CASE STUDIES IN CLIMATE TECHNOLOGY COOPERATION

U.S.-CHINA CFC-FREE SUPER-EFFICIENT REFRIGERATOR PROJECT

EPA

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Foreword

This case study report on the U.S-China CFC-Free Super-Efficient Refrigerator Project provides a number of practical lessons that may be useful to others designing technology cooperation projects or methodologies to promote the transfer of environmentally sound technologies. This foreword highlights elements of the project that may help inform the design of future international technology cooperation programs.

Several key factors were vital to this project's success. The sustained, long-term commitment of key partners in the technology cooperation process was particularly important. For the host-country government, projects that are consistent with strong economic or strategic goals are more likely to achieve a sustained commitment. In this example, early informal consultations revealed that key Chinese government ministries and agencies were committed to both improving energy efficiency—evident for example in China's Energy Conservation Law and targets in its five-year plan—and reducing CFC emissions, demonstrated by the strong interest of China's State Environmental Protection Agency (SEPA) in the Montreal Protocol process.

Host-country commitment at the technical level can also play a critical role in success. Projects may be advanced significantly by finding a champion or champions within government that can provide: 1) a strong commitment to the goals of the program; 2) affiliation with one or more effective in-country technical institutions; and 3) the mandate and capability to work in the selected technical area to implement programs and make decisions. In the Refrigerator Project, the director and senior staff of the China Electrical Appliance Research Institute (CHEARI) brought enormous energy, technical capabilities, and shared vision to the effort. The informal information-gathering process at the beginning of this project allowed EPA and SEPA to establish a working relationship, and to identify CHEARI and officials within that organization—as well as its parent agency, the Ministry of Light Industry—as effective partners in developing the initial project design.

In addition to commitment of the project partners, a successful technology cooperation project requires a strong technological and practical basis. The Refrigerator Project was based on the existence and availability of underutilized, cost-effective, and environmentally benign technologies in the selected market. Market failures, which can be corrected or overcome with policies and programs, create the opportunity for market transformation. Many technological opportunities exist in every developing country. Technology cooperation programs are most likely to be successful where 1) effective alternative technology exists, 2) domestic and international government and institutional partners are highly committed, and 3) an existing successful model of barrier removal and market transformation can be adapted.

Although the initial design stage of this project was not carried out explicitly as a Technology Needs Assessment (as discussed in the United Nations Framework Convention on Climate Change's technology transfer process), it illustrates many of the characteristics of the technology, host country conditions, and partnership arrangements that would be desirable if such assessments are to lead to effective technology cooperation.

This project suggests that the selection of a technology area should not require significant time and resources, and should be an integral part of a larger process of strategic program design and implementation. The decision to cooperate on refrigerator technology was based on informal discussions and a survey of readily available information. Most of the information collection and analysis was appropriately done after the initial technology selection, in the context of designing the strategy for implementing the technology partnership. The partners initially reached agreement to collaborate on a priority technology area and moved on seamlessly to the design and implementation of the strategy, including bringing in additional partners as needed. This approach contrasts with alternatives now being tested, which separate the Technology Needs Assessment process into a stand-alone activity. These alternative approaches may produce lists of technology priorities, but it is not clear that they would lead rapidly into programs and real changes in technology markets. The EPA-China experience points to the value of long-term partnerships that continue from the initial technology selection through implementation of significant market transformation programs. It also suggests that resources can be used effectively in the context of a particular technology area. A needs assessment process that requires significant time and resources, especially if it is separate from the design and implementation of programs, would be inconsistent with this experience.

The Refrigerator Project was organized around the concept of technology market transformation, which contains elements and lessons useful across a wide range of technology areas and national circumstances. The market transformation approach (described in detail in this report) includes a multi-year strategy, multiple interventions in both supply and demand for a target technology, focus on that commercial market as the most efficient mechanism for sustainable technology diffusion, and clear goals of long-term shifts in the penetration of cleaner technologies after completion of the program.

This project also illustrates the complementary benefits and strengths of bilateral technical support programs, such as that of EPA, and larger international financing programs such as the Multilateral Fund for the Implementation of the Montreal Protocol and the Global Environment Facility. It is unlikely that this program could have achieved success without both types of programs. EPA and its technical partners had the long-term commitment and technical experience needed to design and initiate market transformation efforts, but needed international partners to finance the full strategy. The international financing organizations would have had difficulty providing the necessary technical expertise, experience, and assistance for a complex program such as this, but were comfortable and effective in providing larger investments for implementation.

The Refrigerator Project was a groundbreaking effort, including the design and demonstration of advanced technology that had not already been commercialized as well as a market transformation strategy to diffuse improved technology widely. As such, it required an extraordinary level of long-term technical support from EPA and other partners. Elements of the completed program may be transferable to other countries on much shorter time scales and with smaller resources. This suggests that the international discussions on technology transfer need to consider distinctly different types of program. Successful response to climate change and other global concerns may require a mix of groundbreaking projects that demonstrate first-time applications of advanced technology in developing countries, and projects that encourage multiple replications of market transformation in other countries and/or closely related technology areas. The time horizon, costs, and technical support needs may vary significantly between these two types of projects.

In the future, as technology cooperation organizations and agencies continue to gain experience in specific technology areas, it may be possible to offer developing country partners a menu of successful examples that could be applied to technology priorities in their countries. Such an approach would ensure that experienced partners and successful project designs are available from the outset and could also promote cooperation among developing countries. Experienced partners in China, for example, may be able to provide expert technical advice and experience to other Asian countries that identify home refrigerators as a priority technology area.

This project illustrates the importance of active involvement of private-sector and other non-governmental organizations in all stages of the project. Making markets work for clean technology requires a close interaction with private sector representatives in the early design of technology market transformation programs, as well as throughout their implementation. In developing countries that are moving from central planning toward more open market economies, partners may have difficulty identifying market barriers and developing incentives. Consultation with businesses and other stakeholders can bring a reality check to the planning process, ensuring that the barriers to commercial market activity are accurately identified and that proposed activities and programs to address these barriers and provide incentives are credible. The market-based approach also requires understanding consumer interests, preferences, and motivations. This project involved considerable research and data collection to develop an understanding of refrigerator producers and their customers, which was then used to design incentives so that both groups found it in their interest to modify their behavior and practices in favor of cleaner technology.

Capacity-building was designed into every aspect of this market transformation effort. In the long run, it is better to assist a local institution in carrying out research, testing, analysis, program design, and other key activities even if U.S. or international experts could do the work more quickly. The learning-by-doing process in this project, assisted by international experts, enhanced the host-country's capacity for sustained market transformation in the initial technology area (refrigerators), and also for initiating similar efforts in related technology areas (e.g. air conditioners, office equipment, etc.).

The continued close working relationship of key organizations throughout the ten-year Refrigerator Project led to a common understanding of the goals, approaches, and progress among the partners. The strength of the partners' relationships allowed the program to flexibly adapt to changing conditions, the evolving understanding of the technology and the market, and new information. This flexibility was essential to success, especially in a project as ambitious and innovative as this one.

Building on the experience described in this paper, EPA has continued to support cleaner technology cooperation with developing countries, and remains committed to this approach for the future. We welcome the growing attention to international cooperation for comprehensive technology market transformation from countries and international organizations around the world. We hope that this detailed documentation of our experience will contribute to ongoing discussions, thereby helping us to improve our own programs in the future and to facilitate improvement and expansion of similar programs globally.

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Acknowledgments

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Project Timeline

Opportunity identified	1988
Preliminary EPA research begins	1988
Bilateral cooperation begins	1989
Initial technology research	1989
Team educates itself about technology options	1990-1995
Factory selected for manufacturing demonstration	1992
Prototype design selected	1994
Evaluation of prototype field performance	1995
Haier factory conversion	1995-1996
Development of new minimum refrigerator efficiency standard	1995-1999
Development of GEF project	1996-1998
GEF project approval	1998

1. Introduction

This case study report describes bilateral technology cooperation over a ten-year period between the United States and China, the U.S.-China Chlorofluorocarbon (CFC)-free Super-Efficient Refrigerator Project (the Refrigerator Project). The Refrigerator Project offers a useful example of technology cooperation using a comprehensive market transformation approach, and has generated observations and lessons learned that are directly relevant to continuing climate-related U.S. bilateral activities. The activities and findings described here may also offer key insights for other, non-U.S., bilateral or multilateral technology cooperation programs.

The Refrigerator Project was the first of several technology cooperation activities to promote energy-efficient products and equipment that the U.S. Environmental Protection Agency (EPA) has undertaken with China since the late 1980s. On the basis of this initial effort, EPA has subsequently worked with China to strengthen capacity to implement a voluntary endorsement label for energy-efficient products, design and implement market transformation activities for other products[1], establish minimum energy efficiency standards, and develop institutional capacity to implement minimum efficiency standards programs.

This report provides an overview of the Refrigerator Project and its impacts, a narrative description of the technology cooperation process, and a discussion of implications for future projects.

Project Summary

Principal Partners:
U.S. Environmental Protection Agency (EPA)
China State Environmental Protection Administration (SEPA)

Sector:
Household refrigerators

Objectives:
Phase-out of ozone-depleting substances (ODS)
Reductions of greenhouse gases through energy efficiency

Type of Project:
Bilateral technical cooperation

Timeframe:
1989 - 1998

Status:
Bilateral cooperation completed
SEPA-led follow-on program is ongoing

2. Project Overview

The goal of the project was to launch widespread conversion of the Chinese refrigerator industry to production of CFC-free, super-efficient units. This goal was accomplished through research, analyses, technology selection, technology demonstrations, and the design of measures to spread the demonstrated technologies throughout the industry.[2] Various sources of bilateral, Chinese government, private sector, and multilateral funds were accessed to support this process. The project was based on a core partnership between EPA and China's State Environmental Protection Agency (SEPA)[3] and was supported from the outset by U.S. bilateral funding, later to be augmented by additional support from SEPA and others in China, the Multilateral Fund for the Implementation of the Montreal Protocol (commonly referred to as the MLF), other bilateral agencies, and the Global Environment Facility (GEF). EPA-sup-

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1. For a full description of EPA's market transformation activities for room air conditioners in China, see Case Study Report: U.S.-China Energy-Efficient Air Conditioner Project, 2002, available online at http://www.usctcgateway.net
2. At the same time, the project also sought to improve mandatory minimum efficiency standards for refrigerators in China to eliminate the worst-performing models.
3. Then the National Environmental Protection Agency (NEPA).

ported activities under the project began in 1989 and continued thorough 1998, after which additional activities were continued under a SEPA-led GEF project.[4]

2.1 Underlying Conditions

Several conditions set the stage for the project's conception and development:

2.1.1 **U.S. Domestic Expertise**. During the 1980s, EPA began working with U.S. industry to simultaneously phase out the use of CFCs and improve the energy efficiency of household refrigerators. Through this experience, EPA had developed a team of technical and market transformation experts who were available to work with China to achieve these same objectives. This team had expertise in technology research, design, and analysis, as well as in working with manufacturers to adopt new technologies. Significantly, EPA had demonstrated that technologies already existed to make refrigerators both CFC-free and more energy efficient. EPA's Global Change Division was responsible for CFC and climate change issues both domestically and internationally, and led U.S. participation in the Refrigerator Project.

2.1.2 **China's Growing Refrigerator Market**. During the 1980s, China's household refrigerator industry grew very rapidly for a number of reasons. China's economy was becoming more market-based, and new economic policies led to greater consumer purchasing power and increased the freedom of enterprises to produce in order to meet consumer demand. By 1989 the industry was producing 6.7 million units annually, and refrigerators had become one of the first widely available household appliances in China. Refrigerator ownership was improving the quality of life for millions of Chinese. At the same time, as a result of refrigerator market growth, the volume of ozone-depleting substances (ODS) consumed in refrigerator manufacturing was becoming substantial. Data collected at the outset of the U.S.-China cooperation showed that by 1991, China was consuming 1,145 metric tons of CFC-12 and 5,000 metric tons of CFC-11 in refrigerators. Unchecked, consumption of CFCs was expected to grow to 2,630 metric tons of CFC-12 and 10,915 metric tons of CFC-11 in 2000.[5] This dramatic growth in refrigerator ownership meant that the sec-

EPA Energy Efficiency Cooperation in China

EPA began energy efficiency cooperation with China in 1989 with the Refrigerator Project, which addressed the dual issues of eliminating ozone-depleting substances and improving energy efficiency. This work with product efficiency led to subsequent cooperation in related areas:

- **Minimum Energy Efficiency Standards**: The EPA team has worked extensively with the State Bureau of Quality and Technical Supervision (SBQTS) and the China National Institute of Standardization (CNIS) to build capacity for developing and managing efficiency standards for a variety of products. This has included training, joint research and analysis, finalizing new proposed standards, and developing strategic approaches to managing the standards process.
- **Product-Level Energy Efficiency**: Following the Refrigerator Project model, the EPA team worked with China's State Economic and Trade Commission (SETC) and the China Energy Conservation Association (CECA) to develop a strategy for promoting the manufacture of energy-efficient room air conditioners in China.
- **Voluntary Energy Efficiency Labeling**: The EPA team is currently helping to strengthen China's new energy efficiency endorsement label through a partnership with the Center for Energy Conservation Products (CECP), a new organization created in 1998 under SETC to implement voluntary labeling.

4. Additional information on the current status of GEF project implementation can be found online at the project Web site: http://www.r-gefchina.org/.

5. U.S. EPA, Office of Air and Radiation, The Sino-U.S. CFC-Free Super-Efficient Refrigerator Project Progress Report: Prototype Design & Testing, Washington, DC: U.S. EPA, Summer 1997.

tor offered a compelling opportunity to reduce CFC use and reduce air pollution through improved energy efficiency (see Figure 1). Also,energy efficiency was a growing concern among Chinese manufacturers, who sought to expand their exports to countries with more stringent energy efficiency standards.

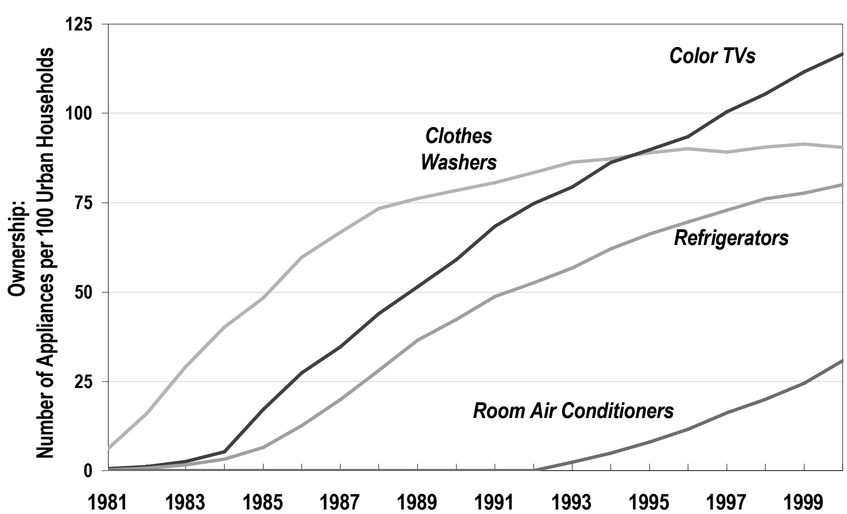
2.1.3 **Opportunity for Technology Cooperation**. Several factors came together to make a technology cooperation project both possible and attractive. As part of its responsibility for implementing the Montreal Protocol, EPA had met with Chinese counterparts beginning in 1986 to better understand their concerns related to the ODS phase-out, which was being negotiated internationally at that time. China was considering ratification of the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol. A major issue raised by China in these meetings was the impact of the phase-out on China's refrigerator industry. EPA was interested in demonstrating to China that the ODS phase-out could be accomplished with little or no negative impact on Chinese industry or consumers. EPA was also interested in building capacity in China to phase out ODS, so that China would be more willing to make binding commitments to eliminate its use of these chemicals. The project also offered EPA an opportunity to demonstrate the commitment of industrialized countries to help developing nations create their own advanced CFC-free technologies.

EPA wanted to ensure that the CFC phase-out did not increase an already significant component of energy consumption in China. EPA knew that refrigerators accounted for a major percentage of household electricity use in the United States, and EPA believed this was also true in China. Moreover, some potential CFC replacements could increase refrigerator energy use by up to 20 percent. Such an increase could mean very significant added electricity costs to consumers (as well as increased pollution related to electricity generation), and possibly weaken support for the ODS phase-out.

Finally, SEPA, which would be responsible for ODS phase-out in China, saw the project as an important part of its strategy to phase out ODS. The ODS phase-out also represented a compelling opportunity to leverage international expertise to modernize Chinese industry.

Figure 1:

Appliance Ownership in Urban Chinese Households
Source: China Statistical Yearbook 2000



2.2 Barriers

The design of the project included identification of barriers to market transformation and implementation of measures to address them in both the supply of and demand for household refrigerators. This project design developed over time as initial activities led to a more complete understanding of China's household refrigerator sector. Project activities addressed the following barriers:

2.2.1 **Uncertainty Over Appropriate CFC Replacements**. While a range of CFC replacements had been identified internationally, neither U.S. nor Chinese experts knew which replacement technologies would be most appropriate for China.

2.2.2 **Basic Industry Information**. The U.S-China team was faced with a lack of comprehensive information on the nature of the Chinese refrigerator market. Few data were available on production quantities for specific models, technologies in use, manufacturer market share, consumer preferences and perceptions, purchasing behavior, and other key matters. Such information was necessary to design an effective project.

2.2.3 **Industry Technical Expertise**. The Chinese refrigerator industry comprised dozens of companies that varied widely in their technical capacities. Initially, most lacked the technical knowledge, experience, and skills necessary to research, select, design, test, manufacture, and market advanced refrigerator technologies.

2.2.4 **Standards Development and Testing Capacity**. China's minimum efficiency standards existing at the outset of the collaboration were relatively weak. Chinese standards were, on average, approximately 30 percent less stringent than U.S. standards. In addition, Chinese performance levels were based on different calculation methods and test procedures, and could not be compared with those of other countries. China's infrastructure for standards development and product testing required strengthening, particularly to develop its capacity to analyze economic and financial impacts, engineering issues, and energy use. China also needed more expertise in developing test procedures, lifecycle cost analysis, modeling, and data-collection methodologies.

2.2.5 **Costs and Savings Information**. The costs and benefits of CFC-free and energy-efficient refrigerators were not well understood by government, manufacturers or consumers in China. Manufacturers were uncertain about the costs to convert their factories, additional manufacturing costs, and whether consumers would want to buy such refrigerators (U.S. refrigerator manufacturers expressed similar concerns during the effort to produce CFC-free super-efficient refrigerators in the United States). Chinese consumers lacked useful information on lifecycle cost savings associated with a more efficient refrigerator design, leading them to focus only on the first cost of new models. Consumers also lacked reliable product information for comparing refrigerator models. Based on market research, it was also believed that dealers would be reluctant to stock or promote CFC-free, energy-efficient models due to their higher first cost.

2.3 Technology Cooperation Activities

To address the barriers described above, EPA and SEPA, in consultation with key experts and stakeholders in both countries, designed a broad strategy that led to a set of bilateral technology cooperation activities from 1989-1998:

2.3.1 **Collecting Basic Industry Information**. The team collected basic sector information from Chinese manufacturers for inclusion in a product database, including data on refrigerator production, sales, market share, technologies, and energy use by model for all models then being produced.

2.3.2 **Identifying Appropriate CFC Replacements, and Building Industry Technical Expertise**. To develop knowledge of the new refrigerator technologies among the Chinese manufacturers, and to select appropriate CFC replacements, the project included a multi-year set of technology exchange activities focused on technology research and testing. The project also included a technology demonstration component that converted production lines of a leading Chinese refrigerator manufacturer to produce a CFC-free, energy-efficient model.

2.3.3 **Building Capacity for Minimum Efficiency Standards Development**. The U.S. team worked with experts at China's State Bureau of Quality and Technical Supervision, and its research arm the China National Institute of Standardization, to strengthen capacity for developing and managing energy-efficiency standards for refrigerators and other products through a series of training activities. This activity also included assisting these organizations in the development and implementation of a refrigerator sector survey, the results of which were used to support development of a new minimum efficiency standard for refrigerators.

2.3.4 **Gathering Information on Costs and Savings**. This information included:

- Information from consumer research about perceived costs of refrigerator ownership
- Cost analysis of compressor efficiency improvements
- A survey of refrigerator manufacturers on technologies, costs, production statistics, and the market environment
- Refrigerator conversion cost analysis

Market Transformation

The Refrigerator Project embodies the "market transformation" approach that gained favor in developed countries in the 1990s. In general, market transformation programs make strategic efforts to intervene in particular markets to cause beneficial, lasting changes in the structure or function of the market—on both the supply and demand sides. These changes should in turn lead to sustained increases in the adoption of energy-efficient products, services, and/or practices.

The term "market transformation" first appeared in the energy efficiency literature around 1990. An early example of this approach was the U.S. EPA's Green Lights Program, which promoted the use of existing but under-utilized efficient commercial lighting technologies. The program provided missing information about the potential financial savings and other benefits associated with these products. By concentrating on inducing sellers of these products to more actively distribute them to consumers, and on helping consumers understand the benefits of these products, significant changes in market behavior occurred. Soon, high-efficiency commercial lighting products were becoming so widespread that most lighting distributors no longer stocked low-efficiency products.

From its early roots, market transformation blossomed into an approach to promoting energy efficiency that is widely sanctioned as effective and low-cost. In fact, market transformation is now a widely accepted energy efficiency policy in Europe, North America, and Australia, and among international development organizations. In developing countries, market transformation programs have made some inroads, but not on the scale found in developed countries.

(Portions of this description are from an outline of market transformation developed by Eric Martinot and Sabrina Birner of the Global Environment Facility)

2.3.5 **Undertaking Additional Market Transformation Measures**. The following activities were conducted beginning in 2000 under a SEPA-led GEF project that was designed by the Refrigerator Project team:

- Technical assistance to compressor manufacturers
- Technical assistance to refrigerator manufacturers
- Incentive and regulatory programs
- Consumer education program
- Monitoring and evaluation

3. Project Impacts

The Refrigerator Project made considerable progress toward transforming the Chinese refrigerator market. Specific results and impacts from the project's activities include:

3.1 Environmental Impacts

The manufacturer of the improved refrigerator produced under the project (Haier) conducted substantial advertising campaigns to promote its new CFC-free energy-efficient refrigerator model. This refrigerator became one of Haier's flagship products. Given Haier's leading position in the market, messages concerning energy efficiency benefits received considerable public attention. The heightened awareness from Haier's advertising campaign was complemented by other major competitors' efforts to develop and market energy-efficient models to compete with Haier (notably Kelon, another leading manufacturer).

Reduction of Ozone Depleting Substances

Direct annual reductions of 29 weighted metric tons ODP (ozone depleting potential) (from the demonstration factory conversion). Several thousand additional metric tons of ODS were eliminated through related follow-on projects.

Reduction of Greenhouse Gases

20 million refrigerators affected

Annual energy savings of 4,400 million kilowatt-hours (kWh)

Product lifetime energy savings of 66,000 million kWh

Annual greenhouse gas emissions avoided of 1,813,748 metric tons of carbon equivalent (TCE), or 6,650,411 tons CO_2 equivalent

Product lifetime greenhouse gas emissions avoided of 27,206,227 TCE, or 99,756,167 tons CO_2 equivalent

3.2 Strengthened Capacity at Key Institutions

The project resulted in significant capacity development at key Chinese institutions:

- **State Environmental Protection Administration**: Over the course of the project, SEPA gained valuable experience working with international technology experts, coordinating technology cooperation activities with key research and government institutions in China, working collaboratively with manufacturers, developing market and consumer research capabilities, and developing major funding proposals to multilateral institutions such as the MLF and GEF.

- **State Bureau of Quality and Technical Supervision (SBQTS) and China National Institute of Standardization (CNIS)**: Through efforts under this and other EPA-supported activities in China, Chinese standards-setting experts at SBQTS and CNIS developed new standards calculation methodologies. SBQTS and CNIS used these new methodologies to strengthen Chinese efficiency standards, while employing internationally accepted metrics.

- **China Household Electric Appliance Research Institute[6] (CHEARI)**: Through collaborative research and acquisition of testing equipment and facilities, CHEARI strengthened its capacity to work with advanced appliance technologies. This capacity contributed to the Refrigerator Project and to later work by CHEARI in other appliance sectors.

- **Haier Company**: Although Haier was already an industry leader in China, its technical collaboration with U.S. and Chinese experts under the project strengthened Haier's research and development capacity. Haier remains a leading refrigerator manufacturer in China, and its advances have spurred other Chinese manufacturers to adopt new technologies similar to those used by Haier.

3.3 Refrigerator Efficiency Gains

The project created a high level of awareness of energy efficiency in the Chinese refrigerator industry by working with leading manufacturers and disseminating results of the project throughout the industry. This high level of awareness influenced the incorporation of energy-efficiency improvements in Chinese refrigerator models. Impacts include:

- Anecdotal reports from Chinese refrigerator manufacturers indicate that energy efficiency became a very important design issue following the commercial development of the Haier CFC-free and energy-efficient model. To remain competitive, some manufacturers followed Haier's lead and developed energy-efficient models of their own.

- China's current voluntary energy efficiency endorsement label, administered by China's Certification Center for Energy Conservation Products (CECP), is an outgrowth of provincial and regional labels that emerged in the late 1990s, based on the popularity of using energy efficiency as a sales strategy. The shift toward using energy efficiency as a selling point occurred following the introduction of Haier's energy-efficient model, and as industry become more aware of the consumer benefits of energy efficiency. China's State Economic and Trade Commission (SETC) subsequently banned the provincial and regional labels in an effort to create a single national label to be implemented by CECP.

3.4 Market and Consumer Information

The project carried out groundbreaking work in assessing Chinese consumer views on topics such as energy efficiency and advanced-technology products. The consumer information developed under the project has continued to inform other efforts to promote product-level energy efficiency in China.

6. Previously the Beijing Household Electric Appliance Research Institute (BHEARI).

3.5 Expansion of Market Transformation

The Refrigerator Project successfully launched market transformation in the refrigerator industry through technology development, efficiency standards development, and other research activities. As a result of additional follow-on activities designed by the Refrigerator Project team, and being carried out under a SEPA-led GEF project, further progress toward transformation of the refrigerator industry is being made. This progress includes:

- **Compressor Efficiency**. The number of high-efficiency compressors produced annually increased from about one-half million in 1999 to more than 2.5 million in 2001.[7] Additional compressor manufacturers have received technical training and assistance to develop models for CFC-free and energy-efficient refrigerator models. Three more compressor manufacturers have requested entry to the project in addition to the ten manufacturers that signed up initially. This growing interest will expand the project's impact and demonstrates continuing and increased attractiveness of the GEF project to manufacturers.

- **Refrigerator Efficiency**. Average refrigerator energy efficiency for the 16 manufacturers included in the GEF project improved by 10 percent between 1999 and 2001.[7] The 16 participating refrigerator manufacturers (exceeding the original goal of 12 manufacturers) have received training in energy-efficient refrigerator design. The manufacturers have committed to achieve specific energy-efficiency goals in order to participate in the project and have developed prototypes for shipment to the international design training center where training and joint energy efficiency design development will take place.

- **Incentive Program**. A market-based compressor incentive program has been launched to encourage compressor manufacturers to develop efficient designs.

- **Efficiency Standards**. The development of new and more stringent energy efficiency standards is underway. Activities have included a workshop held in December 2001, market research, analysis and evaluation of the current energy efficiency standards, data collection, and an economic and engineering analysis.

- **Energy Efficiency Information Labeling**. Work to develop labeling for energy efficiency information is underway. The GEF-supported work is being coordinated with and is leveraging other energy efficiency labeling efforts underway in China, supported by the Energy Foundation and the Collaborative Labeling and Appliance Standards Program (CLASP).

- **Information Center**. A project Information Center was established, and has completed collection of baseline information for compressors and refrigerators for 1999, as well as documentation of initial project results for 2000-2001.

- **Testing**. The project Testing Agency was established and is operational.

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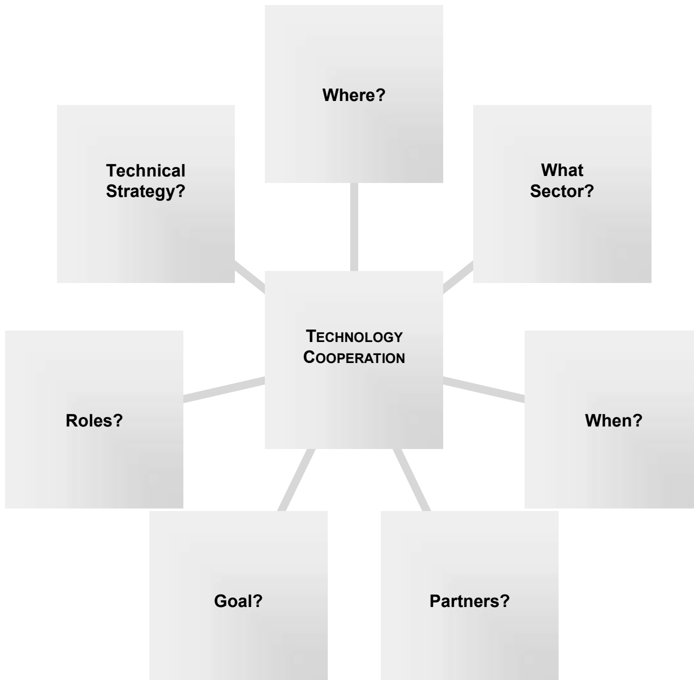
7. Source: China Household Electric Appliance Association.

4. The Technology Cooperation Process

This section outlines the process of technology cooperation between the U.S. and China over the course of the project. It is intended to present more detailed information concerning why and how the cooperation was carried out the way it was, and to explore more fully how project activities addressed key barriers.

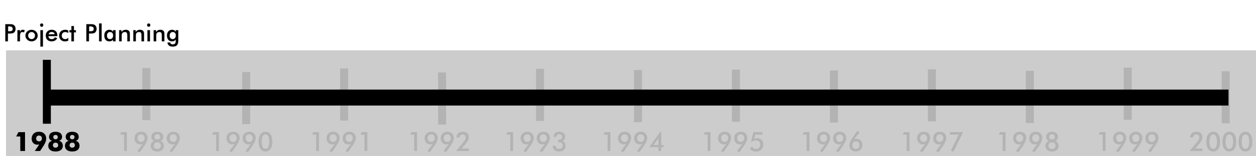


4.1 Planning Technology Cooperation

At the beginning of any technology cooperation process, certain questions must be addressed:

4.1.1 **Where? What sector? When?** As described in Section 2.1, there were several compelling reasons to work on ODS and energy efficiency in the Chinese refrigerator sector beginning in the late 1980s.

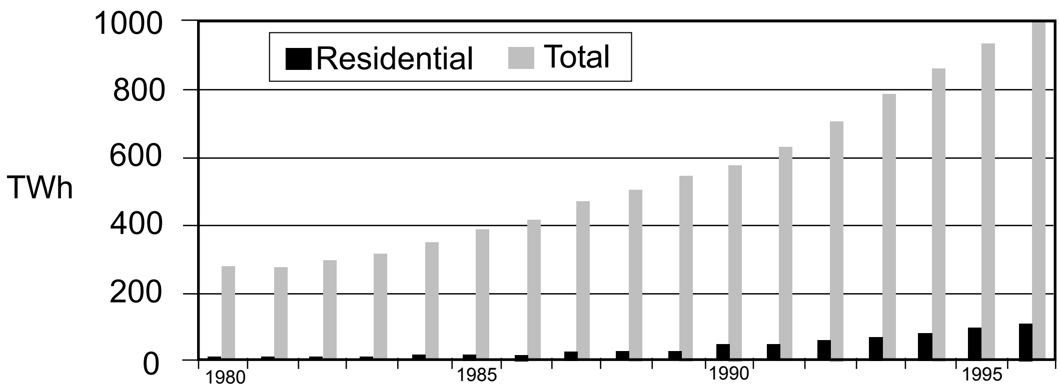
4.1.2 **Who will be the partners? What will be their roles?** The selection of appropriate and effective partners is essential to the success of technology cooperation projects. In the Refrigerator Project, the chosen partners had the skills and formal authority required by their roles in the project. Even more central to the project's success, the partners were able to sustain a high level of dedication to the project for more than ten years. The project promised important gains for EPA, SEPA, and the refrigerator industry. Consequently, the project partners saw the project as advancing their individual core missions. Moreover, the partners shared a commitment to the basic goals and concept of the project.



As part of the informal exchange process leading up to the formalization of a cooperative agreement to work in the refrigerator sector (including travel to China and conference participation), EPA developed an understanding of which organizations might be appropriate partners. EPA also met with experts at the China Household Electric Appliance Research Institute (CHEARI). Once the EPA-SEPA cooperative agreement was in place, EPA and SEPA asked CHEARI to lead technical activities in China based on CHEARI's technical qualifications, connections to industry, and exceptional dedication to the goals of the project. For CHEARI and the Ministry of Light Industry (MLI), the government agency responsible for managing large parts of the appliance industry in China, the project offered multiple advantages: it helped CHEARI develop further expertise in new refrigerator technologies, it provided a vehicle to help strengthen CHEARI's clients in the industrial sector; and it addressed a problem—growing energy use from refrigerators—that CHEARI and MLI were already concerned about. At the time, there were concerns in China that increased energy demand resulting from rapid growth in household energy use could outstrip China's power generation capacity, and CHEARI embraced the idea of building on the coming ODS phase-out to incorporate energy efficiency in new product design (see Figure 2).

Figure 2:

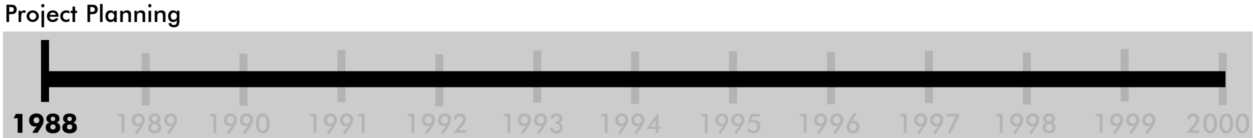
Electricity Consumption in China
Source: China Statistical Yearbook 2000



The director of CHEARI at that time was a strong proponent of investigating technology options for both eliminating CFCs and improving energy efficiency in Chinese refrigerators. Also, shortly after EPA began working with CHEARI, CHEARI's director was promoted to lead the Ministry of Light Industry's (MLI) Science and Technology Department.[8] This promotion raised the profile of the EPA-China collaboration.

The working partnership with CHEARI would have a significant impact on the success of the collaboration. CHEARI's active support of the technology goals of the project, and leadership position in the Chinese refrigerator industry allowed the U.S.-China team to make considerable progress at a rapid pace during the technology development phase of the work.

8. MLI later became the National Council on Light Industry (NCLI), which was later incorporated into the State Economic and Trade Commission (SETC) as the National Bureau of Light Industry (NBLI).



Very early in the collaboration, the team decided that it was critical to develop alternative technology with the active participation of Chinese industry. The team began working directly with the eight largest refrigerator manufacturers in China (accounting for an estimated 85 percent of total market share), in an effort to create the critical partnerships and channels of communication needed for future work, and to identify a specific technology demonstration partner.

At the same time, industry was also highly motivated to participate in the project. Conversion of ODS-based technologies with outside technical and financial resources represented an unprecedented opportunity for China to modernize its industry. China had imported obsolescent production models and manufacturing facilities in the early 1980s, and its refrigerator models and production facilities were largely outdated. There was a pressing need for new technologies. Economic policies (including the deregulation of commercial and industrial sectors) had made the refrigerator industry more competitive, and refrigerator manufacturers saw that their continued existence depended on developing new models. Manufacturers were also interested in developing models that would be more competitive in export markets.

The project's ambitious industry-wide goals required that industry be involved as much as possible from the outset, and CHEARI provided a crucial link to industry. MLI—CHEARI's parent agency—was responsible for overall management of a major portion of the appliance manufacturing industry, including refrigerators. It was largely through MLI that the project was able to gain the active support of the eight leading Chinese manufacturers, from which the Haier company was eventually selected as the demonstration factory (the selection process is discussed below). The partnership also allowed the team to build on the existing technical research by manufacturers and CHEARI, and later helped the project deliver new CFC-free and energy-efficient technologies to industry.

The SEPA-EPA relationship made the project possible (see Section 2.1 of this report). SEPA saw the project as a key early step in China's ODS phase-out, and SEPA's support was instrumental in securing MLF and GEF funding. Active participation in bilateral and multilateral technology cooperation would help China make progress in fulfilling any potential future commitments to the Vienna Convention and other follow-on agreements such as the Montreal Protocol. While the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) funding mechanism to support technology transfer was anticipated to begin operation in the early 1990s, there were perceived limitations on the long-term availability of those funds. Early action on ODS conversion would help to ensure access to these potentially limited funds. EPA brought essential skills and experience, and also secured MLF funding with SEPA's support.

4.1.3 **What are the goals?** From the outset, the project's primary goal was widespread profitable, voluntary production and sale of CFC-free, super-efficient refrigerators. This goal would achieve EPA's objectives of capacity-building and reducing air pollution through energy efficiency improvements, it would achieve Chinese ODS phase-out goals under the Montreal Protocol, and it would achieve CHEARI's goal of leveraging the CFC phase-out to modernize the Chinese refrigerator industry. Capacity-building in China was both a goal in itself and a necessary intermediate step to the primary goal of the project.

4.1.4 **What is the technical strategy?** The project team based its technical strategy on three key elements:

- A commitment to a long-term comprehensive market transformation approach.
- A conviction that CFC-replacement and energy efficiency improvements in refrigerators could be achieved both cost-effectively and simultaneously.
- The core program assets of technical experience at EPA and its U.S. partners, and analytic tools developed during EPA's work with the U.S. refrigerator industry.

Building on this foundation, the U.S.-China team moved ahead using the following strategy:

- Start by addressing the key initial challenge of the project: identifying and demonstrating technologies that would be appropriate for China.
- Conduct a wide-ranging, inclusive technology development process including research, analysis, evaluation, selection, and demonstration, to build important capacity in China and to identify the best technologies for China.
- After the technologies are selected and developed, implement a technology demonstration project to build a foundation for further work.
- Assure the effectiveness of the evaluation, selection, development, and demonstration process by involving the major players in the Chinese refrigerator industry, including manufacturers, research institutes, and government. Because the eventual goal was widespread voluntary adoption, it was important to include partners who would have first-hand knowledge of manufacturing, materials and component availability, consumer preferences, and other issues related to use of new technologies in China.
- Use the technology development process to give the team the knowledge it would need to design activities to foster widespread adoption of the demonstrated technologies, including supply-side measures such as technical assistance to manufacturers and demand-side efforts such as consumer outreach and education.

To advance the strategy, the team used a learn-while-doing approach. In this way, the project proceeded in stages to collect and analyze information and make decisions as the team developed a shared understanding of the situation in China. Periodically the project strategy was modified and refined based on new information, experience, and other factors. Early phases of the project were implemented while the team planned the design, implementation strategy, and funding of later phases.

One key factor in the success of the project was that although EPA had considerable expertise in CFC replacement technologies, it did not begin the cooperation with a predetermined solution for China. The project thus transferred EPA's expertise in technology evaluation rather than transferring a specific technology solution. For example, although U.S. industry was moving toward HFC-134a as a refrigerant, EPA did not promote this particular refrigerant (or any other) and in fact it was not eventually selected under the refrigerator project. This impartiality on the part of EPA was a crucial factor in building trust and credibility among Chinese counterparts.

4.2 Bilateral Cooperation Begins

In 1989, EPA began to evaluate the technical opportunity for developing CFC-free energy-efficient refrigerators in China by leading a mission of U.S. experts to seven refrigerator factories in China, and conducting discussions with SEPA concerning a long-term partnership. EPA saw an opportunity to achieve environmental improvements (i.e., reductions in ODS and energy use) by developing and disseminating cost-effective new technologies. As a result of the mission, EPA also developed contacts at CHEARI.

4.3 Initial Technology and Market Research

Accurate information about the market, including information on manufacturers and their products as well as information on consumer views and behaviors, was critical to planning effective market transformation work. EPA and SEPA asked CHEARI to conduct an initial assessment of the Chinese refrigerator sector to develop a baseline understanding of technologies in use and other market information necessary to design and implement a set of market transformation activities. This was the first of a series of market assessments of different types that the team was to carry out over the course of the project. The research effort was informed by EPA's experience developing supply-side and demand-side measures to promote production and use of high-efficiency refrigerators, lighting, and other products in the United States. EPA specified the basic industry production statistics that would be required to design project activities, along with information about testing centers, testing capabilities, the refrigerator market, government policies, and other matters.

This effort was led by CHEARI in consultation with EPA and with the participation of Chinese manufacturers. One key product of this research was a refrigerator model database developed by CHEARI that would be used as a shared information resource during the collaboration. The database included baseline information on refrigerator and compressor production, sales, specifications for existing models, refrigerant use, and energy use.

Based on this research, EPA and CHEARI developed an understanding of the barriers involved in transforming the Chinese refrigerator market. As outlined in Section 2.2 above, barriers involved:

- Lack of basic industry information
- Lack of technical expertise in China's refrigerator industry
- Lack of capacity in standards development and testing
- Lack of information about costs and savings

From the very beginning, EPA discussed with manufacturers and others the best way to achieve the goal of widespread profitable adoption of CFC-free, super-efficient units. It was clear to both sides that key technologies needed to be developed.

4.4 Project Design

As the barriers to market transformation were identified, the team designed a project drawing on EPA's experience in transforming markets for energy-efficient products. The team moved forward with a program of technology evaluation, selection, development and demonstration. Once this work was completed, the team planned to conduct additional research and then develop a set of additional market transformation activities to address the entire Chinese refrigerator sector.

4.5 The Team Educates Itself About Technology Options

As outlined in Section 2.2. above, one of the key barriers identified during the project design phase was a relative inexperience with CFC-free and energy-efficient refrigerator technologies. The critical elements of the technology barrier included:

- **Questions about technology**. Manufacturers and refrigerator experts—both in China and internationally—had not yet adopted CFC replacement technologies and did not know which CFC replacements were best for addressing critical issues such as refrigeration performance, noise, cost, safety, and energy efficiency. Although certain replacement technologies were being developed and tested in the United States, Europe, and Japan, both U.S. and Chinese experts acknowledged the need for substantial investigation to select the most appropriate technologies for China.
- **Lack of hands-on experience**. Chinese manufacturers and technology experts needed to develop experience with new technologies in order to decide which technologies would be most appropriate for China.
- **Lack of capacity**. Chinese manufacturers lacked the capacity to research and test CFC alternatives and to manufacture refrigerators using the new technologies.

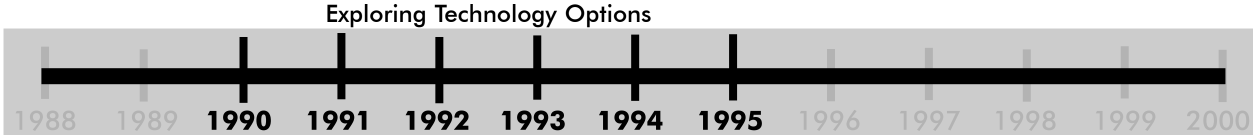
The project design recognized that in order to address these barriers, it was critical to demonstrate alternative technologies in China, with direct participation by Chinese technical experts and manufacturers. The team planned to evaluate a broad range of candidate technologies aimed at developing a specific CFC-free and energy-efficient prototype refrigerator for use in China. This process was expected to result in several key outputs: 1) identification of key technologies; 2) development of knowledge and hands-on experience in how to use those technologies in manufacturing; and 3) confirmation that specific alternative technologies were viable in China.

4.5.1 **The Research Team**. The research team created in 1990 to lead this effort included CHEARI and U.S. experts at the University of Maryland Center for Environmental Energy Engineering (UMD-CEEE). EPA and SEPA chose this team based on several considerations.

UMD-CEEE had worked with EPA for many years researching and analyzing ODS-free refrigerants and high-efficiency refrigerator technologies and provided critical expertise. UMD-CEEE's authoritative knowledge of the new technologies helped fill the knowledge gap among Chinese researchers and manufacturers. Providing objective sources of technical information also helped to build a high level of trust among Chinese counterparts. There was a certain degree of concern on the Chinese side (and among developing countries generally) at the outset of the project that technical cooperation with industrialized countries under the Montreal Protocol framework would reflect the industrialized nations' narrow commercial or technology interests. This project was able to successfully address that concern through an open technology dialogue.

The formation of this team highlighted one of the key strengths of the U.S.-China collaboration: the ability of both SEPA and EPA to access effective expertise to support the goals of the project. Once the UMD-CEEE / CHEARI team was in place, a multi-year process of technology exchange began, focusing on research and testing of potential technologies.

Exploring Technology Options



In 1991, EPA sponsored a training program for CHEARI engineers in the use of the EPA Refrigerator Analysis (ERA) tool, to allow refrigerator researchers to model the effects of potential new refrigerants and related technologies on overall refrigerator efficiency. This training increased the productivity of CHEARI's research substantially, since it allowed CHEARI to model many more potential technology combinations than would have been possible had it been required to build actual refrigerators to test these technologies.

4.5.2 **Advanced Technology Development**. It was the goal of both parties that proprietary technologies neither be used nor created by the project so that the technologies could be adopted to the greatest extent possible throughout the refrigerator industry. This made collaboration within industry more possible because it would not give any manufacturer an advantage, and placed an emphasis on sector-wide technological innovation.

Technical Issues for Refrigerator Redesign

There were several key technical challenges that the project team would have to overcome in order to eliminate CFCs and increase energy efficiency:

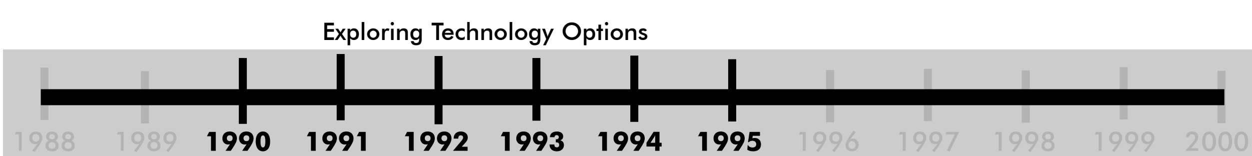
CFC Use

- **Refrigerant**: CFC-12 was the standard refrigerant in use in Chinese refrigerators. Alternatives required good heat exchange properties but with no ozone-depleting potential.
- **Foam**: The foam insulation in refrigerator cabinet panels was blown into place using CFC-11. Alternatives were required that had similar thermal properties, but that were not ozone-depleting.

Energy Efficiency

- **Compressor**: The compressor is the main power-consuming component of a refrigerator, circulating refrigerant and providing the energy for cooling. Chinese compressors were, on average, of low efficiency, and required improvements in design as well as optimization for specific refrigerants.
- **Insulation**: Increasing cabinet insulation thickness is the primary means to minimize heat transfer into the cabinet. The small average size of Chinese refrigerators exacerbated the trade-off between efficiency gains and the loss of interior space from thicker insulation.
- **Gaskets**: Most Chinese refrigerators have separate doors for the fresh food and freezer sections. In combination with thicker insulation, improving the gaskets around these doors is an effective measure to minimize heat transfer into the cabinet from outside.
- **Heat Exchangers**: Heat transfer from inside the refrigerator to the exterior takes place through the heat exchangers (most Chinese models included separate heat exchangers for the fresh food compartment and for the freezer). Improving the design and components of the heat exchangers to allow a greater transfer of heat per unit of refrigerant flow can increase efficiency.

CHEARI, working with EPA experts, UMD-CEEE, and several China refrigerator manufacturers, evaluated a broad range of CFC-replacement and energy-efficient technologies using the EPA Refrigerator Analysis (ERA) tool and lab testing.[9] Based on this evaluation, the research team eliminated certain technologies and selected the most promising technologies for further development.



The use of the ERA tool was a key component of the technology development approach.[10] EPA had used ERA in the U.S. to demonstrate that CFC replacement and gains in energy efficiency could be accomplished through a number of different combinations of refrigerator cabinet designs, insulation systems, and refrigerant systems (see text box, "The EPA Refrigerator Analysis Tool"). To support the Refrigerator Project, EPA modified ERA to conduct a similar analysis for Chinese refrigerators, and made ERA widely available at no cost in China (and elsewhere). ERA had been a major EPA investment, and the application of ERA to China was a core element of the project.

To review the progress of the research EPA hosted a technology workshop for stakeholders in the project in Evansville, Indiana in 1992. The workshop was funded by EPA, and was hosted at a facility owned by Whirlpool (a large U.S. refrigerator manufacturer). Attendees included key project staff from EPA, SEPA, MLI, two other Chinese ministries involved with the refrigerator sector, U.S. compressor and refrigerator manufacturers, the eight major Chinese refrigerator manufacturers participating in the project, two U.S. research institutions, and two Chinese research institutions. This type of open and comprehensive forum helped to bring key technology development issues into the technology research process.

At the end of 1992, as initial findings on alternative technologies were being developed by CHEARI and UMD-CEEE, the U.S.-China team selected the Chinese manufacturing partner that would participate in the technology demonstration. SEPA, MLI, and EPA selected a manufacturer with strong research capability and a significant market share. Selection was also based on the manufacturer's commitment to certain advanced technologies that had emerged as leading candidates for incorporation into a prototype refrigerator design. The team selected the Haier company, based on Haier's strong commitment to the advanced technology, active interest in participation, willingness to share information with other companies, and openness to energy efficiency designs that were unfamiliar at the time in China, such as thick-walled foam insulation.

Haier, UMD-CEEE, and CHEARI collaborated in testing various refrigerator design configurations. They also performed further assessments on component costs, availability, conversion costs, reliability, and other performance issues of the best alternative designs.

The EPA Refrigerator Analysis (ERA) Tool

EPA developed the ERA tool to demonstrate the technical feasibility of replacing CFCs while improving energy efficiency, using a number of different refrigerator designs and technologies.

A key barrier to the development of CFC-free and energy-efficient refrigerators in the United States had been the fact that all refrigerator manufacturers used dissimilar and proprietary engineering models to analyze energy use in refrigerators. The ERA software tool furnished a single analytical framework that could provide manufacturers with objective and credible information on energy savings in new designs.

By allowing U.S. manufacturers to evaluate simulated designs with a variety of technologies, they could consider many more design combinations, and consider them more quickly, than otherwise would have been possible. Once the designs with the highest simulated energy efficiency performance were identified, actual prototype models were constructed and tested in laboratory and field settings.

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9. Assistance in obtaining materials and equipment for testing was obtained from a variety of sources. Advanced refrigerants were donated by several international chemical producers, since these refrigerants were generally not available in China at the time. The U.S. compressor manufacturer Americold also provided 200 custom-manufactured high-efficiency compressors for use in test models.

10. Further details on the operation of ERA can be found in: U.S. EPA, Office of Atmospheric and Indoor Air Programs, EPA Refrigerator Analysis (ERA) Program: User's Manual Version 1.0, EPA-430-R-93-007, Washington, DC: U.S. EPA, June 1993.

The research was complemented by an ongoing program of technology exchange, including:

- A CHEARI engineer was hosted by UMD-CEEE for six months as a visiting scientist during 1991-1992, as part of a larger program of long-term training and joint research by CHEARI engineers and UMD-CEE. These activities involved groups of CHEARI engineers working directly with UMD-CEE, enabling CHEARI to become more familiar with potential advanced technologies.

- EPA organized training and joint research at Underwriters Laboratories (UL) on alternative refrigerant safety issues by a group of CHEARI and refrigerator manufacturer engineers.

- EPA hosted approximately 5-10 Chinese participants each year in the International CFC and Halon Alternatives Conference, held annually in Washington, DC. This forum focused on the technical, political, and program issues associated with ODS phase-out worldwide. EPA saw the participation of its Chinese counterparts in these conferences as an effective complement to the more targeted research being undertaken by the project team. Participation in the conference also allowed Chinese team members to place the research with UMD-CEE in the broader context of international CFC replacement work presented at the conference.

- In 1992, EPA hosted a group of Chinese chemical industry experts on a study tour of alternative refrigerant technology. EPA organized this technical exchange because it knew that the industry would have an important role in determining technology and refrigerant choice for products manufactured in China. The technical exchange helped to ensure that key stakeholders in that industry were as informed as possible about available alternatives, so that they could participate effectively in decision-making with experts at research institutions such as CHEARI and Chinese appliance manufacturers.

Technology Research and Testing

After an initial technology evaluation and screening process, the baseline model to be used as a comparison with alternative designs was selected. The range of CFC alternatives tested included HFCs (134a and 152a), HCFCs (22, and a blend with HFC 152a), isobutane (R600a), and a number of hydrocarbon blends. For foam-blowing agent alternatives, HCFC-141b and cyclopentane were chosen. These CFC alternatives were paired with a number of different designs to evaluate the efficiency gain of improvements compared with the baseline model. Alternative system designs incorporated, for example, modifications of the anti-sweat heater location, the redesign of heat exchangers, control valves, bypasses and intercoolers; and other modifications. Each modification was tested in combination with a number of compressors, evaporators, condensers, and heat exchangers.

The team studied cabinet modifications to assess the optimal amount of additional insulation needed to maximize efficiency. Prototype cabinet panels of various thickness were evaluated for thermal conductivity using both HCFC-141b and cyclopentane as foam-blowing agents. These cabinet modifications were then tested with various combinations of system designs and components.

Testing was performed both at the standard 25°C ambient temperature used in the Chinese test procedure and at 32°C ambient temperature used in the U.S. test procedure. More than 60 tests were performed in total, with test model energy savings ranging from zero to 66 percent compared with the baseline model, which consumed 1.37 kWh/day.

- In 1992, EPA hosted two major Chinese study tours to the United States focused respectively on compressor technologies and refrigerator technologies. Each tour involved approximately ten Chinese participants representing all eight major Chinese refrigerator manufacturers and approximately five Chinese compressor manufacturers. The tours included visits to several U.S. refrigerator and compressor factories, visits to testing labs, and meetings with U.S. research institutions.

- From 1990-1995, project counterparts including EPA, SEPA, and CHEARI met two to three times each year in Washington or Beijing. In addition to discussions on project strategy, interim results, and budgets, these visits often included substantive research work involving experts from CHEARI and UMD-CEEE.

4.6 The Team Selects Prototype Design and Evaluates Prototype Performance

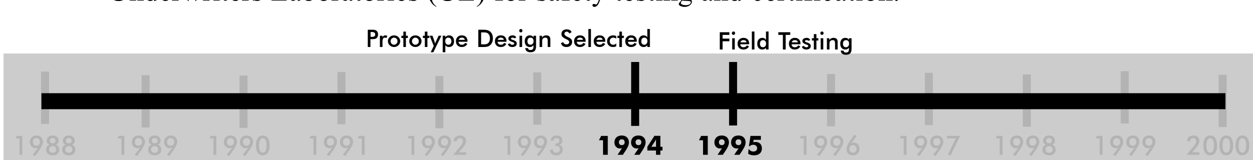
After analyzing the test results, the team chose a prototype design. Based on this design, Haier began modifications to a production line in 1995 to produce units for field and safety testing. Next, the team designed a field-testing program.

4.6.1 **Prototype Field and Safety Testing**. Field testing of the prototypes was necessary to demonstrate the safety and reliability of the refrigerators and to determine the actual energy savings of the models in everyday use. Unlike laboratory testing, home use includes multiple door openings per day, differing food loads, and varying indoor temperatures throughout the day and over different seasons. To capture these variations in three major climate zones, Beijing, Shanghai, and Guangzhou were chosen as the field testing locations. Beijing is in a northern temperate zone with hot summers and cold winters. Shanghai, at the mouth of the Yangzi River, lies in a mid-latitude wet region with hot, humid summers and fairly mild winters with few freezing days. Guangzhou, located in South China on the Tropic of Cancer, has hot summers and warm winters. Households in the three cities vary considerably in terms of space conditioning as well. In general, Beijing households are connected to district heating plants providing heat throughout the winter season, while Shanghai lies outside the central heating zone and households provide their own heating or cooling as needed. Guangzhou households rarely require heating, but employ substantial amounts of air conditioning.

The field tests, managed by Haier staff, started in June 1995 and continued to June 1996 in order to capture the effects of four full seasons of refrigerator use. A watt-hour meter was installed on each unit to record energy consumption. Eighty-five prototype units and 19 baseline units were installed in the three cities.

At the end of the year-long test, the prototype models achieved an average 27 percent savings over the baseline model, compared with 35 percent in laboratory tests. Savings were highest in the warmer cities of Shanghai and Guangzhou, and the Shanghai results (35 percent savings) were identical to laboratory test results. Beijing showed the lowest savings, at 22 percent.

Safety testing was also required. The selection of isobutane, which is flammable, for the refrigerant in the prototype models raised safety concerns in the case of accidental rupture of refrigerant tubes, leakage from the compressor, or leakage during manufacturing. To overcome skepticism about the use of hydrocarbon refrigerants and to determine the safety of the Chinese refrigerators, several new Haier units using isobutane were sent to Underwriters Laboratories (UL) for safety testing and certification.



4.6.2 **Household User Survey**. The field test was followed by a survey, designed by EPA and administered by Haier, of the household residents who had used the prototype to determine their satisfaction with its performance and operation. Since for most households the prototype was larger than their original refrigerator, most respondents indicated that they liked the storage capacity most, followed by its styling and cooling performance. Although two-thirds of the households indicated that their total electricity bill declined, few rated energy efficiency as the prototype's most desirable feature. The prototype's the most-disliked feature was its noisy operation. Noise is a critical issue for Chinese households, as the typically small size of the dwelling often requires the refrigerator to be located in a living area rather than in a separate kitchen. This problem was subsequently addressed and solved in the production model.

4.7 Factory Conversion

Conversion of Haier's production facility, comprising a refrigerant line and a foam-blowing line, completed the demonstration of a commercially viable technology. EPA implemented the conversion of the refrigerant line to isobutane, and the German development agency GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit Gmbh) implemented the conversion of the foam-blowing line to cyclopentane. Haier's ties to Germany dated back to 1986, when Haier was built as a turn-key factory using technology directly imported from Liebherr of Germany. The conversion work was funded in part by the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) and was completed during 1995-1996. The application to the MLF for bilateral technical assistance funds involved a partnership between EPA and GTZ. The converted line had a planned production of 220,000 CFC-free energy-efficient units annually.

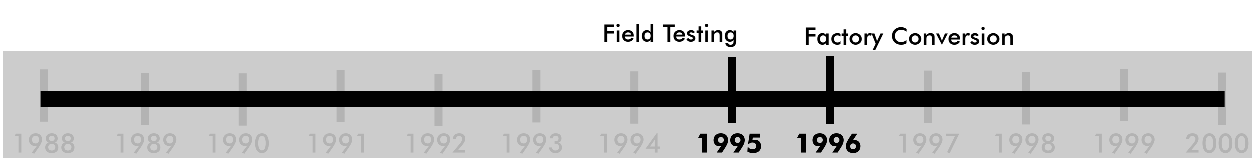
During preparation of the MLF proposal, EPA supported a cost-based manufacturing study at the Haier manufacturing plant by U.S. refrigerator experts to develop estimates for total conversion costs. These estimates were also later used to develop incremental cost estimates for sector-wide manufacturing conversion during the expansion phase of market transformation activities.

4.8 Outreach to Other Manufacturers

As the later stages of advanced-technology development, prototype testing, and factory conversion were being carried out in partnership with Haier, the team continued its outreach to other major manufacturers in the refrigerator industry. This outreach was critically important since the ultimate goal of the project was widespread conversion of the industry. EPA conducted expert missions to other manufacturers to share the results of the ongoing research, and to encourage these manufacturers to undertake their own research.

EPA and CHEARI believed it was important for each manufacturer to make its own evaluation of the technology options available. To help accomplish this goal, the team promoted the use of the ERA tool, to assist manufacturers during the design phase of potential new models. Some manufacturers, notably Kelon (a major manufacturer), were able to rapidly develop their own CFC-free and energy-efficient models, giving consumers a choice of models on the market.

After the Haier factory conversion, the team continued to conduct outreach to other manufacturers. In 1997, the project hosted a workshop in Beijing to present the results of the project's technical



work and to generate interest among other manufacturers for participating in a follow-on set of market transformation activities. A large number of Chinese refrigerator manufacturers participated in the workshop.

4.9 Expansion of Market Transformation Activities

The development and demonstration of alternative refrigerator technology at Haier effectively addressed several key technology and manufacturer-related barriers to transforming the Chinese refrigerator market. However, the team was still faced with significant barriers that had been identified during the initial project design stage:

- **Manufacturer uncertainty**. Manufacturers were uncertain about both the additional manufacturing costs and whether consumers would want to buy such refrigerators (EPA heard similar concerns from U.S. refrigerator manufacturers).
- **Lack of consumer awareness**. Consumers did not know about the potential lifecycle cost savings associated with a more efficient refrigerator design, leading them to focus only on the first cost of more efficient models.
- **Lack of product information**. Consumers lacked reliable product information for comparing refrigerator models.
- **Minimum standards and testing**. China's minimum standards were relatively weak, and the government's metrics and testing procedures were inconsistent with accepted international practice.

The immediate challenge for the U.S.-China team was to investigate the current market to confirm which barriers remained critical to market transformation, develop a better understanding of the potential costs involved, assess the potential positive environmental impacts, and design additional measures to increase production and use of refrigerators using the new technologies.

4.9.1 **Situation Analysis**. Following the successful development of the Haier prototype, the U.S.-China team began several information collection and analysis activities. Early in 1995, as conversion was ongoing at Haier, EPA supported a series of consumer focus groups in China to assess customer attitudes about CFC-free, energy-efficient refrigerators. The focus group research was the first in China on the topic of consumer attitudes toward refrigerators, and provided a baseline from which future changes in consumer attitudes could be measured. To plan and conduct the focus groups, EPA engaged the American Council for an Energy-Efficient Economy (ACEEE), a U.S. non-governmental organization. ACEEE in turn worked with Ogilvy & Mather (a leading international advertising, marketing, and public relations firm) of Beijing to develop and implement the focus groups in early 1995. The focus groups were conducted in Beijing, Shanghai, and Guangzhou.

To update the sector information collected in the CHEARI database in 1991, the U.S.-China team arranged for the Chinese Household Electric Appliance Association (CHEAA) to conduct a broader refrigerator sector survey, addressing both refrigerator and compressor technologies. Key Chinese manufacturers were contacted to update information on production volumes, sales, model sizes, refrigerant use, and energy use. The survey discovered that competition among producers was very strong, and that the effect on cost and price determined whether they would implement any improvements in energy efficiency. This finding emphasized the need for stronger minimum efficiency standards, as it became apparent that many cost-effective measures to improve efficiency were familiar to producers but not undertaken because of the increased costs (as little as $1, for example, in the case of run-time capacitors in compressors). Since existing standards could be met without these measures, they were largely foregone.

To complement the refrigerator conversion cost study conducted by U.S. experts prior to the Haier manufacturing line conversion, the U.S.-China team arranged for an international compressor expert from Zanussi of Italy to conduct an analysis of the costs related to raising compressor efficiency at Chinese compressor manufacturers. This analysis provided data to help estimate the overall sector-wide costs of market transformation.

1995 Consumer Focus Group Results

The project's focus groups were the first in China to probe the importance of energy efficiency to consumers. Findings were much anticipated by the team.

Consumers in Beijing, Shanghai, and Guangzhou ranked quality as the most important refrigerant feature. However, consumers also noted that they had no clear way to judge quality and had to rely on word-of-mouth and advertisements for information, despite the fact that they did not fully trust advertisements. This conclusion highlighted the need for an authoritative label to help guide consumer selection of refrigerators.

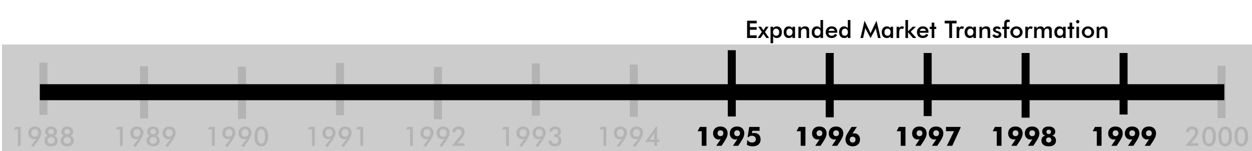
Consumers also looked to "famous brands" to provide the quality they desired, and they generally noted that they would be more likely to buy a CFC-free, energy-efficient refrigerator if it were produced by a famous brand. Consumers also indicated that they would be willing to buy an energy-efficient refrigerator if it saved at least 40 percent in energy consumption and had achieved international quality certification such as ISO 9000. However, in overall ranking of important characteristics, energy efficiency ranked fourth, after durability and reliability, fast and efficient cooling, and low noise.

At the conclusion of this situation analysis, the U.S.-China team had developed an up-to-date understanding of:

- Remaining barriers to transforming the market sector-wide
- Appropriate program responses
- Estimated costs (such as factory conversions, increased manufacturing costs, and consumer outreach)
- Potential environmental benefits

4.9.2 **Developing Additional Activities**. EPA and SEPA worked over the next three-year period, from 1996 to1998, to put together a detailed program to further increase the production and sale of CFC-free energy-efficient refrigerators. This process, together with the previous analysis described in section 4.9.1, involved more than 17 person-months of field visits by the U.S. team to conduct research, carry out initial activities, develop the final implementation plan, and develop project documentation and proposal materials for outside funding sources.

These activities addressed both supply and demand for energy-efficient refrigerators. In developing the response strategy, there were some activities that the U.S.-China team agreed should be implemented immediately under the bilateral partnership, and others that would require additional development and funding by outside sources due to their scope.



4.9.3 **Minimum Energy Efficiency Standards**. As noted above, the U.S.-China team saw an immediate need for efforts to strengthen existing minimum standards for refrigerators first set in 1989. By 1996, it had become apparent that the standard for refrigerators was not suited to a rapidly growing and modernizing industry. On average Chinese standards were 30 percent less stringent than U.S. standards. Moreover, Chinese performance levels could not be compared with those of other countries because of differences in metrics and test procedures.

U.S.-China Minimum Efficiency Standards Collaboration

During the course of the Refrigerator Project, EPA began to sponsor other collaboration in China in the area of efficiency standards.

The team's lead technical resource for standards work, the Lawrence Berkeley National Laboratory (LBNL), had developed substantial experience working with the U.S. standards-setting and analysis process. LBNL first approached China's State Bureau of Quality and Technical Supervision (SBQTS), the institution responsible for product standards, in 1995 to discuss collaboration on developing more stringent efficiency standards. By 1996, agreement had been reached to form a U.S.-China collaboration supported by EPA, involving SBQTS and its research arm the China National Institute of Standardization (CNIS). This agreement led to a sustained collaboration between the LBNL-led U.S. team and the SBQTS-CNIS team that began in 1996 and continues in 2002.

Initial analysis conducted by LBNL identified gaps in the technical capacity of research and decision-making staff: CNIS researchers responsible for providing draft standards to SBQTS decision makers were not familiar with the approach of using engineering analysis to identify technical options for energy-efficiency improvements, and decision makers at SBQTS were not familiar with the use of cost-benefit analysis to determine appropriate levels for standards.

Based on this capacity analysis, collaboration began that was based heavily on training and joint analysis, focused around several product areas of interest to both the Chinese and U.S. teams. More efficient mandatory minimum standards were developed for refrigerators, fluorescent lamp ballasts, room air conditioners, fluorescent lamps, and washing machines.

In 1996, China's State Bureau of Quality and Technical Supervision (SBQTS) decided to begin revising the refrigerator standards while discarding its previous approach and adopting an internationally comparable methodology. To support the development of a new approach to calculating standards, SBQTS agreed to cooperate with the EPA team—specifically, experts at the Lawrence Berkeley National Laboratory (LBNL)—to learn the methodology and tools used in the development of U.S. standards. The team provided technical training to the Chinese agencies involved in this process. Attention was needed in areas such as product categorization, data collection design, technical modeling, lifecycle cost analysis, and application of test procedures. During the summer of 1996, a team from SBQTS and its research arm at the China National Institute of Standards (CNIS) visited LBNL to be trained in the use of the ERA software, used to assess the efficiency impact of different technical measures and to simulate the results of both closed-door and open-door refrigerator tests. Unlike SBQTS's previous approach, which involved a simple statistical calculation of efficiency levels in the market, ERA provided a new approach to considering the feasibility of alternative technical options during the development of a new standards level.

Support from the EPA team, in combination with several years of work at SBQTS and CNIS, lead to a new minimum standard for refrigerators in April 2000.[11]

11. State Bureau of Quality and Technical Supervision, *The maximum allowable values of the energy consumption and evaluating values of energy conservation for household refrigerators,* GB 12021.2-1999, Beijing: State Bureau of Quality and Technical Supervision, August 1999.

This process of cooperation had identified additional gaps in the technical capacity of SBQTS decision makers and technical staff. For example, Chinese researchers who were responsible for advising SBQTS on standards were not familiar with the approach of using engineering analysis to identify technical options for efficiency improvement; and SBQTS decision makers were not familiar with cost-benefit analysis that determines appropriate standard levels. Addressing these gaps became the objective of future EPA-sponsored training activities outside the scope of this project.

In a related development, in response to requirements set out in China's National Energy Conservation Law of January 1998, in 1999 China established the China Certification Center for Energy Conservation Products (CECP), responsible for the implementation of a new voluntary energy efficiency label. The criteria used for the label were developed in tandem with the minimum efficiency standard, allowing any manufacturer to apply for efficiency certification and labeling if a model consumed 75 percent or less energy than the minimum standard. Under a separate effort, EPA currently provides support to CECP in the design and implementation of its voluntary endorsement labeling program for consumer products (see text box on China's Voluntary Endorsement Label for Energy Efficiency).

China's Voluntary Endorsement Label for Energy Efficiency

What are endorsement labels, and why are they important? Endorsement labels can be useful to both consumers and manufacturers of products. Labeling programs internationally have demonstrated that consumers value endorsement labels that help identify superior products. Similarly, manufacturers have found that voluntary labels help them sell more products in competitive markets.

What does the China Certification Center for Energy Conservation Products (CECP) label represent? The CECP label is awarded to products meeting superior energy efficiency performance criteria established by CECP.

Which products get the label? The label is voluntary. Manufacturers decide whether to submit their products for consideration. If those products meet established efficiency criteria, they may carry the label.

EPA-CECP Cooperation. EPA is working with CECP to help strengthen its labeling program and increase sales of labeled products. EPA and CECP are collaborating in a number of key areas important to the CECP label, including:

- Program organization and management
- Program strategy
- Product Development
- Promotion

4.9.4 **Consumer Survey**. A second immediate need was consumer research. Although initial focus groups had been carried out in 1995, as described above, a broader set of information was deemed necessary to complement those results. A consumer survey undertaken in the summer of 1997 provided a second benchmarking of consumer attitudes toward energy-efficient refrigerators, following on the 1995 focus groups. The survey size was set at 1,000 consumers in the five cities of Beijing, Shanghai, Guangzhou, Shenyang and Yixing (Jiangsu province). Important shifts had occurred since the 1995 initial focus group research. Results indicated a rising prominence of performance issues such as energy efficiency among Chinese consumers.

There were two key reasons for increased awareness of, and support for, energy-efficient products. First, the advertising by Haier and related industry activity described in Section 3.1 contributed to heightened awareness among many consumers. Second, the Chinese refrigerator market was maturing rapidly, and increased competition had led to higher quality models. There were fewer differences among refrigerators in terms of basic quality and durability, so other criteria such as after-sales service, energy efficiency, and CFC-free technology were more important—and consumers were willing to pay more for those features. On average in the five cities, energy efficiency had risen to number two in the ranking of preferences on refrigerators, after good after-sales service.

This survey also tested alternative financing methods for purchase of energy-efficient refrigerators. It found that consumers, who traditionally pay for such purchases in cash, were not enthusiastic about bank loans or low-interest financing. Only an offer of a cash rebate elicited significant positive response. This result shaped the development of other parts of the response strategy addressing consumer incentives, outlined below.

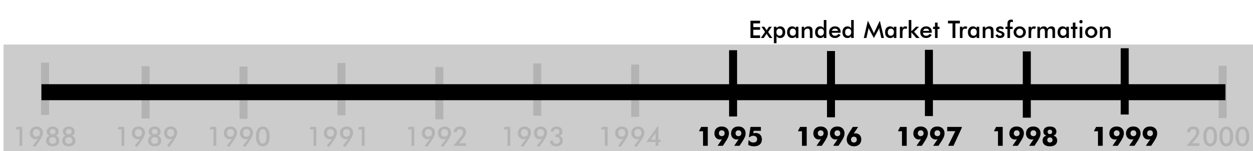
4.9.5 **Additional Market Transformation Measures**. Beyond the standards development and consumer research work undertaken under the bilateral partnership from 1995-1997, the U.S.-China team identified several additional activities that would be needed to complete a comprehensive program of market transformation. These activities had been identified by the team during its earlier work on the project, during the analysis described in section 4.9.1, and were also based on EPA's market transformation experience in the U.S. Activities included:

Compressor Manufacturer Technical Assistance. This activity provides technical assistance to compressor factories to design and produce high-efficiency compressors.

Refrigerator Manufacturer Technical Assistance. This activity provides assistance to additional refrigerator manufacturers in the design and implementation of energy efficiency measures, including international training, assistance in technology selection, engineering modeling training, and support for retooling of production lines.

Incentive and Regulatory Programs. These programs include key activities using regulatory and market approaches to promote energy efficiency, including the following:

- A second round of revision of minimum standards.
- A refrigerator and compressor manufacturers' incentive program providing cash awards on a competitive basis linked to overall improvement in the sales-weighted energy efficiency of their models.
- Development of a mass purchasing program for energy-efficient refrigerators.
- Competitive awards to retailers for increasing sales of energy-efficient models.
- A pilot program to buy back and recycle old, inefficient refrigerators to accelerate their retirement.



Consumer Education Program. This component of the project targets consumers to increase their interest in the purchase of efficient refrigerators. Included among the activities are:

- Development of a national energy efficiency program
- Media campaigns to promote energy efficiency
- In-store dissemination of materials educating consumers on the benefits of purchasing energy-efficient models
- Public relations activities involving print, radio, and TV media promoting energy efficiency
- Training of retailers on how to promote efficient models (in preparation for the competitive award program in the previous component)

*Monitoring and Evaluatio*n. The final component provides the basis for tracking the results of the project, including production, sales, consumer attitudes, and energy savings. The collection of information is organized on an annual basis, and an information center will process and report the results.

4.9.6 **Implementation of Additional Market Transformation Measures**. As had been contemplated at the beginning of the cooperation, institutional and financial support was needed to carry forward the remaining measures outlined above. Based on discussions between EPA and SEPA, this support was to come from a variety of Chinese government and multilateral sources, also including manufacturer contributions. The team worked from 1996 to 1998 to develop the remaining activities, estimate their costs, and design financing mechanisms. They decided that SEPA would submit the remaining set of activities for approval by the Global Environment Facility (GEF), which could fund energy efficiency activities related to climate change

The Refrigerator Project and the Global Environment Facility (GEF)

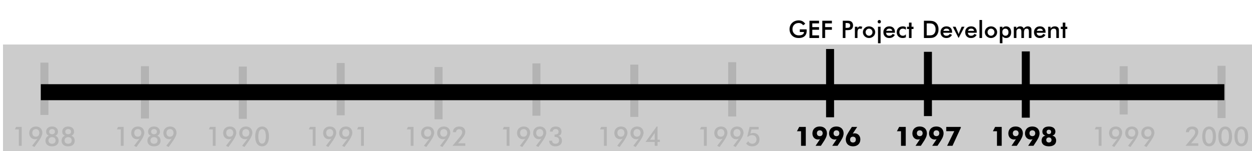
The Global Environment Facility was established to forge international cooperation and to finance actions to address four critical threats to the global environment:

- biodiversity loss
- climate change
- degradation of international waters
- ozone depletion

Related work in areas of land degradation and persistent organic pollutants (POPs) are also eligible for GEF funding. GEF brings together 173 member governments, development institutions, the scientific community, and private sector and non-governmental organizations on behalf of a common global environmental agenda. Any eligible individual or group may propose a project, which must meet two key criteria: 1) It must reflect national or regional priorities and have the support of the country or countries involved; and, 2) It must improve the global environment or advance the prospect of reducing risks to it. GEF projects must involve the sponsorship of one of its three designated implementing agencies:

- United Nations Development Programme (UNDP)
- United Nations Environment Programme (UNEP)
- The World Bank

As described elsewhere in this paper, the Refrigerator Project was able to successfully access GEF funding to support activities related to refrigerator energy efficiency during the expansion phase of the project. GEF Project Development Funding (PDF) supported research and information gathering activities for Chinese project participants beginning in 1996, and final approval of GEF funds was obtained in 1998.



(see text box). The submission involved a two-step process: the initial development of a Project Development Funding (PDF) application to support a full project proposal, and the subsequent development of a final proposal (the GEF Project Brief). In August 1996 China submitted a PDF application through the United Nations Development Program (UNDP).[12] The application was approved in March 1997.

The team developed the GEF Project Brief in 1997-1998. In addition to developing a detailed scope and budget for all activities, including negotiating responsibility for the costs of implementation, the team addressed a host of other issues related to the activities being proposed.

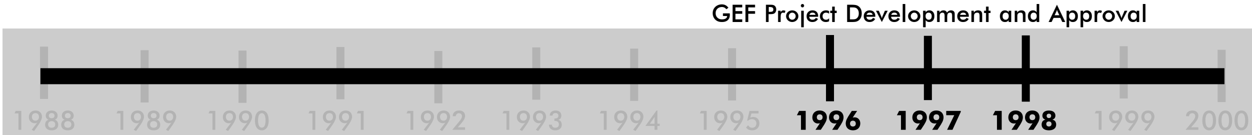
The proposal was the first of its kind involving an end-use consumer product such as refrigerators, and linking CFC phase-out and energy efficiency. These features made the project development process extremely challenging. The team had to ensure that the proposed GEF-funded activities would be well coordinated with related MLF activities in the sector. Since the MLF Secretariat and the GEF Council were separate governing bodies with no formal institutional linkages, the task of ensuring coordination between GEF- and MLF-supported activities required substantial attention. For example, the GEF Council stipulated that the Project Brief be formally endorsed by the MLF Secretariat to ensure that the project complemented other MLF efforts. GEF project reviewers raised technical concerns that required additional efforts from the proposal team.

The GEF Council rejected the initial Project Brief developed in 1997, requiring the team to undertake additional reviews and revisions. Some GEF member countries raised concerns about the novelty of the project's concept and approach: the GEF had never before approved a project aimed at an end-use consumer product such as refrigerators, nor had a GEF-funded project ever involved both CFC replacement and energy efficiency measures, and the GEF does not fund CFC-phase-out work in China.[13] One GEF member country raised questions about the technical approach to efficiency gains, believing (erroneously) that conversion to isobutane alone would significantly improve efficiency.

After responding to these concerns, the team re-submitted the proposal for consideration. It was approved at the October 1998 GEF Council meeting, nearly two years after work on the Project Brief was initiated.

12. UNDP was one of several institutional channels designated for accessing GEF support.

13. This issue was addressed by ensuring that the CFC phase-out and energy efficiency components were funded separately, as indeed was the case since the CFC phase-out work at Haier had already been completed before initiation of GEF-funded activities.



5. Implications for Future Projects

The success of the project was built on these concepts:

5.1 Build Effective Partnerships

The project succeeded because of effective partnerships. The project organizers were careful to select partners who were well-positioned and highly motivated to move project activities forward. Each key partner saw the project as a way to achieve something of great importance to its mission. This coincidence of interests was a major factor in the project's achievements over time.

CHEARI's and MLI's participation in particular contributed strongly to the project's success. CHEARI's formal responsibilities in China meshed perfectly with the role it played in the project, and it brought unusual dedication to the effort. It is important to note that EPA made contact with CHEARI (and later MLI) leaders while conducting initial scoping research before committing to formal cooperation. In the course of its initial research, as has often happened in EPA's international experience, the EPA team encountered counterparts in the host country with a similar high level of interest in the problem being researched.

The project also benefited greatly from the expertise and dedication of other key partners, including ACEEE, LBNL, and UMD-CEEE. ACEEE is a research and advocacy organization focused on promoting energy efficiency. LBNL has a core interest in China energy issues, and LBNL also provides key support to several U.S. Government energy-efficiency efforts including mandatory minimum energy efficiency standards and ENERGY STAR®. UMD-CEEE had a strong, demonstrated track record as a center of refrigerator technology expertise.

Chinese refrigerator manufacturers were also key project partners. They were motivated by their desire to modernize their product lines and factories, and by the opportunity to build expertise among their engineering and research staffs on emerging refrigerator technologies. A key motivating factor for manufacturers was the rapidly intensifying competitive nature of the refrigerator market. Manufacturers were willing to participate in the project since it would help them respond to increasing consumer awareness and demand for energy efficiency.

Early in the project, SEPA and EPA both assumed key responsibilities for implementing the Montreal Protocol in their respective countries, so the project was at the core of their formal institutional interests as well. Within EPA, the Global Change Division was responsible both for implementing the Montreal Protocol and for addressing the principal environmental issues associated with refrigerators: CFCs and energy use. The Global Change Division's leaders had been involved deeply in the negotiation and ratification of the Montreal Protocol, and were committed to demonstrating to China and other nations that the Montreal Protocol, as well as the GEF, could effectively bring about a technology transformation in a key developing country.

A final central factor animating all these partners was the existence and availability of underutilized, cost-effective, and environmentally benign technologies that met the needs of all partners. It was this market failure that drove the cooperation.

These observations suggest several lessons:

- Host-country partners are critical to the success of international technology cooperation, and should be identified based on their skills, formal authority, dedication, and desire to cooperate. Developing-country officials often have very heavy workloads and multiple responsibilities, so the cooperative program must be aligned with their core institutional interests. Projects with strong relevance to their mission will rank very high in their priorities, and they are more likely to provide the kind of host-country leadership that is essential to the success of technology cooperation efforts.
- Other partners must also be chosen carefully, paying attention to their skills and institutional interests.
- Initial scoping research can be an excellent way to identify effective project partners, especially in the host country. When the EPA team started working on this problem, they met other people who shared EPA's commitment to solving the problem.

5.2 Pursue a Clear Goal

A clear, compelling goal enlists committed partners, energizes a project, and elicits creative strategies for achieving success. In this case, the goal was comprehensive market transformation, rather than a more limited objective such as technology demonstration or capacity-building. The market transformation perspective helped the team maintain a focus on the ultimate environmental goal of the project. In turn, the orientation toward that goal fostered a focus on long-term impacts, comprehensiveness, and creativity:

- Project organizers considered the entire system of manufacturing, selling, and using refrigerators in order to design a suite of coordinated measures to increase both the production and sale of energy-efficient, CFC-free units.
- Keeping the environmental goal of the project in clear view, the team considered a wide array of project designs and technology options to reach that goal.
- Recognizing the manufacturers' central role in the sector, initial project activities were designed around a leading refrigerator manufacturer.
- The goal of reducing refrigerator-related energy use and CFC emissions led project organizers to include a refrigerator recycling element in project activities, taking old, inefficient refrigerators out of service to reduce energy use and remove CFCs from circulation.
- The clear goal of the project helped it obtain multiple sources of financial and institutional support.

5.3 Secure Sustained, Long-term Institutional Support

As is often the case with international cooperation, the project organizers in the late 1980s did not foresee that they would be working on this effort for a decade. An initial uncertainty about project timeframes is typical of international technology cooperation, in which one partner may lack experience in the host country or with the target industry, the host country may be unfamiliar with the technology, working relationships must be formed, and international financial mechanisms can be slow and cumbersome.

Fortunately, EPA and SEPA were able to provide sustained institutional and financial support to the effort for the ten years it took to complete. This was critical to the success of the project, and because funding was flexible organizers could design activities in steps, as their understanding of the problem developed over time. Because of the scale of effort required, multiple funding sources were eventually necessary.

An important element of institutional support is continuity of staffing. During the ten years the project was being carried out, many major staff changes occurred in the United States and China. These changes were sometimes part of larger shifts in institutional responsibilities, particularly on the Chinese side, due to ongoing reorganization of governmental units. However, despite these changes, several working-level core team members remained in place. This staff continuity lent stability to the project, and ensured that some degree of institutional memory and learning was accumulated, strengthening the ability of the team to work effectively. This long-term involvement by team members also served to build trust on both sides of the bilateral cooperation.

5.4 Recognize the Need for Extensive Engagement

An important element of this project's success was that the project design included provisions for adequate face-to-face interaction and substantive engagement among project partners, following established best practice of effective organizations in their international work.

Budgets for international cooperation activities are often limited, and international technology cooperation between industrialized countries and developing countries is often seen as a special kind of process. For these reasons, international technology cooperation projects frequently involve only limited face-to-face interaction during short periods of in-country time spent by international experts. Projects can also lack provisions for effective project planning, management, and capacity-building. Such practices are unsuited to the inherent challenges of international technology cooperation, which typically require an extraordinary level of planning and management. Cross-cultural cooperation also requires unusually extensive communication efforts, and capacity-building requires extensive, long-term involvement.

The Refrigerator Project provides many examples of how the technology cooperation process should consider the methods employed by effective organizations in their international work. The project included a variety of approaches widely used by private industry and others to advance their core missions, such as attending conferences, conducting tours of factory and research facilities, offering training programs of several months' duration, performing cooperative research in which international and Chinese experts worked side-by-side on central project challenges, planning meetings similar to corporate retreats, and levels of international travel (for both Chinese and international counterparts) seen at many of the most effective multinational organizations. Moreover, to ensure that the cooperation stayed on track, EPA engaged full-time permanent in-country project staff.

As a result of this approach the project:

- Ensured a comprehensive and high-quality technology research and development process informed by leading experts in the field.

- Strengthened the capacity of Chinese experts and institutions involved in the project through substantial direct collaboration with international experts on core project activities.

- Ensured sustained planning and management of project activities, largely through frequent direct communication between U.S. and Chinese counterparts.

- Facilitated decisions through effective relationships and a shared understanding of key issues gained through collaborative research activities.

5.5 Draw on Domestic Experience and Expertise

The U.S. team included experts with experience in market transformation, refrigerator energy efficiency and CFC replacement, and international technology cooperation. Much of this skill had been developed working with industry in the United States. The team's experience allowed it to focus on deepening its understanding of the situation in China and learning how to apply lessons from the U.S. experience.

5.6 Know the Host Country's Industrial Organization and Business Practices

For the Refrigerator Project, the core U.S. team comprised a handful of staff who had long prior experience in China, and who were fluent in Chinese and could work effectively with Chinese counterparts. The bilingual core U.S. team members had technical and management skills in addition to their Chinese language skills. This meant they could play a key role in many of the bilateral and multilateral negotiations during the project. The presence of these bilingual team members was important particularly when immediate communication and decision-making were critical, or when use of professional interpreters would not have elicited all the information necessary for team members to participate effectively in discussions. Nuances of communication can sometimes be lost even by the most skilled interpreters, and having both language and substantive skills combined in several key team members was an invaluable asset to the project.

Similarly, having a team that was familiar with Chinese culture and business practices was a key asset. Being able to understand the perspectives of bilateral counterparts, being aware of certain constraints that those counterparts are working under, and being able to anticipate the capacity of both sides for modifying their views are skills that can be valuable in both forming consensus and in handling honest differences of opinion. The presence of these skills on the team allowed the bilateral partnership to remain strong over the ten-year period of the project, despite the many difficult technical and management issues that accompany ambitious projects of this size and scope, and situations with competing interests.

These skills, in addition to the other expertise brought from EPA's U.S. refrigerator industry experience, meant that the U.S. project team approached the work with very few weak points that could have introduced more risk to the cooperation. Only the China refrigerator industry was initially unfamiliar to the U.S. team, which was a manageable risk in light of other team strengths.

6. Next Steps

The Project Brief approved by the GEF Council did not include an implementation plan (consistent with GEF procedures). The bilateral team completed its work after the GEF project was approved by developing the detailed plan. The plan was based on the experience gained during the course of the Refrigerator Project, and on EPA's U.S. market transformation experience. Implementation of the GEF project began in 2000. As described elsewhere in this report, EPA has continued cooperation on energy efficiency projects in China, including minimum energy efficiency standards, other energy efficiency market transformation, and voluntary energy efficiency endorsement labeling.