly ozone-destroying property without contributing to the greenhouse effect as the replacement material 134a had done. Lohbeck left

for Dortmund at once to inform himself and found his supposition confirmed: "From that point on I knew hydrocarbons were what we wanted."
February 1991: at Domotechnika, the appliance trade fair in Cologne, Greenpeace found refrigerators from the East German firm DKK Scharfenstein with a CFC-free insulation of pentane-propelled polystyrol - the only ones of their kind. "This was certainly not the CFC- and HFC-free refrigerator we were looking for," Lohbeck cautions. "It used 134a as a coolant and the insulation was sadly inadequate. But one thing was clear: if we could get the company to use hydrocarbons as a coolant we would have at least the prototype of an environmentally-friendly refrigerator at last!"
"Why don't you use propane?" Lohbeck asked the technicians of the little firm in the Erz mountains. "Ja. Why not?" the folks in Niederschmiedeberg agreed. "Suddenly someone remembered that in the '40s there had been a Professor Schmidt in the firm, and this professor had been a specialist for propane/butane." Wolfgang Lohbeck's question had sparked a chain reaction. A search through the files uncovered some of the professor's notes and the thermodynamic behaviour of hydrocarbons became the centre of interest once again.
"Ja. Why not? It was really so simple." Wolfgang Lohbeck attempts his own explanation: "During the German Democratic Republic they used CFCs as coolants at DKK Scharfenstein as at all other refrigerator manufacturers in both East and West - CFC 12 to be specific. Now, after German unification, they wanted to get on the conversion bandwagon and were trying out 134a, which they had procured in small amounts in the USSR." Even in Niederschmiedeberg no one had thought of the hydrocarbon option.
In the following months Lohbeck drove repeatedly to Niederschmiedeberg in Saxony. The first tests were encouragingly successful. Then one blow followed another: on July 13, 1992 - only a few days after Greenpeace had concluded a "historic contract" to build a prototype on the mixed propane/butane coolant basis - the Treuhand, the trust company of the unified German state, which was responsible for privatising all former DDR firms following reunification, announced the dissolution of DKK Scharfenstein.
"On July 16 we held a press conference that turned into a prime media event," says Lohbeck. "More than 200 people from the press showed up in the remote town in Saxony. It was clear to everyone that the West German refrigeration industry wanted to brush aside a small, annoying competitor. We were of course on the side of David against this Goliath and came up with the first 'Greenfreeze' - a little prematurely because it wasn't all worked out." After some hours of debate before the assembled press, the Treuhand declared that it would not prevent the Greenfreeze project and would cooperate with Greenpeace.
The competition could relax, because the eco-refrigerator Greenfreeze seemed to be less energy-efficient than refrigerators with 134a.
August 1, 1992: Greenpeace starts an advertising campaign to provide the East German firm with advance orders for the eco-fridge. August 4: the propane-butane refrigerator attains the same energy-efficiency as refrigerators with CFCs. A wave of advance orders rolls in. August 8: Environmental Minister Klaus Töpfer is convinced of the performance capabilities of Greenfreeze. He states that this refrigerator might be the only one with a chance to win Germany's Blue Angel environmental award. August 13: the mail-order company Neckermann announces that it has ordered 20,000 refrigerators in Niederschmiedeberg and has an option on another 50,000. August 27: further testing by DKK Scharfenstein shows that the propane-butane hydrocarbon mixture is a much more effective coolant than CFCs. November 24: the Treuhand announces the privatisation of DKK Scharfenstein, which is renamed "Foron".
In retrospect how can Greenpeacer Wolfgang Lohbeck explain the stubborn resistance of all large West German refrigerator manufacturers to substituting hydrocarbons for CFCs? Technical considerations were never a reason. Lohbeck takes a broad view: there are a multitude of reasons and they are understandable. First of all hydrocarbons belong to an old-fashioned technology. "Engineers like to think into the future," he says. And for years and for decades the connections between the chemical and refrigeration-technology industries had been clear: the chemical industry had developed CFCs and made them available for refrigeration, and then when CFCs got a bad name, everyone simply expected chemistry to come up with a substitute. "And who wants to be the only one to speak up and do something different from everyone else?" Lohbeck asks rhetorically. The possibility that the substitute needn't be elaborate, synthetically-produced hydrofluorocarbons but mere natural gases simply boggled the imagination. Then, too,

at the back of everyone's mind was the dangerous flammability of the hydrocarbons in their grandparents' ice boxes, and that for just this reason they had turned to the "safe" CFCs in the first place.

"But of course," Lohbeck knows, "there were also tangible economic considerations." Giant chemical companies like Hoechst, ICI or Du Pont had invested in major production facilities for 134a. This investment capital had to be amortised, and the compliant functionaries in the trade felt they had to wage a regular economic war against Foron and Greenfreeze. "They made real fools of themselves. Because more pragmatic minds in West German refrigeration companies quickly recognised the superiority of hydrocarbon technology and rushed to develop their own CFC- and HFC-free products."

Lohbeck has had some hard arguments in recent years - "sometimes aggressive to hostile". But he has seen that knowing one's stuff technologically pays off sooner or later. "We had something to offer: a specific environmentally friendly product which was technically superior to boot, and that was what made us invincible." In the Greenfreeze campaign we could talk to the public quite differently than we had when we were just saying "no" to using CFCs. And what really surprised me was that we could suddenly talk quite differently with industry, too. That didn't go so well before. Our message was no to the end. Now we were seen as partners in a dialogue."

In October 1993 Lohbeck won the Alternative Marketing Prize for "new methods in product marketing". He is pleased with the honour, but he also knows that "at the outset it wasn't all planned the way it turned out. It was a piece of luck that this firm was there, that it was up to its neck in troubles, that Germany reunified, that the Treuhand had such a ridiculous policy, that DKK Scharfenstein still had its own compressor production and could develop the propane/butane prototype on its own. It was a piece of luck that we could win one company over to our way of thinking and that this firm could turn facts quickly into marketable realities. Greenpeace learned a lot from the Greenfreeze campaign!"

Since that time Lohbeck has not let up. He has cultivated close contacts to the Montreal Protocol, staged exhibits with Greenfreeze in China, shown the eco-fridge in Tokyo, and put Foron in touch with the Indian government. Thanks to him the German firm Liebherr refitted a refrigerator factory in Qingdao, China, with the new hydrocarbon technology. "Our original suspicion that industry was only switching over for cosmetic reasons has been laid to rest," he concludes. "German industry simply understands that although hydrocarbons may have an old-fashioned image, they are not only more environmentally friendly but are also the better, more energy-saving and effective technology. But in the rest of the world we still have a lot of convincing to do."

The pragmatic orientation of the Greenfreeze campaign has also had a spin-off that Greenpeace would like to transfer to non-industrialised countries free of charge. "We think it would be easier to convince non-industrialised countries to switch to hydrocarbon technology if that technology were easier to come by. So we want to help them make their own refrigerating gas. At a cost of DM 200,000 to DM 300,000 we are developing and testing a gas-purification system together with an engineering office in Dortmund. Then we'll give away the blueprints."

Safe Refrigeration

Bernd Eusemann

"Only five or six cigarette lighters' worth!" exclaims Engineer Gerd Siemon, Product Service Division Head in Hanover of the German technical safety inspectorate TÜV (Technischer Überwachungsverein). "That's all the hydrocarbons the cooling circuit needs. When it comes to fire, any ordinary gas kitchen stove is more dangerous than the refrigerators," he goes on.

So the new refrigerators that use substances like propane or butane instead of CFCs are certainly not in any way explosive. Because these replacement substances are flammable, however, safety is an important consideration nevertheless. The product must be subject to new operating specifications. And manufacturing facilities must be adapted: during the production process highly flammable chemicals are indeed handled in amounts that make safety a significant factor. The changeover to hydrocarbons from CFCs, which though environmentally destructive were easy to handle during manufacture, requires adjustment to a very demanding technology. When the strong trend to hydrocarbons became clear in Germany, the producers of refrigerators made safety part of their planning from the start.

The manufacturers started getting ready for the newly popular technology in close cooperation with the TÜV because even though this "new" technology had been well known for a long time, a whole series of snags still needed to be smoothed out. CFCs had dominated the realm of cooling technology unchallenged for decades, so that all technical tables, standards and manuals - practically the entire science of cooling technology - conformed to their use. These had yet to be developed for the replacement materials, at least in part.

In the meantime in Germany the new technology is considered tried and tested, and has left a first imprint even on the technical manuals. Since no binding criteria for testing hydrocarbon refrigerators existed, a commission was formed to define these criteria. Thus a norm has now been proposed, and the cooling norm will soon be supplemented with one for flammable coolants, says TÜV engineer Gerd Siemon. Incidentally, after comprehensive testing his division was awarded the seal of approval "Tested for Safety" for hydrocarbon refrigerators.

From a safety point of view the production process - an area virtually unknown to the consumer - is much more relevant. The insulating material in the refrigerators presents no risk to the consumer whatever. But in production the CFC propellants formerly used for polyurethane foam have now been replaced by flammable hydrocarbons like pentane. Thus the managers of production facilities must now come to grips with the problem of fire- and explosion-prevention.

A key step in the change to the new refrigerator technology is thus the conversion of foam-producing installations. "That's why a team from various work-groups from the TÜV in Ulm specialised in just this area," explains the engineer Karl-Josef Richardt. "This is not only a matter that concerns refrigerator producers," says the Group Leader for Plant Safety and Reliability. "The distributors of machinery and production facilities also have to adapt - and the licensing authorities, too."

Facilities for the production of moulds for polyurethane must have a permit, and are therefore subject to a series of rules and regulations. The conversion of a facility from one propellant to another, for instance, is considered an integral alteration in the process. So Richardt urges that each facility minimise risks by coming up with a safety plan before it converts to flammable substances. He and his work group have served as advisors to German manufacturers during conversion - from new construction right up to the obligatory final inspection. The knowledge acquired in the process has come to be in demand internationally: for example, TÜV experts are active in firms in both Turkey and China.

Just what does a safety plan entail? Because pentane is readily flammable, and pentane fumes mixed with air are potentially explosive, all the parts of the plant that conduct pentane must be thoroughly checked: specifically, from transportation and delivery, to tanking and storage, all the way to the foaming installation, through the tangle of pipes, pumps and mixture containers throughout the entire factory. The plan may be applied according to what is technically possible in each step, but one basic fact underlies the whole process: the technology is used by people, and these people must be trained to handle the new kind of production.

This technology adheres to the classic definitions laid out in the technical manuals for fire and explosion prevention. TÜV engineer Richardt describes the safety philosophy behind design of the key parts of the plant.

The first step is to design all components so that an explosive atmosphere cannot form in the first place. If this is not immediately possible, the danger may be prevented by proper ventilation. The second step is to create components in such a way that any existing explosive mixture cannot ignite. The third step is to install warning systems that detect explosive substances and start up preventative measures automatically.

The forms for moulding foam were observed with particular care. During standard foaming operations some pentane is normally released, so it is not unlikely that during foaming an explosive gas may suddenly form inside the mould. This danger may be met through adequate ventilation. Another possibility is to use nitrogen as an inert gas to prevent electrostatic ignition of any pentane mixture.

All of this has no effect on the consumer. The insulating material in his refrigerator is safe, and the coolant is installed in the factory. But what about during use? Even with only 20 to 30 grams of hydrocarbons isn't the refrigerator a risk just the same - even if it is less of a risk than a kitchen stove?

In order to pinpoint this risk, TÜV expert Gerd Siemon has conducted gas-leakage tests on refrigerators. If the vaporiser and switches were both inside the refrigerator, for example, then when the door was shut an explosion could indeed take place. For this reason the manufacturer must design his product to preclude this risk. That is, if the vaporiser is internal, any electric switch must be external.

These experiments demonstrate that refrigerators with flammable coolants like propane or butane can be built and operated safely. Nevertheless, negligence has been simulated to create a worst-case scenario. The entire coolant has been allowed to leak out at once and a lighter held to it. The result is of course a loud pop! A person kneeling directly in front of the refrigerator might indeed be slightly burned. But this small explosion is not life-threatening, says Siemon. Even ordinary clothes would provide sufficient protection. The worst that might happen would be a few singed hairs.

Ecofrig - Promoting Hydrocarbon Refrigerators in India

Othmar Schwank

India's refrigeration appliance industry has not yet adopted an alternative to chlorofluorocarbons (CFCs). Should it choose the hydrofluorocarbon 134a, which may cause global warming? Would hydrocarbons be a better replacement? The Ecofrig project, launched in 1992 as an Indo-Swiss technology cooperation project and supplemented by GTZ/GATE, seeks to show industry the advantages of hydrocarbons. The project disseminates the hydrocarbon technology used by the German company Foron.

In 1991, India's consumption of ozone-depleting substances was 10.370 tonnes. In terms of the ozone-depleting potential, about 15 per cent of these substances are used as coolants and 12 per cent in the production of foam. In the refrigeration sector only 310 of the 2000 tonnes of CFCs consumed are used for domestic refrigerators. But according to forecasts this sector is all set for rapid growth.

In 1993 1.46 million units of domestic refrigerators were sold in India. The 165-litre model, which accounts for almost 93 per cent of the market, contains about 140 grams of CFC 12 (produced in India) as a coolant and 450 grams of CFC 11 in its polyurethane foam insulation. For 1994 sales in the order of 1.9 million units are expected, indicating an annual growth rate of 23 to 30 per cent. Annual production is expected to increase to 8 million units in ten years, when there will be 58.4 million refrigerators in Indian households. Unfortunately, this market growth implies a substantial annual increase in CFC emissions as well.

In September 1992 India became a party to the Montreal Protocol on ozone-depleting substances. India, operating under the provisions of Article 5 (with a per capita consumption of ozone-depleting substances of less than 0.3 kg in 1996), is eligible to obtain assistance from the Multilateral Fund. It is committed to phase out CFC use by 2010. However, pressure has been increasing on the Indian refrigeration industry to review the technical options for the CFC phase-out earlier and to submit proposals to the Multilateral Ozone Fund now. The CFC phase-out process of the programme in India will start in 1998 and should be completed by 2004/5. Multinational corporations and the World Bank (as implementing agency of the Multilateral Fund) are pushing hydrofluorocarbon (HFC) fluids to replace CFCs, however. As a replacement foam-blowing agent the World Bank still recommends hydrochlorofluorocarbons (HCFCs) for Article 5 countries. In 1992 HCFCs for non-Article 5 countries were included in the list of controlled substances because of their reduced but nonetheless measurable ozone-depleting effects. Thus they may be seen as replacements for a transitional period only. Fluorocarbons (HFCs and HCFCs) have the merit of being noninflammable, but they have the disadvantage from an environmental viewpoint of high global warming potential and of fluoridization of the atmosphere with unknown environmental impacts. Hydrocarbons are flammable but have the environmental merits of a natural fluid: no ozone-depleting potential, negligible global warming potential. Furthermore, hydrocarbons have excellent coolant properties.

A major obstacle to a return to natural fluids is that they have no lobby, no chemical industry to push them on global markets and to the implementing agencies of the Montreal Protocol that weigh the various technical options. So external technical assistance will be needed if this technology - widely accepted in Europe - is to be adopted in India.

In 1991, Switzerland launched a global environment fund intended - among other things - to promote North-South technology cooperation for sustainable development. The Indo-Swiss project Ecofrig takes the Montreal Protocol a step further toward the broader objectives of sustainable development. Thus the Swiss contribution to Ecofrig - as pledged at the Rio Conference - is an addition to the Swiss contribution to the Multilateral Fund.

Since German Industry is a global leader in the development of ozone-friendly technology for domestic refrigeration, the German Ministry for Economic Cooperation and Development (BMZ) has seized the initiative in promoting these technologies through bilateral agreements. GTZ has been commissioned to implement among other measures a project in cooperation with India. The Indo-German Ecofrig project is intended to complement the Indo-Swiss programme.

Infras, the Swiss interdisciplinary research and consulting group for environmental economics and politics, is implementing the Ecofrig Project on behalf of the Swiss Development Cooperation (SDC) and GTZ. The aim is to support conversion to hydrocarbon technology of at least one Indian refrigerator production line as a pilot project for India.

The Ecofrig project was initiated with a reconnaissance visit of Infras to Indian industry and research institutions in September 1992. This prefeasibility phase was terminated with the visit of an Indian delegation to Switzerland and Germany in June 1993. Part of the visit programme was a meeting with Foron at Niederschmiedeberg.

By spring 1993 the first hydrocarbon domestic refrigerators with the Greenpeace-Foron "Greenfreeze" technology were available on the German market. Foron came out with a hydrocarbon mixture, and Liebherr and Bosch followed with isobutane as coolant. The message that Greenfreeze technology was feasible under European market conditions was heard in India, too.

During the next phase a preliminary assessment of Greenfreeze technology was made under Indian conditions. Based on the thermodynamic property data of hydrocarbons received from Foron, the Indian team, coordinated by the Indian Institute of Technology (IIT) in Delhi, worked out a prefeasibility report which indicated that hydrocarbons were a promising technical option for India as well. During a second Ecofrig mission in September 1993, in which Foron and the Research Centre for Refrigeration Technologies and Heat Pumps (FKW), Germany, participated, a plan of action was drawn up for the next nine months.

The three major Indian manufacturers of domestic refrigerators, Godrej-GE, Kelvinator Ltd. and Voltas Ltd., sent two 165-litre refrigerators each to Foron for test and design adjustment to the hydrocarbon mixture. Hyderabad Allwyn followed by submitting another two refrigerators to the test programme. Compressors designed for CFC 12 do operate on the basis of a hydrocarbon mixture. The refrigeration circuit needs minor adjustment. In May 1994 Foron presented the first results: The cooling performance achieved with 44 - 46 g of coolant charge was most encouraging!

In March 1994 the first Indian refrigerator converted to work with the propane/isobutane mixture without design adjustment was put into operation at IIT in Delhi. All three manufacturers have now started initial hydrocarbon conversion tests of their 165-litre models.

In the Ecofrig project special importance is attached to safety and the development of a safety-related infrastructure. Customers may be concerned about the quality of Indian products containing flammable liquids. Consumer-oriented information is therefore included as a component of the project. Another problem is inept handling of hydrocarbon coolants by the service sector. Tests by the German technical safety inspectorate TÜV have shown that there is no danger if design criteria are related to safety. In India, however, a comparable impartial institution that could issue a "seal of safety" for the production and servicing of a hydrocarbon refrigerator has not yet been established. Potential hazards associated with the use of hydrocarbons as coolants must be considered in the production process, household use of refrigerators and in the service sector. Factory personnel are trained to work with hydrocarbons. German TÜV standards and know-how in risk assessment need to be adapted to Indian conditions.

If Indian industry moves towards hydrocarbon technology in the long term, it will have two options with regard to coolants. An important argument in favour of the coolant isobutane as a long-term technical option in vapour pressure cycles for domestic refrigeration is its significantly

lower use of energy - an important argument in Europe. On the other hand the mixture of propane and isobutane, with thermodynamic properties very close to CFC 12, does not call for a redefinition of compressor design.
One option is to convert CFC 12 compressors in one stage to isobutane - a demanding step which European manufacturers completed in two years. Another is to operate CFC 12 compressors with minor cooling circuit modifications and a propane/isobutane mixture and to convert to isobutane at a second stage. World compressor- production of some 60 million units per year cannot, however, be converted as quickly as in Western Europe. Since consumers in poorer countries cannot afford to pay for a full redesign within a few years, the hydrocarbon mixture is probably the cheapest transition solution. Since CFC 12 compressors can still be used with this mixture, the market price will be lower.
A key part of the next project will be the realisation and operation of a pilot production plant headed by the industry consortium Voltas/Godrej-GE. For engineering support and hydrocarbon equipment a Swiss-German bilateral contribution has been requested. The pilot plant is to test in the field some 1000 refrigerators of different designs (mixture, isobutane). Cyclopentane will replace CFC 11 as a foaming agent.
The total cost for two research and development and pilot production facilities is estimated at DM 6.55 million. This amount also provides for research and feasibility studies to meet safety requirements and create a service and training infrastructure. A Swiss-German contribution of DM 3.55 million - disbursed through regular technical cooperation channels (an outside financial mechanism under the Montreal Protocol) - and a contribution of DM 3 million by the two Indian industry partners Voltas Ltd. and Godrej-Ge will cover these project costs. The Government of India has submitted through appropriate channels a request that the Swiss and German Governments implement this project. The executing agency for the Government of India is the Ministry of Environment and Forest.
Still, India wants to keep industry's option of applying to the Multilateral Fund open until it can make decisions on technology based on its own applied research results. India's position is based on its experience with the Multilateral Fund: any project proposal with a research and development component is put on hold and delayed at least 12 months.
The state of India does regard favourably a CFC phase-out in favour of hydrocarbons. It will not force a technical option on industry, however, so industry must decide. And industry decision-makers can see that the HFC 134a will have to be imported and will thus establish new dependencies. So it makes sense to convert to HCs, which can be made in India. Furthermore, the natural substances guarantee industry that it will not have to change its technology more than once. If industry were to opt for HFCs - as did the USA and Japan - it might have to switch again if HFCs become controlled substances under the Climate Convention at some point in the medium term.

Ecofrig: Managing Changes in Technology

Ajay Mathur and Pankaj Bhatia

The trilateral Indo-Swiss-German project called Ecofrig has already passed several successful steps of cooperation between industry and research institutes. Although the safety issue is still the strongest argument in the discussion about hydrocarbons the Ecofrig project has made an impressive impact on the hydrocarbon technology choice process in India.
The Ecofrig project was initiated by the Swiss consulting organization Infras with the support of the Swiss Development Corporation, SDC, to assess and support the transfer of hydrocarbon technologies for phasing out CFC use in the Indian refrigerator industry. Indian industry's participation in the project has been spurred by the short time-window within which it has to decide on the CFC-free technologies of choice, and by the uncertainties associated with the available technological options. The Ecofrig project is facilitating the serious consideration and assessment of HC-based technologies by the Indian refrigerator industry.

The project has been flexible and has evolved through short and crisp phased modules. Three phased modules have been completed since ist inception, and the fourth begins in January 1995.

Each phase culminates in a milestone in the long term objective and provides the necessary information and experience for planning the next phase.

During the first phase, Indian industry representatives and R & D professionals were exposed to HC refrigerator technologies during a visit to Germany. This resulted in a better understanding of HC technology and an assessment of the possibilities of ist adotion in India. Testing of Indian refrigerators with HC mixtures as refrigerants was conducted at the works of the German refrigerator manufacturer Foron in the second phase. The experience provided the rationale for carrying out testing and adaptation in India. In collaboration with Foron, a work plan for the development of pilot facilities by two leading Indian manufacturers, Voltas and Godrej who account for 60 per cent of the domestic refrigerator market in India, was drawn up in the third phase of the project.

The stage is now set for Voltas and Godrej to establish testing facilities for evaluating HC mixtures as refrigerants and pilot production facilities for utilizing cyclopentane as a foaming agent. Cyclopentane foaming process related technical information would also be transferred to other refrigerator manufacturers in India. This would enable them to assess both product performance and factory retooling and redesign requirements associated with cyclopentane foaming, and create the multiplier effect for the rapid dissemination of the technology throughout the industry.

The experience and competence gained by two refrigerator manufacturers in handling hydrocarbons as foamingagents and refrigerants would also help in breaking the psychological mindset in the industry that is apprehensive of the use of flammable materials. Simultaneously, the industry would benefit from the development of safe operating practices, and of an infrastructure to minimize the risks associated with handling hydrocarbons inside refrigerator factories.

In the fourth phase of the Ecofrig project, the strategic leadership and overall coordination is being provided by Infras, SDC (through their office in India), and the German agency for international aid, GTZ. GTZ is supporting the provision of technical expertize from Foron to the two Indian manufacturers, as well as the supply of specialized equipment in the pilot facilities. Other costs related to these facilities (such as land, buildings, manpower and other recurring costs) would be provided by the two manufacturers. The associated compressor life tests and the foam quality tests are to be coordinated by the Indian R & D organization National Chemical Laboratory, NCL, Pune. The Indian Institute of Technology, IIT, Delhi, is optimizing the refrigeration system design for use with HC-mixture refrigerants. The cradle-to-grave safety issues associated with hydrocarbons transportation, storage and use are being addressed by the Indian energy research organization, the Tata Energy Research Institute, TERI, Delhi. TERI isalso the coordinator for the Ecofrig project within India.

The institutional networking created for achieving the goals of the project is assisting the two manufacturers in the rapid assessment, adapation and adoption of HC-based technologies. In the process, the research institutions have also been strengthened in their capabilities to support the further development of HC-based refrigerator industry, and to generate and disseminate technical know-how.

Trends indicate that the Indian refrigerator industry is becoming increasingly convinced of the advantages of cyclopentane technology for foaming. The technical and financial inputs available through the Ecofrig project are helping the adaptation and adoption of this technology throughout the industry.

The final choice of refrigerant technology is, however, still uncertain. The framework within which technological decision making is occurring in the Indian refrigerator industry is quite different from that which faced their European counterparts. In Europe, the decision to use Hcs was largely market driven, propelled by public concerns for global climate stability. By contrast, in India refrigerator ownership levels are still very low, and refrigerator market expansion is extremely price sensitive. Consequently, refrigerant selection by Indian refrigeration industry is largely influenced by the Indian consumer's perception of product safety and reliability, and the initial product cost.

These market and consumer characteristics suggest that HC-refrigerator safety issues have the potential to be exploited in the marketing of non-HC refrigerators in the Indian market. Consequently, the key issue in the commercialization of HC-refrigerators in India is safety - in transportation and storage of Hcs; in their utilization in factories; in refrigerators inside homes; and in the servicing and recharging of these refrigerators (largely by semi-skilled technicians in the informal sector). The obverse side of the coin is that Hcs have been in use in India for long, and with enviable safety records. The Ecofrig project and ist success will provide the examples necessary to underline that HC use in refrigerators is equally safe as well.

Interview with Dr. Omar El Arini Chief Officer / Secretariate of the Multilatearal Fund (MF) of the Montreal Prototcol

Helping Developing Countries to Phase Out CFCs

Akzente: Status of MF projects: How much of the money available has been allocated to projects, and how much of this money has been spent? How many projects have been completed? Is there something like an average time span from project idea to submission for approval to completion?
El Arini: As at September 1994, US $ 212,300,984 has been allocated to projects of which US $ 13,713,579 has been spent on 126 completed projects. The project completion rate is very low and rarely concerns investment projects (only seven investment projects have been completed). The available data indicate that up to one year was for calculation of the average time span from project idea to submission. However, this depends on the Article 5 country concerned; for example Colombia only ratified the Protocol in 1994, but was able to develop projects shortly after that. Some Article 5 enterprizes move very quickly with the implementation of projects, once such projects have been approved by the Executive Committee.
Akzente: Are Article 5 countries anxious that there might not be enough money available in future? Is there something like a run to act as quickly as possible to secure the increment of costs? How does the MF Secretary rate the future of the MF?
El Arini: Some fear of this sort obviously exists. Whether this is a trend that will develop into a run remains to be seen. As long as there is a need to phase out ozone depleting substances in developing countries the Multilateral Fund is, for the time being, the only and best equipped mechanism put in place to do the job.The future of the MLF rests with the political will of both developed and developing countries to see to it that the objectives of the MP can be achieved in a cost effective manner.
Akzente: After the MF had been founded the new hydrocarbon technology emerged thanks to the pressure of Greenpeace Germany. How are the MF Secretariat and the Executive Committee responding to this new situation? Is there any way that, say, a bilateral contribution could help?
El Arini: We believe that all institutions of the Multilateral Fund (Executive Committee, Secretariat and Implementing Agencies) have reacted in a positive way to the emerging hydrocarbon technology, especially in the foam blowing area, judging from the number of approved projects for the use of cyclopentane as a foam blowing agent.
However, we would like to emphasize that the original choice amongst available alternative technologies was not made by the Secretariat or the Executive Committee. This choice was made by the implementing agencies, and was only presented to the Committee for approval. In this case, bilateral assistance should have a greater role to play by developing projects containing alternative technologies and presenting them to the Committee for approval.
Akzente: The Article 5 countries still have quite a number of years as a grace period, so they could lean back and wait. What are the driving forces behind this early phase out process? How important are market forces? How much is subsidy via the MF? What powerful incentives are there? Where would you like to see reinforced or new approaches?

El Arini: While it is true that Article 5 countries do not have to do anything up to the beginning of 1999, we believe that the MLF has been extremely instrumental in catalyzing an accelerated pace of phase-out activities in those countries. Market forces have been pivotal in the process where multinational subsidiaries are operative in some Article 5 countries, and where export to non-Article 5 countries is an integral part of the Article 5 country national economy.
Akzente: Is there enough technical expertise in the world, in particular for the new technologies like hydrocarbons, to give the necessary technical support to all the conversion projects? What can be done to improve the situation? And is there any way that, for example, a bilateral contribution could help?
El Arini: So far the MLF has supported the full incremental costs of conversions. This, in itself, is the most significant single incentive. We would like to realize phase out projects based on national sectoral strategies.
The issue should not be whether there is enough technical expertise, especially with regards to emerging technologies. It is rather the acceptability of such technologies by not only Article 5 countries but also by non-Article 5 countries. We do not characterize the situation of the emerging technologies as being bad. We believe a transitional period is required in order to adjust to the ever changing market demands.
Akzente: What part have bilateral projects played so far?
El Arini: Bilateral assistance has accounted for less than 3 % of approved funding so far. It is limited to very few countries where the implementing agencies have been very active in ongoing programmes.
Akzente: The German BMZ/GTZ are now taking an initiative for the hydrocarbon technology. How are these activities seen and rated by e.g. members of the ECM? What do you expect from these activities? What is the part the German GTZ could play with their efforts? Do you have any advice for these and future bilateral German projects?
El Arini: It is difficult to know how different Executive Committee members rate hydrocarbon technology as no such discussion has ever flourished during the meeting. However, and with reference to Point 2 above, it deserves to be pointed out that the choice of technologies is done basically by the implementing agencies and not the Executive Committee. We believe that the serious efforts being exerted by BMZ/GTZ in this direction should be integrated, where applicable, in the host country's strategy for the phase out of ODS.
Akzente: This year the MF is undergoing supervision of its procedures and performance. Where do you expect changes? Where would you like to see more efficiency?
El Arini: Recently, the Fund has been running the risk of being short funded. In some cases, the anticipated delivery rate of projects for approval has not been realized and the rate of project implementation (investment projects in particular) is very low. Hopefully, this could change for the better.
We would like to have more and more standardization of projects with the main focus being directed to the phase out of maximum quantities of ODS as cheap and as fast as possible.
Akzente: There seem to be a lot of complaints amongst the applicants about the cumbersome procedures to projects approved: up to half a dozen and more stages of careful checking, sometimes years of suspense for the applicant. Is there any major change in sight to make it simpler and more effective?
El Arini: In working with the implementing agencies, the Fund has inherited a very elaborate and cumbersome process (that of the agencies) in drafting, approving and implementing projects. This issue has been addressed and is continuously being addressed by the Executive Committee. The agencies are reviewing their internal project cycle process and are constantly looking for ways to speed up the process. Improvements have been made and several suggestions during Executive Committee meetings have been adopted that will speed up the process. In other words, we have made some headway towards simplifying procedures but still have some distance to go. For your information, it takes a maximum of seven weeks from submission of a project (to the Committee) and for its approval and communicating the decision to the country concerned. What is still frustrating is what happens after approval.
Akzente: Where in particular are the bottlenecks or delays in approving? And is there any way that, for example, a bilateral contribution could help?
El Arini: The main bottleneck in approval has been when a project presented a new issue that the committee had not dealt with before. Even here, permission to proceed with the further

development of the project is given pending the resolution of the issue. We believe the same situation could arise in bilateral projects.
Akzente: They say that there is a rather strict ruling of the MF ECM not to reimburse any R & D in Article 5 countries but to insist instead that they adopt the worked out sophisticated industrial solutions. Isn't there a rather new situation with the hydrocarbon technology which needs to be adapted to other models, other climates, other safety standards in these countries, especially for the hydrocarbon blends that seem to allow something like tailor-made conversions of old CFC compressors?
El Arini: The rules of the Fund stipulate that only proven technologies should be adopted. Research to adapt the new technology is admissible. However, research to develop the new technology would pose serious problems regarding the ownership of patents (if any) and the time frame within which specific results are to be expected.
Akzente: What trends do you expect within the MF as well as outside? If you had three wishes - just like a figure in a fairy story - for the sake of the MF, what would you change?
El Arini: A final, simple, cheep ozone benign technology that took care of its own implementation.

The History of CFCs

1892-1907
The Belgian chemist Frederic Swarts describes the properties of synthetically produced groups of molecules in which chlorine and fluorine are grouped around the carbon atom - the CFCs.

1929
Thomas Midgley of General Motors has the compounds patented. Technical application begins.

1930
Midgley suggests that trichlorofluoromethane, termed CFC 11, and dichlorodifluoromethane, termed CFC 12, be used as a substitute for the cooling agents sulphur dioxide and ammonia, and has the substances patented. General Motors manufacture the "Frigidaire" refrigerator.

1932
The American Carl Iddings uses CFC 12 as a propellant for spray cans.

1936
CFC 11 and CFC 12 enter the market.

1942
The first aerosol insecticide is employed by the US Army in Indochina to protect soldiers against a bothersome insect plague.

1953/54
Aerosol production begins. CFCs are used in scent, hair and deoderant sprays, shaving creams, perfumes, glues, varnishes and paints.

The seventies
CFC application experiences a boom. The substances are now also used as cleansing agents in the electrical engineering and textiles industries, and as propellants for plastics. Halones are used in fire extinguishers.

1970
The British scientist James E. Lovelock detects CFC 11 in the atmosphere.

1972
CFC manufacturers worldwide meet in Massachusetts at the "Seminar on the Ecology of Hydrocarbons".

1974
Sherwood Roland and M.J. Molina, University of California in Irvine, publish their theory that CFCs could be destroying the protecting ozone layer of earth in the stratosphere in the scientific journal "Reviews of Geophysics and Space Physics".

1978
In the USA, a ban is imposed on CFC 11 and CFC 12 in aerosols. An exception is made in the case of pharmaceutical applications.
In the European Community, a reduction of 30 percent in aerosols is achieved.

1985
The ozone hole over the Antarctic is discovered. The Vienna Convention on the Protection of the Ozone Layer is agreed. It is a skeleton convention that does not contain any concrete protective measures. These remain subject to agreements in follow-up protocols.

1987
The Montreal Protocol is adopted as a completion of the Vienna Convention. 46 countries sign an agreement aimed at a step-by-step reduction of the production and use of fully halogenized CFCs to 50 percent of the 1986 level by 1999.

1988
The EC decree on the Introduction of the Montreal Protocol in the EC comes into force. In the Federal Republic of Germany, the Vienna Convention and the Montreal Protocol are ratified. The Enquete Commission of the German Federal Parliament submits an intermediate report containing demands that are more far-reaching than the requirements stipulated in the Montreal Protocol.

1989
The German Parliament approves the recommendations of the Enquete Commission on the protection of the earth's atmosphere. The US Congress passes a CFC taxation scheme: $ 1.37 per kilogramme of CFC related to the "ozone depleting potential".

1990
The stipulations of the Montreal Protocol are tightened up in London. In accordance with its new version, a reduction of CFCs by 50 percent is to be achieved by as early as 1995, while a 100-percent phase-out is to be
completed by 2,000. Article 5 countries are entitled to a period of grace of a further ten years. The establishment of the Multilateral Fund, which is funded by the industrialized nations, gives developing countries the opportunity to claim financial aid for a phase-out of CFCs.

1991
The CFC halone ban decree is ratified in Germany. As from January 1, 1995, it is forbidden to produce or use CFCs in Germany.

The nineties
The international consortia "PAFT" (Programme of nineties Alternative Fluorocarbon Toxicology Testing) and "AFEAS" (Alternative Fluorocarbon Environmental Acceptability Study), both of which are funded by the CFC manufacturers, look for alternatives. The refrigerator industry starts to switch to HFC-134a as a cooling agent, and employs a mixture of semi-halogenized CFCs as foaming agents.

1992
The east German company Foron presents the first CFC and HFC free refrigerator, in which pure hydrocarbons are used for cooling and insulating purposes.

1994
In Europe, the employment of hydrocarbons becomes widespread in the refrigerator industry. The USA and Japan continue to insist on using HFC 134a.

Hydrocarbons Versus HFC-134a

Horst Kruse

Chlorofluorocarbons (CFC) have to be phased out in refrigerators by 1996 in the industrialized world, and up to ten years later in the developing countries. There are two options: an older one, HFC-134a, and a newer one, hydrocarbons. At present, opinion worldwide is divided on the substitute. While the USA and Japan have opted for HFC-134a, industry in Europe first switched from CFC-12 to HFC-134a and then, only two years later, to hydrocarbons. Is this the final solution? Which is the best substitute for industrialized and developing countries?
Only very few appliances are as widespread and are such an important part of our life as refrigerators. In the developed countries the refrigerator has been the last link of the cold chain for food for several decades, whereas in the developing countries this development has just started. Here, refrigerators are the first important investment of families in order to preserve food and chill beverages. Therefore, the number of refrigerators is expected to increase drastically in coming years. The problem posed by finding a suitable substitute for the refrigerant CFC-12 has demonstrated that the technology of a refrigerator is not as simple as commonly assumed, and that it has to be adapted to the conditions of its application, in industrialized as well as in developing countries.

The Refrigerator Principle
Each refrigerator needs a working fluid circulating in a hermetic circuit to generate cold. Figure 1 presents such a circuit, which consists of a compressor, condenser, capillary tube and evaporator. In the case of a two-temperature refrigerator the evaporator is divided into one for the chilling and one for the freezing compartment. The compressor sucks refrigerant vapour from the evaporator at a low pressure and compresses the gas to a higher pressure in the condenser. Today, compressors of the hermetic type jointly enclosed with the electrical motor in a gas-tight housing, find universal use. The refrigerant condenses in the condenser, which in most refrigerators is mounted on the rear wall. During this process heat has to be emitted to the ambient. The refrigerant reaches the capillary tube as a liquid. Its pressure is reduced when it flows through the capillary tube. Subsequently, the refrigerant evaporates in the evaporator, which is installed inside the refrigerator cabinet. Due to the heat absorption during evaporation the cabinet is cooled.
RefrigerantIn this process the refrigerant has to meet several of requirements. With respect to these requirements, there are at present two major alternatives for the refrigerant CFC-12 :
hydrofluorocarbon (HFC-134a),
hydrocarbon - either isobutane or a mixture of propane and isobutane.

Each of these alternatives has merits and demerits, so that the appropiate solution can differ depending on the specific conditions of the market.

Production Process
Redesign of Components
The conversion to a substitute refrigerant requires a redesign of the compressor swept volume. In the case of HFC-134a, the swept volume has to be increased slightly, by about 10%, whereas isobutane, due to its low refrigerating capacity, requires an increase of about 70% compared to CFC-12.
However, a hydrocarbon mixture can be defined by adapting a composition that does not necessitate a redesign of the compressor. In this respect, the mixture would be the cheapest replacement with only small modifications in the evaporator and the condenser. In addition, particularly in the case of a two-temperature appliance, the use of a mixture can lead to a reduction in energy consumption of about 20%, as shown by Radermacher [1].

In Western Europe, industry has favoured isobutane to a mixture for two reasons. Due to their increased size, the compressors required for isobutane are more energy-efficient. Second, their noise level is significantly lower when using isobutane instead of the mixture.

Insensibility to Contamination

The standards in the production process of refrigerators are very high, since a refrigerator is expected to have a lifetime of 15 years. Thus, the refrigerator has to operate for about 70,000 hours, normally without any servicing.

Several problems were identified in the introductory phase of HFC-134a in Europe. They were caused by the remains of a great variety of chemicals used in the production processes of the components in the refrigerant circuit. Although these problems were solved later by a thorough examination of the entire production process, conversion to HFC-134a requires many changes in manufacturing. Even if the desired quality in the production process can be achieved in the factories in developing countries, a sufficient level of quality in the manufacturing of the various component suppliers is doubtful, whereas it is certain that the unorganized service sector will not be able to fulfill all the requirements of proper operation.

No problems of this kind are known for the use of hydrocarbons as refrigerant. Here, the same standard of production as achieved with CFC-12 seems to be sufficient.

Lubricant

Lubrication oil plays an important role in the refrigeration cycle. It is mainly needed to lubricate the compressor parts but some oil also gets into the refrigeration cycle, where it is not desired. In order to ensure a good heat transfer in the evaporator and to enable the oil to return to the compressor, a sufficient solubility of oil and refrigerant is essential.

Mineral oils used up to now with CFC-12 are fully soluble in the liquid refrigerant. This is also true for hydrocarbons. In contrast, mineral oils are not miscible with HFC-134a. Therefore, oils of other types have to be used for HFC-134a, namely the significantly more expensive ester-based oils (Figure 2) which are very sensitive to humidity (Figure 3). Humidity can be absorbed from the air during storage if not stored properly, especially in the very humid climate of many developing countries. A humid oil cannot guarantee a sufficient lubrication and will severely damage the compressor (igure 4). In this case, the most expensive part of the refrigerator must be replaced.

Servicing

One important factor in reaching a decision about the future refrigerant is the consideration of the service sector - especially in developing countries. In Europe, North America and Japan, a refrigerator is simply scrapped if it is not working properly. It is only in minor cases that a new appliance is repaired by well-trained technicians who are equipped with proper tools for the job. In developing countries, refrigerators are repaired several times for cost reasons. It is necessary to repair them much more often due to harder working conditions, such as higher voltage fluctuations, high ambient temperatures, frequent door openings - and minor quality in production and servicing.

Repairs are carried out mainly by the so called unorganized or informal sector. These people are independent of the refrigerator industry, and their level of training and knowledge is relatively low. In addition, appropiate tools for repairs are not available to them.

If there is a conversion to a replacement refrigerant in the industry, it will be virtually impossible to train the whole unorganized sector in the handling of sensitive refrigerants, lubricants and the other equipment with respect to cleanliness, humidity, etc., as described above. Since HFC-134a is much more sensitive to improper handling than the hydrocarbons, and on account of the hazard humidity constitutes for the lubricant required for HFC-134a, isobutane or the mixture of propane and isobutane are better choices for refrigerators in developing countries.

Retrofitting

Retrofitting means the use of a different refrigerant from the one the refrigerator has been designed for. This factor is of very high importance for developing countries, where CFC-12 refrigerators still have to be repaired for economic reasons when CFC-12 is no longer available or will be too expensive for these countries.

In order to enable a repair of these appliances, the new refrigerant has to be compatible with the remaining refrigerant and the old lubricant. For the reasons given above - immiscibility with lubricant, insensibility to contaminants etc. - , HFC-134a cannot be used for retrofitting.
If the same compressor can be employed again, the hydrocarbon mixture can be used as a replacement because of the same refrigerating capacity. Even if the heat exchangers are not modified, the refrigerator will cool somehow, but with a slightly lower efficiency.

Energetic Efficiency
A high efficiency of the refrigerator is most important since the main known environmental impact of these appliances is caused by the energy consumption, and not by the refrigerant itself if a non ozone-depleting substance is used. A first comparison always shows a poor performance of a new refrigerant compared to a substance already introduced. However, further adaptation of the components has resulted in comparable energy efficiency for all alternatives, HFC-134a as well as hydrocarbons, compared to CFC-12. From the energetic point of view, all alternatives are equal. The use of mixtures as refrigerants offers further potential to increase efficiency.

Flammability
The major objection to the use of hydrocarbons as refrigerants is the flammability of these fluids, whereas the alternative HFC-134a is nonflammable. The necessary requirements for safety have to include production, use by the consumer and servicing. However, experience in Europe, where hydrocarbon refrigerators are accepted as safe by independent institutions and where a large number are already on the market, demonstrates that the flammability problem can be solved.
Flammable fluids are handled in many production processes all over the world. Since the refrigerator industry had not been using flammable fluids up to now, there are some objections. But for production, it is possible to fit the appropiate safety installations, to adopt the manufacturing process and to train the staff.
For the consumer, the risk the use of a flammable refrigerant involves is negligible for two reasons. First, the refrigerator has to be modified by the manufacturer to minimize the risk of a leakage and ignition, and second, the charge of hydrocarbons is very low and can be reduced further by optimizing the circuit. In comparison to HFC-134a, the charge of hydrocarbons is about 40%, which means that an average refrigerator contains 20g-40g of flammable substances, which is the same amount as in a lighter.
In the service sector, handling flammable fluids will not cause any problems given their small amount and the knowledge and experience about it. Even today, the service sector use flammable fluids for soldering, where the amount stored and used is much higher than the amount used as a refrigerant.

The Solution
In principle, both alternatives, hydrocarbons and HFC-134a, are suitable replacements for CFC-12 in the developed countries. The aspect of minor cost advantages for one alternative is of less importance. Industry has proved its capability of producing reliable refrigerators with both refrigerants. However, with their lower greenhouse warming potential, hydrocarbons have an additional environmental benefit in comparison to HFC-134a, even though their energy consumption has a higher significance for the environmental impact. Also, other possible environmental impacts of hydrofluorocarbons during production and atmospheric destruction can be avoided by using hydrocarbons.
For developing countries the servicing of old (CFC-12) and new refrigerators is of considerable importance for economic reasons. Due to the anticipated problems in the use of HFC-134a in servicing, and since it will not be possible to give efficient training and equipment to the service sector within the next few years, hydrocarbons are more suitable, especially for these countries. The mixture may be a fast substitute whereas isobutane is a long-term solution.

Sources :[1]
Radermacher, R.; Rose, R.J.; Jung, D. : Testing of Domestic Two-Evaporator Refrigerators with Zeotropic Refrigerant Mixtures: ASHRAE Transactions 1992, V. 98, Pt. 2[2]

Kuijpers, L.J.M.: Development Status and Cost Aspects of Alternative Refrigerants for Domestic Refrigeration; Eindhoven, June 1994

Table 1 : Changes involved in refrigerant change				
Refrigerant	CFC-12	HFC-134a	isobutane	mixture
Lubricant	Mineral	Polyolester	Mineral	Mineral
	+	-	+	+
Compressor modification		yes	yes	no (yes)
		-	-	+ (-)
Manufacturing		change	no	no
process conditions		-	+	+
Safety provisions		no	yes	yes
		+	-	-
Servicing		-	+	+
Retrofit for HFC-12 without		no	no	yes
compressor change		-	-	+
Retrofit for HFC-12 with		no	yes	yes
compressor change		-	+	+

The Two-Step Phase-Out

Dieter Thierbach

"Bosch-Siemens Hausgeräte GmbH" are among the largest companies of the world. And just like all the other large manufacturers of refrigerators, subject to the pressure of the Montreal Protocol, the company found out for itself that R 134a was the quickest and best alternative for CFCs - and switched over to the new substance. And then there was news from the east of Germany that made hydrocarbons worthy of debate. Once again, Bosch Siemens changed their cooling agent - and now there is certainty that in opting for isobutane and cyclopentane one has struck the right course.

The world's largest refrigeration appliances works is situated in Giengen on the Brenz, roughly 40 kilometres northeast of Ulm. It has an annual turnout of about two million refrigerators and freezers. In September 1993, the 40 millionth refrigeration appliance came off the production line. "Bosch Siemens Haushalte GmbH", BSHG for short, are also the biggest employers in Giengen, the second largest domestic appliances company in Europe, and come Number Five on a world scale.

On the noticeboard in the entrance area you can study the "Autumn Hits '94" - cut-price offers for works employees. Of course they also include products made by the company itself. And these products immediately strike the eye. "100% free of CFCs" it says resplendent against a pale blue background. Just a few steps further on, two steel doors close behind us, and we are right at the hub of activities, where a refrigerator comes off the production line every eight seconds.

The "birth" of a refrigerator is very unspectacular. As if by magic, the body of the refrigerator is fully automatically brought into the right shape out of a five millimetre thick white plate under high pressure and great heat by a vacuum drawing apparatus and then stored. It is subsequently "married" to the flat evaporator, the cooling unit. Given the appropriate shape by a bending machine, it is then stuck to the housing with the aid of a foil.

A few metres further on, each refrigerator body enters an oven and is heated up to 40 degrees Celsius. Then it is off to the roundabout. A lance is directed into the hollow space between the the sheet metal side parts and the housing and applies a fixed quantity of a light brown mixture that distinctly smells of "chemicals". One conspicuous feature of the roundabout is that part of it is sealed off with plexiglass, and that the refrigerator bodies move through plastic curtains at the entrance and exit.

This may be unspectacular, but it is nevertheless sensational. And, as Dr. Udo Wenning, a diploma physicist, and head of the research and development department, explains, it is precisely here that one of the most fundamental alterations in the production process was implemented. Until recently, the polyurethane foam was still foamed with CFCs. Three quarters of the total amount of CFCs that a refrigerator received then was employed here. Only one quarter was used in the refrigeration cycle.

Given these large quantities of CFC, activities aimed at finding substitutes initially concentrated on the foam. "for the Montreal Protocol meant that a number of new issues had to be dealt with," says Dr. Wenning. A large number of substances were examined, and several experiments were conducted in Giengen. Initially, in 1988, the CFC quantity employed in foaming was reduced by half.

About 800 substances had already been discussed systematically as foaming agents. Killer criteria were sought for the selection process, and in the case of the hydrocarbons, they were soon found. The argument was that it was out of the question to use an inflating substance that was flammable. This was all the more the case since one believed at the time that CFCs, the safety propellant and cooling agents par excellence, had solved all problems. The net result of considerations then was that hydrocarbons were totally unacceptable. "Now that we were up to our necks in terms of finding a solution, the only option left was to undertake another intensive examination of this group of substances. That was at the beginning of the nineties," says Udo Wenning.

It is shortly before 2 p.m. The early shift in the Giengen works is drawing to a close. For a few minutes, the conveyor belts stop and are refitted for another type of refrigerator. The shed is no longer quite as deserted as it was at the beginning of our tour of the works. Staff are gathering to clock in on time.

According to Udo Wenning, it quickly became clear that the use of hydrocarbons as propellants presented no problems on the customer side. The finished foam burns roughly in the same way, irrespective of whether it is propelled by CFC or hydrocarbons. The danger of an explosion in the kitchen can be ruled out completely. Thus the conclusion was that responsibility now lay solely with the manufacturer. So what would have to be done to ensure that the substance could be handled safely?

After talks with the "Technischer sberwachungsverein", an extensive safety package was compiled in Giengen, for handling flammable substances in the works was something completely new. The greatest precautions had to be taken. Measurements and tests were carried out on a reduced scale to find out the quantities of explosive mixtures that could accumulate under unfavourable circumstances. Expressed numerically, about five percent of gas in terms of weight is involved in the foaming process. Roughly 500 grammes of hydrocarbons is concealed in large cooling appliances with insulation quantities of about ten kilogrammes. And then there is a substantial number of possible sources of an ignition, such as electrical components or plastics that may become charged.

The finished safety management concept takes both aspects into account, the elimination of ignition sources and the prevention of an explosive atmosphere. A huge manpower effort was required to put the theory into practice. There were no finished concepts, and nothing could be taken over.

Certain parts of the production process, such as this foaming plant, were virtually encapsulated and fitted with ventilation systems, monitors and sensors. The refitting effort was immense, for there are a total of 17 plants that facilitate decentralized, on-the-spot foaming directly in the production line for doors or housings.

Decentralisation also means that mixing is performed outside the production process. 30,000 litres of pentane that is delivered straight from an oil refinery, and 150 tons of polyole are stored in large tanks outside the production shed. This plant supplies the various production units via 800-metre long pipelines. Thus the transportation of pure pentane across the works site is avoided. The pentane polyole mixture is flammable, but it is not nearly as critical as the pure hydrocarbon.

Permission for a conversion of the plant was granted in just over a year - a speedy process by German standards. "Representatives of the authorities even turned up in the evening whenever we were conducting tests, and they did as if this was just routine." At this stage, it was also important to give staff adequate training. The first step in this repsect was to ban plastic clothes. Everyone had to wear cotton overalls and conducting shoes.

"In the implementation phase, we were literally overrun by other interested parties. Visitor groups turned up from other parts of Europe, South America, and Japan. Since this issue is affecting everyone worldwide, we did not keep our knowhow to ourselves." Since August 1993, foam at the BSHG has no longer contained CFCs. In the meantime, the new method has become a world standard. Towards the end of 1993, Udo Jenning was given the "Stratospheric Ozone Protection Award" by the American Environmental Protection Agency (EPA) "in recognition of years of achievement in the development and introduction of methods as a substitute for CFCs in the insulation of domestic refrigeration appliances."

We are now standing in front of the foaming plant, where surplus pentane can degas and is sucked away by a high-power ventilation system. The air current and the concentration of the gas are permanently monitored and registered by sensors and probes.

Some metres further on to the left there is an array of compressors standing on pallets. They are black, and they are pretty heavy. What immediately strikes the eye is a small sticker indicating flammability.

"This is where our second problem cropped up," says diploma engineer Walter Holz, head of the experimental department. Mr Holz, who is accompanying us throughout the tour, explains that the "killer criterion" that precluded hydrocarbons for insulation technology naturally also applied to the cooling agents. "A flammable substance was out of the question."

So R 134a crystallized as a substitute cooling agent, for its technical performance was very similar to that of the classic CFCs, and it was non-flammable. However, research regarding the compatibility of the cooling agent and oil was necessary not only on the pure material side, but also on the compressor side. After all, the reliability of the closed circuits had to be guaranteed for the entire lifetime of an appliance.

During the five-year development phase of 134a, one discovered after two years that the oils employed up till then were not suitable for this combination in the compressor. Deposits in the throttle pipes in the coldest section of the cooling agent cycle could result in a complete blockage. "Appliances would fail after a while." So this was a cul-de-sac and lost time, for now, new oils had to be developed. By 1993, the compressor manufacturers had managed to solve problems in the production process, enabling the BSHG to switch over entirely to 134a. "At this stage, everyone thought that this was the solution for the next few years, and worldwide at that."

Reports about a refrigerator from the former German Democratic Republic that was operated with a mixture of propane and isobutane were not really taken seriously by anyone here in Giengen. It was only when the mail-order firm Neckermann had adopted the model in their sales catalogue that the rest of Germany's domestic appliances industry pricked their ears. "We were completely convinced that this could not be the right solution. But in the end, we wanted to show that we were capable of applying it as well," says Walter Holz.

With "gentle force", the German manufacturer of compressors was persuaded to supply a suitable compressor. But according to Walter Holz, the auxiliary suppliers viewed this decision with mixed feelings. Their argument was that surely one could not develop a third series of compressors in parallel to 134a, for the CFC series was still in operation. Where could one obtain explosion-proof testing units in such a short space of time?

FinallyUltimately, some hydrocarbon technology appliances were manufactured only to be stored in the warehouses for an indefinite period. Or at least this was what everyone believed at the time. For one was reckoning with zero demand. But the first thousand appliances turned into 10 000, and within a quarter of a year, 30 000 were sold. "The ball had started to roll, and now nobody could stop it."

Events came thick and fast. By December 1993, BSHG had changed course completely. A resolution at board of directors' level ordered that the new technology be applied throughout the entire range of the company's products.

Terms were also agreed with a Japanese manufacturer of compressors, with a production plant in Singapore. "Since there was a general need to produce hydrocarbon compressors, we were able to convince them that this was an opportunity for them to enter markets they might not have even realized at the time," Walter Holz recalls. In three quarters of a year, production was ready to commence. This had been made possible at least partly through the excellent compatibility of the cooling agent and oil.

It was at this stage that the BSHG also decided not to use a mixture of substances, but one single substance, isobutane, called R 600a. In the course of 1994, throughout almost the entire collection of products, the fluorohydrocarbon R 134a will be replaced by hydrocarbon isobutane, which is similar to natural substances, as a cooling agent.

There are a handful of exceptions. For two types of appliance, the BSHG has to observe certain restrictions. This is the case with the so-called no frost models and those types that are fitted with internally suspended evaporators, in which parts of the refrigeration cycle and electrical switching elements have been mounted in the interior of the refrigerator. If it were to come to it, interior lighting at each door opening would pose a possible ignition source.

We are continuing our tour. Three women are soldering the copper pipes onto the still empty compressor in traditional style. "Work done by hand has clearly proven to be better to an automatic system on every count," says Udo Wenning. One single opening remains unsealed, so that the cooling agent can be filled in at the next work station.

While there has already been a breakthrough regarding hydrocarbon in Europe as far as the foam is concerned, about 85 percent of all German manufacturers will have switched to isobutane as a cooling agent by the end of the year.

Regarding a worldwide breakthrough, Walter Holz is "very, very sceptical". Even the most brilliant solo effort is not much use if the rest of the world does not join in. "Alone the American automobile industry alone uses about 70,000 tons of CFCs for its air conditioning appliances. In Germany we have employed just 1,000 tons for the entire range of household appliances."It is said that the Americans and the Japanese have no desire to address the issue in their countries. So what objections are there? "The safety risk," is the unanimous answer. A Japanese delegation that recently visited Giengen argued that anxiety was the main concern in Japan. The Americans are worried about liability that often reaches astronomical proportions.

Appliances of the latest production series contain between 20 and a maximum of 100 grammes of hydrocarbons. This is one third of the amount of CFC that a refrigerator used to contain. Large refrigerator combinations even used to require up to 300 grammes. So far, a few million appliances incorporating hydrocarbon technology have been manufactured. What is the worst thing that can happen if isobutane escapes? Are the new refrigerators kitchen time-bombs? Risk assessment studies were commissioned to qualified external institutions, such as the renowned Engler-Bunte Institute in Karlsruhe. The result was that, at worst, a deflagration in connection with the liberation of hydrocarbosn can lead to a door being pressed out of its frame. Human casualties can be ruled out. Since the process is so rapid, there is no danger of burns either. "These results ultimately prompted us to switch to hydrocarbons."

At the next station, the filling unit, life is breathed into the refrigerator by a staff member. A valve is stuck into the end of the sole remaining open copper pipe. Via a black, corrugated hose, an precisely defined quantity of isobutane flows into the compressor - a routine work process. A crushing forceps seals the hose. Two metres to the right, a staff member takes off the valve and, astonishingly, solders a seal on the filler pipe using an open flame.

Subsequently, there is a quality check. Every single refrigerator has to undergo a scrutinous examination. The electrical characteristics, such as power intake, are controlled. "If just two cubic centimetres of isobutane too little has been filled into the refrigerator, then it will not operate the way it is supposed to," says Udo Wenning. "And this is spotted immediately." The appliance is

also checked for possible leakages. A mass spectrometer, a sensitive analytical apparatus employed in large-scale chemical laboratories, is used to this aid.
The works inspection is drawing to a close. We have now reached the point where the finished appliances are waiting for dispatch. Refrigerator manufacture in Giengen started in 1949. Just like today, the original refrigerators produced at the plant were absolutely free of CFCs. In the initial phase, glass wool as an insulator and sulphur dioxide in the refrigeration cycle were regarded as the state of the art, although this was never seen as an advantage. Quite on the contrary. When the magic formula CFC was introduced some years later, the first polyurethane foamings and the non-toxic, non-flammable R 12 were employed in the refrigeration cycle, this was thought to be the ideal solution.
What does the future hold in store? There are about a dozen chemical and physical alternatives for hydrocarbon refigeration technology, Udo Wenning explains. "We are certainly keeping an eye on them, but at the end of the day, the degree of efficiency is crucial. And this is where the present system clearly comes off best."

Interview with Mr. Rolf Segerström, Electrolux

Akzente: Electrolux is one of the most important refrigerator manufacturers on the international market. Why did Electrolux first take the decision in favour of HFC 134a as a CFC substitute?

Segerstrom: Electrolux took the early decision to develop products and components for HFC 134a because it was a fully chlorine free chemical which could be used worldwide. At the time of the decision HCFC refrigerants and refrigerant blends were being promoted by other firms. Hydrocarbon options were considered, but were not chosen because the time for full industrialisation was found to be long. And, more importantly, international and national safety standards ruled out flamnzahle refrigerants.

Akzente: How did you feel about the environmentalist group Greenpeace starting to promote hydrocarbon technology? What were the discussions with Greenpeace like?

Segerstrom: All in all, we felt frustrated. We knew that it was absolutely necessary for us to continue and finalise our conversion to HFC 134a in order to match European and nationally legislated CFC bans by 1994 and 1995. All other technologies including HCs, could only be industrialised in a part of the production. Our impression was that Greenpeace were not giving any consideration to these issues. We also felt that household refrigerators were being drastically overemphasised in the CFC debate. We were of the opinion that we were doing more and spending more than most other CFC user in-dustries, although we were only using about 3 % of the CFCs.

Akzente: in the end, Electrolux decided to use hydrocarbons as well. When exactly did you change your mind, and what were the reasons?

Segerstrom: in the case of cyclopentane, we never changed our mind.
HFC 134a was not yet available in quantities, and had not yet proven to be non-toxic. It was to be ready by September 1992. We chose to introduce this CFC free solution commercially as from February 1993.
In the case of isobutane we decided to start an ambitious development project in January 1993. Investigations were made prior to that. The reasons for starting were the big impact Greenpeace had made on public opinion and the favourable test results that had been achieved. Later, together with our partners Quelle in Germany, we decided to launch a large range of fridges with HC technology. Only offering a few models would dissatisfy the consumer since the chances were that he would not find his model in the rangerange on offer. In January '94, Quelle offered by far the biggest refrigerator range in the world.

Akzente: Despite the expenses you already had converting to HFC 134a, you decided to convert once more. Are there any good reasons concerning the market and a demand for environmentally beneficial products?

Segerstrom: Again we Were forced to continue the introduction of HFC 134a compressors in order to respect CFC-banning legislation. The obvious reasons are that HC offers a next step of further adaptation to the conditions of the environment, and that we hope to sell these products to the increasing quantity of environmentally concerned consumers.

Akzente: What are the Electrolux strategies concerning the international market? Does the company produce different refrigerators for different countries, e.g. hydrocarbons for the German market and 134a for others? If so, which countries have opted for which products?

Segerstrom: we started with HC fridges m Germany because of capacity constraints, our ambition to offer a big range of products and the fact that German consumers were actively looking for the products with HC. We are not actively entering other Countries in Europe with these products. In some countries there are still formal safety restrictions on their sale. We plan to have achieved a technical conversion of 80/90 % of offered models in the course of 1995. In the USA there is still no possibility to introduce HC refrigerants in refrigerators due to safety standards and product liability concerns. In new ventures all over the world we are always planning for the latest environment friendly technologies.

Neckermann Gets Things Going!

Peter Schwarz

How the Wholesale Mail-order Giant Closed the Door on CFCs

"Greenfreeze: cool without CFCs. A simple mixture of lighter- and camping-gas fuels the fridge of the future." These words in the end-of-July 1992 Greenpeace magazine made Hans Peter Dorlöchter sit right up. Responsible for environmental protection matters at Neckermann, Germany's third-largest mail-order firm - with DM 4 billion annual turnover - he passed the article straight on to his colleagues in purchasing. A few days later Dorlöchter and two other managers were on the way to Niederschmiedeberg in the Erz mountains near the Czech border. The little town was home to DKK (Deutsche Kühl- und Kraftmaschinen) Scharfenstein - as Foron Household Appliances was called at that time: the first East German firm to use the new refrigeration technology in its products.

Neckermann's keen interest was no accident. For several years Dorlöchter and his colleagues had been hunting for environmentally friendly products for their 50,000-article assortment. This search was part of the environmental policy to which Neckermann had committed itself in 1991, and the eco-refrigerator came right on cue.

But the visit to DKK Scharfenstein was a sobering experience. The state-of-the-art refrigerator, said to employ neither ozone-depleting chlorofluorocarbons (CFCs) nor earth-warming hydrofluorocarbons (HFCs) in its cooling process, existed only as a prototype. And a number of questions were unresolved: the eco-fridge used too much energy - could it be made to use less? What if the coolant fluid propane/isobutane leaked out - would it self-ignite? Would the TÜV (Technischer Überwachungsverein), the German technical safety inspectorate, approve it in the first place?

In spite of the uncertainties the Neckermann managers decided to go with the Niederschmiedeberg fridge. They ordered 20,000 units on the spot and put in an option for a further 50,000. Hans Peter Dorlöchter recalls, "We felt that this firm - and with it the entire Greenfreeze project - were teetering on the brink. At that time DKK Scharfenstein belonged to the Treuhand, the trust company of the German government, and had either to come up with some orders or be declared bankrupt." Neckermann's environmental protection man admits it was a little risky, leaning out the window so far at that time. He shrugs his shoulders. "We just relied on the Greenpeace predictions."

The courage the Frankfurt mail-order firm managers showed in their trip to DKK Scharfenstein was quickly rewarded. The technical problems of the new cooling technology were resolved in a

couple of months. In March 1993 Neckermann presented the eco-refrigerator in a special advertisement. Four months later the appliance from the Erz mountains graced the back of the catalogue. Not only had it passed the TÜV, it was the first refrigerator to win the Blue Angel award for outstandingly environmentally friendly products. The customers helped, too. The ground-breaking fridge may not have been a sensation at the cash register, but nevertheless, Dorlöchter concedes, "we made a tidy little profit."
The key point was that the experience led the mail-order firm to carry nothing but refrigerators cooled without CFCs. That the new technology could elbow its way onto the market so quickly was the Frankfurt firm's real triumph. Dorlöchter points out, "The Treuhand saw that wholesale distributors were ready to take the chance and go with Greenfreeze.

The Hydrocarbon Domino is running!

German Bilateral Projects supporting the Hydrocarbon Technology
Klaus Meyersen / Peter Baz / Othmar Schwank

Of course, there are the "facts". They have been dealt with in depths in the foregoing contributions. But there are also some other "aspects" (In our definition. aspects are something that we sometimes can "see", sometimes "feel", but something that we are not really sure about, yet something that we notice and something that is important enough to talk about!) connected with these phase-out efforts: It seems not only that the hydrocarbon technology itself is running like a domino. There are other trends connected with these ecological activities. Trends beneath the most obvious which everybody sees - namely that the hydrocarbon technology is spreading fast. The tremendous speed at which this technology transformation is taken place suggests that there are "good forces" at work. Resulting in trends that make obviously a lot of sense to a lot of people, so that things are moving fast. So these might be trends which may also apply in general and to other international activities. The main domino "Hydrocarbon" hence triggers a lot of side effects that may prove equally important for the success. Trends that create hope for future work!

"We must make the Protocol work. The Montreal Protocol is a unique experiment in global cooperation for the protection of our environment,and on its success depends not merely the protection of the ozone layer,so vital for the very survival of the human race and other life forms, but also on the validity of the entire effort of international co-operation towards saving and protecting our planet."(Shri Kamal Nath, Minister of Environment and Forests, India; 6th Meeting of the Parties to the Montreal Protocol, Nairobi, October 6th, 1994)

The "International Learning Domino"
New Technologies create a New Situation for the Multilateral Fund
After the Multilateral Fund was founded this completely new (in reality "old" but revived) technology emerged in domestic refrigeration: the Hydrocarbon Technology (HCT). This could not have been anticipated by the architects of this Protocol almost a decade ago. Now, after some years of trying hard, which led only to in-between solutions at least in home refrigeration, this techonology implies the need for reconsideration of attitude, thinking and planning, since no longer just one non-flammable liquid will have to be exhanged against another non-flammable liquid, which was the common practise for the cfc-substitutes up to this year. Now extra care has to be taken due to the flammability of these natural gases. So this creates a learning situation for the Fund and all related institutions / agencies. And since it the Montreal Protocol is so far the one and only international ecological treaty that had been put to work by the international community all the hopes are focussed at its efforts.

This new Fund situation may therefore be seen as a rather far-reaching learning-by-doing process. - The "International Learning Domino" is running!

The "Technical Domino"
Some General Aspects on HCT
The following aspects may in brief describe the present status.

Hydrocarbon technology is now considered very widely, indeed almost everywhere, as the technology of the future since it is completely CFC- and FC-free, is a "green" product which does not contribute to global warming, and has an energy consumption that is considered better then 134a.

In total there seems to be no scientific argument against hydrocarbon technology, but many for it.

There are only a few minor commercial and cost arguments at the technical level in comparison to other substitutes. But this is likely to be resolved in favor of Hydrocarbon Technology as soon as a few real cases exist and can be evaluated.

The mayor concern is flammability. Of course apprehensions of this kind have to be taken very seriously and every sensible step must be taken to make hydrocarbon a safe technology.

However, although with this technology there is now a very limited, yet personal risk related to household refrigeration, this should not be unduely exaggerated. The flammability hazard is quite common among other industries (Lighters, Gas Cooking, Aerosols, Chemistry e.g.). They have proven that this is a risk that can be coped with by handling these gases with care.

The "Technical Domino" is running. In the end the longterm ecological advantages of these natural substances plus the economical advantages, like the simplicity of this rather inert chemistry and its related technical simplicity will convince industry quickly, and worldwide.

The "Regional Domino"
Regional Aspects on Hydrocarbon Technology
This change is happening now. And there is more going on than meets the eye.
Without doubt the epicenter of this shock wave is Germany. All German refrigerator manufacturers will have changed completely to hydrocarbon, cyclo-pentane for foaming, isobutane for cooling, by about the time this Akzente issue appears.

The wave is spreading across Europe.
In August 94 Electrolux announced that within a year it would be switching its entire European production to hydrocarbon coolants (cyclopentane as the foaming agent had already been chosen earlier). This means that by the end of 1995 virtually all of European industry will have turned to hydrocarbon.

In these very days developments are spilling over to China, where an official decision has been taken to convert one production line of the quality market leader, Haier Qindao, to hydrocarbon. This will serve as the pilot conversion, for the remainder of the industry, Iit is aimed for completion by middle 95 at the latest. Yet at least three other companies, amongst them Kelon, the market leader, are keen to move ahead. They are filing Montreal applications and are seeking know-how partners.

India is actively and seriously considering the next steps towards conversion to hydrocarbon, stiil undecided is wether to go blends or straight to isobutane: Two leading manufacturers, Godrej and Voltas, are ready to install pilot foaming plants in one of their production lines putting them into a position to study hydrocarbons as coolants in depth with the help of the Swiss-German Ecofrig programmes.

The next campaigns may be in Russia and Usbekistan: One of the biggest manufactures, the combinate of Krasnojorsk, is negotiating conversion on a commercial basis and is seeking German support, necessarily outside the Montreal Fund since Russia is a donor country by definition.
The leading manufacturer in Usbekistan also wants to commence conversion.

And the other countries?
Japan several manufacturers are said to be switching to hydrocarbon soon.
In the USA, rumor has it that General Electric have indicated that they are considering a switch as well.

The rest of the world?
Only a question of time we predict. Everybody (everybody!) is testing the new technology. The "Regional Domino" is running!

The "Domino of Support"
There is need for extra funding.
At least in the initial phase, these hydrocarbon undertakings need extra public and private funding. The mainstream technological options pushed by Multinationals and the Worldbank as implementing agency of the Multilateral fund are HFCs to replace chlorofluorocarbons. The worldbank still recommends hydrochlorofluorocarbons as a substitute foam blowing agent for article-5-countries, although hydrochlorofluorocarbons have become already controlled substances in non-article-5-countries. These fluorinated chemicals have the merit of non being flammable but show from an environmental viewpoint, the demerit of a high Global Warming Potential and are causing a fluorinzation of the atmosphere with unknown future environmental impacts.

Hydrocarbon`s are flammable but have the environmental merit of being natural fluids. They bear no Ozone Depleting Potential, and have only a negligible Global Warming Potential. Futhermore they have excellent properties as refrigerants, superior to HFCs in this respect (134a requires for example special synthetic oils as lubricants rendering the whole system extremly hygroscopic in nature, which results in numerous complications). The only global drawback these natural fluids have, is the fact that they have no chemical industry behind them to push their case. Even the source industry, the petro-chemical industry, has no real interests due to the relatively small quantities needed worldwide by comparison what this industry is used to. In the absence of market forces and hence a lobby the superior environmental properties of natural fluids (hydrocarbons in this stage, others such as ammonia, carbon dioxide, air may follow later) justify public funding to get a technology which is successful in Euorope of the ground, firstly in Asia, India and China, later in other article-5-countries as well as in non-donor countries.
The "Domino of Support" is running! Proven by the fact that not only countries like Switzerland and Germany are willing to support certain activities outside and additional to the Montreal Protocol, like in India, but that the private industry is contributing to these pilot projects too as shown by all (!) the companies involved in the Chinese and Indian projects having themselves committed to substantial contributions which are likely not be refunded by the Multilateral Fund.

The "Domino of Cooperation"
Initiatives incorporating the German Bilateral Projects
Since this new technology developed in Germany it is quite natural that the German Government should take the initiative to make this knowhow available to the Montreal Fund.
We believe that this can be done best by creating bilateral projects taking full responsibility and leadership for at least a number of model projects, and by full use of the good offices BMZ and GTZ have to the German industry, which at the moment is the only practically experienced source of knowhow in the world. All of our projects will work on the same principle namely to win the most experienced group of industrial people and give them the task of a general contractor to convert and train according to the best standards available in Europe.

But this is only part of the story, the national part, so to say. For these projects are embedded in a wealth of newly developing collaborative ventures.

During the last two years, there has been hitherto inconceivable co-operation between the German industry and Greenpeace after Greenpeace started this campaign with a new attitude, the attitude of active support. The climax may have been the Shanghai Refrigeration 1994 were in June this year almost the entire German refrigerator industry, represented by their top officials (!) joined forces with Greenpeace and GTZ to bring hydrocarbon technology to China. (cf. series of "historical snapshots"). Needless to say that such an unusual working relationship will last only for the transitional time when mutual interests line up such a phalanx and will then fall apart. One will go back to business as normal, as soon as the breaktrough is achieved.

Yet there are other, perhaps less spectacular but equally fruitful and promising examples of co-operation. They are arising out of the will to join forces, to avoid doubling efforts, to attempt to do good housekeeping.

Switzerland and Germany working together in India in a very close cooperation at various levels, e.g between the federal institutions, SDC and BMZ, as well as between the implementing agencies and consultants, GTZ and Infras, the Swiss ecological consultanc experts.

The same in China, where USEPA and GTZ have just agreed to cooperate in a long-term effort to align energy saving and CFC-phase-out by hydrocarbon technology together for the sake of the atmosphere. Trying to combine efforts at the working level of these agencies makes sense, since they can handle these things quickly and effiently. Large organisations that learn internationally like the Multilateral Fund and the Worldbank never do so quickly and hence need much more time to adapt at the political level.

The internal India relationship, where the refrigerator industry, research organisations and the ministries are "travelling together" (in reality!) and are working smoothly to come up with the right answer which will be supported by everyone in the end, is yet another unusual example.

There seem to be a lot of instances where the people involved say, yes, we can do it, so we will do it. It is this personal contact on the efficient working level that creates the success of a programme or a project. Hopefully, some of these experiences may rub off onto other international tasks. The "Domino of Co-operation" is running!

The "Domino of Rethinking"

The Attitude towards Refrigeration

The risks of refrigeration were supprcssed for decades. The invention of the nonflammable chlorofluorocarbons in the thirtics gave mankind the illusion that one could use these cooling systems in the shapc of artifical technical devices like a refrigerator or an air-conditioner. and generatc low temperatures with high user comfort without causing any risks.

Rowland and Mollina (1974), in their initial publication on the potentially ozone depleting properties of chlorofluorocarbons destroyed this illusion and significantly contributed to bringing mankind back to realities. Refrigeration unavoidably causes risks, first and foremost environmentally. Or it creates safety risks instead when we use hydrocarbons.

And these safety risks, which in a sense are more personal, will teach us more self-responsibility, and will make us aware that we are taking a more personal risk now instead of affecting later generations in the case of ozone destroying chlorofluorocarbons. By using hydrocarbons, the generation benefiting from the refrigeration comfort automatically also has to learn to handle the risks. Communicating this message against the temptation of markets to postpone risks to later generations is one further reason for investing public funds to make this new technology acceptable to society.

Refrigeration using hydrocarbon now has a clearly visible risk. However, being clearly visible, it can be dealt with. And with modern technology we will just make sure that this risk is very limited indeed. No single private enterprise - be it Swiss, German, Chinese or Indian - will risk its money before the safety infrastructure and the public acceptance of a flammable fluid has been established.

So, geared by the in this case unav.oidable circumstances that force us to take into our own hands what we have tended to leave to later generations in most other cases, hydrocarbon technology is leading us to more selfresponsibility. The "Domino of Rethinking" is running!

The "We-dont-knowhow-to-ca ll-it-yet Domino"
GTZ Working along Borderlines
There is one other aspect related to these projects that
somehow opens up new borderlines and that needs answers, or at least attention or awareness.

As an overall objective, GTZ wants to establish a know-how collecting and dissemination centre for hydrocarbon technology, and especially to build up knowhow for hydrocarbon blends. It will in this function build up, support and provide technical and engineenng experts and consultants, in future hopefully also to implementing agencies of the Montreal Fund like UNIDO and the World Bank.

However, this expertise is rare throughout the world. And the efforts with which the projects are slimmed down by the Multilateral Fund Executives and by the implementing agencies may lead to the situation that no (!) renowned engineering firm or consultant will even be interested in taking part in bidding since they may not only make no profit but at thc end of the day might even run into some financial risk. Full support will be given by GTZ to build up consultant capacity in east Germany. where it all started! and where the original experts are sitting. But chances are that these experts will find themselves in a position with no money to earn due to too tight? sometimes academic calculations.

This has an even more serious effect on another aspect. In the implementation phase of of hydrocarbon technology, special attention should be given to Hydrocarbon Blends Technology (HCB) which could be considered an "Appropriate Technology" for both Article S countries and other non-donor countries like those of the former Eastern Bloc,
which cannot afford a complete switch-over to isobutane technology due to the large investments a complete change in compressor design would involve.

HCBs seem to offer the chance of more tailor-made solutions for medium size and smaller manufacturers, at least to bridge the time until money for a larger investment becomes available. Yet the larger companies who san afford going straight to isobutane are setting the scene, and thus a world standard. With this situation, there is the danger that know-how for HCB will vanish due to the fact that the only source in the world with practical experience, FORON in east Germany, is drying out. FORON themselves were forced by the European market to switch to isobutane.

Unless there is an initiative by one, or better a group of Article 5 countries to take up a thorough investigation of hydrocarbon blends to form their own adapted solutions, this technology will likely be
lost within a few years' time. if not in months.

It is this aspect which now gives our Indian project a dimension that is wider than just to find a solution for India. If succesful, India may serve as a source of hydrocarbon blends know-how for other Article 5 countries, thus encouraging appropriate solutions which may enable poorer countries' economies to move ahead soon and also save the Multilateral Fund a lot of unnecessarily high incremental costs as well, thus making funds available for other purposes. In total it could speed up conversion worldwide due to a lower entrance threshold to hydrocarbon technology. In addition to to bilateral efforts like in India, the Multilateral Fund Executive Committee Meeting would have to take action on its own to try to acknowledge the role hydrocarbon technology could play, especially in view of increasingly scarce funds, and support further investigations particularly on the valuable hydrocarbon blends technology.

This Domino, which we may call the "Support-theless-sophisticated-tai lor-madeSolution Domino" is not (!) yet running! It could be initiated if the Executive Committee and the Parties were to opt for new attempts to fulfil the Protocol in "letter and spirit" in a way that would truly call for co-operation between the North and the South in sticking to the Rio consensus that technology transfer shall be favourable to development and the environment. This would mean changing the indicative list of incremental costs, and actively allowing and supporting true participation in adaptation and development work. Ecological and cost effective technologies are at hand. Let us remove mental and procedural barriers constraining their promotion!

Glossary

"Article 5 countries"
Non-industrialised countries whose annual per capita consumption of ozone-depleting substances is less than 0.3 kg. These countries are signatories to the Montreal Protocol, and they are eligible for assistance from the Multilateral Fund.

CFCs (Chlorofluorocarbons)
CFCs are hydrocarbon compounds in which the hydrogen atoms are completely or partially replaced by fluorine and chlorine compounds. They are used as propellants in spray cans, as coolants for refrigeration and air conditioning, and as foaming agents. The substances most frequently used are known as CFC-11 and CFC-12 - instead of by their chemical designations. CFCs do not burn, they are not toxic, and they are easy to handle. They are extremely stable and inert. Thus they are stable in the atmosphere as well. So chlorine compounds, tightly combined in the CFC molecule, can rise as high as the stratosphere, where at last they break away and deplete the ozone layer.

GATE
GATE, German Appropriate Technology Exchange, was founded in 1978 for the purpose of transferring appropriate technologies to non-industrialised countries.

Greenfreeze
A CFC- and HFC-free refrigeration technology in which the hydrocarbons propane and butane are used as coolants and cyclopentane is used for insulating foams. The environmental organisation Greenpeace has promoted the Greenfreeze refrigerator, which was first developed by the Foron company in Germany.

Greenhouse effect or global warming
Anthropogenic emissions of the gases carbon dioxide, methane, nitrous oxide and CFCs warm the earth's atmosphere. CFCs account for about 25 per cent of this effect. The ozone hole and the greenhouse phenomenon influence one another. The link in the cause-and-effect chain is marine plankton: CFCs are blown into the stratosphere, the ozone hole lets ultraviolet radiation through the atmosphere, the radiation damages plankton in the sea and the plankton assimilate less carbon dioxide, so that the earth's temperature rises.

GTZ
Deutsche Gesellschaft für technische Zusammenarbeit, GmbH (GTZ) is an organisation belonging to the German Ministry for Economic Cooperation and Development. Its task is to support projects in non-industrialised countries in matters of technology and economics.

HCFCs (Hydrochlorofluorocarbons)
HCFCs are used as replacements for CFCs. Their ozone-depleting potential is less than a tenth of that of CFCs. Under the terms of the Montreal Protocol, however, these substances are also to be phased out.

HFCs (Hydrofluorocarbons)
The chemical industry advocates HFCs as a replacement for CFCs. The USA and Japan, for example, have opted for the hydrofluorocarbon HFC 134a. HFCs do not destroy the ozone layer, but they do contribute to the greenhouse effect.

Hydrocarbons
These natural substances have excellent refrigerating qualities, no ozone-depleting potential and only negligible global warming potential. They have the disadvantage of being flammable, but the German technical safety inspectorate TÜV has certified production plants and refrigerators safe if German technical standards are followed. Greenfreeze technology is based on hydrocarbons. They have been adopted by European refrigerator manufacturers as a coolant (a propane/butane mixture or isobutane) and for use in insulating partitions (cyclopentane).

Montreal Protocol
The Montreal Protocol on Substances that Deplete the Ozone Layer was signed in 1987 and has been ratified since by 127 countries. The signatory countries have adopted a programme for phasing out ozone-depleting substances. The phase-out date for CFCs in industrialised countries is 1 January 1996. Longer phase-out periods were approved for the 88 non-industrialised countries referred to in the Protocol as "Article 5 countries". They must phase out CFCs by 2010.

Multilateral Fund
The Multilateral Fund for the Implementation of the Montreal Protocol was established in 1990 to help non-industrialised countries meet the requirements laid down in the Protocol. During the first implementation period (1991-1993) the Fund's budget was US$ 165 million. In the 1994-1996 period, the Fund will distribute US$ 51 million for CFC replacement programmes.

Ozone-depleting potential (ODP)
CFCs and other substances do not deplete the ozone layer to the same extent. Their ozone-depleting potential is expressed relative to that of CFC-11, the ODP of which is taken to equal 1. Halon 121, used in fire extinguishers, thus has an ODP of 3, that of the HCFCs is 0.2 or lower.

Ozone hole
The ozone layer forms a thin shield in the stratosphere protecting all life on earth from the sun's harmful ultraviolet radiation. In 1985 the discovery of an "ozone hole" over the Antarctic shocked the world. In October 1993, the ozone layer over the Antarctic thinned out by 65 to 70 per cent at altitudes of 14 to 19 kilometres. Scientists have measured an ozone depletion of 30 per cent at some points over the earth's Northern Hemisphere. Effects of depletion of the ozone layer could include a higher incidence of skin cancer and cataract, lower plant productivity and deterioration of the marine food chain.