

# A Case Study in Costa Rica: The Impacts of Refrigerants



Submitted by:

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WORCESTER POLYTECHNIC INSTITUTE

# **A Case Study in Costa Rica: The Impacts of Refrigerants**

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in partial fulfillment of the requirements for the Degree of Bachelor of Science by

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## Abstract

Hydrochlorofluorocarbons (HCFCs) have a global warming potential thousands of times that of carbon dioxide and are ozone-depleting substances. This report evaluates Costa Rica's HCFC phase-out with a focus on the refrigerant sector. We assessed the progress of the private sector in making technological changes, as well as the regulatory measures that the public sector imposes to ensure a smooth transition to low or non-global warming potential refrigerants. We determined that an end-of-life refrigerant management plan must be implemented. This plan includes the development of a nationwide refrigerator recycling program, progression in a developing destruction operation, implementation of reclamation technology in the private sector, and a transition to natural refrigerant use.

## Authorship

Hailey Cambra – Hailey contributed to writing the abstract and executive summary, a large portion of the background, a portion of objective 3 and the majority of objective 4 of the methodology, and the majority of the second section of the results and analysis sections. She had a large role in writing the introductory portions of each section. She took a role in editing each section of the paper, and wrote a portion of the original scripts for each interview.

Joseph Hill – Joseph contributed to drafting the introduction, a portion of the first objective of the methodology, the first draft of the natural refrigerant section in the results and analysis, gathered information for the cost-benefit analyses, and took a role in editing each section of the paper. He compiled and formatted the final report, and was the primary translator for all Spanish interview scripts.

David Knutson – David contributed to drafting the introduction with Joseph, a portion of the background, a portion of the second and third objectives of the methodology chapter, the first section of the results and analysis, a large portion of the destruction and natural refrigerant sections within the second section of the results and analysis, and collaborated with Hailey on the original scripts for each interview and with Joseph on translating scripts to Spanish. David also helped in editing the paper.

Sunny Sang Nguyen – Sunny Sang participated in writing a portion of the background, a portion of objectives 1 and 2 of the methodology, drafted the conclusions and recommendations, and had a large role in writing the summary sections of each chapter. Sunny Sang took a large role in editing the entirety of the paper with Joseph.

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## Glossary

Term	Definition
"C-Neutrality Note"	A national document signaling the country's commitment to carbon neutrality by supporting change within the industrial sector in order to nationally reach carbon neutrality by 2021
Clean Development Mechanism (CDM)	A funding method from the Kyoto Protocol in which Annex 1 countries form partnerships with non-Annex 1 countries so that the non-Annex 1 countries can improve their environmental sustainability while earning credits for the Annex 1 country.
Costa Rican Voluntary Domestic Carbon Market (MDVCCR)	The local carbon market in Costa Rica where companies who offset or prevent carbon emissions can earn credits and sell them on the marketplace. This system is still being developed.
Cámara de Industrias de Costa Rica (CICR) - Costa Rican Chamber of Industry	An organization that listens to the needs of the public sector and communicates with the government to enforce regulations while maintaining the financial competitiveness of its private industrial sector members.
Deutsche Gesellschaft für Internationale (GIZ) - German Society for International Cooperation	Provides specialized solutions for environmental efforts to foster international cooperation and to achieve global sustainability. This organization was developed by the German government to aid other countries that need improvement.
Dirección de Gestión de Calidad Ambiental (DIGECA) - Department of Environmental Quality Management	A department of MINAE that is in charge of all issues of contamination, working in a preventive method.
Dirección sectorial de Energía (DSE) - Management of the Energy Sector	Organization in charge of developing and promoting integral energy projects
Fondo de Financiamiento Forestal de Costa Rica (FONAFIFO) - National Forestry Financing Fund of Costa Rica	A governmental institution that finances forestry projects for the sequestration of carbon, or carbon equivalents
Global warming potential (GWP)	A rating that shows how much a substance contributes to Global Warming, with CO <sub>2</sub> being the baseline at 1
HCFC Phaseout Management Plan (HPMP)	Costa Rica's plan to eliminate HCFC import, storage, and other uses in the country, especially the industrial sectors.
Instituto Nacional de Aprendizaje (INA) - National Institute of Learning	The national job training school, whose students complete comprehensive courses in many different occupations
Interinstitutional Committee	Founded under MINAE to promote collaboration among the

	private sector, public sector and international community in achieving the goals stated in the National Strategy to Phase-Out HCFCs
International Standards Organization (ISO)	Organization in charge of adopting standards that nations agree upon
Kyoto Protocol	An international protocol that commits agreeing parties to reducing greenhouse emissions
Methodology AMS-III.X	Clean Development Mechanism methodology in the Kyoto Protocol which can be used for domestic refrigerators. Energy Efficiency and HFC-134a Recovery and Residential Refrigerators Version 2.0
Ministerio de Ambiente y Energía (MINAE) - Ministry of the Environment and Energy	Formally known as MINAET, provides solutions and implements policies to eliminate HCFCs
Montreal Protocol for Ozone-depleting Substances	An international protocol in which agreeing parties must work to reduce the emission of Ozone-depleting Substances.
Multilateral Fund	A fund provided by the Montreal Protocol to assist Article 5 countries in their elimination of Ozone-depleting Substances. Money is put in by non-Article 5 countries.
National Development Plan (NDP)	Costa Rica's National Development Plan to improve the state of the country
Oficina Técnica de Ozono (OTO) - Ozone Technical Office	A department of DIGECA that works to protect the ozone layer through regulations and projects, in accordance with the Montreal Protocol.
Ozone-depleting substance (ODP)	A substance that depletes the stratospheric ozone layer.
Proklima	A GIZ-funded program based in Germany
U.S. Environmental Protection Agency for Responsible Appliance Disposal (RAD)	A voluntary partnership program that recovers ozone-depleting chemicals from appliances, mainly a collection program for household appliances.
Waste Electronics and Electronic Equipment (WEEE)	A European Union directive that dictates rules and regulations for the disposal of electronic waste.

## Executive Summary

The small country of Costa Rica boasts the highest percentage of biodiversity throughout the world. The country thrives off of its plentiful environment, with agriculture and ecotourism comprising approximately 20% of the gross domestic product (CIA, 2014; Blanke, J. and Chiesa, T., 2013). Both global climate change and stratospheric ozone layer depletion threaten environmental health throughout the world—but Costa Rica’s high rates of biodiversity and economic reliance on the environment make these impacts especially dire (Norval et. al, 2011; Jenkins, 1998).

Because of the ubiquitous use of refrigerants in appliances, it is not only up to the government of Costa Rica to make changes in policy and regulation—the private sector must also carry out these changes. The Chamber of Industry of Costa Rica (CICR) works with the private sector to maintain competitiveness within business while incorporating high standards for environmental sustainability. This organization not only provides consulting, training sessions and other services, but also importantly serves as a connector between the public and private sectors in Costa Rica. To this end, CICR has been working with both sectors to find feasible solutions for refrigeration and air conditioning companies to end the use of ozone-depleting and high global warming potential refrigerants.

After the phase-out of the most potent group of ozone-depleting substances and highest global warming potential refrigerants, chlorofluorocarbons (CFCs), the milder yet still environmentally harmful group of refrigerants hydrochlorofluorocarbons (HCFCs) replaced them. As a part of CICR’s efforts to advance HCFC phase-out, we were called upon to investigate the progress of the phase-out of HCFCs in the private and public sectors. After some investigation, we developed an end-of-life refrigerant management plan for HCFCs and other environmentally harmful refrigerants. To advance the development of this plan, we completed four objectives:

- Objective 1** - *Assess the progress made by Costa Rican public sector organizations towards passing legislature and protocols to help eliminate HCFCs.*
- Objective 2** - *Assess the progress made by Costa Rican private sector companies towards recycling/destroying their used HCFCs and switching to natural refrigerants.*
- Objective 3** - *Determine the relationship between the public and private sectors to evaluate the barriers preventing further communication regarding HCFC phase-out.*
- Objective 4** - *Evaluate the implementation of international HCFC management plans and research technology to offer feasible recommendations.*

## Background

Costa Rica is known for its aggressive policies to combat global climate change. The country has been a global partner in combating anthropogenic environmental changes like stratospheric ozone layer depletion and global climate change through the ratification of the Montreal and Kyoto Protocols (Ozone Secretariat, 2011; Kyoto Protocol, 2014). In recent years, Costa Rica has passed their C-Neutrality note, committing to the goal of achieving carbon neutrality by the year 2021 (Ministry of Environment, Energy, and Telecommunications, 2009). The nation has

already dedicated much effort toward eliminating the use of fossil fuels and reforesting their country to sequester carbon dioxide (Lopez, 2014; Grupo ICE, Orozco, Ramirez, & Solano, 2014).

Refrigerant gases such as CFCs and HCFCs pose a double threat to the environmental health of the atmosphere. This knowledge was gained in hindsight after CFCs were originally used to replace natural refrigerants. CFCs proved to be both safer to handle and less expensive than natural refrigerants, and became widely used in industry (Ministry of Economy, Trade and Industry, Japan, n.d). Only when atmospheric scientists began to realize that our stratospheric ozone layer began to grow a gaping hole because of these gases, were we able to realize that our seemingly perfect replacement was actually a global nightmare. In 1986, Costa Rica and many other nations responded by signing the most widely ratified protocol in history, the Montreal Protocol (Ozone Secretariat, 2011).

Almost all countries in the world have phased out ozone-depleting substances and replaced them with fluorinated gases. Costa Rica aims to do one better by phasing out ozone-depleting substances *while still* avoiding the use of hydrofluorocarbons (HFCs), which impact global climate change. Substances such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are not only ozone-depleting, but they are also potent greenhouse gases. CFCs have a global warming potential of about 10,000 times that of CO<sub>2</sub>, and HCFCs have a global warming potential of about 1,500 times that of CO<sub>2</sub> (Pachauri, Rajendra K, 2008). Following the worldwide CFC phase-out, HCFCs now remain.

Although CFCs are no longer actively used in Costa Rica, the country requires a refrigerator recycling program to recover CFCs from old appliances and destroy them. The infrastructural deficiency in the CFC phase-out plan needs to be corrected to prevent current and future CFC and HCFC emission. The ultimate transition to natural refrigerants is the end goal in Costa Rica since natural refrigerants neither deplete the ozone layer nor have a high global warming potential. Despite the government's discouragement, the use of HFCs remains a problem in the private sector. Many companies are avoiding the use of natural refrigerants because, according to them, natural refrigerants are more expensive than HFCs. To add to the reluctance of refrigerator and air conditioning companies, the use of natural refrigerants requires equipment retrofitting, whereas HFC use does not. The future looks hopeful though. We learned that the points of resistance to use natural refrigerants are slowly becoming invalid. Companies report that the prices of HFCs are continuing to rise, largely due to the shift in the global refrigerant market as a result of their phase-down<sup>1</sup>. The rise in HFC price indicates that natural refrigerants will become less expensive relative to HFCs. Already, a handful of companies are beginning to use natural refrigerants in some of their equipment, a promising sign for the future.

## Methodology

To complete objectives 1 and 2, we assessed the progress made by the public and private sectors in HCFC phase-out through interviewing refrigeration and air conditioning companies in the private sector, and major players of HCFC phase-out in the public sector. We asked the private sector questions regarding the types of HCFCs used, their available recovery and disposal

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<sup>1</sup> Phase-down is the gradual reduction of use, without guarantee of the cessation of use.

equipment, methods for disposal, whether or not they were stockpiling refrigerant and, if so, which refrigerants were being stockpiled, and what kind of technician training they employed. We included both refrigerator and air conditioning companies in our interviews, covering the domestic, commercial, and industrial sectors. Because we were requesting information that could jeopardize the companies, we did not include company names or provide company-specific information when discussing interview results.

In the public sector, we interviewed one representative from the National Institute of Learning and one representative from the Ozone Technical Office. The National Institute of Learning is the primary public technical school for refrigeration technicians, so we asked the representative questions about how the training was done, if they trained for natural refrigerants, which companies use their services, and what regulations there are regarding training in Costa Rica. We asked the representative from the Ozone Technical Office questions concerning the progress of HCFC phase-out in Costa Rica and important regulations concerning phase-out, such as whether or not their 10% consumption reduction deadline had been met, what progress needs to be made in the future, and what regulations exist concerning technician training and certification. In addition, we interviewed companies that could possibly fund the solutions we proposed for the end-of-life refrigerant management plan. We included one bank, a non-profit organization, and an energy service company to explore a variety of funding options. We asked these organizations if they had previously funded recycling projects, if they had certifications to fund projects, how they fund projects, and how much money they would be willing to invest in a refrigerant recycling program. Once we completed our interviews, we used actor-network theory to generate both a textual and graphic actors map, outlining the players of HCFC phase-out and their roles. This actors map was used to determine the relationship between the public and private sectors to evaluate the barriers preventing further communication regarding HCFC phase-out, completing objective 3.

To achieve our final objective, we evaluated the HCFC phase-out plans of several countries. We researched their regulations, the actual HCFC Management Plan (HPMP), and the actions taken to fulfill the goals of said regulations and plans. This included developing refrigerator recycling programs and organizations to oversee the programs, infrastructural considerations to ensure the efficiency of these programs, and technology used to destroy HCFCs and other refrigerants. We included the United States, the United Kingdom, Japan, and Brazil in this evaluation of international models. The inclusion of at least one developing country, Brazil, allowed us to foresee possible obstacles in applying these HCFC elimination models to Costa Rica because of their similar economic resources. We took into account the differing demographics of each country to ensure that our evaluation of the applicability to Costa Rica was valid. Following this evaluation, we sought out reclamation and refrigerator recycling equipment to submit to a cost-benefit analysis, taking into consideration the purchasing, maintenance, operating, and labor costs associated with the equipment, as well as the savings from using reclaimed refrigerant instead of virgin refrigerant, and the savings from the recyclable material recovered from refrigerators. We performed this analysis using current economic literature and U.S. EPA guidelines for performing economic analyses. We researched the advantages and disadvantages of natural refrigerant use and proposed a funding strategy for retrofitting equipment. We summarized the extent of use and development with the destruction facility in Costa Rica and gave input on how to move forward with the facility. Finally, and most importantly, we assessed

the environmental impacts of HCFC use in Costa Rica to justify these changes from a social perspective, using U.S. EPA social carbon costs and their guidelines to economic analyses.

## Results and Recommendations

**Costa Rica urgently needs a refrigerator recycling program.** Prior to 2013, the majority of Costa Rica's HCFC consumption was sourced from the domestic refrigerator market. Without a refrigerator recycling program, CFC and HCFC emissions from old appliances is inevitable. Currently, these appliances are simply disposed of in landfills in their entirety, and it is likely that uncertified technicians are dismantling them for parts. We researched equipment that could be used for such a refrigerator recycling program, and found several examples that could be used in Costa Rica. *We performed a cost-benefit analysis on refrigerator recycling equipment and found that approximately \$40 can be gained per recycled refrigerator, including operation costs, once an initial return on investment is achieved.*

To provide a reliable proposal for the infrastructural needs of a nationwide refrigerator recycling program and to research other HCFC elimination measures regarding HCFC phase-out for application in Costa Rica, we evaluated the United States, the United Kingdom, Japan, and Brazil for their HCFC phase-out plans and actions. *One major take-away from our evaluation is that each country has made an effort to develop a refrigerator recycling program. We have used components of each country's refrigerator recycling program to develop a program that is likely feasible for Costa Rica.*

We used the developed countries as models for programs, regulations, and to determine which parties would be responsible for certain components of the refrigerator recycling program in Costa Rica. For example, we examined how a program similar to that of the Responsible Appliance Disposal (RAD) program in the U.S. could be applied to Costa Rica. On the other hand, Brazil was mainly used to recommend sources of funding options for Costa Rica, since their similar economic status makes both countries eligible for certain funds that developed nations do not have access to.

**We have proposed Costa Rica use a collaboration-based program, like the European Union.** The program can be described as a cooperative association between producers and manufacturers of refrigerant containing appliances. Such a collaboration-based program fosters a sense of mutual responsibility among the companies that have the highest impact on HCFC consumption. A major flaw with using a program that solely uses the components of the European Union is that there is only one major manufacturer of domestic refrigerators in Costa Rica. To alleviate such a huge burden on this manufacturer, we propose the refrigerator recycling program include a component of Japan's program, which requires appliance retailers to participate in responsible collection.

When the retailer delivers a new refrigerator, he takes the old refrigerator back with him to transport to a collection and recycling facility. We have suggested that a portion of the transportation costs that the retailer is responsible for are alleviated through using visible fees tacked onto new refrigerator prices. Thus, the consumer would pay a portion of the cost of recycling the old refrigerator. When a newer refrigerator replaces an old refrigerator, there are inevitably energy savings due to the more advanced equipment technology. Thus, the energy

savings from this switch to energy efficient equipment is a source of savings for consumers, and could be marketed to support participation in a refrigerator exchange program.<sup>2</sup>

**We recommend a program be developed in Costa Rica through the Ministry of Environment and Energy, like the Responsible Appliance Disposal Program (RAD) in the U.S.** This program, like RAD, would oversee collection and recycling facilities as well as destruction facilities. The government of Costa Rica already has a facility in place for the destruction of ozone-depleting substances. The Ministry of Health has very recently approved protocols to be used with all ODS substances used in Costa Rica. To add to this advancement, the Ministry of Health has also approved a protocol for the destruction of HFCs. The RAD-like government program would provide annual updates on the disposal and recovery rate of appliances and destruction of refrigerants to ensure efficiency of the refrigerator recycling program and the destruction operation. The members of the program would make improvements to the program as it progresses, and the members would work with the association of companies responsible for collecting a certain quota of appliances, so that both the private and public sector work collaboratively on this program.

**As a major recommendation to overcome the financial barriers in developing a refrigerator recycling program in Costa Rica, we recommend that the private sector and public sector work together to apply for the Clean Development Mechanism using Methodology AMS.III.X. to complete this project.** Costa Rica has already used the Clean Development Mechanism for a reforestry project through FONAFIFO, so application for the funding should be a familiar process (Rodriguez & Fondo Nacional de Financiamiento Forestal [FONAFIFO]). The AMS-III.X. methodology would incorporate the use of natural refrigerants and the destruction of high global warming potential gases in domestic refrigerators. CDM Methodology AM0060 could also be used for industrial and commercial refrigerator retrofits to transition the entire private sector to natural refrigerant use.

**We recommend that the public sector provide companies with some financial incentive to retrofit.** We realized that the public sector has expectations that the private sector cannot meet on their own given the resources they currently have. This disconnect is largely due to the lack of communication between the two sectors. For example, the public sector is pushing for the use of natural refrigerants, but does not give any financial incentive to do so. Retrofitting is an expensive change to the equipment that the private sector has to make before transitioning to natural refrigerants. *A direct financial incentive, like a tax break, or an indirect incentive such as an official mark of environmental stewardship (i.e. a sticker) may provide some motivation for the private sector to transition to natural refrigerants.*

**We recommend that the private sector begin using reclamation technology to reduce their overall costs from buying virgin refrigerant.** Such change would support a retrofitting project in the future through generating new revenue after a return on investment. To this end, we have provided examples of equipment to use for reclamation that include at least one piece of equipment that can be used in domestic, commercial, and industrial refrigeration and in the air conditioning sector for domestic and central air conditioning systems. *We found that the*

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<sup>2</sup> A refrigerator exchange program entails exchanging an old refrigerator for a new refrigerator.

*financial gains from reclamation range from about \$80 to hundreds of dollars in savings, depending on the refrigerant.*

**We recommend that Costa Rica adopt U.S. practices in mandating a licensure exam for all technicians, nationalizing the certification process and including training processes from each company.** Aside from the lack of communication between public and private sectors, we discovered that due to the lack of record keeping and enforcement of current regulations, the public sector lacks efficient regulatory standards to support the private sector. This inefficiency is apparent in technician certification regulations, and was expressed by the private sector in our interviews. Some companies do not use the public technician training centers, citing that the institute does not train properly for the processes that the company uses. The biggest regulatory limitation is the lack of a developed registry for refrigerant technicians. *We found that although there are standards for certified technicians, these technicians are not required to register in any type of registry.* In the United States, after passing a licensure exam, technicians are registered in a national technician registry. Only technicians that are registered can service equipment and handle refrigerant containing appliances at the end of their life cycle. A registry system to restrict the servicing of equipment to certified technicians is desperately needed in Costa Rica to prevent poor practices from affecting the environment and the integrity of the private sector.

**We recommend that CICR provide quarterly or biannual newsletters highlighting their accomplishments.** Above we discussed the need for better communication between the public and private sectors. *We found there is also a need for better communication between the two sectors and CICR.* Many company representatives expressed a lack of knowledge about CICR's efforts. Some interviewees went so far as to state that they thought the CICR was irrelevant in the HCFC phase-out process. Providing a newsletter to CICR's associated companies would keep them updated on CICR's advancements on behalf of the private sector.

**We recommend that CICR construct sector-based networks of companies to foster a stronger sense of community within the refrigeration and air conditioning sector.** To strengthen both their actual and perceived role, we recommend that CICR strengthen their networking strategy. Refrigeration and air conditioning companies must work together in the phase-out so they can all remain as competitive as they are now. In addition, we recommend more frequent meetings with all their members in the refrigeration and air conditioning sector so their members can voice their concerns and provide updates. Having more frequent meetings with their associated companies will allow CICR to provide accurate and well-informed recommendations to the public sector.

Once HCFCs are completely phased out, and only natural refrigerants are used in the private sector, Costa Rica will undoubtedly make a positive impact on their environment. To bring the impacts of the end-of-life refrigerant management plan into a social perspective, we calculated the impact of HCFCs on the environment using the U.S. EPA's central estimate of the social cost of carbon for 2015, and the latest Multilateral Fund HCFC consumption data from 2009 (United Nations Environment Programme, 2011; U.S. EPA, 2013; Environmental Defense Fund, Institute for Policy Integrity, & Natural Resource Defense Council, 2014). These costs include impacts on human health, agriculture, and damages from increased severity of natural disasters. *In total, HCFCs have an impact amounting to 421,549 metric tons of carbon dioxide, translating*



*to approximately \$17 million in social carbon costs.* The costs are expected to be even greater considering the impact on the ozone layer that HCFCs have, with damage to agriculture and human health due to increased UV-B ray exposure (Jenkins, 1998; Martens, 2013). Because of these impacts, we urge the people of Costa Rica to heed the results of this report.

## 1.0 Introduction

Climate change and ozone depletion are worldwide environmental issues. Their potential for damage in Costa Rica is apparent and profound. Costa Rica has the highest percentage of biodiversity of any country in the world, making it one of the most popular ecotourism destinations (Take a Trip to the "Happiest Country on Earth", 2012). Costa Rica's ecosystem is not only an environmental resource, but it also serves as an economic resource, generating approximately 20% of the Gross Domestic Product from agriculture and ecotourism (CIA, 2014; Blanke, J. and Chiesa, T., 2013). As such, Costa Ricans are deeply concerned about the status of their environment. To protect themselves against these threats to their environment and economic well-being, Costa Ricans have made it a national goal to combat them. Their plan is to achieve carbon neutrality by 2021 as well as to eliminate ozone-depleting substances (NDP; National Development Plan). Prior to developing this ambitious national plan, Costa Rica had ratified two international treaties, the Kyoto Protocol and the Montreal Protocol, that address global climate change and ozone layer depletion, respectively.

Hydrochlorofluorocarbons (HCFCs) are a key contributor to Global Climate Change and Ozone Depletion. HCFCs are ubiquitous; they are found in refrigerants, cleaning solvents, propellants, and foam blowing agents, to name just a few common sources (Kim, 2011). Many countries throughout the world have made efforts to phase-out HCFCs. Many of their efforts involve replacements with hydrofluorocarbons (HFCs), which are greenhouse gases that have nearly equal global warming potentials to HCFCs. Costa Rica has uniquely considered HCFCs to be a greenhouse gas whereas other countries, such as the United States, have not. With this greenhouse gas consideration, Costa Ricans are keen on implementing solutions that eliminate HCFCs and are completely free of harmful atmospheric properties, such as natural refrigerants like ammonia.

The Costa Rican government has appointed organizations such as the Ministry of the Environment and Energy<sup>3</sup> (MINAE: Ministerio de Ambiente y Energía) to provide solutions and implement policies to eliminate HCFCs (Ministry of Environment and Energy, & Partnership for Market Readiness, 2013). Most of these organizations work within the government and public sector. Unlike most chamber organizations in other countries, the Costa Rican Chamber of Industries (CICR: Cámara de Industrias de Costa Rica) works with the private sector to contribute to Costa Rica's environmental goals. CICR has several hundred members that include various companies in Costa Rica, including refrigeration and air conditioning companies. These members pay an annual fee for the services that CICR provides, such as training, technical consultation, conferences, and most importantly a voice representing the private sector in governmental decision making. Their training programs range from courses in making spreadsheets to International Standards Organization (ISO) certification, a process used to ensure the reliability of an organization's sustainable practices. The conferences that CICR holds can range from meetings to discuss new technology to collaborative meetings with the public sector.

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<sup>3</sup> Between 2006 to 2012, MINAE was formally known as MINAET

CICR's services are especially important for issues where regulations and policies will affect business. Because HCFCs are widely used in industry, CICR has been working with the private sector to gradually eliminate them, while maintaining the financial stability of companies whose costs may rise as a result of the changing policies. If successful, CICR, together with the public sector, will help reduce HCFC emissions by 97% by the year 2030 (Diaz, Rodriguez, Guzman, & Alfaro, 2011, p. 27). As part of reaching their goal of HCFC reduction, an interinstitutional committee to eliminate HCFCs has been developed, with members representing the private and public sectors as well as the international community. MINAE and CICR are the main organizations representing the public sector and private sector, respectively. GIZ, or the German Society for International Cooperation, represents the international community in this committee. GIZ provides specialized solutions for environmental efforts to foster international cooperation and to achieve global sustainability. This organization was developed by the German government to aid other countries in areas that need improvement. In short, the interinstitutional committee represents the public and private sectors of Costa Rica as well as the international community, allowing for a rich collaboration of ideas and perspectives to provide solutions to phase-out and eventually eliminate the use of HCFCs.

To assist in the phase-out HCFCs, CICR has recruited our group to help develop a plan for the management of HCFCs in the industrial sector. Specifically, our project focuses on recycling technology that will in turn reduce the need for HCFC imports to Costa Rica, as well as possible alternatives to HCFCs that are neither greenhouse gases nor ozone-depleting substances. We reviewed Costa Rican companies that import, sell, and use HCFCs. Since Costa Rican companies do not produce any HCFCs, the HCFC consumption constitutes HCFC imports. Although it is known that many companies are cooperative, it is also well-known that HCFC smuggling is an issue (Environmental Investigation Agency, 2014; United Nations Environment Programme, 2013; United Nations Environment Programme & World Customs Organization, 2012). The low cost of HCFCs and their availability now that many countries are phasing them out makes smuggling more attractive than system-wide solutions. Even those companies that want to make the change and are not smuggling refrigerants into the country lack the technological knowledge to make changes. On the other hand, some companies may have the technological knowledge, but either lack the funding to make the changes or do not have enough incentive to make these changes.

One of our primary goals of this project—a goal which had to be met before any other solutions could be developed—was to understand why companies have not made the changes necessary to completely eliminate use of HCFCs. Existing information provided by CICR allowed us to understand the current state of the HCFC phase-out plan in Costa Rica and gaps in information that need to be filled. For example, training programs for natural refrigerant servicing were supposed to begin as of January 2015, but the progress of this is unknown, due to a lack of communication between companies and the government.

After determining the current progress of HCFC elimination in Costa Rica, we reviewed and analyzed HCFC recycling methods and alternative refrigerants used by developed and developing countries. The results revealed successful examples, as well as failures that should be avoided. We have proposed a four component end-of-life refrigerant management plan that addresses: refrigerant reclamation, refrigerator recycling, natural refrigerant use, and destruction

technology in Costa Rica. With this proposal, CICR will be able to work with the private sector to begin the conversation about possible solutions to aid in the elimination of HCFC usage among private companies.

## 2.0 HCFCs in Costa Rica: A review of environmental progress, treaties, and technology

In this section, we provide a broad overview of Costa Rica's pledge to environmental stewardship, as well as of the effects of HCFCs on Costa Rica's environment. We outline Costa Rica's mission and progress regarding HCFC phase-out, including their ratification of both national and international protocols. We then present a brief overview of technology that can be used to recover, recycle, and destroy HCFCs.

### 2.1 Costa Rica's Pledge to Environmental Stewardship

Costa Rica prides itself on its environmental stewardship. This is because the country not only values its natural beauty, but Costa Rica also has an ecosystem that contributes significantly to its economy. Climate change and ozone depletion in Costa Rica challenges these values. In response, Costa Rica has ratified both the United Nations Montreal Protocol and the Kyoto Protocol, thus making the phase-out of ozone-depleting substances and greenhouse gases its international duty. Exceeding international standards, Costa Rica submitted a "C-Neutrality Note" in 2007, implementing a "long-term economy-wide transformational effort to enable carbon-neutrality" (Ministry of Environment, Energy and Telecommunications, 2009). This national document signals the country's commitment to carbon neutrality by steering away from a 'business as usual' operation and supporting change within the industrial sector in order to nationally reach carbon neutrality by 2021; in contrast, a business as usual operation would mean that the country would be ignoring these issues altogether (UNFCCC, 2011). Costa Rica's desire to model sustainability through developing its "C-Neutrality Note" will hasten its carbon neutrality agenda and aid in the country's international advancement and global recognition.

This C-neutrality note was not the first initiative towards environmental sustainability that the government and people of Costa Rica have committed to. The Costa Rican government pledged to international treaties prior to this national initiative. Originally designed to protect the ozone from ozone-depleting substances, the Montreal Protocol was signed in 1987 and ratified by Costa Rica in 1991; every subsequent amendment to the protocol has been ratified by Costa Rica. The universally ratified protocol provides new scientific information and technology while also offering reduction deadlines for participating nations (Ozone Secretariat, 2011). Additionally, its provisions include sanctions aimed at enforcing the set reduction deadlines, which are the year 2020 for developed countries and the year 2030 for developing countries (Ozone Secretariat, 2011). The protocol coincided with the proposed carbon neutrality plan by 2021, wherein Costa Rica's National Plan indicates its focus on refrigerant chemicals, not only due to their high ozone-depleting potential, but also for their global warming potential. This unique stance and accelerated timeline sets Costa Rica apart from other developing countries.

Costa Rica has also ratified the Kyoto Protocol, which sets emission targets for greenhouse gases, rather than ozone-depleting substances (Kyoto Protocol, 2014). Like the Montreal Protocol, the emission targets of the Kyoto Protocol are internationally binding. This protocol demands the most from developed nations because they emit the majority of greenhouse gases. Because of this expectation, several major industrial countries did not sign. Costa Rica, by

committing to this protocol, agrees to emit no more than 5% of the emissions produced during the year 1990, eventually reaching approximately 82% reduction by the year 2020 (Kyoto Protocol, 2014).

To reach these emission targets, the Kyoto Protocol offers market-based mechanisms following a cap-and-trade mechanism, including the International Emissions Trading Mechanism, Clean Development Mechanism (CDM) and Joint Implementation (JI). These mechanisms promote green sustainable investment, projects and camaraderie, which thereby help participating nations meet their emissions targets cost-effectively (Kyoto Protocol, 2014). Following the lead of the world's most environmentally conscious countries, along with the Kyoto Protocol, the Costa Rican Government intends to establish its own Costa Rican Voluntary Domestic Carbon Market (MDVCCR) as an additional effort to bring the country towards its goal of becoming carbon neutral by 2021. The MDVCCR will establish guidelines for the production, issuance and the exchange of carbon credits along with promoting reforestation projects and conservation efforts that will capture and sequester carbon dioxide. As stated in their market readiness proposal, this policy will provide a "financial incentive for investment in low emissions technology research, development and commercialization" for businesses in the industrial sector (MINAE, 2013). Because refrigerants are both greenhouse gases and ozone-depleting substances, these businesses will be eligible to participate in this domestic carbon market once it is established.

## **2.2 HCFCs Role in Climate Change and Ozone Layer Depletion**

The current industrial sector of Costa Rica uses processes that have caused massive atmospheric consequences for the country. Substances being used in this sector have a high global warming potential and will absorb infrared radiation, adding to the greenhouse effect (Tressaud, 2006, p.66). The concern with ozone depletion is that it reduces protection from UV-B rays, which gives rise to health risks such as cancer and can damage the global ecological network (Ozone Secretariat). The elimination of HCFCs is key to tackling both climate change and ozone depletion within Costa Rica and can be advanced by focusing efforts on the areas of high usage.

### **2.2.1 What are HCFCs?**

HCFCs are a family of halocarbons commonly used as refrigerants, foam blowing agents, cleaning solvents, and propellants. These various uses, especially in refrigeration, are abundant in Costa Rica and unfortunately pose multiple opportunities for HCFCs to be released into the atmosphere. HCFCs can then break down in the atmosphere and release their chlorine atoms to destroy ozone molecules. This destruction of the ozone is an increasingly serious problem for Costa Rica; due to its close proximity to the equator, the territory receives a higher degree of radiation from sunlight that subsequently harms the environment. HCFCs are also potent greenhouse gases, having a global warming potential 5000 times that of CO<sub>2</sub> (Kim, 2011). These consequences of ozone destruction and global warming have motivated the regulation of HCFCs, especially in Costa Rica. Costa Rica's high motivation for environmental concern has led to the creation of a national strategy to target HCFC reduction in order to safeguard the environmental health of Costa Rica.

## 2.3 HCFC Phase-Out Plan for Costa Rica

Achieving complete elimination of HCFCs by 2021 requires cooperation between the private and public sectors. The partnership between the public and private sectors including the Ministry of Environment and Energy (MINAE) and Chamber of Industry of Costa Rica (CICR), respectively, has fostered the creation of a national plan to eliminate HCFCs. CICR communicates with the public sector entities on behalf of the private sector companies associated with the Chamber. These companies pay a fee to CICR for that communication, and other benefits such as consulting. The Management Plan to Eliminate HCFCs in Costa Rica (HPMP) was published by MINAE in 2011 on the heels of the C-Neutrality Note, and includes the work already done to eliminate HCFC use in Costa Rica, data on HCFC emissions, deadlines to gradually eliminate HCFC use, and the responsibilities of each organization involved in HCFC phase-out.

The Ministry of Environment and Energy (MINAE) is a major player working on HCFC phase-out in the public sector. Several branches of MINAE are involved in HCFC phase-out, including the Ozone Technical Office (OTO), an office of the Department of Environmental Quality Management (DIGECA: Dirección de Gestión de Calidad Ambiental), the Management of the Energy Sector (Dirección sectorial de Energía: DSE), and the Management of Climate Change (Dirección de cambio climático: DCC). In addition to MINAE, other governmental organizations are involved either directly or indirectly with the phase-out, including the National Institute of Learning (INA: Instituto Nacional de Aprendizaje), the Ministry of Health, the Ministry of Tourism, and public universities like the University of Costa Rica, among others. Why are there so many different agencies involved? Each agency works on its own side of this very complex process. While MINAE focuses on the implementation of regulation and policy creation, the other public sector entities play a role in carrying out these regulations. For example, INA trains Costa Rican refrigerator technicians. INA is therefore responsible for ensuring that these technicians are updated on new technology and regulations relevant to refrigerant servicing. INA also researches new technology to properly eliminate or re-use HCFCs in the form of destruction and recycling, respectively. The Ministry of Tourism is indirectly involved for different reasons. As previously mentioned, ecotourism is greatly affected by global climate change. Because HCFCs are so relevant to global climate change, it behooves the Ministry of Tourism to become involved in the HCFC phase-out plan. Furthermore, as anyone who has been to a tropical climate will know, central air conditioning systems are commonly used in hotels to keep guests comfortable. Thus, the Ministry of Tourism has the capability to regulate HCFC use in central air conditioning systems within the many hotels existing in Costa Rica. This regulation is enforced through the monitoring of air conditioners that are installed and serviced in certain hotels, based on their rating of stars from three to five and from their size in general. Bigger and higher rated hotels are allowed a larger amount of HCFC use, which is monitored through regular inspections of the hotel. (MINAE-HPMP, 2011) Through the regulations that MINAE imposes on HCFCs and the branches that enforce them, Costa Rica has a strong set of government organizations fighting HCFC consumption.

However, it is important to underscore that HCFC consumption in Costa Rica solely consists of HCFC importation. HCFCs are not produced in Costa Rica, and consumption through reuse, recycling, or reclamation does not contribute to HCFC consumption. Thus the Costa Rican national strategy to eliminate HCFCs provides data on import and export of HCFCs, storage of HCFCs, technician training, quota establishment (No. 37614-MINAE), and the fostering of eco-efficient use of refrigerants, such as the implementation of new technology to increase energy efficiency and the use of natural refrigerants in place of HCFCs (MINAE-HPMP, 2011) (MINAE, 2014).

To address all components of HCFC phase-out, the national plan to eliminate HCFCs is divided into three phases, with each organization playing different roles. MINAE sets the regulatory groundwork for phase-out; specifically, the Ozone Technical Office gathers much of the data and heads the development of new regulations. The Ministry of Health is required to give the go ahead for projects involving major recycling programs and destruction facility operations. Each entity plays these roles throughout the process, and no one agency is more involved in one phase than the other. Here are the three main phases:

- The first phase was completed as of the year 2015 and included a freezing and investment project in the foam sector. Thus, HCFC use in foams was restricted to recycled or reused HCFCs. The baseline for HCFC importation is approximately 339 metric tons of HCFCs (2010 estimation), which must be reduced by 37.5% from 2011 to 2015.
- The second phase includes assistance to the service sector to establish national campaigns to increase awareness of the government's efforts to eliminate HCFCs.
- The third phase includes prohibitions and incentives for efficient cooling system equipment used by the industrial sector.

Once these phases are complete by 2030, Costa Rica will have a maximum HCFC consumption at 2.5% of the established baseline (NDP; National Development Plan). We discovered from our interviews that phase 1 was successful. This is important so that we can establish the current progress of companies in their mission to phase out HCFCs. Our knowledge of the timelines and these phases is limited to the HCFC national strategy report, which is not as current as the information that organizations such as MINAE have.

This HCFC phase-out plan is based upon the previous CFC phase-out, which was completed in 2010 in Costa Rica. The process of CFC phase-out has somewhat provided a framework for HCFC phase-out, as these chemicals serve the same purpose of cooling in refrigerators and air conditioners. This framework ranges from legislation, training programs, a consensus among actors in the phase-out, national coverage, and disposal of CFCs. The preceding CFC phase-out also provided a layout for infrastructure insofar as there exists a destruction facility for ODS, which can be used for HCFCs (MINAE-HPMP, 2011; personal communication, Rodolfo Elizondo, Ozone Technical Office; personal communication, Agustin Rodriguez, Chamber of Industry of Costa Rica). However, this infrastructure lacks serious logistical development. Protocols have only recently been approved for destruction after a year's delay by the Ministry of Health (personal communication, Agustin Rodriguez, Chamber of Industry of Costa Rica). Collection facilities do not currently exist for refrigerators, air conditioners, or refrigerants themselves, and transportation plans have yet to develop. Although there is much work to be



done, the availability of the framework resulting from the CFC phase-out process will make the elimination of HCFCs easier than it would have been without this preceding phase-out process, mainly because a destruction facility is already built, which is half the battle.

The total cost of the HCFC phase-out plan is estimated to be 2.9 million USD. Funding is split amongst the Costa Rican government, the private sector, and the Montreal Protocol's Multilateral Fund (which CR has access to as a developing country) (Matlievska, 2013). The plan focuses on industries that use HCFCs for cooling systems and foams, specifically. Most funding is allocated to national campaigns to promote awareness of the effects of HCFCs and training for refrigerant servicing. Currently, there is no funding to pay for recycling technology projects. With that in mind, part of our project was to find possible existing avenues for funding, which are separate from complete investment on the private sector's part. Avenues for funding include the funding mechanisms offered by the Kyoto Protocol, the Proklima program funded by the GIZ, and energy servicing companies. In addition, if avenues of funding this project don't exist aside from complete company investment, the less costly solutions will be more attractive.

## 2.4 International Models

Throughout the world, countries have begun to implement their management plans for gas emissions. The plans and implementation differ from country to country. With regard to HCFCs, these policies regulate levels of emissions and promote recycling or destruction.

Developed countries, such as the United States, Canada, and Japan, have moved quickly to implement their policies so as to meet the 2020 deadline of the Montreal Protocol (UNFCCC, 2011). The technological advancements promoted by these policies include recovery, recycling, and destruction techniques.

Developing countries, such as Brazil, Macedonia, Trinidad and Tobago, and Mexico, have moved more slowly to meet their 2030 deadline (UNFCCC, 2011). They benefit from the progress of the developed countries, but are limited in economic and political resources. Costa Rica, however, is an exception. Its political will and relative economic strength, plus a citizenry that prizes green values, are the reason for its advantage over other developing countries. Nevertheless, the developing countries may be a better model to assess and advise Costa Rica due to similarities in their size, economy, and HCFC elimination progress. These similarities between developing countries and Costa Rica will allow a useful side-by-side comparison to see how and why certain countries have progressed further than others.

## 2.5 Gauging HCFC Emissions and Use in Costa Rica

Costa Rica gauges HCFC emissions through a bottom-up approach, as opposed to a top-down approach, to measure HCFC usage. The bottom-up approach is more accessible and can easily be applied to one company or another since this method gauges chemical emissions based on economic data (Stohl et. al., 2010). This type of approach can help identify major targets for projects to reduce emissions, such as the foam retrofitting project completed in 2013 by Mabe in Costa Rica, which was funded in part by the Multilateral Fund (United Nations Environment

Program, 2013). Bottom-up approaches are excellent when it is difficult to measure exact quantitative data, such as how much HCFC is released into the atmosphere annually. For example, an inventory of refrigerators can indicate how much refrigerant is in the country. This kind of analysis can be used across industries and throughout Costa Rica to identify all sources and estimate their size, although the analysis can be compromised by lack of information. Another example of a bottom-up approach to gauge HCFC emissions would be to quantify the amount of HCFCs being imported into the country, based on reports from the customs office under the No. 37614-MINAE quota regulation (MINAE, 2014).

A top-down approach looks at different information. Such an approach would measure exact atmospheric data, most likely by utilizing a weather balloon that takes complicated measurements constantly. This approach is unnecessary and too difficult and time consuming to use effectively. But the bottom-up approach is not without its own limitations. The main limitation with using a bottom-up approach is that the customs office is not impervious to maliciously mislabeled or unreported imports. Further research may be necessary to check for any misreporting, including a comparison of the quantity of imported HCFCs to the quantity of reported HCFCs exported from the countries the imports are coming from. Usually, this type of discrepancy between reported imports and exports of HCFCs arises from illegal importation, or smuggling of HCFCs. A recent report from the Environmental Investigation Agency concluded that in 2013, China reported exporting three times more HCFCs to Costa Rica than Costa Rica acknowledged receiving (Environmental Investigation Agency, 2014, p. 2). A year prior to this, the discrepancy between Costa Rica's imports from China and reported imports was not large, and did not warrant alarm. However, the data from 2013 tell a much different story, and according to our sources at CICR, as much as 40% of HCFCs (primarily HCFC-22) are being smuggled into Costa Rica. Thus, a bottom-up approach to gauge emissions in Costa Rica may present challenges in providing reliable emissions data, but it is able to highlight discrepancies in import/export reporting data.

An extended example of a bottom-up approach may be illustrative. Between 2006 and 2009, Costa Rica imported 858 metric tons of HCFCs. Of this, 89.32% is accounted for by five companies. These companies are MABE, Beirute, Fibrocentro-BASF, Dole, and OMEGA. MABE sells refrigerators to home-owners, whereas Beirute sells them to industry; OMEGA is also a refrigeration company. Fibrocentro-BASF is a chemical company that advocates green chemistry. Dole is a popular fruit packager (MINAE-HPMP, 2011). Should these five companies significantly reduce their need to import HCFCs, Costa Rica can cautiously assume that HCFC emissions will be reduced according to their national strategy. Of course, it would be wise to perform a follow-up analysis to ensure that the import data matches the export data of countries supplying the HCFCs.

Our project will try to understand how these companies, as well as other companies using refrigerants, are faring financially with the HCFC regulations, progress they have made to phase-out HCFCs, their future plans for sustainable development with regard to refrigerants, and how the representatives of each of these companies feel about the helpfulness of the HCFC regulations in maintaining their business.

## 2.6 HCFC Recovery, Recycling, Reclamation and Destruction

To properly manage HCFCs, the different recovery, recycling, reclamation, and destruction methods must be understood so that companies can utilize the most cost-effective method for them. A large limitation to implementing technology tends to be the cost required to deploy the equipment. A company cannot just begin using a new process solely for utilitarian environmental benefits, because not all of the economic benefits accrued from environmental benefits affect each company or even each sector of industry equally. Companies must stay afloat whilst being environmentally responsible; they cannot sacrifice one for the other. Therefore, those concerned with this issue must show these companies that the economic benefits align with the environmental benefits to a standard that allows companies to maintain profits, or at the very least competitiveness.

Large scale uses of HCFC include industrial and domestic refrigeration and air conditioning (Tsai, 2002). Since almost every business and home has some sort of refrigeration or air conditioning system, HCFCs are extremely prevalent in everyday life. Overall, the presence of HCFCs being used either in industry or at home creates a need for management and, ultimately, elimination from the environment. To reach this goal, special equipment and in some cases, training will be needed.

Recovery of HCFCs prevents any refrigerant from being leaked or vented to the atmosphere. After recovering, the refrigerant can then be stored in a certified container that can be sent either for recycling, reclamation, destruction, or in the worst-case scenario, just stored.

Once material is recovered, it will need to be recycled. Recycling technology is available, but can be expensive. Recycling systems take the recovered HCFC and insert it back into either the same system or a new one, eliminating the need for importing more HCFCs into the country. Because of contamination, however, not all recovered refrigerants can be recycled. If the recovered refrigerant is contaminated due to a malfunction in the compressor of the refrigeration system or another mechanical failure, recycling the HCFC right away is impossible. Technologies exist that can take these contaminated refrigerants and reclaim them, removing the contaminant and producing useable refrigerant. The refrigerant can then be recycled and used again in a refrigeration system. Although a great solution for reducing the importation of HCFC, recycling only further expands the lifecycle of HCFC.

An alternative to recycling is destruction. Destruction of HCFC-containing refrigerants breaks up the HCFC molecules and generates waste, such as water or CO<sub>2</sub>. Carbon dioxide can be used as an alternative refrigerant. There are a number of methods that can be used to completely destroy the HCFCs. Each of these destruction methods requires specialized equipment and trained individuals. These methods have various benefits, such as complete HCFC elimination, as well as drawbacks, such as high-energy usage, which should be considered. Some methods may eliminate close to 100% of the refrigerant being destroyed, but leave harmful wastewater that must be treated after. Other methods may require a great deal of energy to superheat the refrigerant so that the molecules can break down to non-harmful chemicals, but this energy comes at a cost, especially in Costa Rica where energy costs are high. We have identified the

need for these destruction processes in Costa Rica, following our interviews with the private sector, which is discussed in Chapter 4.

### 2.6.1 HCFC Alternatives

In addition to recycling, reclamation, or destruction, alternative chemicals must be used at some point or another during HCFC phase-out. Once the HCFCs are gone, companies need to charge their appliances with refrigerants that are just as effective as or better than HCFCs. Considerations must be made, such as: how energy efficient are the new chemicals? Are they safe? Will a company need to retrofit their equipment to use the alternative? All of these considerations determine how likely a company is to adopt the new chemical in their processes. Natural refrigerant alternatives include carbon dioxide, hydrocarbons, and ammonia, although hydrofluorocarbons (HFCs) are also frequently used as a regular alternative. However, as previously mentioned, because HFCs have a high global warming potential (GWP), Costa Rica would like to “leapfrog” to natural refrigerants, while most countries have used HFCs to replace HCFCs. Costa Rica intends to pilot applications of these alternatives in hospitals, governmental buildings, hotels, and even water coolers. These programs will generate data that indicate the effectiveness of alternatives to HCFCs (MINAE-HPMP, 2011). Although these refrigerants have low GWPs, these alternative chemicals also have drawbacks. Many of the chemicals cause a number of health concerns for those who handle them, and require equipment retrofitting. Therefore, companies are apprehensive to invest in the training and technology to deal with them. In our results chapter, we give an overview of the advantages and drawbacks to natural refrigerant use.

## 2.7 Chapter Summary

The Costa Rican people have made considerable efforts to reduce their environmental impact for the sake of their economy, their countrymen, and the global community. The ratification of the Montreal and the Kyoto Protocols, as well as their commitment to become carbon neutral by 2021 exemplifies their commitment to the betterment of the environment. Because of the great environmental impact that HCFCs have on the environment, with high global warming potential and ozone-depleting potential, and their presence in so many every day appliances it is imperative that all actors involved in the regulation and use of HCFCs take swift action. Fortunately, action is already being taken. However, Costa Rica has a long way to go before the ultimate phase-out of HCFCs is realized. The private sector must be cooperative in the HCFC phase-out, and the Chamber of Industry of Costa Rica has called for us to identify the current weaknesses preventing progress and to propose solutions for the ultimate elimination of HCFC use in accord with governmental policies.

### 3.0 Methodology

The implementation of a feasible HCFC management plan in any country is a multifaceted process. In the United States, for instance, the acceptance of global climate change is a large barrier. If half of the members in Congress believe that global climate change is not taking place or that human activity does not play a critical role in global climate change, then passing bills to alleviate the role that human activity plays in global climate change becomes nearly impossible. Luckily, the Costa Rican government does not face this issue, and even the private sector tends to be very open to making change to combat global climate change. Thus, getting the public to accept measures to eliminate the use of HCFCs because of their ozone-depleting potential and their high global warming potential has not been an issue in Costa Rica. Rather in Costa Rica, there are issues with communication between the public and private sectors, and the enforcement of current regulations is lacking.

Providing a plan to eliminate the use of harmful refrigerants in Costa Rica is a multistep process, requiring intermediate objectives. In this chapter, we have provided our methodology used to complete our project objectives. We used interviews, actor network theory, cost-benefit analysis, and literature review to achieve our objectives. We also explain the limitations and complications we faced during the completion of each objective, as well as how we overcame these adversities.

In order to recommend a feasible plan to manage HCFCs in Costa Rica for CICR, we completed the following objectives:

Objective 1 - Assess the progress made by the Costa Rican public sector organizations towards passing legislature and protocols to help eliminate HCFCs.

Objective 2 - Assess the progress made by the Costa Rican *private sector* companies towards recycling/destroying their used HCFCs and switching to natural refrigerants.

Objective 3 - Determine the relationship between the public and private sectors to evaluate the barriers preventing communication between these two sectors in HCFC phase-out.

Objective 4 - Evaluate the implementation of existing HCFC management plans and research technology to offer feasible recommendations.

Our first two objectives work to assess how each sector has contributed to the elimination of HCFCs. The public sector has passed legislation for each step in the process of handling HCFCs. This legislation includes the halt on HCFC import, permits for equipment using HCFCs, and certification processes for technicians that work to with HCFCs. The private sector is either required to follow these some of these processes, while others are on a voluntary basis. Whether or not these measures are working, especially with respect to voluntary measures, was unknown at the start of this project. For these first two objectives, we gathered information through background research and interviews with the major governmental organizations working on the HCFC phase-out and the companies that use HCFCs. The information we gathered allowed us to assess the progress each of the sectors have made in the HCFC phase-out process.

Our third objective, to determine the relationship with the public and private sectors and evaluate the barriers preventing further progress in HCFC phase-out, could not be achieved until we

completed our first two objectives. We assessed the barriers to collaboration between the public and private sector, as well as the feasibility of Costa Rican companies to carry out legislation and voluntary measures set up by the government. Such questions of feasibility include whether or not the measures favor transnational companies more than small national companies. For example, the transnational companies have a larger budget for major technological changes. The smaller budget that a smaller company has can drive them to disregard voluntary measures, so that they do not spend excess capital and become less economically competitive. If these feasibility issues exist, there needs to be clear communication between the public and private sectors to help overcome these obstacles. This third objective was essential in allowing us to provide CICR with recommendations to improve the relationship between the public and private sector in order to promote the success of the HCFC phase-out plan.

Our last objective incorporated all of the Costa Rica specific information we gathered, allowing us to properly evaluate the policies and technology that other countries have used, as well as possible technology that could be used outside of these plans, all with Costa Rica in mind. This last objective was only achieved once we had completed our first three objectives; we assessed what had already been tried and failed and what had been successful. Without this information, a feasible recommendation for CICR would have been impossible. Through completing these four objectives, we provided CICR with a recommendation on how to help the private companies to recycle HCFCs cost-efficiently and effectively.

### **3.1 Objective 1 - Assess the progress made by the Costa Rican public sector organizations towards passing legislature and protocols to help eliminate HCFCs**

For the first objective, we obtained information about the implementation of laws, regulations, and international documents regarding the use of HCFC-containing refrigerants in Costa Rica. Government officials and professionals from the Ministry of the Environment and Energy (MINAE: Ministerio de Ambiente y Energía) have an essential role in the creation and enforcement of Costa Rica's HPMP. MINAE is comprised of several agencies, including the Ozone Technical Office (OTO: Oficina Técnico Ozono), the Management of the Energy Sector (DSE: Dirección de Sectorial Energía), and the Management of Climate Change (DCC: Dirección de Cambio Climático). The National Institute of Learning (INA: Instituto Nacional de Aprendizaje) is another organization funded mostly by the government, that trains refrigeration technicians. As a whole, Costa Rican governmental organizations have generated the national HCFC phase-out plan, including its goals, deadlines, regulations, and guidelines for technician training. The ultimate goal of the regulations they have implemented is to cease HCFC use and promote alternative refrigerant use that inhibits high global warming potential replacements (Gobierno de Costa Rica, 2013).

Aside from the current state of the HCFC phase-out plan, we hoped to learn about how the public sector views Costa Rica's progress with HCFC management and what future plans they have to further this progress. These governmental organizations have continuously worked with Chamber of Industry (CICR: Cámara de Industrias de Costa Rica) to advertise solutions to the HCFC problem, such as the use of natural refrigerant systems. Recycling technology has not



been a part of this solution until now. Our goal of obtaining this information was to fill in gaps of information relevant to the HCFC phase-out plan. This included the details of the second and third phase of the plan, which were not available in any published literature, as well as the progress made in the past few years. This information is necessary to assess how the incorporation of recycling technology ties in with Costa Rica's goals for the future.

For regulatory agencies, being aware of available refrigerant technologies in the market is important for their regulation in the industry sector. When regulatory agencies are not aware of the state of technology, there is a disconnect between the ideal goal and what is actually achievable. When the public sector cannot comprehend the difference, the private sector is forced into a position that violates regulations which, in actuality, are not achievable. Thus, part of achieving this objective was to find out how much the public sector knew about recycling technologies and other technologies they would like to implement, and whether or not they were aware of the feasibility of this technology. We were then able to identify gaps in information within the public sector regarding not only their knowledge of technology, but also with respect to what the public sector knew or thought about what actions the private sector is taking to eliminate HCFC use. From our interviews, we obtained information on the government's insight into the private sector and what they thought the companies had achieved. This information was then compared to the information gathered from interviews with the private sector. This information was necessary to assess the communication quality between the two sectors.

### **3.1.1 Development of Interview Questions**

To obtain information from these public organizations, we conducted semi-standardized interviews. This common method has proved useful in creating focused meetings based on open-ended questions resulting in a more relaxed atmosphere. It also provided opportunities to delve deeper into topics we had not considered prior to the interview (Sangasubana, 2011). Each interview began with a series of traditional entrance questions to add more familiarity between the interviewees and us, such as their own interpretation of the organization and their role. This friendly social interaction allows the interview participants to "develop a degree of rapport before more serious and important questions are asked" (Berg and Lune, 2012). Additional questions were then added to gauge specific topics of discussions for each organization. Example interview questions for the public sector include: What policies, laws, and regulations affect Costa Rican companies with regard to the use and disposal of HCFCs?; What are the origins and scope of these policies?; What is the certification process for training technicians?; What is the impact on companies and their response to these policies? (Public Interview Questions: Appendix E and H). These questions give an idea of the kind of information we were looking for from the public sector. We needed to assess how governmental actions are helping to phase-out HCFCs, why they chose said actions, and how these actions have been received. For example, a certification process for technicians is in place in Costa Rica. Though it is a mandatory process for refrigerant certification, there is only a minor fine for servicing a refrigerator without being certified. Whether or not the benefits outweigh the costs for companies is a central theme to regulations such as this one, and with no real enforcement agency for these regulations, we must assess the effectiveness of these regulations through interviewing both the public and private sectors.

### **3.1.2 Considerations and Limitations of Our Interview Process**

We recognized that there are important ethical issues when talking to organizations that have a wealth of knowledge about the private sector. Because these public organizations were able to give us information about the lack of compliance of several companies, we had to assure that the reputations of these companies were not compromised. In order to do so, we made sure that all the information given about specific companies could not be used to name the specific company. This includes details such as the specific type of equipment or refrigeration sector they dealt with, that could lead the reader to conclude which company we wrote about. Business anonymity is especially important for a small country like Costa Rica, where it can easily be determined through the process of elimination which company is discussed. Furthermore, delicate information such as the suspicion of HCFC smuggling was a topic of conversation. This made the process of anonymity that much more vital to the ethical execution of this objective. Thus, we read through a consent script at the beginning of each interview to ensure that we were abiding by ethical guidelines provided by the Institutional Review Board. The full interview scripts can be found in Appendix A-J.

Not only was anonymity an issue during these interviews, but so too were the cultural differences we faced. This included differences in business etiquette and language. The business etiquette in Costa Rica is more informal than we are used to. The informality of the interviews led to a more relaxed and unstructured atmosphere. Because of this, many times through the course of the interviews, the conversations would deviate from the structured set of questions. There were both disadvantages and advantages to this discourse. Often times we were quite afraid time would run out before asking many of the essential questions. However, we did benefit from this informality: the interviewees would frequently mention topics of discussion we had not previously been aware of. Additionally, as our project is focused in Costa Rica, the language barrier between our formal Spanish teachings versus the native Spanish of our interviewees did cause problems in voicing the topics in question. For instance, we frequently wrote out questions in English that were then literally translated into Spanish. The literal translations we developed, however, would sometimes cause confusion between what was originally the purpose. Despite these cultural and ethical limitations, we were able to complete our management plan in a comprehensive manner.

### **3.2. Objective 2: Assess the progress made by the Costa Rican private sector companies towards recycling/destroying their used HCFCs and switching to natural refrigerants.**

For our second objective, we evaluated how companies that utilize refrigerants are affected by policies regarding HCFC use. We categorized these companies by size and specialization, in order to ensure we were interviewing at least one company representative of the refrigerant market in Costa Rica. Companies utilizing refrigerant for air conditioners have different needs than companies utilizing refrigerant for domestic refrigeration. The type of HCFC used differs, and the services offered by the company may differ. Many air conditioning companies offer to service equipment for their clients, while domestic refrigeration companies do not usually offer this. In addition, because the type of HCFC used differs, available alternatives for these HCFCs



are different and in some cases, limited. We also took into account whether or not the company we were interviewing was an international company, and tailored our questions to the type of company we were trying to understand. Companies having a strictly Costa Rican clientele or an international clientele, must follow either strictly Costa Rican regulations, regulations set forth by other Central American countries, or countries outside of the Central American region. Differences in a company's geographic clientele base affect the actions that a company makes. For example, if a company in the Central American market using HCFCs only faces strict regulations in Costa Rica, then they are less likely to follow these regulations and instead pay fines if the cost of using HCFCs is cheaper than paying fines. A company that operated only in Costa Rica would more likely follow regulations in this case because they are likely to have a smaller clientele and as a result, the fines they pay would be more costly than using HCFCs. Among the economic differences is the funding of each market, which provides the companies with substantially different resources all together. Companies in the international market have the benefit of widespread funding while companies that are limited to the Central American market or Costa Rican market do not have the proper funding to keep up with the international regulations that lead the technological changes in Costa Rica. Other differences among companies include whether or not the company specializes in a certain cooling system, such as commercial refrigeration versus industrial refrigeration. There may be sufficient alternatives for commercial refrigerators, but not for industrial refrigerators due to the required physical properties of the refrigerant. Because of technological limitations such as these, we focused on identifying the types of processes each company utilized.

We sought out those companies that were making strides in utilizing alternative refrigerants, as well as those companies that were not, to find out what the reasons were for pursuing alternatives or not and the obstacles they faced in making the switch from HCFCs if they did. Because we included both model companies and companies that were lagging behind in HCFC elimination, we were able to identify possible obstacles that other companies may face when implementing natural refrigerants. Companies that have been resistant to using alternatives shared their concerns, which we used to ensure that the solutions we provided addressed these concerns. Because our project focuses on both alternative refrigerant use and HCFC recycling, we probed companies for answers as to why they have not been using recycling technology, or if they have what has worked and what has failed.

The information we uncovered from the private sector differed significantly from that of the public sector as these companies deal directly with these refrigerants and know exactly what is happening with their products. Thus, we obtained a clearer picture of the recycling infrastructure available in Costa Rica from the private sector than from the public sector. In addition, we uncovered how these companies deal with regulations, and whether or not the representatives of these companies felt that the changes the public sector were implementing are feasible. This information allowed us to assess how well the public and private sectors were communicating, and if they were working together effectively or not. Through gathering information from the private sector we could understand the technological and economic hurdles in implementing effective solutions to recycle HCFCs and the use of natural refrigerants.

### **3.2.1 Development of Interview Questions for the Private Sector**

We conducted semi-standardized interviews with various companies that work with HCFCs or natural refrigerants. Through these interviews, we gathered information on Costa Rican companies and their approach to the use and disposal of HCFCs. We tailored each private company interview to the specific services or products of that company. Undertaking these interviews required us to be knowledgeable on the company's role in the market, and as such the focus of our interview questions was on how the company handles HCFCs in their industry. We asked the companies about the different types of refrigerants they used, noting those that contained HCFCs. This information was useful in determining a number of refrigerants that are potentially dominating the refrigerant market and may need management. We also inquired about how the companies are actively trying to mitigate their impact on the degradation of the ozone layer and global warming. This mitigation could be achieved through several implementations like switching to using natural refrigerants, recycling or reclamation equipment, destruction equipment, and even simply exuding good practices. By questioning these companies with several company-specific topics and preparing ourselves with possible follow-up questions, we were able to probe companies in how they handle HCFCs in the private sector. For our final HCFC management proposal, some plans were more beneficial for larger companies than smaller ones and vice versa. This is one of the major reasons our interviews used questions that could uncover the differences between companies, so that in the end we could potentially provide a solution for the entire industrial sector of Costa Rica.

### **3.2.2 Ethical Considerations and Limitations**

The company representatives that we spoke to put themselves at risk by speaking about how their company manages their HCFCs and how they may or may not follow the regulations put in place by the government. By promising them anonymity, we were able to assure these companies that they would not suffer any consequences as a result of their answers. This promise of anonymity is crucial for CICR because as representatives of the industrial sector in Costa Rica, they must communicate with the public sector about the problems in the industrial sector without compromising the current business of the companies they represent. These companies we have interviewed are essentially clients of CICR. As such, anonymity is not only in the best interest of these companies, but it is also in the best interest of CICR. In our report the companies or organizations we interviewed were represented in the general term of "company" or "entity". The company specific information provided through our interviews for our report were redacted to vague descriptors, in order to maintain their anonymity. The consent scripts that were read to each entity, accompanied by their interview questions, are shown in Appendices A-J and can be referenced for further information.

Our group also faced challenges when interviewing the private sector. A major limitation with the private sector was their lack of responsiveness when we reached out to them. This may be due to the rigorous schedule that most private companies have but could also have been due to the reluctance to disclose information. We were forced to contact companies through several communication routes and to request our sponsor's intervention when a company avoided responding to us or neglected to acknowledge our efforts to contact representatives.

### **3.3 Objective 3 - Determine the relationship between the public and private sectors to evaluate the barriers preventing further progress between these two sectors in HCFC phase-out.**

Through interviews with public organizations and private companies, we gained valuable information on how the two sectors interact and communicate. Understanding this relationship is key to making industry-wide changes in regards to HCFC use. The public organizations that we interviewed provided information on the current regulations and the future benchmarks for HCFC use. They also explained their role in promoting HCFC alternatives and recycling technologies available to the private sector. We cross-checked these statements when we interviewed companies within the private sector in order to discover whether these regulations, benchmarks, and advertisements of contemporary technology were actually being passed down to these companies. For example, once we knew of the destruction technology available in Costa Rica, we asked the public sector and the private sector the same question: Why is this facility not being used? We uncovered whether or not the private sector even knew about the destruction facility or if they knew why a facility constructed for their use was not in fact being used by them, or if it was, how they could use this facility and others could not. The public sector provided the information regarding what is actually going on with the facility because they are the sector responsible for its operation. They were able to articulate the political preventing the facility from being available. We also asked each sector about the available technology and what the other sector was doing about either providing the proper regulations to support better technology. We included questions regarding topics such as energy efficiency mandates on imports by the public sector, and whether or not the more energy efficient technology was readily available to the private sector. Through these questions, we discovered whether or not these companies were effectively communicating with the public sector organizations, either through CICR or through indirect impact based routes such as the availability of new regulations. We also learned about how the members of each sector believe that they are doing in terms of HCFC management, along with how they feel about the other sector's role.

#### **3.3.1 Identifying the roles of each organization and their interactions through an actors map**

Our ultimate goal in developing an actors map was to present a description of the refrigerant market in Costa Rica. It should be made clear that the actors map itself is a deliverable that was created using two methods: actor-network theory and interviewing. Our objective with the actors map was to identify the current political and technical state of HCFC phase-out, as well as to highlight areas that must be improved regarding communication and technological advancement. We included actors that play a role in creating regulations and enforcing them, actors that follow these regulations and make technological changes, and actors that fund major environmental projects. One aspect of progress that we included was the current use of natural refrigerants in the refrigerant market and which parts of the refrigeration sector switched to them. This gave us an idea of how well these ideas were communicated within the HCFC management network, which is vital for the next step of the HCFC management plan as natural refrigerant use has been a topic of discussion in Costa Rica. However, their widespread use is limited. We have also included a future actors map, which includes actors that need to play a more prominent role in Costa Rica, and the ideal state of each actor in the future to move forwards in HCFC phase-out.

Both actors maps were generated using the same methods, but the future actors map is a recommendation whereas the current actors map shows the current state and is a part of our results.

We utilized our previous interview data to generate a map of actors also referred to as an actor-network. A map of actors is sometimes used to examine interactions between different entities involved in a network. In our case, the network is all of the entities involved in HCFC management. As John Law, one of the founders of Actor-Network Theory (ANT), describes: “[an actor-network] is a body of empirical and theoretical writing which treats social relations, including power and organization, as network effects” (John Law, 1992). Actor-Network Theory is a relatively new concept. Prior to its genesis, Social Networks were used to describe relations that were strictly among humans, (although non-human networks were used in hard sciences like biology) (Borgatti, Mehra, Brass, and Labianca, 2009). John Law, Michel Callon, Bruno Latour, and others worked together to develop the Actor-Network Theory in order to broaden the context of network analysis in the social sciences. This group of researchers wanted a model that could analyze the interactions between any entity within a system of related entities, including technology, organizations, texts, devices, architecture, humans, animals and any other non-human thing. John Law states in *Notes on the Theory of an Actor-Network: Ordering, Strategy, and Heterogeneity* that “in this view [of the actor-network] the task of sociology is to characterize the ways in which materials join together to generate themselves and reproduce institutional and organizational patterns in the network of the social.” Generally, the focus of an actors map are roles, grouping and relations (Designing Product Service Systems, 2015). The roles in an actors map describes what exactly each actor does in relation to the other actors. Grouping and relations show the link between each actor; how they are related and a map of actors can be presented either textually or graphically, both of which our group chose to present.

Our graphical map, discussed in the next chapter was structured as a hierarchy, with MINAE at the top of that hierarchy, CICR in the middle, and the private sector and funding companies at the bottom. CICR behaves as the mediator between MINAE and the private sector, while the private sector receives regulations passed down from either CICR or directly through MINAE. We chose to present both types of maps in order to provide an illustration, whilst also maintaining the necessary details of our results. Below is an example of an actors map that focuses on an evolving network of actors and intermediaries that contribute to and influence the political culture and legal framework that ultimately work together to design systems and create legitimate agendas.

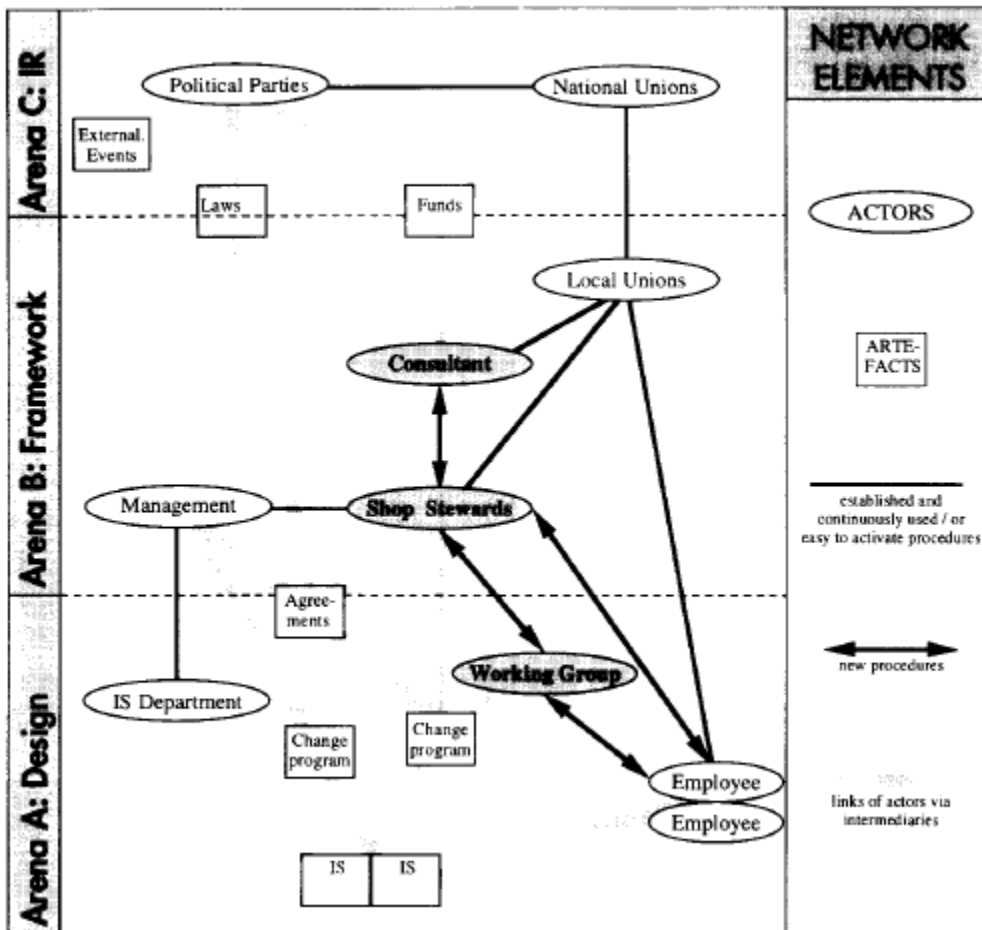


Figure 1. Example Actors Map (Gartner and Wagner, 1996)

In completing objective three, we focused on the role each actor plays in refrigerant recycling. The term “actors” includes organizations within the public sector and companies within the private sector. The actors within the public sector include the aforementioned governmental organizations such as MINAE and their offices, as well as government-funded training centers. The participating organizations of the Interinstitutional Committee, which was founded to promote collaboration among the private sector, public sector and international community in achieving the goals stated in the National Strategy to Phase-Out HCFCs, are also represented under public sector actors. We presented the role of each organization either in the regulation of importation, usage of HCFCs, or training for refrigerant servicing. We contextualized the role of training centers and their relationship with both the public and private sectors. The actors within the private sector includes importers, purchasers of HCFC from importers, funding companies, and purchasers of refrigeration equipment. Due to time constraints equipment buyers are comprised of only refrigeration companies and not their clients. Their clients would be comprised of supermarkets, banks and universities among others such as hotel management. We chose not to call these equipment buyers “consumers”, as the word “consumer” indicates an involvement of the general public, which we did not include in our actors map. Rather, an

equipment buyer is a larger company or institution. CICR also serves as a major actor in HCFC management and is included under the umbrella of the private sector. Though their role is a subtle one, they were vital in developing a successful recycling system as CICR serves as the branch between the public and private sectors. Because of this, they were portrayed in between the public and private sector on our graphic map of actors. Thus through our actors map, we clearly presented the roles of important actors throughout the entire lifecycle of HCFCs within the HCFC management network in Costa Rica.

### **3.3.2 Technical Limitations of the Actors Map**

Although we were able to elucidate valuable relationships between the public and private sectors in the HCFC management network, there were limitations to the actor-network method. Not all actors could be included due to our limited time. Because of this, we worked to include different types of companies within this actors map, which included large and small-scaled companies. These companies had different budgets available for sustainable projects and technological changes, which we must considered when proposing solutions. We know of companies presently using natural refrigerants and some still using HCFC-22. It is important for us to know the progression of each company in their individual HCFC phase-out process. Some companies are national while some are transnational. The companies that are transnational obey other regulations and rules set forth by their host countries. In addition, transnational companies are part of a larger refrigerant market than national companies, which affects their decisions. Moreover, there are companies that specialize in industrial refrigeration, whereas others specialize in commercial refrigeration. These two different areas of specialization require refrigerants with different physical properties due to their differing uses. We must consider these factors when determining how effective or appropriate an alternative refrigerant is as well as understanding why companies are using their current types of refrigerant. With these considerations in mind, we included at least one company with each of these characteristics (i.e. small or large, specialization, national, etc.).

Another issue with using an actor-network is that all entities are described in the same terms, whether or not the entity is human or nonhuman. Because this type of description can cause confusion, we only included organizations and companies as actors with no representatives of the entities as actors. This aided our objective as it kept all companies anonymous, especially the interviewees representing these companies.

### **3.4 Evaluate the implementation of existing HCFC management plans and research technology to offer recommendations.**

Once we identified the actors and how they were interacting (or not interacting) to achieve their mutual goal of HCFC phase-out and sustainable refrigerant use, we needed to begin to find solutions. This required that we review the literature on different HCFC phase-out plans of other countries, and the major developments they have made to take action.

We thoroughly researched literature, including academic journals, company websites, and government publications to find technology suitable for the various companies in Costa Rica using HCFCs. This technology included both reclamation technology for the private sector and refrigerator recycling technology that could be incorporated into a nationwide program. We

tested the feasibility of implementing this technology using cost-benefit analysis. Beyond recovery, reclamation and recycling of refrigerants or refrigerators is the ultimate destruction of the environmentally harmful refrigerants. We provided an overview of the current state of destruction technology, what needs to be done in the future to move forward in its use, and an estimation of some of the costs of operating the destruction facility in Costa Rica. The final leg of the complete phase-out of not only HCFCs, but all high global warming potential and ozone-depleting substances in the refrigeration and air conditioning sectors, is the complete switch to natural refrigerants. We researched the advantages and disadvantages of switching to natural refrigerants to give a qualitative evaluation of their use in refrigeration and air conditioning. The goal of this objective was to offer CICR feasible recommendations for their clients in the private sector that aligned with the expectations of the public sector.

### **3.4.1 Evaluation of existing HCFC management plans and technology in other countries**

In completing objective four, we evaluated existing management plans in the United States, the United Kingdom, Japan, and Brazil. We chose both developed and developing countries to evaluate, as each group offers its own advantages. Developed countries like the United States, the United Kingdom, and Japan have a more advanced HCFC phase-out process. As such, we used these processes to predict possible technologies that could be used in Costa Rica, as well as infrastructure that could be applied to Costa Rica. Despite the United States and Japan having developed their own HCFC management plans, their status as powerful and wealthy countries made it difficult to utilize their technologies and policies in their entirety, considering Costa Rica does not have an equal amount of wealth. On the other hand, developing countries like Brazil resemble Costa Rica's infrastructure and economic resources. Thusly, through evaluating these countries, we understood more of the obstacles that arise from implementing certain technologies. We were also able to recognize which recycling technologies and infrastructure could be implemented in Costa Rica by looking at countries with a similar economic status.

Developing countries, referred to as Article 5 countries in the Montreal Protocol, are eligible to receive funding through the Multilateral Fund of the Montreal Protocol. These countries have all taken advantage of the Multilateral Fund, as well as other international organizations that work to help developing countries pursue environmental projects. As such, through using at least one developing country in our analysis, we were able to identify possible funding avenues for Costa Rica. Beyond identifying sources of financial aid, we evaluated each management plan focusing on their strategy to phase-out HCFCs concentrating on the regulations, certification processes, deadlines, and technological modifications used to permit phase-out, such as retrofitting, recovery, recycling, reclamation, and destruction processes. Additionally, we examined the alternatives each country chose in replacement to HCFCs and the reasoning for their choice. We also investigated the challenges of implementing these changes to look for potential challenges Costa Rica might experience when implementing their own changes.

### **3.4.2 Developing our End-of-Life Refrigerant Management Plan**

After our evaluation of international models, we began our research on technology that is available on the global market to reclaim refrigerant. Because consumption of HCFCs is based



solely on importation and not any form of reuse or destruction processes, the incorporation of technology to reuse or destroy refrigerants greatly decreases HCFC consumption. We identified the need for and have provided examples of reclamation equipment for Costa Rican companies that lack sufficient reclamation technology, including at least one piece of equipment that could be used in each area of refrigeration and air conditioning. Recovery of refrigerants from appliances and recycling technology for refrigerants are already widely used by Costa Rican refrigerator and air conditioning companies. Thus, we decided to focus our efforts mainly on reclamation technology since a greater need for this equipment was expressed during our interviews with the private sector.

Through completing our prior objectives, we realized the need for a refrigerator recycling program. To this end, we have provided examples of equipment that could be used. As such, we compared the costs of equipment utilizing HCFCs to equipment utilizing alternative refrigerants based on energy consumption and price of the equipment. We have interviewed public sector and private sector representatives to understand why the cement kiln is not being used, and we have provided the possible costs that may be accrued moving forward based on a case study from the United States.

Each of these components requires a funding source. In some cases, it may not be feasible for a company to completely invest in a given technology. To ensure that companies would not have to pass too many costs on to the customer, we looked for inexpensive technologies that were also effective in eliminating the use of HCFC in industry. Aside from considering inexpensive technologies, we spoke with a representative from BAC, a bank that has an ISO certification to fund sustainable projects, to see if funding through this bank could potentially be an option for funding. We also considered the possible use of Energy Service Companies and a non-profit organization called Fundecooperacion to help fund these projects.

For the refrigerator recycling program, the major nationwide component of this plan, we considered the possibility of using the Clean Development Mechanism through the Kyoto Protocol. As a party of the Kyoto Protocol, Costa Rica is eligible to participate in this program, to set up projects that will offset carbon emissions. Aside from finding avenues for funding for this plan, we considered a mitigation strategy as well. It is possible to use a major forestry project to offset some HCFC emissions. The major reason for this consideration is due to the fact that of the technological changes we have suggested may not be feasible to implement by phase-out deadlines. We contacted the National Forestry Financing Fund of Costa Rica (FONAFIFO: Fondo de Financiamiento Forestal de Costa Rica), a governmental institution that finances forestry projects for the sequestration of carbon, or carbon equivalents. This organization has the capacity to offset greenhouse gas emissions, which CFCs, HCFCs, and HFCs are. In the end, we were able to provide recommendations for the acquisition of technology and the overall achievement of our proposed end-of-life refrigerant management plan.

### **3.4.3 Evaluating the feasibility of our solutions**

After we determined the components of our proposal for an end-of-life refrigerant management plan, we performed a basic cost-benefit analysis on two of the five components. We provided a qualitative evaluation of both the natural refrigerant and destruction facility components of our



plan. The qualitative analyses were better suited for these components based on their complexity, lack of available data, and time constraints. Because of these limitations, we decided to focus our quantitative analyses on the two major components of our plan: reclamation technology implementation and refrigerator recycling. The cost-benefit analyses we performed were solely economic and apply to different audiences depending on the component. In one case, we performed a cost-benefit analysis strictly for companies in the private sector, which included the reclamation technology component. In the other, we included costs and benefits for whichever entity would be largely in control of the refrigerator recycling program, likely the public sector. An environmental impact analysis is provided following the economic cost-benefit analysis. All components of the plan contribute to the environmental impact analysis since they all play a role in phasing out high GWP/ODS refrigerants.

The purpose of performing the environmental impact analysis in this way was to ensure that we provided a holistic picture of the environmental benefits of the solutions we have provided. To complete these analyses, we used guidelines provided in a publicly available handbook for preparing economic analyses authored by the U.S. EPA. This handbook provides information on conducting a cost-benefit analysis, from determining a baseline to discounting future benefits and costs. Although this handbook was used primarily for the environmental impact analysis, it was useful in providing a general idea of how to approach the cost-benefit analysis. We also took advantage of CICR resources, such as advice from their engineering professionals. We considered the current recycling infrastructure in Costa Rica, and we have provided a qualitative evaluation on implementing effective infrastructure on a national level for the refrigerator recycling program. In another case, we provided solutions that could be utilized by a singular company, and in this case technologies would be paid for by businesses acquiring them. This comprises the reclamation technology component of our proposal.

#### ***3.4.3.1 Economic Cost-Benefit Analysis of Reclamation Equipment***

As we sought to provide the most information possible through this analysis, we considered all economic costs associated with implementing new equipment. Costs commonly associated with technology deployment include purchasing the equipment, installation, maintenance, operations, and labor. As aforementioned, we have provided the cost of purchase to the best of our ability, or provided estimation. We did not include shipping costs in our analysis due to the ability of each company to negotiate shipping costs with a manufacturer, depending on the quantity shipped. We considered installation of the equipment negligible due to the fact that these types of equipment normally do not require installation. Maintenance costs include the price of a filter drier from approximately \$28 to \$65, which must be replaced regularly (Century Tool and Equipment, 2015). Filter driers are used in recovery systems, so each system that has a recovery component requires the filter drier. Since many companies already have recovery equipment, we decided not to factor the maintenance cost into our analysis since these companies likely already purchase filter driers, so it is not a new cost. The operation cost covered in this analysis is the energy cost associated with running the equipment, which was based on both the recovery method and the power usage. There are no other operations costs associated with implementing this equipment. The energy costs were calculated as follows:

$$E_{\$} = \frac{1}{R} * W_C * P * 0.2$$

Where  $E_{\$}$  = energy cost in USD per canister,  $R$  = recovery rate in lbs/min,  $W_C$  = weight of the canister in lbs,  $P$  = power usage in kW (input), and about \$0.2 is the cost of one kWh in Costa Rica (Business and Investment Law, 2013). The labor costs were considered negligible since there is no real training required to use this equipment, other than the training technicians already have. In addition, the use of equipment such as this would only require an additional step to the recovery process already taking place in these companies. Should the technicians have inexperience with this equipment, the operating manual of this equipment should suffice, and a training course is likely unnecessary given the expertise and training of these technicians. Thus, there is no considerable labor cost associated with acquiring this equipment. For each piece of equipment, to calculate the return on investment, we calculated how many canisters would need to be reclaimed to make up for the cost of the equipment. We subtracted the energy cost from the virgin refrigerant cost to calculate how much money could be made from reclamation. The maximum energy cost for each canister was used for this calculation, but if the equipment purchasing cost had a range, this was represented in the results.

#### ***3.4.3.2 Refrigerator Recycling Economic Cost-Benefit Analysis***

The same considerations that were made regarding costs for the reclamation technology were made for this cost-benefit analysis. We contacted manufacturers for prices of equipment, and were able to get responses from two of the three manufacturers, and a range of equipment cost from the third manufacturer's item listing. We took into account how many operators would be necessary to run the equipment, and used the average salary of an individual with the highest degree possible in Costa Rica, to be on the safe side of our estimations. We then calculated how much the total cost of operators would be per refrigerator based on a these operators working all weeks of the year for 40 hours to reach their salary. We did not include installation costs or shipping costs for the equipment, which admittedly may be in the range of hundreds of dollars for this equipment. However, in relation to the price of the equipment itself, it would be a fraction of the cost and finding this information is almost impossible to get without consistent correspondence with the manufacturer and an ultimate promise to purchase the equipment. We calculated energy costs in the same way that we did for the reclamation technology.

We identified refrigerator recycling equipment, from several different sources with different specifications and costs to evaluate the costs and benefits of implementing refrigerator recycling equipment. For each piece of equipment, we calculated the benefits of recycling a refrigerator based on the amount of material that could be recovered. We did not explicitly include the monetary benefit gained from reclaimed refrigerant, as many of the refrigerators being recycled will likely have CFCs for the first few years of recycling. For refrigerators using HCFCs or HFCs, less than 1 lb. of refrigerant is in the system, a majority of which is present within the foam, and the savings from this are likely to be negligible considering that the company would also have to reclaim the refrigerant to use it. In addition, we have considered the market impact this recycling program would have. For example, when a refrigerator recycling program is put in place and more consumers are incentivized to recycle their old refrigerator, this opens up the door to buy a newer, more efficient refrigerator.

### 3.4.3.3 Limitations our cost-benefit analyses

Our analyses for the equipment were subject to considerable limitations. Obtaining the relevant information for these analyses was a significant barrier to achieving our goals in detailing the financial costs and benefits for the implementation and use of this equipment. The equipment that was available mostly included recovery equipment for automobiles, especially equipment that included a price with its listing. We sought to find equipment that can be used for refrigerators and air conditioners. The issue with using equipment suited for automobiles, as we found out from correspondence with Chloe Yuan from Tektino in China, is that the equipment operates at lower pressures than for home and central air conditioners and refrigerators. Some of the equipment could solely recover from refrigerators and air conditioners, but recovery equipment is equipment that the Costa Rican private sector mostly has already. Recycling equipment was easier to find than reclamation equipment, but less available than recovery equipment. Recycling equipment was less of a necessity than reclamation equipment due to the fact that more than one company in Costa Rica uses and/or sells recycling equipment. The larger issue is that these companies are completely lacking in reclamation equipment. A problem noted over and over was that the current equipment used by these refrigeration and air conditioning companies cannot purify the refrigerant to a high enough purity level. To our dismay, reclamation technology is difficult to find, and difficult to find pricing for. This is likely a major reason that companies have not acquired reclamation technology.

To overcome these barriers, we have included equipment from several different countries of origin, to give an idea of the global market, and we have made efforts to contact the companies with equipment listed without a price tag. In the end, for much of the equipment we found, we were forced to give an estimate of the price, based on the price ranges available for the equipment found on the company website. We have also ensured that the equipment listed can in fact recover refrigerant from refrigerators and air conditioners, and not just automobiles.

### 3.4.4 Environmental Impact Analysis

Environmental benefits should be synonymous with economic benefits. Although we could not quantify some environmental benefits in a concrete economic sense, we tried our best to estimate them based on the relative decrease in HCFC emissions. The relative decrease in HCFC emissions can be translated to ODP and GWP metric tons. We used these quantifiable values to approximate the reduction of Costa Rica's environmental footprint. To determine the benefits of reclaiming greenhouse gas, we first determined how many carbon equivalents each virgin can of refrigerant would eventually emit. Every new canister of refrigerant is considered consumption of a greenhouse gas. We used the following equation to calculate carbon equivalents from each refrigerant (Environmental Protection Agency, 2004, p. 5):

$$(1.36 * 10^{-8} * GWP * 0.2727) * 1000000 = MTCE$$

The number  $1.36 * 10^{-8}$  is the mass in million metric tons of the refrigerant in the canister (30 lbs.). This unit was needed to use the 0.2727 conversion factor for million metric tons CO<sub>2</sub> to

carbon equivalents. MTCE stands for metric tons carbon emissions, and the 1000000 is used to convert back to metric tons from million metric tons.<sup>4</sup>

To calculate the costs of carbon on one's economy, one must calculate the social costs of carbon (SCC) (United States. Environmental Protection Agency. Office of the Administrator, 2014, p. 6-14). This is an inherently difficult task, requiring the consideration of impacts on human health, agriculture, and increased damages from natural disasters. However, the U.S. EPA and other organizations provide estimates of this cost per metric ton of carbon dioxide. This value changes over time and is given in the results section along with our final calculations.

An improvement in Costa Rican health can also be expected as a result of decreased UV-B ray exposure (UFCCC, 2011). We then tried to qualitatively evaluate the impact on health using previous data from United Nations Environmental Program reports and other data due to ozone-depleting gas emission. We included the environmental and health benefits as a part of an analysis from a utilitarian perspective. This is because the environmental benefits contribute to health and economic benefits felt by all citizens of Costa Rica, since the entire country shares these benefits, not one singular entity.

### 3.5 Chapter Summary

Our goal was to recommend a feasible plan to manage HCFCs in Costa Rica for CICR and its partners. To achieve this goal, we assessed the progress made by both the Costa Rican public sector organizations and the private sector companies to phase-out HCFCs; we determined the relationship between the public and private sectors in order to evaluate the barriers preventing their further HCFC phase-out progress; and we evaluated the implementation of existing HCFC management plans. We used interviews, actor-network theory, cost-benefit analysis, and literature review to formulate data necessary in developing an HCFC management plan. These methods were used because the data they provided was appropriate for our needs and yielded requisite data. However, in each method used, we faced many limitations. These limitations included cultural differences such as business formalities, anonymity, language barriers, and time constraints, as well as use of specialized terminology in the actors map and researching current technologies. As a result, we adapted our methods in order to effectively address these limitations while successfully completing our objectives. Through fulfilling our objectives, we provided a feasible HCFC recommendation plan for CICR and its partners.

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<sup>4</sup> To calculate the carbon dioxide emissions, we omitted the conversion factor for carbon dioxide to carbon 0.2727, which is just a ratio of the atomic mass of carbon to the molecular mass of carbon dioxide (12/44)

## 4.0 Results and Analysis

After conducting interviews, continuing our literature review of HCFC phase-out plans in other countries as well as available reclamation and refrigerator recycling technology, we synthesized the information we obtained and generated an end-of-life refrigerant management plan for Costa Rica, with components relevant to both the private and public sectors. We have given a summary and analysis of the information we gained from interviewing the private and public sectors. We also identified the existing problems between and within the public and private sectors in regards to cooperation in eliminating the use of HCFCs. Part of our analysis is presented in the form of an actors map in order to give a holistic picture of the current state of Costa Rica's HCFC phase-out.

Following these results, we presented our plan, which consists of four components and concludes with an environmental impact analysis. These components include both quantitative results, such as cost-benefit analyses, and qualitative results including discussions regarding the use of natural refrigerants and the extant destruction facility in Costa Rica. We evaluated the advantages and disadvantages of switching to natural refrigerants and the reasons why the destruction facility has not been used since its construction, with a discussion on the challenges of moving forward and how to overcome them. To us, the most moving component of our plan is the consideration of the environmental impacts that HCFC consumption can have on Costa Rica. We have quantified the social carbon costs, to be discussed within the last section of this chapter, of HCFCs. We also found that the environmental impacts of this plan, and HCFC elimination in general, outweigh any other economic costs associated with elimination. The environmental impact analysis serves as a reminder of the moral imperative the Costa Rican people have, regardless of their association with any given entity, in relation to environmental stewardship.

### 4.1 HCFC phase-out progress: Private and Public Sector Perspectives and Actions

We interviewed several companies within the private sector, including companies specializing in each type of refrigerant use from air conditioning to industrial refrigeration (see Appendix A-J). When interviewing each company we noticed several overarching themes while discussing environmental sustainability. The representatives we talked to expressed their company's desire in becoming environmentally sustainable. One of the reoccurring themes in our interviews was the issue of sustainably using and disposing of refrigerants and how it is not an issue of a company's commitment, but more of an issue of regulatory oversight, cost, and logistics of acting on that commitment. Another theme was poor communication between the public and private sector. On several occasions, we received conflicting information that confirmed this. For example, the public sector has failed to follow through with promises it has made in the past as stated by company representatives in the private sector. Using the information gained from our interviews, we identified common issues that were then compiled in an actors map (Figure 2) to create a visual representation of relationships and HCFC elimination progress in both sectors. Overall, we found that the public sector needs to accelerate their pace on implementing protocols and regulations for HCFC import and disposal.

#### **4.1.1 Public Sector Progress: Regulations, Technological Awareness, and Impacts on the Private Sector**

From our correspondence with public sector representatives in the Ozone Technical Office, we learned that there are equipment certification processes that are based on tests performed by ICE. These tests determine the energy efficiency ratings of the equipment being imported. This is an important step in regulating energy efficient equipment. Energy efficiency of these refrigeration appliances is highly dependent on the type of refrigerant that is used. Equipment using HCFCs have the lowest energy efficiency ratings. Thus, the public sector has put an indirect measure in place to regulate the import of HCFCs. The issue with this regulation, however, is that the energy efficiency ratings currently allowed are not high enough. CICR has recommended before, on behalf of their clients, that the energy efficiency rating should increase from 8 to 13. This would effectively eliminate all HCFC-reliant equipment. This recommendation has not been carried out even though it has been three years since its original suggestion. This is a problem for Costa Rica as it enables importation of equipment using HCFCs.

This energy efficiency rating recommendation was made at a time when the HCFC phase-out was first taking hold in Costa Rica. At the same time this recommendation was made, an Interinstitutional Committee was founded that includes several representatives from different branches of MINAE, CICR, and INA. This committee is supposed to meet several times throughout the year, but it seems this committee has achieved virtually nothing since it began in 2013. We were told that many times in committees such as these, meetings usually consist of voicing problems rather than addressing them. Many interviewees stated that this is largely due to the cultural customs that exist in Costa Rica. The people are very averse to confrontation or even disagreement. This lack of action expressed by the people, is a surprise considering the value that Costa Rica, the government especially, places on carbon neutrality. It may be that government officials are not being informed enough about this pressing issue. When addressing carbon neutrality, discussions are generally about fossil fuels rather than refrigerants. Because of the popularity of fossil fuels, they overshadow the detrimental effects caused by refrigerants. We believe this to be the cause of the lack of action we are seeing.

To say that we observed a lack of action by the public sector is not to say that there has not been some progress. Costa Rica has reached their 10% HCFC consumption reduction goal for this year. In 2010, the government banned HCFC importation beyond that set by quotas designated for each company that imported HCFCs prior to the phase-out. They have made the importation of equipment illegal by 2020. In order to buy and use HCFC equipment legally, importers have to hold what is called a Tech-Note 38 permit. There are also certification regulations in place for technicians. Government funded training institutes, such as INA, train technicians on everything about refrigerant equipment, from theory to practice.

#### **4.1.2 Private Sector Progress in HCFC phase-out: Technological Progress, Limitations, and Perspectives on Public Sector Cooperation**

A company needs to economically sustain itself and maintain competitiveness within the market. That said, Costa Rican companies are also held to a high standard of corporate responsibility with respect to environmental stewardship. We have found that Costa Rican refrigeration and air conditioning companies are doing the best that they can with their current resources to maintain a



balance between economic and environmental sustainability. The company environmental officials are aware of the negative impact HCFCs have on the environment.

To ensure negative environmental impact is minimized, each company has a training program for their refrigerant technicians. This includes emission prevention measures. Whether technicians are trained through INA or companies train the technicians on-site, the decision is up to the company. We found many companies deciding to train on-site, citing that their programs are more suited for their own processes, and in some cases elite to that of training institutes. Although these companies train technicians, an issue that was brought up time and time again was that although there are regulations in place that dictate technicians be certified not to emit refrigerant gas, there are no enforcement measures or any way to track which technicians are actually certified. Because of the lack of oversight by the government on this issue, these companies face competition with uncertified technicians. These technicians can be hired at a lower rate than certified technicians as well as buy refrigerants from importers without the importers knowing whether or not the refrigerant will be handled responsibly. Of course, those importers selling refrigerants do not want to reject anyone suspicious, for fear of driving off customers, who will undoubtedly buy the refrigerant elsewhere.

In the end, these companies face a dilemma they cannot get out of. They ultimately need the government to exercise their power in providing more oversight on technician certification. Fortunately, one of our interviewees forwarded an email to us from the Ozone Technical Office (OTO) regarding this very issue. It turns out that the OTO is in the beginning phases of generating a database of certified technicians in Costa Rica.

In the same way that company representatives expressed the need for more government intervention, they made it clear that they need the government to uphold their promises. We discovered while asking these companies about destruction methods, that there is a cement company called Holcim that is being contracted by MINAE to destroy HCFCs and CFCs. The Ministry of Health has lengthened the use of the cement kiln for reasons that are not clear. CICR representative Agustín Rodríguez suspects this is in part due to the in-process development of the HCFC destruction protocol and in part due to the nature of Costa Rican politics. Several companies were aware of this operation, and were unsure as to why they could not use it. Only one company, under contract by MINAE, uses the cement kiln operation. MINAE also supplies the transportation for used refrigerants as well as a trial destruction protocol for Holcim. This experimental contract is free of charge for both Holcim and the participating company. Despite our questions, the company did not reveal why they are using the cement kiln operation, but we suspect that they have been using the cement kiln as a part of a trial to test the HCFC destruction protocol. The confusing part about that theory though, is the length of time the company has been using this operation through MINAE. Why such a trial would go on for so long is something worth examining. It could be just another example of how laggardly the government is in completing tasks it sets for itself. Or it could be an example of the power of political connections (perhaps between the company in question and the Costa Rican government) to influence government decisions. A follow-up interview with cleared up some of the confusion with what is currently happening, as of April 2015, with the destruction facility. This is discussed further in our end-of-life refrigerant management plan proposal in section four of this chapter.

Some companies not only have HCFC-22 stockpiled, but they also have CFCs stockpiled from the old CFC phase-out as a result of a promise to destroy CFCs that the government failed to adhere to. Though we know many companies are committed to environmentally sustainable practices, we have to consider that these companies also must profit to stay in business. Space for stockpiling refrigerants is space that can be used for other work processes. It is possible that some companies have already emitted some of their stockpiled refrigerants in an effort to appear as though they are making progress in eliminating HCFCs. Keeping track of what refrigerants are disposed of is difficult for the government when there is no way of recordkeeping or data reporting. Companies could in theory simply declare that they recycled their HCFC stockpiles and are using it now, but there would be no way to know for sure since the government does not require reporting on destruction or recycling. **The bottom line is, this destruction technology needs to be available to all companies right away in order to ensure that stockpiled ODS are not emitted and companies can move on to the next step in phase-out.**

Along with the lack of destruction technology, these companies have also been burdened with the costs of carrying out the HCFC phase-out. One of the remedies for these costs as stated by one of our interviewees was the Multilateral Fund. This Fund assisted this company's switch from HCFCs to HFCs and natural refrigerants. Aside from international funding the government has not provided any incentive to modify or change technology. Despite the lack of help, many companies have still switched to HFCs and natural refrigerants from HCFCs. For many of the old systems that use HCFCs or even HFCs, the equipment must be retrofitted for natural refrigerants. By investing in retrofitting, systems become more energy efficient. However, for companies to make this change and invest in this new technology there must be incentives that accompany funding.

The lack of waste management infrastructure in Costa Rica is a major logistical hurdle in implementing recovery and recycling technology. This means that there is no current way to dispose of appliances utilizing refrigerants. Refrigerants can be found in foams and cooling systems, both of which tend to be landfilled along with the rest of the appliance. The majority of refrigeration companies could technically recover the refrigerant within the system, yet many of them choose not to remove refrigerants from the cooling systems on account of not having reclamation technology and the unavailability of destruction technology. There is no system in place for the companies to collect the appliances, and reasonably so, since they do not have demanufacturing capabilities to merit a collection. Costa Rica desperately needs infrastructural changes to recover and recycle refrigerant containing appliances in order for these companies to properly dispose of used equipment.

In addition to the lack of incentives available for the private sector, there are societal disincentives at work. Many clients of the refrigerant companies hold the belief that using natural refrigerants is inherently dangerous. They believe that equipment can explode because of the high flammability of the refrigerants, but in most cases, the only real cause for concern is in manufacturing facilities that hold large quantities of refrigerants. Each interviewee cited that precautions can be made to prevent this, and that there is minimal risk to their clients who buy their equipment. Both interviewees from companies that use natural refrigerants and companies that are not currently using natural refrigerants expressed this idea of minimal risk. The main issue is that the public is not aware of the low risk or the ubiquity of natural refrigerants in the global refrigeration market, especially the European market. This is an issue that the government



is more equipped to handle; this could be done through a public awareness campaign. This misconception prevents consumers from purchasing more energy efficient equipment and companies from making the switch over to natural refrigerants and HFCs.

#### 4.1.3 Actors Map of Key Players in Refrigeration Industrial Sector: Relationships and Progress

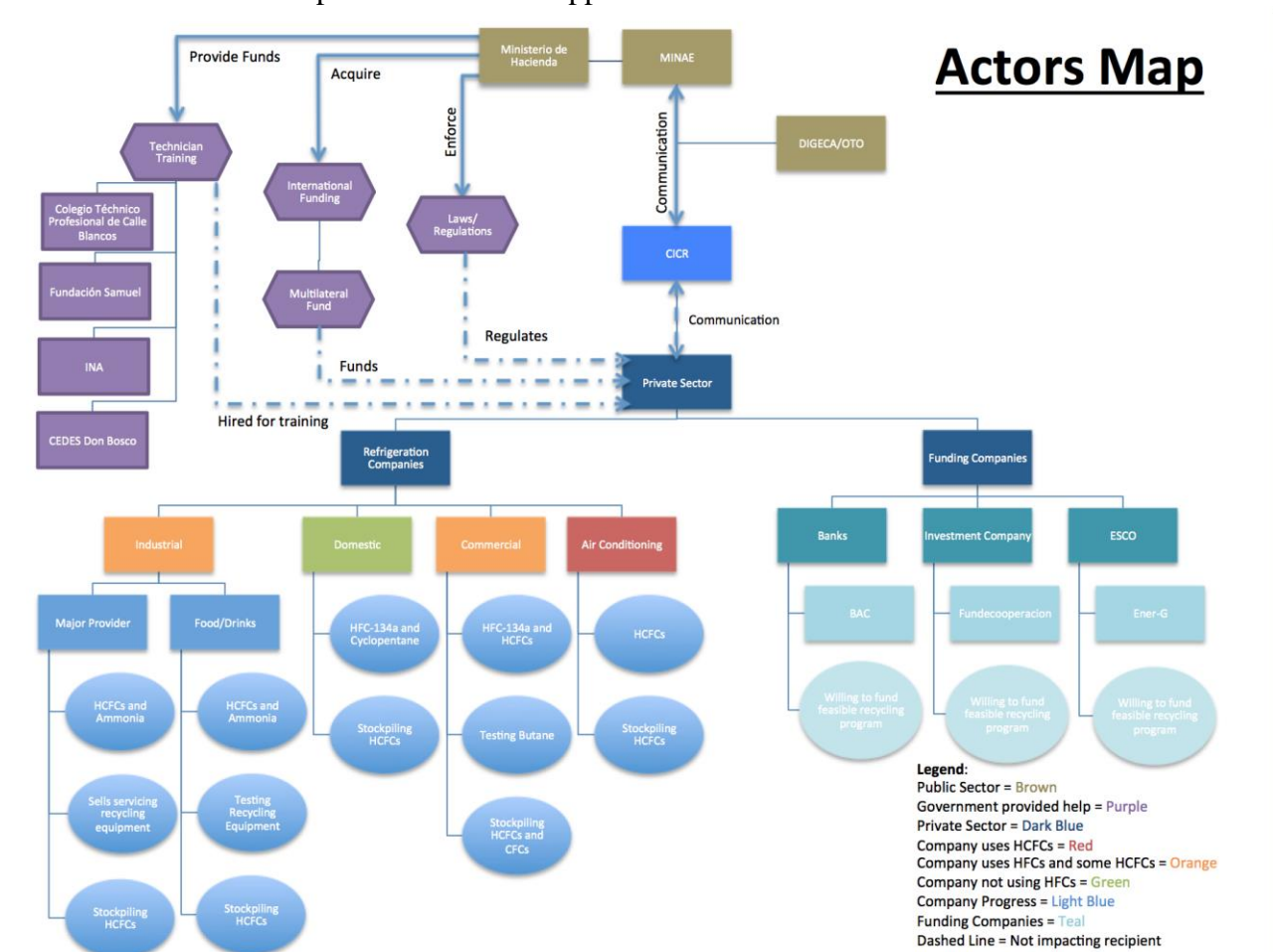
As a culmination of the previously discussed interviews with the public and private sector, we developed an actors map, of the key refrigerant players, for our sponsors. Figure 2 shows the final draft of the actors map that will be provided to our sponsor as part of this deliverable. This map was generated as a summary of some of the most important results of our interviews with the private and public sector, such as the relevant relationships and progress.

The colors and arrows depicted in the actors map are a representation of these findings that we interpreted from our interview results. The shapes and colors have specific meanings and there is a legend in the bottom right corner to show this. The colors are used to represent certain sectors that are the same. For example, all of the brown colored boxes represent the public sector. The red, orange, and green colors are used to represent the current progress in HCFC elimination for that section of industry for the private sector. The light blue circles below the refrigeration companies show current progress updates for each of the sectors. The purple hexagons in the upper left represent the impacts the public sector has on the private sector, while the actual arrows in the diagram show the effect of these impacts or flow of information. For example, the flow of communication is seen through CICR, which is a point we want the actors map to make. Broken arrows show how the impacts from the public sector are not effectively reaching the private sector. The other half of the private sector is represented by the teal colors, and they include the funding companies that could participate in the progress of HCFC elimination through the supporting of new projects. Using these symbolic elements in the actors map, we hope it will be a simple tool that CICR can use to see the progress of the public and private sectors and what needs to be done in the future.

From generating this actors map, we identified multiple areas for improvement in the current HPMP of Costa Rica. One area for improvement is the progression from HCFCs to natural refrigerant. This has been sluggish due to limitations such as a lack of technology and a preconception of these refrigerants as dangerous. Additionally, using our finished actors map, we identified potential flaws in communication within the network. With CICR being at the center of this problem, it is vital that they begin to confront it. This can be done through multiple small campaigns in the private sector to increase communication between companies and CICR. Other issues are derived from the lack of impacts that public sector regulations are having on the private sector and the long waiting times the private sector experiences when looking for change like destruction protocols. These improvements will take effort from the public sector, private sector, and CICR to create a real difference and reach future sustainability goals in Costa Rica.

To represent the future sustainability goals of Costa Rica, we developed an ideal version of the actors map to show the individual goals that each sector should reach for to meet the country's

goals as a whole. In the ideal actors map, we included existing recycling facilities in place for refrigerants along with the companies that should utilize them. Companies specializing in refrigeration recycling, yet not utilized by refrigerant users, are identified, as actors within the network and any prior relationship between the companies are included in the actors map. By including this information in our actors map, we identified potential gaps in technology implementation. For example, certain recycling facilities are unavailable or located too far from refrigerant users. This information allowed our group to determine a baseline of infrastructure to work off of for our next objective of implementing an effective recycling system. This ideal version of the actors map can be found in Appendix O.



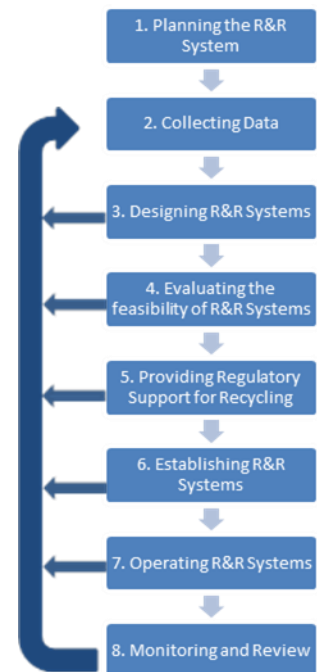
**Figure 2. Actors Map of Major Refrigerant Players in Costa Rica**

## 4.2 Proposal of Our End-Of-Life Refrigerant Management Plan for Costa Rica

After evaluating the current progress of the public and private sector in HCFC phase-out, we were able to identify what next steps must be taken to provide a suitable proposal to advance the phase-out process. To ensure that our proposal meets common recovery and recycling system guidelines, we have incorporated a framework developed specifically for recovery and recycling of refrigerants (OzonAction Programme, Multilateral Fund for the Implementation of the Montreal Protocol, 1999). Looking at the process diagram to the right, this proposal covers up to step 4 in implementing recovery and recycling systems, or in our case, an end-of-life refrigerant management plan. We have provided recommendations for regulatory support (step 5), but it is ultimately the responsibility of the Costa Rican government to bring these recommendations to fruition. The establishment of the proposed nationwide recovery and recycling system will require significant cooperation between the public and private sectors, as will the operation of these systems. Because of this, we have placed a considerable amount of effort developing recommendations to improve the communication between these two sectors in our recommendations chapter.

To begin planning for an end-of-life refrigerant management plan, we collected both qualitative and quantitative data. We inquired about how many refrigerators are being disposed of annually; we evaluated the need for the recovery and recycling system, and identified relevant stakeholders. Much of this has already been described earlier in this report in section 4.1. We have an estimation of the refrigerators disposed of annually based on personal communication with a CICR representative, who is considered an expert on the current HCFC phase-out in Costa Rica. We have identified relevant stakeholders through interviewing the private and public sectors, and evaluated the need for the recovery and recycling system both through interviewing Costa Rican companies and organizations and through evaluating the actions taken by other countries to phase-out ODS refrigerants. We have reviewed third party data from reports such as the Multilateral Fund executive summaries, which includes HCFC consumption data (United Nations Environment Programme, 2011; United Nations Environment Programme, 2013; United Nations Environment Programme, 2015). The data we have collected thus far is sufficient to allow us to take the next few steps in proposing a recovery and recycling program, on a company-by-company basis as well as on a national basis.

The following steps that we discuss in this section include: design of the R&R system components, examples of possible equipment and their specifications, and an evaluation of the feasibility and the economic viability of implementation that includes recommendations for funding. The development of the end-of-life refrigerant management plan was executed in part through the evaluation of the regulatory measures and programs in several other countries: the United States, the United Kingdom, Japan, and Brazil. We focused on what major components of



**Figure 3. R&R System Planning Process.**

(OzonAction Programme, Multilateral Fund for the Implementation of the Montreal Protocol, 1999, p.14)

the HCFC phase-out plans and recycling programs could be applied to Costa Rica. We have also included technological aspects of phase-out from each country, where it is relevant. For example, Japan sells equipment on the global market, so a discussion on the equipment available in Japan is included in our proposal.

When considering the limitations of applying the same programs and regulations from other countries to Costa Rica, we considered the demographics of each country. How many refrigerators are recycled per year in a country is relevant to the scale of a refrigerator recycling program. The geographic size of a country dictates the transportation infrastructure that is needed for a refrigerator recycling program. Furthermore, the population size plays a role in starting a nationwide consumer campaign to recycle refrigerators. We also accounted for possible cultural differences between Costa Rica and each country when considering regulatory measures, with a focus on Costa Rica's culture, based on what we have learned from company and government representatives. For an in depth country by country evaluation with these demographics, see Appendix X. We do not explicitly state the demographics here, but consider them as we provide the textual blueprints for a refrigerator recycling program in Costa Rica based on our evaluation of each country.

We found that the most suitable plan would require a majority of components that outline managing end-of-life refrigerants. There are four major components to our proposal.

**Component 1** *includes our proposal for a nationwide collection and recycling program for refrigerators, with a focus on domestic refrigerators.*

**Component 2** *includes regulatory improvements relevant to end-of-life refrigerant management, and an evaluation and analysis of technology and equipment for implementation of the plan.*

**Component 3** *provides a discussion on the advantages and disadvantages of using natural refrigerants.* The refrigeration and air conditioning sector in Costa Rica must slowly switch to natural refrigerants so that their impact on the environment is minimal. This component is largely qualitative, largely based on a review of the current literature and our interviews.<sup>5</sup>

**Component 4** *is an environmental impact analysis, calculating the environmental impact of HCFCs of a do-nothing or business-as-usual scenario.* The environmental impacts of refrigerants in Costa Rica can be alleviated by all the aforementioned actions: to adopt reclamation technology, to implement a refrigerator recycling program, to utilize the destruction facility in Costa Rica, and to switch to natural refrigerants. Each of these actions individually will undoubtedly make an impact, but it is the fulfillment of complete phase-out of environmentally harmful (high GWP and/or ODP) refrigerants that will eventually lead Costa Rica attain the highest standards of environmental sustainability in the refrigeration and air conditioning industry

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<sup>5</sup> An analysis of the economic costs and benefits of the entire private sector switching to natural refrigerants would require knowledge on retrofitting several different systems including industrial, commercial, and domestic refrigeration and air conditioning units, and is beyond the scope of this proposal.

#### **4.2.1 Component 1: Nationwide Refrigerator Recycling Program**

This program is largely based on programs that the United States, the United Kingdom, Japan, and Brazil have implemented. We start with the process of refrigerator recycling, identifying responsible parties in the program and their roles. We then move on to the regulatory improvements and new programs necessary to implement the refrigerator recycling program in Costa Rica. The overwhelming majority of emissions the domestic refrigeration sector produces are sourced from this sector making the inclusion of this component vital to this proposal. This component will require the participation of both the public and private sectors, although the government has the majority of the responsibility to implement the program.

##### ***4.2.1.1 A Plan for the Refrigerator Recycling Program in Costa Rica***

We have developed a refrigerator recycling program based on the countries we have evaluated and the needs of Costa Rica. Consumers are the starting point for recycling an old refrigerator, as they are the group of people that will ultimately dispose their old refrigerators. To encourage participation in a refrigerator recycling program from a financial standpoint, we urge that a refrigerator exchange program be developed, in which new refrigerators are exchanged for old refrigerators. Like in the United States, this program would highlight the energy savings from using more efficient refrigerators (Consumers Energy, 2015; Frederick County Maryland, 2015; Southern California Edison, 2015). With the high price of electricity in Costa Rica, we think this method would work well to convince consumers to exchange their refrigerator, along with promoting environmental sustainability.

To provide sustainable funds for the entire lifetime of the program, we suggest that a visible fee is tacked onto the new refrigerator, like in the European Union. We posit that if the fee does not exceed the savings made in at least one year from energy efficiency savings, then this may be enough to pay for a significant amount of the cost, which can be approximately \$100 and as much as \$250 (Consumers Energy, 2015; Frederick County Maryland, 2015; Southern California Edison, 2015). This fee will pay for part of the cost, likely the transportation fee to transport the old refrigerator to a collection facility. In the UK, the United States and Japan, there are municipalities that can cover part of the collection process (Ministry of Economy, Trade and Industry, 2000, U.S. EPA, 2014; UK Government, 2014). Since Costa Rica is a much smaller country than any one of these countries and municipal recycling programs to collect refrigerators would likely cost more time and effort, we propose that the retailer take the full responsibility of transportation to a collection and demanufacturing facility. The retailer of the refrigerator will be responsible for taking the old refrigerator when they bring the new refrigerator to the consumer.

The visible fee on the new refrigerator should be designed to cover the transportation cost to a collection and demanufacturing facility. The collection and recycling facility should run by manufacturers and importers of refrigerators, like they are in Japan, but we also urge that in Costa Rica, the retailers have a responsibility to pay for the operations of the collection and recycling facility as well (Ministry of Economy, Trade and Industry, 2000). The way these costs will be divided should be based on a percentage being paid for by the manufacturers and

importers, which should also be proportional to what they make on the refrigerator when selling to retailers. The retailers would then invest in the operation of the collection and recycling facility based on a proportional difference in price between the manufacturer's price of the refrigerator and the retailer's price of the refrigerator.

After the refrigerators are brought to the collection facility, the refrigerators can be demanufactured and recycled while recovering refrigerant and recycled parts. The recycled parts can be sold to scrap companies to make money from the recycling process after receiving a return on investment. Refrigerant that can be re-used can be reclaimed, and refrigerant that cannot be re-used, like CFCs, can be destroyed. This percentage of profit gained from the recycled material should be equal to the percentage of costs of recycling. Because only the manufacturer buys or imports refrigerants, the re-used refrigerants should go directly to the manufacturer. The idea of this cost division is a novel one on our part, taken from the concept that the UK uses to collect refrigerators and other electrical appliances (ICF International 2009; Touchdown Consulting, 2012; UK Government, 2014). The main goal is to ensure that the division of cost is fair, and not any one party has more responsibility than what is reasonable.

#### *4.2.1.2 Fostering Cooperation within the Private Sector and Maintaining Government Oversight of the Refrigerator Recycling Program in Costa Rica*

We find it likely that an association of all of the companies responsible for this program would foster a sense of cooperation among the companies involved, making each company check that the other is cooperating with one other. In the EU, there are associations called compliance schemes that consist of manufacturers and importers, which must be registered with the government (UK Government, 2014). These uses of compliance schemes come from the Waste Electronics and Electronic Equipment (WEEE) directive that the entire EU uses (Touchdown Consulting, 2012; UK Government, 2014). These compliance schemes force responsibility onto product producers to collect old appliances, which are registered and compared to the producers' total equipment sold in a year. Equipment producers are required to pay for the collection, recovery, treatment and disposal processes of this equipment. This includes hazardous ODS and any substance with a GWP greater than 15, thus it would apply to CFCs, HCFCs, and HFCs (ICF International, 2009; Touchdown Consulting, 2012).

One of the major benefits of using a compliance scheme approach is that because one of the requirements is registration with the government, the companies required to participate will be monitored for compliance, hence the name compliance scheme. The major difference we propose from the usual compliance scheme is that the sole party for collecting the refrigerators is the retailer, not the manufacturer. There is only one major domestic refrigerator manufacturer in Costa Rica, and putting all of the responsibility on that one manufacturer would be a large burden to bear. The responsibility of the retailers to collect the refrigerators should be proportional to the amount that they sell each year to make the collection responsibility fair. Should they follow the rules of the program, this is inevitable because they will only collect old refrigerators when they sell a new refrigerator. The fact that the retailers are only adding an extra



step to an already existing process is convenient, and will likely serve as an advantage to collecting the refrigerators in this way.

The government needs to play a role in the oversight of this refrigerator recycling program. Costa Rica has been relying on the DIGECA-Ozone Technical Office for the enforcement of regulations on refrigerants, and with all of the other tasks that these offices have, there may not be enough manpower to oversee the refrigerant recycling program. The United States developed a specific program within the U.S. Environmental Protection Agency for Responsible Appliance Disposal (RAD), a voluntary partnership program that recovers ozone-depleting chemicals from appliances (U.S. EPA, 2015). This program is mainly a collection program for household appliances.

The RAD program has saved over one hundred million dollars for consumers and one million metric ton equivalents of CO<sub>2</sub> (RAD Partner Meeting, 2014). Hundreds of thousands of pounds of HCFC-22, and HCFC-141b have been reclaimed or destroyed by RAD partners. In 2012 alone, about 886,677 units, including a/c units, stand-alone freezers, and refrigerators have been processed by RAD partners (RAD Partner Meeting, 2014). This data serves as both a relative testament to the success of the program, and as an example of what data the program in Costa Rica should include in reports on the efficiency of its own program. It should be noted here that this program was not entirely successful and is likely due to the large geographic size of the U.S. as well as its large populace. Like the EPA does with the RAD program in the U.S., the program developed by MINAE/DIGECA-OTO should mandate a recordkeeping process for this program to keep track of how many refrigerators are being disposed of every year, and how many refrigerators are actually being recycled to track their progress and the effectiveness of the program. For a more in depth discussion on the RAD program in the United States, see Appendix X.

Through the RAD program, the EPA performs random inspections of solid waste landfills and metal recycling facilities. Fines then enforce both of these actions where violators of EPA regulations can be charged up to \$37,500 per day for breaches of ethical conduct (U.S. EPA, 2014). These consequences may seem severe and if implemented in Costa Rica would have to be changed to fit the anti-penalization tax culture (personal communication, Chamber of Industry Representatives). Should this program be applied to Costa Rica, we recommend a program that rewards landfill operations and metal recycling facilities to show their commitment to environmental stewardship, such as a label that can be used on the company website or place of business.

To ensure the successful implementation of this program, a sense of environmental stewardship must govern the responsibility of each player in the recycling of refrigerators. The Basic Act of Establishing a Sound Material-Cycle Society in Japan works to “promote comprehensively and systematically the policies for the establishment of a 'Sound Material-Cycle Society' and thereby helps to ensure healthy and cultured living for both the present and future generations of the

nation” (Ministry of Economy, Trade and Industry, 2000). A ‘Sound Material-Cycle Society’ represents a society in which the consumption of natural resources is conserved and the environmental load is reduced to the greatest possible extent. This type of public campaign should be promoted in Costa Rica to encourage refrigerator recycling awareness. Such environmental campaigns seem successful in Costa Rica, with many citizens and companies well aware of the importance of the environment, and will likely be successful if applied to the refrigerator recycling program.

#### **4.2.2 Component 2: An Evaluation of Technology and Equipment and Relevant Regulatory Improvements**

This component of our plan serves to provide the necessary information to move forward with treating refrigerants and refrigerators in their end-of-life phase. Recovery of refrigerant is an integral part of end-of-life refrigerant management. It is the first step before destruction or reclamation, and is a step included in refrigerator recycling. Many companies throughout Costa Rica expressed that Costa Rica needs to improve their regulations revolving around technicians. As refrigerant technicians are the party responsible for recovery of refrigerants, we have included possible improvements in technician certification in this section. Without confidence that those handling this equipment or refrigerants in general are being responsible, there is no guarantee that technological development will be successful in preventing emissions.

The two post-demanufacturing<sup>6</sup> options include either destruction of the refrigerant or reclamation of used refrigerant. A destruction facility is already constructed and will be able to be used in the near future. We provide a discussion on its current status and what next steps must be taken to fully incorporate its use. To provide a model for the prediction of costs of the destruction facility, we have used information drawn from a destruction facility in the United States.

We give examples of equipment that can be used to carry out the end-of-life refrigerant management plan, either for, with, or independent of the refrigerator recycling program. We first evaluate recovery and reclamation equipment that companies can implement independently of the government. As we have stated previously in section 4.1, many companies need reclamation equipment to re-use contaminated refrigerant. Reclamation equipment can be utilized both with the program and without, primarily for contaminated refrigerant, and applies to the entire refrigeration and air conditioning companies throughout Costa Rica. This equipment is especially important to include because it can be used now. The development of the refrigerator recycling program will likely take an immense amount of effort and time before it is implemented, and it is imperative that Costa Ricans act now in any way they can to eliminate HCFCs and HFCs.

The last part of component 2 of our end-of-life refrigerant management plan is an evaluation of refrigerator recycling equipment. We conducted a cost-benefit analysis to assess the feasibility in implementing this component of the plan. Part of this cost-benefit analysis is providing avenues for funding. The cost-benefit analyses for the equipment are separate, and as such, the funding opportunities are discussed separately for the two different types of equipment.

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<sup>6</sup> post-demanufacturing: after dismantling and separating equipment components.



#### *4.2.2.1 Regulatory Improvements for Technician Certification and End-of-Life Refrigerant Management*

The success of an HCFC phase-out plan requires a set of regulations that are continually enforced and prevent companies from ignoring them. An effective way to ensure that companies follow these regulations is through continued monitoring and imposing consequences on companies and individuals that do not follow these regulations. Costa Rica is in dire need of enforcement of current technician certification regulations, as evidenced by our interviews with the private sector. The United States has a set of regulations that would provide meaningful change when applied to current regulations in Costa Rica. The most pressing regulatory improvement relevant to end-of-life refrigerant management is the national certification of refrigerant technicians. The U.S. Environmental Protection Agency (EPA) has a nationwide certification test that all technicians must pass and is the first step in regulating refrigerant technicians for good practices in servicing this refrigeration equipment (U.S. EPA, 2014). Costa Rican technical schools also have exams that their trainees must pass as well; however, many technicians are trained by the company they work for. There needs to be consistency among refrigerant technicians in order to ensure that all technicians are receiving the proper education.

The purpose of a nationwide exam also serves to provide an opportunity for the next change in the current refrigerant technician training system. The United States EPA requires technicians to register in a national database of all of the certified technicians once they have passed the certification exam. They use this database mainly as a method of restricting the sale of refrigerants to these registered technicians. Costa Rica can use the certification exam for the same purpose. Costa Rica has begun the process of registering its certified technicians, but it has only just started and will take some time to build an accurate database, and the U.S. can provide a model for the process of registering technicians. The problem with implementing these policies in Costa Rica is the fact that most of the companies we talked to expressed the opinion that the training schools, such as INA, lacked training techniques used by the company.

With resistance from most companies to certify their technicians using technical schools, Costa Rica may have to implement some enforcement regulations on top of these new policies. One of the methods that the United States has used to deal with this issue is by using costly fines that force all companies to follow their regulations. By using these regulations in the Costa Rica, emissions from bad practices via uncertified technicians in the servicing sector of Costa Rica could be reduced, which is part of the HPMP plan to be completed by 2025 (MINAE, 2011). Since the Costa Rican government tends to avoid using costly fines whenever necessary<sup>7</sup>, we suggest that the government take a more cooperative approach than the United States, at least when initially imposing this new regulation. Since many companies expressed the need for a training program that fits their day to day operations, we suggest that while developing this program companies have the opportunity to send their training program curriculum or requirements they need that would eventually be developed into the nationalized program. Once the national certification program has been developed, it may be necessary to impose fines on those companies that do not follow regulations to ensure the continued effectiveness of the program.

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<sup>7</sup> This information regarding the tax culture in Costa Rica was learned through personal communication with at least three Chamber of Industry representatives.

Costa Rica lacks a regulation that tracks what is happening to refrigerants once they have reached the end-of-life phase. The refrigerant end-of-life regulations in the United States require the last person in the refrigerant disposal chain be identified through a signed statement that includes the date the refrigerant was recovered as well as information necessary to contact the signee. Stickers are not usually used as a form of verification, unless it includes the date of recovery as well as the name and address of the signee (U.S. EPA, 2014). The development of a system to enforce responsible disposal of refrigerants would provide Costa Rican companies and the government with a way of data reporting and recordkeeping to ensure compliance with disposal regulations.

#### *4.2.2.2 Destruction Facilities in Costa Rica and a Cost Evaluation Based on Data from the United States*

When a refrigerant canister is full and ready for processing, the two handling options are either reclamation or destruction. However, the destruction process is necessary for CFC management since these refrigerants can no longer be used in any equipment in accordance with the Montreal Protocol (UNFCCC, 2011). Destruction can also be used for refrigerants that have been re-used extensively and cannot be reused anymore. Currently, every company we have interviewed has some quantity of stockpiled contaminated refrigerants that need either a destruction or reclamation solution.

Costa Rica currently has two options for destruction of refrigerants through cement kiln companies, Holcim and Cemex. Cement facilities utilize a cement kiln incinerator in their industrial processes that can be used concomitantly for refrigerant destruction. The cement kiln incinerators operate at high temperatures that can break down refrigerants. During this incineration process a product called clinker is produced (Ahling, 1979; Vijgen & McDowall, 2009). Clinker appears as nodules or clusters in the cement mix, and is a traded commodity, with 57 million metric tons sold annually throughout the world (Harder & OneStone Consulting Group GmbH, Buxtehude/Germany, 2008). The clinker is ground down into a fine powder, and used as a binding product in many types of cement. Because of the economic advantages a cement kiln provides, it is a great way to eliminate the refrigerants while also generating revenue for the cement company (ICF International, Destruction of ODS in the U.S., 2008). We did not look into alternative options for destruction in Costa Rica for one primary reason: the use of an already available destruction facility is much less costly than it would be to construct a new facility (ICF International, Study on the collection and treatment of unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 countries, 2008).

One drawback from using the cement kiln is that it can produce emissions from several different gases, including CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> (Ahling, 1979; Vijgen & McDowall, 2009). The Costa Rican government has been running trials with Holcim and a major refrigerant importer to test the emission levels of Holcim's cement kiln. This is necessary to ensure that the environmental impact of using the kiln does not outweigh the benefits of using it. Thus, levels of certain noxious or environmentally harmful gases were tested and compared to nationally acceptable levels. These trials have been ongoing for some time<sup>8</sup> and there have been three successful trial

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<sup>8</sup> The trials began in June 2014, and we received official news that the trials were complete in April 2015.

runs that include CFCs, HCFCs, and HFCs. We have included the technical results of these trials in Appendices Q-W.

To get an idea of how costly running a destruction operation will be in Costa Rica, we evaluated destruction facilities in the United States. From this evaluation, the Costa Rican government and private sector can gain an approximate prediction of what the costs for destroying refrigerants will be. To put the costs of destroying ODS into perspective; we found it appropriate to include some information on facilities used in the United States. There are less than 10 ozone-depleting substance destruction facilities in the United States. These destruction facilities utilize rotary kilns, cement kilns, lightweight aggregate kilns, fixed hearth units, plasma arc technology, and lightweight aggregate kilns. The total hazardous waste destruction capacity of the United States is 6,188,600 megatons per year. While hazardous waste destruction is not exclusive to ODS, it is important to consider since ODS waste can be, and often is, included when reporting data on hazardous waste in the United States (ICF International, Study on the collection and treatment of unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 countries, 2008). Destruction costs in the U.S. range from approximately \$2.00 to \$13.00 USD per kg of ODS, without considering transportation costs (ICF International, Study on the collection and treatment of unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 countries, 2008). Cost depends on transportation needs, the type of ODS, the composition or purity of the ODS, the quantity of ODS, and the type of container the ODS is stored in.

The costs for transportation vary depending on the transportation method, which is dependent on the quantity of ODS that needs to be transported, and whether or not transportation crosses state lines. A similar cost to transporting over state lines may be applicable to the Costa Rican transportation system due to the tolls that exist on their freeways.<sup>9</sup> ICF International, a reputable consulting agency that has published reports on many different ODS refrigerant evaluations, illustrates the variation in transportation costs well in their 2008 publication *Study on the Collection and Treatment of Unwanted Ozone-depleting Substances in Article 5 and Non-Article 5 Countries*. This consulting agency reports that one U.S. destruction company transporting 86,000 kg of ODS waste in a rail car spends approximately \$800 total in state, while the cost doubles for out of state shipments. A tank truck on the other hand, carrying 19,000 kg of ODS waste can cost upwards of \$700 total for in state shipments. Another destruction company reported that the cost to transport ODS waste ranges from \$0.33-\$0.66 per kg, depending on the type of refrigerant. Yet another company charges \$6.45 per kilometer for transport in a pressurized ISO container – containers made especially to store ODS, which are more costly than non-ISO containers. Alternatively, this same company will lease the tanker for \$1,000 per month with a minimum lease period of 1 year. This transport method of using pressurized ISO containers is the most likely method that will be used in Costa Rica, as this is how most companies stockpile their refrigerants.

Aside from the transportation costs to run a destruction operation, there are technical limitations. The type of ODS destroyed can slow a reaction in a cement kiln due to the presence of chlorine in the ODS, necessitating an increase in operation capacity (Ahling, 1979; personal communication, Agustin Rodriguez). The reaction speed within the cement kiln will increase as

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<sup>9</sup> This information was gained from personal experience.

the concentration of chlorine decreases and decrease as the concentration of chlorine increases. Thus, since CFCs have a greater quantity of chlorine for any given volume of gas than HCFCs, CFCs will be less cost-effective to destroy than HCFCs. This is especially relevant to Costa Rica since a cement kiln is being used for destruction. Destruction facilities are also concerned with limiting the bromine and fluorine feed rates due to corrosion of equipment and emissions limits (ICF International, Study on the collection and treatment of unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 countries, 2008). To alleviate this problem, destruction facilities may upgrade their equipment, but upgrades are usually expensive and not cost effective (ICF International, Study on the collection and treatment of unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 countries, 2008).

The high operation costs from destruction and transportation alone are a barrier to using this type of technology. Even with Costa Rica's small country size they will still have to manage the cost of transporting mass amount of chemicals across the country to a destruction facility. Not only are there hard logistical costs to consider, but there are also regulatory barriers to consider due to safety hazards. As a party of the Basel convention, Costa Rica is required to follow high standards for transporting hazardous waste (Basel Convention, 2011). The government will have to spend time and money to develop a protocol for the transportation of the contaminated refrigerant, since it is considered hazardous waste.

Destruction technology is necessary for the complete elimination of contaminated refrigerants and reclamation byproducts. Although there are high costs and some limitations to using destruction technology, the environmental benefits likely outweigh the limitations, which will become clearer in the final section of this chapter. Destruction of refrigerants is a surefire way the Costa Rican people can guarantee that they are actively preventing environmentally harmful gases from being released into the atmosphere by destroying them before emission is possible. The next steps that the Costa Rican government must take is the overall cost-benefit analysis of the cement kiln operation, since they have already approved the protocols to destroy all three types of environmentally harmful refrigerant gases. With Costa Rica's devotion to the environment, we are confident that the destruction operation will be adopted in full in the near future. In fact, from our personal communication with Agustin Rodriguez of the Chamber of Industry, we learned that the operation will likely be up and running within about a year's time.

#### ***4.2.2.3 Reclamation Technology***

When contaminated refrigerants can be reclaimed instead of destroyed, it is usually more cost effective to reclaim them. Reclamation is also an option that can be used by companies independent of the government run destruction facility. In non-technical terms, refrigerant can be reclaimed when results of an initial chemical analysis indicate contaminants are not too high for reclamation technology to purify the refrigerant to a high enough standard. The reclamation process purifies recovered refrigerants to either AHRI 700 or ISO 12810 standards, which simplified means that the refrigerant is of high enough purity grade to be used in the same way that virgin refrigerants are used (The Alliance for Responsible Atmospheric Policy, 2007). Currently, the lack of reclamation technology is adding to the need to stockpile refrigerants that the lack of destruction technology has already made inevitable. Some companies do have recycling technology, but often recycling does not allow for re-use in newly sold equipment. In fact, it is required in the U.S. that newly sold equipment only contain reclaimed refrigerant (U.S. EPA, Refrigerant Reclamation Ozone Layer Protection - Regulatory Programs, 2014). In the

worst-case scenario, Costa Rican companies will illegally release refrigerants from old equipment to recycle parts, since there is no reclamation solution.

The Costa Rican private sector has yet to integrate reclamation technology into the HCFC phase-out plan. There is warranted resistance from these companies, citing cost issues with buying new technology. In addition, many companies have not thoroughly researched reclamation technology, either due to time constraints or lack of regulatory incentive. Here, we provide several examples of possible equipment that could be used in a given company, based on the sector each piece of equipment can be used in. It should be made clear that this analysis does not serve to provide the ideal piece of equipment for any given company or sector, but is rather an evaluation of the equipment available on the global technology market with an analysis of the costs and savings any given equipment would entail. We do provide suggestions as to which pieces of equipment would be better suited for larger or smaller companies, or for air conditioning or refrigeration companies, but these pieces of equipment are not necessarily the ideal choice for any given company. They serve more as an example of the type of savings and costs accrued for the acquisition of this technology.

To make this equipment more attractive to the private sector, we have included only equipment that can work with HCFCs, HFCs, and in some cases CFCs. We found the inclusion of equipment that can manage a variety of refrigerants imperative. Such equipment can also be used to help to recover CFCs in old equipment, especially in domestic refrigerators. Just as importantly, the inclusion of equipment that can use HFCs such as R-410A and R-134a would allow companies to use the equipment post-HCFC phase-out, further increasing the chances of equipment adoption by refrigeration and air conditioning companies.

To allow for a proper evaluation of the equipment by interested companies, we have provided the specifications available for each piece of equipment. This information will/would allow companies to decide which piece of equipment would best suit their needs, and also gives them an opportunity to see the range of abilities of the equipment available on the market. Importantly, we have made our best effort to provide, calculate, or estimate energy costs of the equipment based on power input. Where information on power input was not available, power supply information was used, given the voltage and amperage of the unit to yield how many watts the equipment uses. We used the following equation to calculate power usage:

$$V * A = W \text{ (for monophasic equipment)}^{10}$$

We found that the Serv-I-Quip RC series was comparable in capacity, at least for smaller models of the Serv-I-Quip RC series, to the Eco Cycle RC series and is marketed in a similar manner. The Reco520S equipment is also comparable to the EcoCycle RC series in recovery rates. Thus, we have estimated the power input of the Eco Cycle RC series to be between the Serv-I-Quip series and the Reco520s equipment. In another case, where power supplies were similar, but the power input was only given for one of the pieces of equipment, the power input was estimated to be the same. This is the case for the Cyclepak Model 2090, which has available power input and

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<sup>10</sup> Where V = volts, A = amps, and W = watts. It should be made clear that for larger equipment, the power usage is multiphasic, which would require a slightly more complex equation. For simplicity, we have used this equation, and thus it provides more of an estimate of the power usage. Where the amperage values were not available, the power usage was estimated based on the scale of the equipment.

supply values, and the RCC-8A which has only power supply information available, without any amperage value (see Table 1).

We were forced to give equipment price estimates to the best of our ability based on comparing this equipment to other equipment that had similar specifications (Niazi, Dai, Balabani, & Seneviratne, 2006, p. 564). We estimated the cost of the Serv-I-Quip RC series equipment and the Eco Cycle RC Series. This was based in part on the cost of the RCC-8A equipment, since this was the largest piece of equipment we had a price for. Thus, the Serv-I-Quip RC series equipment had to be greater than \$1,000 (the price of the RCC 8A), and we capped the price at \$100,000, as we estimated the cost to be around the price of demanufacturing equipment with similar dimensions to the Serv-I-Quip machine. We also spoke with Agustin Rodriguez at the Chamber of Industry of Costa Rica for his expert opinion on our estimations. We estimated the price range of Eco Cycle RC series based on both the RCC-8A cost and the recovery rates given. The recovery rates were less than half of what the Serv-I-Quip equipment was, so we adjusted the range proportional to this. We could not find a precedent for making a cost estimation of the purchasing the equipment, so after personal communication with an economics professor at our home university, we decided to estimate the purchasing cost to the best of our ability.

#### *4.2.2.4 Economic Costs of Reclamation Equipment*

The costs associated with acquiring the equipment can be found in the two tables below. Table 1 shows two equipment examples that can be found outside of Asia. One is for larger capacity reclamation (Serv-I-Quip), and the other is for smaller capacity reclamation (Cyclepak). Table 2 shows three examples of equipment that can be found in either Japan or China, and are examples of equipment that can be used for either large refrigeration systems, such as industrial or commercial systems, or for domestic refrigeration and a/c units. Although the RCC-8A unit requires modifications for use in home and domestic refrigerators, it purifies refrigerants to AHRI 700 standards, whereas it is not clear if the Reco520S does, but from the product description, it does not use a distillation process. Rather, the Reco520S uses a filter drier, which usually entails recycling, which would yield a product that is not of a high enough purity grade. Thus, the Reco520S equipment cannot be used for reclamation with confidence. The inclusion of the Serv-I-Quip and Cyclepak equipment allows us to compare the costs and parameters of equipment that companies already have with new equipment that they could purchase. This serves to provide an approximation of how feasible it is to purchase the reclamation equipment for the companies interested in purchasing it.

Individual companies that use refrigerants would be buying this equipment themselves. The general consensus among all companies in the refrigeration and air conditioning sector, which includes domestic, commercial, and industrial subsectors, is that their stockpiled refrigerant cannot be reused because recycling methods do not suffice. To show how cost-effective the reclamation technology actually is, we used the price of each refrigerant listed in Table 3 to calculate how many canisters would need to be reclaimed to make up for the cost of the equipment. A canister of HCFC-22 costs around \$350, and is only expected to increase, and with the energy costs for reclamation as little as a fraction of a cent, and the greatest at a little more than \$2.00, with each canister reclaimed, a given company can expect to see hundreds of dollars in savings per canister. It's not long before financial savings amount to thousands of dollars. We did not take into account CFC-12 due to the fact that it cannot be re-used. At most, the amount of canisters of R-22 required to pay for the estimated cost of the most expensive equipment (Serv-I-



Quip) would be around 288 canisters in all. Depending on how many hours it takes to complete the job, which is also dependent on the type of equipment used, this could take days or months to reach. This is just under two years' worth of canisters that one company is estimated to have in the Costa Rican private sector.

We are aware that the amount of canisters of HFC-134a needed to be reclaimed to make a return on a company's investment is over 1000 canisters. However, one need only consider the lowest quantity of canisters to make up the cost of purchasing the equipment. It does not matter whether the company chooses to reclaim both HCFC-22 and HFC-134a right away at the same time, so long as they reclaim at most 288 canisters of HCFC-22, since this will make up for the cost regardless. It may take less than 288 canisters, should they reclaim the other refrigerants at the same time, but it may take longer to receive the return on investment than reclaiming solely HCFC-22, since it takes about 4 canisters of HFC-134a to reclaim refrigerant of an equal price to HCFC-22. This ratio is based on the amount of canisters of HCFC-22 (288) it takes to achieve a return on investment of the equipment versus HFC-134a (1158). This should not be a problem, however, since HCFC-22 is the refrigerant that is mainly being stockpiled, along with CFCs. After the return on investment, the economic savings are incredible.

Name	Serv-I-Quip RC series		Cyclepak Model 2090
Function	Recovery and Reclamation		Reclamation
*Recovery Rate (lbs./min)	0.96-13.5		N/A
Dimensions	74"H x 60"W x 72"D		290 L x 275 W x 362 H mm
Company	Serv-I-Quip		Refco Manufacturing Ltd.
Refrigerants	R-134A, R-22, R-502, R-410A		R-12, R-22, R-134a, R-500, R-502
Price	Est. \$1,000-\$100,000		\$377.99 (used-eBay)
Power Supply	480V/3Ø, 60 A		100v/60Hz
Power Input	Calc. 28.8 kW		650W
ENERGY COSTS per 30 lb. canister (USD)	\$0.21-\$3		\$0.12*using 0.55 as the reclamation rate
Country of Origin	United States		Switzerland
Notes	Requires chilled water supply, large capacity; four different models: 0915, 3950, 4950, 5950		Must be used in tandem with a recovery unit; for smaller companies
Canisters reclaimed to repay equipment cost:	Min. cost of eq. R-22: 3 R-134a: 12 R-410A: 9	Max cost of eq. R-22: 288 R-134a: 1158 R-410A: 931	R-22: 1 R-134a: 4

**Table 1. Equipment Costs and Specifications: United States and Switzerland.** \*Recovery rates depend on type of refrigerant, the compressor inlet (if it can be changed) and whether the recovered refrigerant is liquid, vapor, or is being recovered using the push-pull method. If the information was available for liquid, vapor, or push-pull rates, it is indicated. Otherwise, the type of recovery used within the equipment could not be found. (Asada Co., Ltd.) and (Serv-I-Quip).



Name	Eco Cycle RC 500, 1000, 2300		RCC 8A	RECO520s	
Function	Recovery/Reclamation		Recovery/Reclamation	Recovery/Recycling	
Pull/Push Rate (lbs./min)	N/A		N/A	24	
Vapor Recovery Rate (lbs./min)	N/A		0.55	1.1	
Liquid Recovery Rate (lbs./min)	1.15, 2.3, 5 (for respective models)		N/A	8	
Dimensions	530 L x 610 W x 1,000 H mm; 610 L x 711 W x 1,143 H mm; 610 L x 711 W x 1,524 H mm		700 L x 630 W x 1230 H mm	485 L x 220 W x 365 H mm	
Company	Asada		Tektino	Guangzhou Zhigao Freeze Equipment Limited Co.	
Refrigerants	R404A, R507A, R412A, R509A, R12, R22, R500, R502, R134a, all CFCs, HCFCs, and HFCs		R410A, and more	R12, R134a, R401c, R40, R22, R401a, R401b, R407c, R407d, R408a, R409a, R411b, R412a, R502, R509, R402a, R404a, R407a, R410a, R507	
Price	Est. \$1,000-\$50,000		\$1,150 (personal communication with Chloe Yuan)	\$400-\$750 (Alibaba.com)	
Power Supply	Made to order		110V/60Hz	220V/50Hz 6A	
Power Input	Est. 1-30 kW		Est. 650 W	Calc. 1.32 kW	
ENERGY COSTS per 30lb canister (USD)	Est. (min): \$0.09, \$0.04, \$0.02 Est. (max): \$2.70, \$1.20, \$0.60		Est. \$0.11	Est. P/P: \$0.005 V.R.: \$0.11 L.R.: \$0.01	
Country of Origin	Japan		China	China	
Notes	Distillation; for large chiller and a/c systems		Requires some part alterations for use in refrigerators and a/c	Automotive air conditioning, home air-conditioning, central air conditioning and cold storage repair system	
Canisters reclaimed to repay equipment cost:	Min eq. cost R-22: 3 R-134a: 12 R-410A: 9	Max eq. cost R-22: 144 R-134a: 570 R-410A: 464	R-410A: 11	Min eq. cost R-22: 2 R-134a: 5 R-410A: 4	Max eq. cost R-22: 3 R-134a: 9 R-410A: 7

**Table 2. Equipment Costs and Specifications: China and Japan.** (Asada Co., Ltd.; Launch UK: Pioneering Technical Solutions in the after market; Guangzhou Zhigao)

Refrigerant	Price of Canister (30 lbs.)
HCFC-22	\$350
CFC-12	\$800
HFC-134a	\$89
HFC-410a	\$110
CO <sub>2</sub>	-----

**Table 3. Costs of Refrigerant.** ; Costs- R-22: amazon.com, R-12-ebay.com, R-134a-samsclub.com, R-410a-refrigerantguys.com

#### 4.2.2.5 Acquisition of Technology

It is possible that refrigeration and air conditioning companies throughout the refrigerator and air conditioning sector do not have funding to begin this project, especially smaller companies that do not see profits above six figures in one year. This is especially true if smaller companies find that it is necessary to buy a piece of equipment with a purchasing cost upwards of \$10,000. Even larger companies may prefer funding help to invest in reclamation technology so they can minimize their initial investment. Funding aid is likely not necessary for a company that decides that their capacity is suited for one piece of equipment costing only hundreds of dollars. In any case of using a loan or line of credit to purchase technology, the interest accrued will need to be taken into account for the overall cost of implementation.

After speaking with three different organizations about funding, we have concluded that either a non-profit organization such as Fundecooperacion, or a bank such as BAC in Costa Rica, are viable options for a company seeking financial help in deploying this technology. Fundecooperacion indicated their interest in aiding projects such as refrigerant recycling, and have worked with companies like the Costa Rica Recycling Network in Cartago. Fundecooperacion has worked on several recycling projects in Costa Rica, and has funded projects costing up to \$150,000, thus any one of these pieces of equipment would qualify for funding by Fundecooperacion. From our correspondence with a Fundecooperacion representative, we learned that this organization would enjoy participation in a new area of environmental projects. The project would likely be funded by a revolving line of credit in which the debtor can pay periodically. Fundecooperacion's familiarity with recycling projects could provide an advantage for the companies requiring funding, since this organization is aware of the common hurdles with funding recycling projects.

A bank like BAC would be a viable option due to their ISO accreditation and their participation in refrigeration projects. This bank has formerly provided loans for equipment retrofitting and for air conditioner exchange programs, in which a less efficient air conditioner is exchanged for a more efficient air conditioner. The bank also has a program in place to deal with environmental projects called PYMES. This program allows for greater specialization and expertise in funding environmental projects. PYMES provides consulting for each company they work with to ensure the project moves along smoothly. Their familiarity with refrigeration and air conditioning companies allows for some more reliability on behalf of the companies we are suggesting this technology to, and their PYMES program would assure that the proposed program would be viable for the company in question, ensuring success.

#### *4.2.2.6 Refrigerator Recycling – The Costs and Benefits*

Apart from having destruction and reclamation options for refrigerants, responsible disposal of refrigerators must be pursued to bring Costa Rica up to par with its fellow parties of the Montreal Protocol. We have already given a proposal for infrastructure that should be developed based on our evaluation of several different countries in Appendix X. The benefits and costs of this infrastructure is beyond the scope of this analysis, as we are primarily focusing on how the private sector can become more environmentally sustainable in accord with the mission of the Chamber of Industry of Costa Rica. However, we recommend that the government of Costa Rica seek funding for a refrigerator recycling program both to aid the private sector in acquiring refrigerator recycling technology, which is discussed in the following section, and to fund the development of the program itself. In addition, should the acquisition of this technology prove to be infeasible for the private sector based not only on available resources, but logistical considerations such as the size of this technology, transportation, and collection programs, the government of Costa Rica may need to take most, if not all, of the responsibility for this project. For example, should the largest refrigerator manufacturer in Costa Rica claim that such a refrigerator recycling facility is beyond the capacity of their warehouses, there are two options. The first is to modify the warehouse such that the equipment can be installed. This would require additional financial investment on behalf of the company. This option is unlikely to be willfully chosen by a company facing this obstacle, as it would take much time, effort, and money to complete such a project that candidly, when these companies currently do not have an interest in funding in the first place. The second option would be for the government of Costa Rica to take charge and build a facility that would house this equipment. Of course, the goal of this analysis is to convince both the private sector and the government that investing in this technology as partners is worth the cost. We cannot, however, provide false or biased results in favor of or against implementation, which is possible when making cost estimations. To this end, we have done our best to include hard economic data when available, so that we are providing solely fact-based information unperturbed by any one individual's opinion, such as a government official or a company representative.

From implementing a refrigerator recycling program itself, there are economic savings to be had, such as the energy efficiency savings the consumer experiences from exchanging a new refrigerator for an old refrigerator, as discussed in section 4.2.1. Environmental benefits are also a huge factor, considering that most old refrigerators, especially those manufactured before 1998, contain CFCs in Costa Rica.<sup>11</sup> Aside from benefits that the overall implementation of a refrigerator recycling program, the recycling of refrigerators themselves have financial benefits. Parts from the refrigerator contain aluminum, copper, stainless steel, plastic, and polyurethane foam can be recycled and sold for a profit. The refrigerant can also be reclaimed using the technology previously discussed, from which the manufacturer can profit, since the manufacturer of refrigerators usually has to import refrigerant to charge the refrigerator. After taking into account the cost of operators and energy costs, we were able to calculate a profit of around \$40 per refrigerator, not including the savings from reclamation.<sup>12</sup> The maximum amount of refrigerators that need to be recycled before a return on investment is met is about 28,000 refrigerators total. Working at minimum capacity for 24 hours straight, it would take the given

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<sup>11</sup> We gathered this information from our interviews with the private sector.

<sup>12</sup> We consulted Agustin Rodriguez to check that our prices for the materials recovered based on U.S. prices were approximate to what the prices are in Costa Rica to assure this number was accurate enough to include.

piece of equipment (QZ 2500 HD) about 13 days to recycle the 28,000 refrigerators. In Costa Rica, there are approximately 50,000 refrigerators disposed of every year. Any one of these pieces of equipment could thus fulfill the need for refrigerator recycling. The main obstacle to implementing this program is the logistics of a project such as this. Transportation arrangements and costs must be met, and the proper infrastructure must be in place to collect, transport, and ultimately recycle the refrigerators, which we have proposed a general scheme for in section 4.2.1. The actual recycling must take place in a facility equipped to handle such large pieces of equipment, and a new warehouse may have to be built in order to house the equipment.

Name of Equipment	MXII Waste Refrigerator Recycling Machine	RF-1	RF-2	RF-3
Specialized Use	waste refrigerators, air conditioners, washing machines	waste refrigerators (commercial included), waste TV	waste refrigerators (commercial included), waste TV	waste refrigerators (commercial included), waste TV
Capacity (units/hour)	10 to 15	15 to 20	40.00	60.00
Material recovered	polyurethane, copper, aluminum, iron, plastic	polyurethane foam, steel, non-ferrous metal, plastic	polyurethane foam, steel, non-ferrous metal, plastic	polyurethane foam, steel, non-ferrous metal, plastic
Price of Equipment (USD)	\$331,366.00	Est. \$500,000.00	Est. \$750,000.00	Est. \$1,000,000.00
Equipment Power (kW)	100.00	120.00	260.00	500.00
Dimensions	23000 X 12000 X 5000mm	200 sq.m.	320 sq.m.	500 sq.m.
Power Supply	AC 380V/50Hz, 200KVA	AC 380V/50Hz, 200KVA	AC 380V/50Hz, 200KVA	AC 380V/50Hz, 200KVA
Company	Jiangxi Mingxin Metallurgy Equipment Co.,Ltd	Hunan Vary Tech. Co. Ltd.	Hunan Vary Tech. Co. Ltd.	Hunan Vary Tech. Co. Ltd.
Energy Costs per hour (USD)	\$20.00	\$24.00	\$52.00	\$100.00
**Energy Cost per refrigerator (USD)	\$2.00	\$2.40	\$2.60	\$2.50
*** Operators	5.00	5.00	6.00	8.00
****Total Costs of Operators/refrigerator (USD)	\$3.18	\$0.79	\$0.64	\$1.27
Refrigerators Recycled to Meet Costs	7972	11481	17238	23270
Benefits per refrigerator After ROI	\$41.59	\$43.57	\$43.53	\$42.99
Equipment	China	China	China	China

<b>Country of Origin</b>				
<b>Source</b>	<a href="http://www.alibaba.com/product-detail/Scrap-recycling-machine-Waste-refrigerator-recycling_674552094.html">http://www.alibaba.com/product-detail/Scrap-recycling-machine-Waste-refrigerator-recycling_674552094.html</a>	<a href="http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html">http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html</a>	<a href="http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html">http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html</a>	<a href="http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html">http://vary.en.alibaba.com/product/360844063-213155031/Fridge_Recycling_Equipment.html</a>
*Estimations based on estimated prices for RF-1 to 3 given on Hunan Vary Technology Site, and is based on capacity.				
**Energy costs calculated for one hour then for one refrigerator based on lowest capacity in units per hour to compare to savings. Costa Rican energy prices used to calculate energy costs.				
***Estimations based on information available for Hunan Vary Tech. equipment				
****Based on average salary of Licenciatura degree workers making approximately \$1101/month, or \$13,220/year then calculated for all operators per hour working 40 hours per week 52 weeks of the year				

**Table 4. Refrigerator Recycling Equipment from China**

<b>Name of Equipment</b>	<b>QZ 900</b>	<b>QZ 1200</b>	<b>QZ 1600 HD</b>	<b>QZ 2000 HD</b>	<b>QZ 2500 HD</b>
<b>Specialize Use</b>	waste refrigerators, all types, and several other applications	waste refrigerators, all types, and several other applications	waste refrigerators, all types, and several other applications	waste refrigerators, all types, and several other applications	waste refrigerators, all types, and several other applications
<b>Capacity (units/hour)</b>	20 to 30	20 to 30	30 to 40	50 to 70	90 to 120
<b>Material recovered</b>	polyurethane, stainless steel, iron, sheet metal, aluminum, copper, plastic, etc.	polyurethane, stainless steel, iron, sheet metal, aluminum, copper, plastic, etc.	polyurethane, stainless steel, iron, sheet metal, aluminum, copper, plastic, etc.	polyurethane, stainless steel, iron, sheet metal, aluminum, copper, plastic, etc.	polyurethane, stainless steel, iron, sheet metal, aluminum, copper, plastic, etc.
<b>Price of Equipment (USD)</b>	Est. \$750,000.00	Est. \$750,000.00	Est. \$900,000.00	Est. \$1,000,000.00	Est. \$1,250,000.00
<b>Equipment Power (kW)</b>	75.00	90.00	160.00	250.00	315.00
<b>Dimensions</b>	N/A	N/A	N/A	N/A	N/A
<b>Power Supply</b>	N/A	N/A	N/A	N/A	N/A
<b>Company</b>	ANDRITZ MeWa GmbH	ANDRITZ MeWa GmbH	ANDRITZ MeWa GmbH	ANDRITZ MeWa GmbH	ANDRITZ MeWa GmbH
<b>Energy Costs per hour (USD)</b>	\$15.00	\$18.00	\$32.00	\$50.00	\$63.00
<b>**Energy Cost per refrigerator (USD)</b>	\$0.75	\$0.90	\$1.07	\$1.00	\$0.70
<b>***Operators</b>	6.00	6.00	8.00	8.00	10.00
<b>****Total Costs of Operators/refrigerator (USD)</b>	\$1.91	\$1.91	\$1.69	\$1.02	\$0.71
<b>Refrigerators Recycled to Meet Costs</b>	17011	17069	20462	22357	27570
<b>Benefits per refrigerator After ROI</b>	\$44.11	\$43.96	\$44.00	\$44.75	\$45.36

Equipment of Origin	Country	Germany	Germany	Germany	Germany	Germany
Link						
*Estimations based on estimated prices for RF-1 to 3 given on Hunan Vary Technology Site, and is based on capacity.						
**Energy costs calculated for one hour then for one refrigerator based on lowest capacity in units per hour to compare to savings. Costa Rican energy prices used to calculate energy costs.						
***Estimations based on information available for Hunan Vary Tech. equipment						
****Based on average salary of Licenciatura degree workers making approximately \$1101/month, or \$13,220/year then calculated for all operators per hour working 40 hours per week 52 weeks of the year						

**Table 5. Refrigerator Recycling Equipment from Germany**

Material	Value (USD/lb.)	Quantity in 1 refrigerator (lbs.)	Price per refrigerator (USD)
copper	\$2.2	9*	\$19.80
aluminum	\$0.5	9*	\$4.50
stainless steel	\$0.065	123	\$8.00
ferrous metal	\$0.1	9*	\$0.90
ABS plastic	\$0.47	25	\$11.75
polyurethane	\$0.18	10	\$1.80
<b>Total Weight of 1 refrigerator:</b>		209**	
<b>Total Savings/refrigerator</b>			\$46.745
<i>*Assuming that the metal besides steel is evenly divided</i>			
<i>**This includes the compressor, without the compressor a refrigerator is about 175 lbs.</i>			

**Table 6. Cost of Recyclable Material from Refrigerators**

***4.2.2.7 Acquisition of Funding for the Refrigerator Recycling Program, including Refrigerator Recycling Equipment***

To fund a project as large as this refrigerator recycling program, we urge the Costa Rican government to seek help using the domestic voluntary carbon market in Costa Rica (DVCM), GIZ, or the Clean Development Mechanism of the Kyoto Protocol. Because much of the funding allocated for Costa Rica through the Multilateral Fund has been used, it is likely not a viable option for this project. The DVCM of Costa Rica may be a viable option since the project would offset the emission of greenhouse gases. The only, albeit major, issue with using the DVCM in Costa Rica is that it is not yet fully developed. Because of this, we have fleshed out other refrigerator recycling projects that have gone through the GIZ, other countries' DVCM, and the Clean Development Mechanism, which we hope will inform the government and the private sector about how to fund the refrigerator recycling project in Costa Rica through the Costa Rican DVCM.

The German international organization, GIZ, could help fund a refrigerator recycling project through their Proklima program. The GIZ already works with the CICR and other governmental organizations in Costa Rica, so it may be an accessible organization to work with on this project. A refrigerator recycling project through the GIZ in Brazil has already begun and is still operating. In 2008, Brazil had over 50 million old household refrigerators that were inefficient and contained CFCs. This caused the Brazilian government to focus on recycling domestic refrigeration equipment in their country. As Brazil began to take on this problem, they realized that they needed to look for outside help to fix it. The GIZ stepped in and developed a plan in 2008 to create a pilot plant in Brazil for the recycling and recovering of CFCs from approximately 350,000 refrigerators annually. The annual reduction of CFC-11 was then calculated to prevent 138 ODP tons and 890,000 tons of carbon dioxide (GIZ, n.d.; Fischer V., 2011). The Querstromzerspaner (QZ) machine, one of the examples included in our cost-benefit analysis, was purchased from a German company called ANDRITZ-MeWa to recycle the refrigerators (Roberts T., n.d.).



There are two different cases in Brazil where the funding for the Querstromzerspaner (QZ) machine was provided by a foreign organization. The GIZ sponsored project had a budget of 5,000,000 €, approximately 5.4 million USD, for the entire implementation of the refrigerator recycling program (GIZ, n.d.). The installation, full-service delivery, on-site training for the refrigerator recycling plant, and the cost of equipment cost 3.5 million €, or approximately 3.9 million USD (Franziska Froelich, GIZ, personal communication). The German Federal Ministry funded this project as a part of Germany's International Climate Initiative to help countries reduce their environmental impact. Thus, Costa Rica could likely use the GIZ and the funds of the German Federal Ministry for implementing their own refrigerator recycling program, and use this project as an estimation of the costs of implementing a refrigerator recycling program in Costa Rica. In fact, the refrigerator recycling program will likely cost less than the program in Brazil, since Costa Rica does not dispose as many refrigerators annually as Brazil.

The other refrigerator recycling plant in Brazil was funded through a Swiss organization called Fair Recycling through a partnership with Industria Fox, a Brazilian refrigerator recycling company. Fair Recycling sells carbon credits in the Swiss industrial sector and repurposes the profits directly into Industria Fox to recycle refrigerators in Brazil (Fair Recycling, n.d.). These carbon credits are rooted in the Swiss carbon market, which follows the standards of the Clean Development Mechanism, which will be discussed shortly. Both funding mechanisms rely on assistance from a foreign country to intervene and provide support, and Costa Rica could receive funding for a refrigerator recycling program in the same way.

There are lessons to be learned from Brazil's refrigerator recycling programs. One of the major flaws in Brazil's program was the lack of consideration of the major geographical barriers in transporting the refrigerators. It could take up to three days by truck to move only approximately 15-30 refrigerator units (Fischer V., 2011). This slow transportation time did not provide the recycling facility with enough units to be economically viable. Thus, the capacity of the refrigerator recycling plant<sup>13</sup> was much greater than the quantity of refrigerators received. The benefit of implementing a refrigerator recycling program in Costa Rica is that Costa Rica is less than 1% the size of Brazil, and its population size is significantly smaller (Central Intelligence Agency, 2015). Thus, the transportation barrier for refrigerator recycling is not expected to be as great.

As a party of the Kyoto Protocol, Costa Rica could take advantage of the international carbon market, utilizing The Clean Development Mechanism (CDM). The use of the CDM would require a sponsorship of sorts. This sponsorship entails having a private entity of an Annex I, or developed country that has signed the Kyoto Protocol, pay for the project through a private entity in Costa Rica so that they can benefit from the carbon credits gained from preventing emissions of greenhouse gases. Thus the first step in this process would include having to seek out a company in an Annex I country to work with a Costa Rican company on the refrigerator and recycling program, much like the Fair Recycling and Industria Fox partnership in Brazil. The CDM could possibly be used for the refrigerator recycling program since it addresses the recovery HFC from domestic refrigerators, which have been used in domestic refrigerators in Costa Rica since 1998. Several methodologies have already been developed by the United Nations Framework Convention on Climate Change to address HFC use and methodology AMS-

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<sup>13</sup> The amount of refrigerators that a recycling plant can recycle in a given time

III.X. could apply to this program. The typical projects associated with methodology AMS-III.X. include “replacement of existing, functional domestic refrigerators by more- efficient units and recovery/destruction of HFCs from refrigerant and foam.” Thus, should the government and/or companies be able to prove that the HFCs are recovered and re-used or destroyed, this project may qualify for the Clean Development Mechanism. Aside from using the CDM itself, the Costa Rican DVCM could adopt the methodology and the government could implement the project in its entirety through the DVCM.

The refrigerator recycling project could be paired with either further development of the destruction facility in Costa Rica and the reclamation technology deployment project or both, should the compilation of these projects prove to be a better fit for this methodology than any one project alone. The use of the CDM – or the CDM methodology in the case that the DVCM takes over the project— may also be able to provide incentive for companies toward what is considered the next component of this proposal, which is replacement of high GWP and ODP refrigerants with natural refrigerants by providing financial help if they agree on a complete switch to natural refrigerants within a year of the start of the project. One of the conditions under which the methodology is applicable includes that the refrigerator replacements contain refrigerants and foam blowing agents having no ODP and a GWP lower than 15. Currently, the majority of refrigerators in Costa Rica already contain cyclopentane as foam blowing agents. The next step would be to switch to a natural refrigerant in the cooling system, which the major manufacturer of domestic refrigerators in Costa Rica is already considering.

#### **4.2.3 Component 3: The Switch to Natural Refrigerants**

The refrigeration and air conditioning sector in Costa Rica must slowly switch to natural refrigerants so that their impact on the environment is minimal. This component is largely qualitative, based on a review of the current literature and our interviews.<sup>14</sup> The Chamber of Industry of Costa Rica has been searching for refrigerant alternatives for refrigeration and air conditioning companies so their members can replace HCFCs. Many refrigeration and air conditioning company representatives in Costa Rica claimed in our interviews that the technology to use natural refrigerants is not available; however, although the equipment may not be immediately available in Costa Rica, there is equipment available on the global market.

As such, we researched Japan’s use of natural refrigerants and sale of equipment utilizing natural refrigerants. Japan possesses state-of-the-art refrigeration equipment utilizing HFCs and natural refrigerants. Many of the world’s eco-friendly refrigerant manufacturers and importers are of Japanese origin and much of their technology available on the market is completely reliant on HFCs (such as R-134a and R-407) and natural refrigerants (such as ammonia, propane, and carbon dioxide). REI-TECH’s AHT Cooling Systems Showcase<sup>15</sup> is a commercial freezer that utilizes R-290. This freezer contains a variable speed compressor, reducing high electrical consumption and pollution—and it is user friendly. Additionally, there have been over 530,000 energy-saving units sold all over the world by REI-TECH. And, since 2014, sales for these Plug-in hydrocarbon showcases have increased by 35% annually depicting its rise in popularity

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<sup>14</sup> An analysis of the economic costs and benefits of the entire private sector switching to natural refrigerants would require knowledge on retrofitting several different systems including industrial, commercial, and domestic refrigeration and air conditioning units, and is beyond the scope of this proposal.

<sup>15</sup> A showcase is a type of freezer, one that has its doors parallel to the ground so that the consumer can peer into the freezer through the top.

(Tatewaki, 2015). This Japanese company and its equipment serve as an example of the rising popularity in use of natural refrigerant containing equipment around the world. To add to the concept that natural refrigerant use is being adopted around the world, an organization called Greenpeace reports that “Since March 15, 1993, when the first GreenFreeze [natural refrigerant using] refrigerator rolled off the assembly line, 300 million units have been sold in Europe, Russia, Asia and South America by leading brands including Whirlpool, Bosch, Panasonic, LG, Miele, Electrolux, and Siemens” (Carbajal, n.d.).

Costa Rican refrigeration and air conditioning company representatives expressed in interviews that one of the largest barriers to using natural refrigerants, aside from the lack of available technology, is the high cost of replacing current equipment with equipment that is compatible with natural refrigerants. Should a financial barrier exist that exceeds the capability of any one company to replace equipment with natural refrigerant using equipment, the CDM, or its methodologies can be used. The domestic refrigeration market could possibly utilize the previously discussed CDM, and the commercial and industrial refrigeration market could use methodology AM0060 (UNFCCC & CDM Executive Board, 2008; Federal Ministry for Economic Cooperation and Development & GIZ Proklima, 2008). This methodology could essentially be used to retrofit the equipment in commercial and industrial refrigeration companies in Costa Rica.

Aside from the funding options available for companies to overcome financial limitations, refrigeration and air conditioning companies can expect to see financial gains from switching to natural refrigerants. Currently, the price of energy is expensive in Costa Rica, so Costa Rican citizens and businesses do all they can to limit the amount of energy they use. For businesses that use several automated processes, it is very difficult to lower energy consumption. This is especially true for businesses that use large-scale refrigeration systems. In fact, industry leaders such as the CICR have been cited before claiming that the energy prices in Costa Rica are hurting the industrial sector (Arias & The Tico Times, 2014). Energy costs from refrigeration makes up a large portion of companies’ overall energy costs. It is estimated that in ice cream production, 70% of all energy costs are from refrigeration; for cold storage, this number jumps up to 90% (The Carbon Trust, 2011). This is a significant amount of money that is being spent on refrigeration each and every day. If any of these new natural refrigerant technologies saves energy, then the monetary savings could be great and would thus motivate companies to make the change out of their own self-interest.

Ammonia and hydrocarbons (propane and butane) are the most efficient refrigerants in use today. They are up to 5% more efficient than R-22 (Hansen, 2000), but until recently have consumed more energy than HCFC and HFC based refrigerants due to the need for indirect heating for these natural refrigerants. Fortunately, technological improvements have been made in recent years that have vastly improved the efficiency in indirect cooling systems. In fact, the use of natural refrigerants can be up to 40% more efficient than the use of HFCs (Carbajal, n.d.). This means that the use of natural refrigerants is not only environmentally beneficial, but can also directly cut costs by lowering energy consumption. A chart of natural refrigerant replacements for the refrigeration sectors can be seen in Figure 1. This chart was developed by MINAE-DIGECA to show companies that there are natural refrigerants currently being used in every refrigeration process. This is important for refrigeration companies, since 70+% of their

costs are spent on the refrigeration process, the 5% extra efficiency from natural refrigerants could save a large company thousands of dollars a year.

**ALTERNATIVAS SOSTENIBLES Y AMIGABLES CON EL AMBIENTE PARA (CASI) TODAS LAS APLICACIONES Y REGIONES**

AC móvil	Refr. doméstica	Refr. comercial	Refr. industrial	AC	Espumas
CO <sub>2</sub> , HC	HC	CO <sub>2</sub> , NH <sub>3</sub> , HC	NH <sub>3</sub> , HC	HC, NH <sub>3</sub>	CO <sub>2</sub> /HC, Renewable

Una atmósfera saludable es el futuro que queremos...

**Figure 4. MINAE-DIGECA presentation slide of natural refrigerant replacements.** Translation: Sustainable Alternatives and Friendly with the environment for (almost) all applications and regions. (Ministerio de Ambiente y Energía, 2014)

Energy efficiency savings are not only important for the refrigeration and air conditioning companies to save money in the future, but these savings also present a route of funding besides those of the CDM. A company in Costa Rica called Ener-G is an Energy Service Company with a business plan based around the implementation of energy efficiency projects. Ener-G could potentially sponsor natural refrigerant retrofitting project, and has done so in the past. Ener-G is a funding option that companies in Costa Rica should be aware of as the pressure to switch to natural refrigerants intensifies, as it is expected to.

The only other alternatives to natural refrigerants available are HFCs which are highly harmful to the environment, and are likely to rise in cost given their phase-down in many countries, just as HCFC phase-out has caused the rise in price of HCFC canisters. Costa Rica will likely begin to impose regulations on HFCs, like many other countries, since the public sector is adamant about the switch to natural refrigerants. This sentiment is something that we learned through our

interviews with the public sector. The Costa Rican government can take direction from countries such as members of the EU to phase-down HFC use. Towards the end of 2014, the European Union (EU) expanded fluorinated greenhouse gas (F-gas) regulations to include annual sales reporting and import quotas. Many newly enacted regulations in the EU are focused on promoting natural refrigerant technologies (Department of Environment, Food & Rural Affairs, 2014). Because of newly imposed quotas on HFCs and other F-gases, the availability of HFCs in the EU market is projected to decrease by 79% between 2015 and 2030, and HFCs are becoming increasingly expensive (Department of Environment, Food & Rural Affairs, 2014). To ensure that the private sector feels the same pressure to phase-down HFC use and to use natural refrigerants instead, the Costa Rican government should consider enacting similar regulations. Besides the quotas the EU have imposed, the EU has set up an HFC registry to monitor the phase-down. This requires any producer or importer with an existing total or partial quota to supply HFCs to the EU market to register the quantity imported or produced, including HFCs imported from outside of the EU to assure that no novel HFCs are imported. This HFC registry is a potential monitoring solution for both HFCs and HCFCs that could be implemented in Costa Rica. This registry would serve to provide registered quotas to compare to the value of imported substances from customs to ensure compliance, preventing smuggling (Department of Environment, Food & Rural Affairs, 2014). Financial disincentives such as import quotas and recordkeeping measures to prevent smuggling will greatly support the phase-down of HFCs. To promote the switch to natural refrigerants, financial gains from energy efficiency should be more widely publicized, as should the use of natural refrigerants throughout the world. A regulation requiring that the import of equipment with energy efficiency ratings high enough so that only equipment using natural refrigerants can achieve this rating will promote the import of natural refrigerant-using equipment. The last barrier to using natural refrigerants in equipment is to address exaggerated safety concerns and to put them into a realistic perspective for both the private sector and the public.

The only drawback to using natural refrigerants is the health and safety concerns they present when compared to other refrigerants (United States Department of Labor, n.d.; Federal Ministry for Economic Cooperation and Development & GIZ, 2010; Federal Ministry for Economic Cooperation and Development & GIZ Proklima, 2008). Hydrocarbons, such as butane and propane, are more flammable than HCFCs and HFCs, which have low or nonexistent flammability ratings. In Costa Rica, many people, including some working in refrigeration, believe that the equipment using natural refrigerants are akin to small bombs waiting to explode; however, most Costa Ricans use hydrocarbons for cooking, in their car, or even in their own homes, without the same concern. The risk of explosion from natural refrigerants is really only limited to facilities using large quantities at once, and there are highly developed protocols to ensure the safety in all cases of natural refrigerant use (Federal Ministry for Economic Cooperation and Development & GIZ Proklima, 2008; The Australian Institute of Refrigeration, Air Conditioning, and Heating, 2013). Ammonia poses a different issue. It is a highly corrosive chemical that can burn the skin, eyes, and lungs if not handled properly. Those handling ammonia refrigerants need to wear hazmat suits, oxygen masks, and other protective gear. Although it seems worrisome that this gas may leak from the system into a factory, it is actually extremely easy to notice a leak early and prevent any harm. There are alarm systems that automatically shut down the operation to prevent further leakage, and if that somehow fails, small traces of ammonia can be smelled in the air, which is a warning sign to shut down the

refrigeration system and evacuate the area (United States Department of Labor, n.d.). With these types of systems in place, the benefits of incorporating natural refrigerants into the market should outweigh the issues that could arise. Aside from the safety concerns a company may have, there are more practical concerns, such as the expense of having all employees in hazmat suits, and training them to be able to handle a highly corrosive chemical. In the end, the safety concerns of using natural refrigerants are minimal, especially when compared to the environmental impacts that their alternatives have.

#### 4.2.4 Component 4: An Environmental Impact Analysis

The environmental impacts of refrigerants in Costa Rica can be alleviated by all the aforementioned actions: to adopt reclamation technology, to implement a refrigerator recycling program, to utilize the destruction facility in Costa Rica, and to switch to natural refrigerants. Each of these actions individually will undoubtedly make an impact, but it is the fulfillment of complete phase-out of environmentally harmful (high GWP and/or ODP) refrigerants that will eventually lead Costa Rica attain the highest standards of environmental sustainability in the refrigeration and air conditioning industry.

Refrigerant	GWP (based on 100 years-AR4)	Carbon equivalent emissions (metric tons) of 1 canister	CO <sub>2</sub> equivalent emissions (metric tons) of 1 canister	ODP
HCFC-22	1,810	6.72	24.62	0.05
CFC-12	10,900	40.43	148.3	1
HFC-134a	1,430	5.30	19.5	0
HFC-410a	2,088	7.74	28.4	0
CO <sub>2</sub>	1	3.71 * 10 <sup>-3</sup>	1.4E-02	0

**Table 7. Virgin Refrigerant Costs and Environmental impact.** Source: <http://www.ghgprotocol.org/files/ghgp/tools/Global-Warming-Potential-Values.pdf>;

With each canister HCFC-22, the environmental cost can amount to as much as 6.72 metric tons of carbon equivalent and 24.62 metric tons of CO<sub>2</sub> equivalent emissions. The 2009 consumption data from the Multilateral Fund report published in 2011 indicates that 232.9 metric tons of HCFCs were consumed (United Nations Environment Programme, 2011, p. 3). That amounts to approximately 17,000 canisters of HCFCs, or approximately 421,549 carbon dioxide equivalents. The consumption of refrigerants is not expected to change, thus the carbon dioxide emissions will only increase or remain about the same with HFC replacements. This is due to the relatively similar global warming potential of HCFCs and HFCs. Thus, it is absolutely imperative that Costa Rican companies begin to recover, reclaim, and destroy as much high GWP refrigerant as possible, should they maintain a level of environmental sustainability that meets national standards.

The U.S. EPA, as well as several other agencies, has developed a model to calculate the social cost of carbon (SCC), and according to the U.S. EPA, the SCC for 2015 (in 2011 dollars) using the central estimate is about \$40 per metric ton of CO<sub>2</sub> and is expected to increase to about \$70

by the year 2050 (U.S. Environmental Protection Agency, 2013). The increase in cost over time is due to the intensity with which environmental impacts increase over time, making damages and therefore costs greater (Environmental Defense Fund, Institute for Policy Integrity, & Natural Resource Defense Council, 2014). Thus, in the year 2015 alone, using the 2009 HCFC consumption data in Costa Rica, the SCC will be approximately \$17 million and will increase to about \$29 million by 2050 should high GWP refrigerants continue to be used and subsequently emitted into the atmosphere. This is concerning, considering that currently consumption of HCFCs has only begun to cease, and nearly all refrigeration and air conditioning equipment in Costa Rica contains CFCs, HCFCs, or HFCs. In addition, with the use of HFCs continuing, it is likely that the yearly SCC will remain the same or increase due to the high GWP of HFC refrigerants. It should be made clear that these estimates are based on consumption data, and not necessarily emission data due to lack of atmospheric data reporting in Costa Rica. However, with no current reclamation equipment in place, and no current data reporting regulations in place to tell whether or not companies are emitting, the worst-case scenario should be assumed. Furthermore, without any recycling strategy for old equipment, it is highly likely the landfilled air conditioners and refrigerators are contributing to carbon dioxide emissions as they are decomposed and release their gases, especially considering this equipment inevitably contains CFCs, which have about ten times the GWP of HCFCs. Thus, this estimate is likely an underestimation, rather than an overestimation.

Approximately 30-50% of all cultivated plant species are deleteriously affected by UV-B radiation (Teramura & Sullivan, 1994; Jenkins, 1998). With such a dependence on agriculture in Costa Rica for economic sustainability, the responsibility these refrigerant and air conditioning companies have with regard to maintaining the welfare of their country is clear. The health benefits associated with decreasing the use of ozone-depleting substances in Costa Rica cannot be quantitatively assessed in this report because quantitative information could not be found. Although the impacts of ozone depletion cannot be quantitatively assessed, the impacts of ozone depletion are known to include health impacts such as increase in skin cancer incidence and cataracts and immune suppression (Martens, 2013). It has also been reported that the interactions between global climate change, which solely accounts for increased greenhouse gas emissions, and ozone depletion may enhance the health effects of increased UV-B radiation (Norval et al., 2011). In the U.S. it was reported by the E.P.A. that with Montreal Protocol policies in place, that 6.3 million U.S. lives will be saved by 2165 that would have otherwise been lost to skin cancer (United States. Environmental Protection Agency. Office of Air and Radiation, 2007).

With all of these environmental effects of both climate change and ozone depletion in mind, it is clear that the aforementioned proposal components must be carried out, or at least a program having the necessary components of this proposal must be implemented. The refrigeration and air conditioning companies in Costa Rica are the main consumers of refrigerants and must take responsibility by being environmentally proactive. They need not only think of their individual economic benefits, but must take into consideration the effects their actions have on their country, specifically, the economic and environmental tolls their actions have on Costa Rica. The private sector, however, cannot take on the entirety of this plan alone. These companies require both financial help and incentives to make major technological changes. In our next chapter, we provide recommendations to promote effective communication and cooperation between the two sectors to ultimately achieve the goals of this plan.



## 5.0 Conclusions and Recommendations

After conducting interviews with officials from the Costa Rican public and private industrial sector and CICR, along with our own analysis of available technologies and international regulations, we were able to provide three specific recommendations for CICR in regards to their end-of-life refrigerant management plan. In the following recommendation section, the three specific recommendations are detailed; we also provide a few considerations and their possible solutions that should be addressed by CICR to ensure successful phase-out of hydrochlorofluorocarbons and environmentally detrimental halons while promoting competition in the industrial sector.

### 5.1 Conclusions

Although Costa Rica is touted as being advanced in its environmental goals and policies, there is significant progress to be made on the actions that should follow from these policies and to fulfill these goals. The private and the public sectors both showed a degree of miscommunication between them that is hindering their progress. The public sector is looking towards the private sector to change from HCFC refrigerants to natural refrigerants. The public sector also desires to inform the public that natural refrigerants are not explosive and are frequently used in our daily lives. The private sector is waiting on the public sector to provide a better technician-training program, a method for destruction of stockpiled refrigerants, and more incentives to invest in new refrigerant reclamation technology.

Both sectors are clearly dedicated to achieving the goals of the HPMP. The disconnect between the public and private sectors on what accessible technologies the private sector has and how feasible it is to change their technologies, versus what the technologies the public sector thinks is feasible, is a major barrier to accomplishing the goals of the HPMP. The regulations that the public sector provides, versus the regulations the private sector needs, to maintain both environmental sustainability and economic sustainability are not aligned. This prevents the private sector from making swift and impactful changes. The general consensus on natural refrigerant safety is not agreed on between the public sector and private sector. From our results, the clients of the private sector have a similar disagreement on natural refrigerant safety. From interviewing representatives from the Costa Rican public and private sector, it is clear that both sectors need to pull their weight and heed the results of our international model evaluations for future progress in this area. The international models have shown great success and can be looked upon for methods of funding, regulating, and enforcing new parts of Costa Rica's HPMP. In order to continue developing Costa Rica's HPMP, our proposal for reclamation and destruction technology, refrigerant equipment recycling and natural refrigerant use should be given attention. We have found that incorporating these strategies could save approximately \$17 million in social carbon costs, and for each component, there are direct economic benefits to be gained. Both the private and public sector will benefit from considering our recommendations that follow. This is a time for Costa Rican private and public sectors to make a self-assessment based on our results and to determine what steps they need to take, both individually and together, to reach the ambitious goals they have set for themselves.

## 5.2 Recommendations Regarding Technology

Several Costa Rican organizations in the public sector have mentioned the desire in addressing the nation's environmental stewardship. One of the obstacles the nation faces, when targeting the industrial sector, is the high global warming potential and ozone-depleting potential caused by continuous use of environmentally detrimental substances like those of HCFCs and HFCs. Costa Rica wishes to address these concerns as soon as possible. **We recommend for the industrial sector to start implementing and utilizing reclamation technology, investing in more recycling technology, and begin thinking and switching over to natural refrigerants and equipment.**

*By implementing and utilizing reclamation technology, the industrial sector will get a jump-start on most Central American countries as reclaiming becomes popular.* The price of HCFC-22 is trending upwards due to its global phase-out, while the market becomes flooded with alternative environmentally friendly refrigerants (Rajecki, 2015). HCFC-22 supplies will become scarce and reclaiming technology will dominate the servicing and re-selling HCFC-22 demand until all the commercial systems still operating with HCFC-22 reach the end of their life cycles. Unfortunately, many in the industry are wary of reclamation and their growth as there is a lack of enforcement to prevent refrigerant venting during service or storage (Rajecki, 2015). This is the same case as Costa Rica. But even so, many companies were excited at the thought of reclamation due to it being environmentally friendly and responsible. By reclaiming HCFC-22 from equipment, companies and service homeowners can continually reuse them without ever producing virgin HCFC-22. In addition, by reimbursing system owners for their used refrigerant as an incentive, they will be more likely to minimize leaking and ensure that the refrigerant is properly managed (Rajecki, 2015). Reclamation technology is advantageous in that it not only can be applied to HCFC-22 but also to many types of HCFCs and HFCs, as well as some natural refrigerants.

*Investing in retrofitting and equipment such as recycling technology capable of reaching high purity standards much like those set by AHRI 700 as well as natural refrigerant equipment is necessary for companies concerned for the environment and their own self-investment.* As mentioned prior, prices of already phased-out and currently phasing-out products are increasing at a fast rate due to their scarcity in the market. Natural refrigerants in effect, are readily available in the market with new and efficient natural refrigerant equipment continuously being showcased. However, since companies cannot afford to simply replace all their technology, for example retrofitting systems<sup>16</sup>, is one remedy. Retrofitting systems would depend on the equipment and the feasibility for the companies in question. Though, the overall benefits of switching to natural refrigerants include more cost-effective equipment and minimal effects on the environment. For companies who wish to switch over their equipment in its entirety, we suggest contacting an ESCO such as Ener-G. This would be beneficial as Ener-G's business plan is based around the implementation of energy efficiency projects. If a contract were made, the host company would spend no money. Instead, Ener-G would invest in equipment that would be used by the company. Ener-G would then collect the money, resulting from energy savings, from the company. Eventually, Ener-G would collect their investment, along with a profit, allowing

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<sup>16</sup> Systems could be retrofitted with steel piping refrigeration compressors in lieu of replacing entire systems.

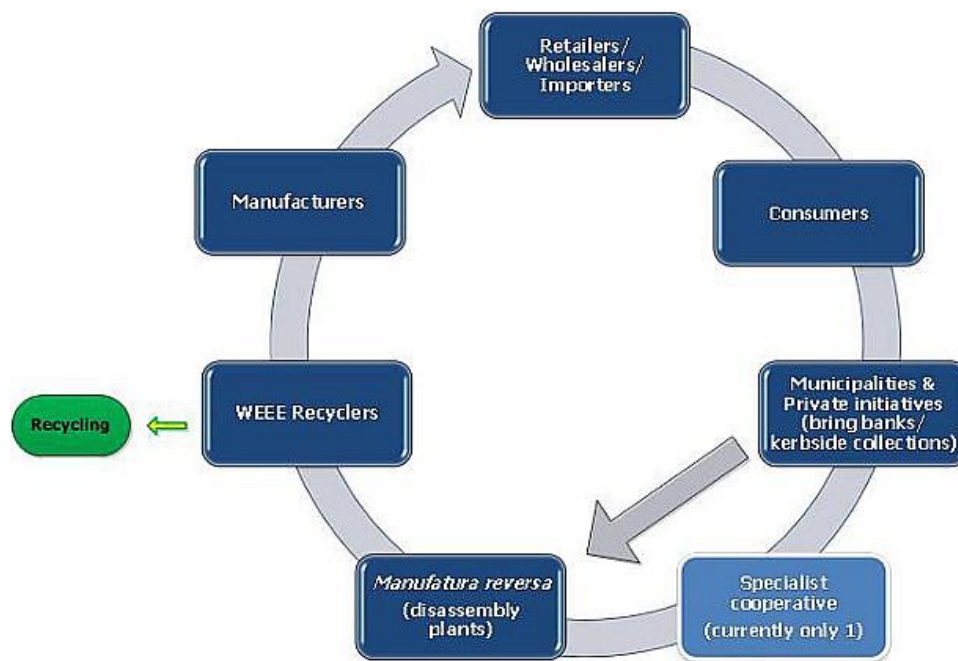
them to switch ownership of the equipment to the host company. Another approach companies can take without replacing technology is through investing in decentralized recycling technology capable of purifying, to AHRI 700 standards, a large yield of chemicals to elongate their life while reducing the need to purchase and stockpile excess refrigerants. Specific AHRI 700 standards for refrigerants can be found in Appendix M.

We must also address the issue of recycling and reclamation byproducts that arise from these technologies. As described earlier, Costa Rica has begun looking into solutions such as using cement companies in disposing these byproducts. *We suggest expanding their cement destruction facilities by incorporating CEMEX, a cement company, to maximize disposing capabilities.* These highly effective and profitable methods in disposing of byproducts are capable of destroying the chlorine and fluorine atoms in halons and HCFCs. This happens when the atoms merge with the cement at high temperatures ultimately rendering them environmentally harmless (Dellinger et al., 2009). Other than CEMEX, Holcim is another existing cement company in Costa Rica. Holcim has been involved in trial runs with instructions from MINAE to ultimately develop a refrigerant disposal protocol for the industrial sector. There have been three runs testing the destruction efficiency of different halons and HCFCs that have all been successful. If CEMEX is incorporated into this protocol, Costa Rica will maximize disposing capabilities.

Although investing in reclamation and recycling technology is ideal, one of the many problems we found with the industrial sector is a lack of overall infrastructure. *We suggest developing a waste management plant capable of reclaiming, recycling and disposing refrigerants and appliances utilizing updated technology.* This not only provides Costa Rica with a way to manage their equipment, but this is the most cost effective and plausible method for all three sectors: domestic, commercial and industrial. Drawing from research focusing on ANDRITZ MeWa Recycling in Hungary and its “Querstromzspanner” UNI-CUT<sup>®</sup> (QZ) recycling machine, we strongly believe it is possible to develop a waste management plant in Costa Rica. ANDRITZ develops and manufactures recycling machines for the recycling of WEEE, refrigerators, oil filters, household and domestic waste, used tires and more. Additionally, ANDRITZ builds plants, sometimes in joint projects, for the processing of electrical and electronic scraps or the professional recycling of refrigerators. The QZ recycling machine is one machine available on the market by ANDRITZ and is a machine that has “set international standards in the field of electronic scrap, cooling system recycling and the open-up of metal compound” (Mewa Recycling Anlagen, n.d.). Benefits of this machine include single-step disassembly and destruction, and the degassing of insulation foams. One downside of the QZ machine is its overall cost. For Costa Rica to invest in such a product, funding options should be further explored, such as that of the Clean Development Mechanism discussed in the section 4.2.2.7. In addition, the infrastructure of Costa Rica must be developed to suit a refrigerator-recycling program. It is possible for ANDRITZ to provide consulting for the government on this matter, but again, funding is required for this major change.

A consequence of lacking an overall infrastructure is that many industrial companies in Costa Rica stockpile refrigerants of all types. From our interviews, we learned that this is because the companies have been waiting for the government to intervene with their promised recycling

protocol like the cement kiln operation mentioned previously. However, because the government has yet to intervene, we propose using GIZ's Brazil Refrigerator Recycling Program and Industria Fox's Recycling Plant as frameworks for developing a waste management plant. The GIZ Brazil project resembles that of EU's WEEE reverse logistics program, instilling responsibility and funding on that of the retailers, wholesalers, importers and manufacturers. The shared responsibilities of these players, in the refrigeration market, should be determined by the WEEE agreement, if approved. Thus, the funding provided will go towards recycling facilities, collection, transport, treatment and recovery of WEEE, with the intention of reintroducing supplies back into industry. A typical reverse logistics process for WEEE is illustrated below in Figure 5. This figure describes the cycle of refrigerators beginning from consumer purchase and their eventual return to vendors. Unlike the GIZ Brazil project, Costa Rica will face fewer obstacles related to geographical and transport concerns, yet must still overcome logistical concerns such as placement and construction of storage facilities, disassembly plants and WEEE treatment sites. As these logistical concerns must be overcome through construction of necessary facilities, for funding, we suggest looking into the Clean Development Mechanism of the Kyoto Protocol, which refers to project based co-operations between two countries where GHG emission reductions take place in the country with lower abatement costs. In other words, projects are done jointly between industrialized Annex I countries and developing Non-Annex I countries, such as Costa Rica, to potentially reduce industrialized countries' costs of meeting Kyoto Protocol targets while supporting the host countries' projects regarding environmentally sustainable development (Carbon Watch, n.d.).



**Figure 5: Typical WEEE Reverse Logistics Process.**

### 5.3 Recommendations Regarding Communication

While conducting our interviews with officials of the industrial sector for both public organizations and private companies as well as representatives of CICR, we discovered a large problem in information transferring between sectors and CICR. Because of this, **we recommend better communication between CICR and the private sector, and between companies within the private industrial sector.**

*One of the ways communication can be enhanced is through establishing networks between companies.* By establishing networks, we promote knowledge transfer and allow managers who face similar market conditions to learn from each other's experience. This ability to transfer knowledge "represents a distinct source of competitive advantage for organizations over other institutional arrangements such as markets" (Reagans and McEvily, 2003). This is because networks, whether it is between non-overlapping or overlapping networks, improve productivity, as organizations are able to gain diverse knowledge. Networks also help build strong interpersonal connections between organizations and especially when introducing a necessary third-party, in this case CICR. The network allows each member to check that all members are behaving appropriately and allows each member to recognize the successes of others, disincentivizing bad behavior and promoting good behavior. Thus, an efficient network would promote compliance and corporate responsibility. In terms of HCFC management, a network like this would allow companies to advance their HCFC elimination by using ideas from other companies' successes and to build up competition within the private sector for green practices. Networks would be created based on corporation size, distance between one another, major manufacturing products or other similar criteria.

At this moment, our team is unaware of any meetings between companies of the industrial sector. *For that reason, we have set up a hypothetical timeline for the year 2016 of meeting dates and conferences to help establish effective communication (Appendix P).* With consideration of Costa Rican and religious holidays, meeting dates should be made as frequently as once a month, and consistently held on any day but Monday or Friday, since most holidays fall on these days. Conferences, twice a year and preferably the third or fourth Friday in May and November, should also be established between CICR and private sector much like the EXPO that CICR puts on once a year. Justifications for these dates can be found in Appendix P. There, network representatives should discuss issues of concern, on behalf of their network of companies, such as law and regulations, environmental concerns, and news on general technology. Companies should also be updated on general technology. By compiling ideas between networks within the private sector, feasible recommendations could be made to the public sector in order to fulfill the private sector's current needs in terms of HCFC management. As the middleman between sectors, CICR should publish a quarterly or even an annual digital publication that includes up-to-date technology utilizing HFCs, natural refrigerants, their efficiency and costs, current laws and regulations being imposed by MINAE, and even proposed plans the government is looking to tackle. This would reinforce the position of CICR and strengthen the communication between sectors.

## 5.4 Recommendations Regarding Educational Training for Refrigerant Technology

During our interviews, we inquired both sectors on the issue of establishing a nationalized refrigerant technician program. Some of the advantages expressed by the sectors for establishing a program were that it would increase competitiveness and appeal of certified company technicians. Some of the disadvantages included unspecific training programs that did not fit the needs of some companies and a lack of up-to-date technology training. To ensure that all technicians receive high quality and relevant training as well as to provide a record keeping strategy to deter un-certified technicians from servicing equipment, Costa Rica needs to develop a mandatory national training program for all refrigeration technicians. **We recommend creating a nationalized refrigerant technician program able to fit the needs of the private sector while also requiring technicians to pass a licensure exam in order to handle and service refrigerants and be eligible for inclusion in a national registry of refrigerant technicians.**

By creating a nationalized program, in which technicians complete the training at INA and eventually pass a licensure exam, technicians would be nationally recognized and have an advantage in the industrial sector. This certification would insure that all technicians working in the industrial sector hold sufficient knowledge in regards to safety, their well-being, and general mechanics. It would also work in tandem with a registration program where certified technicians would be registered in a database of refrigerant technicians for Costa Rica, like the database in place in the U.S. (EPA Section 608, n.d.). Companies would use this database, mostly importers and manufacturers of refrigerants, to ensure the sale and purchase of refrigerants or refrigerant equipment are sold to those who can legally handle them. This would bring down the numbers of rogue technicians who handle and service refrigerant equipment without much regard to good practices or the environment. This would also provide the public with a list of certified and environmentally aware technicians for job inquiries. Currently, a database of INA-certified technicians is slowly being updated in a record system for the Costa Rican refrigeration market (Interview with OMEGA Johanna, 2015). The problem is now implementing regulations and incentives to enforce a nationalized refrigerant technician program.

Many interviewees who do not use INA's training program expressed their concerns for the nationalized program. Their concerns included the fact that INA's program does not fit the needs necessary to service some of the more updated HFC and natural refrigerant technologies. *We suggest restructuring INA's technician program or requiring approved certification specifications for training programs to be implemented at the companies rather than at INA.* This allows certification to be done at companies with training specifications fitting their needs. However, the companies would have to propose a training program that includes training specifics for their company but also all the approved training that would be done at INA. This training proposal would then be submitted to MINAE or INA to be approved. If the training proposal is not approved in an appropriate time frame, the company should be allowed to continue employing non-official certified technicians. This is to assign some responsibility towards the public sector rather than the private sector. To also popularize nationally certified technicians, educating the public on good practices and environmental consequences of bad



practices is necessary. This raises public awareness and emphasizes the need to hire nationally registered technicians.

### **5.5 Recommended Inquiries for Future Projects**

In our limited time, we provided as much insight as we could for CICR. We reached several conclusions and acquired more questions than time could allow us to answer, some of which include further analysis of Costa Rican based refrigerant companies such as Fogel and Clima Ideal. We have heard from multiple sources that both of these companies have successful recycling technology that is being used in the market. Unfortunately, we did not receive responses from these two companies and have not been able to verify their technology first hand. In addition, we urge that more research be done to assess the feasibility of utilizing the Clean Development Mechanism for the refrigerator-recycling program. Research topics include further understanding of Kyoto Protocol mechanisms, discovering potential Annex I industrialized countries to partner with and proposing desirable environmental sustainability projects. Furthermore, an assessment of the public's knowledge on HCFCs and natural refrigerant safety should be performed in order to decide whether or not to pursue a public campaign on the environmental impacts of refrigerants and the low safety risks of natural refrigerant use. This could be done through physical or electronic surveying techniques around educational or industrial areas such as schools, governmental or industrial buildings. Following these recommendations, CICR will assist in Costa Rica's overall environmental sustainability efforts as well as solidifying the organization's own role in the public and private industrial sectors.



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## Appendices

### Appendix A – BAC Interview Questions and Summary

**Interview April 13th 10:00 am BAC, Sra. Karla Rivera Morales**

**Location: BAC,**

**las Oficinas Centrales, calle 0, avenidas 3 y 5, en el 4° piso, Calidad.**

**Telephone: 2295-9000**

**Prompt: Hello Sra. Karla Rivera Morales,**

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about your company. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR and will be publishing this information in a research paper. From this interview we hope to learn about how your company could play a role in helping fund recycling programs in the industrial sector. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern, you can ask questions now.

#### Questions:

1. In your own words, please explain what your company does?
2. What role do you play in this company?
3. Does your company usually fund projects or programs for companies? (i.e. loans)
4. Have you funded any projects that involve recycling in the past?
5. Does your company have certifications for these projects? (i.e. ISO certs)
6. Could you tell us how much money your company usually invests in these projects?
7. How many other banks in Costa Rica participate in projects like these?
8. Are you aware of the environmental impacts of certain refrigerants, such as HCFCs? (If not, tell him about it)
9. How do you get reimbursed for these projects, is it through the companies that hire you or does the government ever give you credits for projects that are environmentally beneficial?
10. Do you think it would benefit your company to be involved in a recycling technology implementation program for refrigerants?
11. What are the limitations to doing projects such as implementing a recycling program?

**Entrevista: 13 de abril 10 a.m. BAC, Sra. Karla Rivera Morales**

**Lugar: BAC, las Oficinas Centrales, calle 0, avenidas 3 y 5, en el 4 ° piso, Calidad**

**Teléfono: 2295-9000**

**Prompt: Hola Sra. Karla Rivera Morales,**

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). La Cámara quisiera aprender más sobre de su empresa. Nos gustaría su permiso para pedir preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR y publicaremos la información en nuestra investigación. De esta entrevista esperamos aprender si su empresa podría jugar un papel en ayudar a los programas de reciclaje de fondos en el sector industrial. Esta entrevista debe tomar aproximadamente 30 a 45 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

### **Preguntas:**

1. En sus palabras, por favor explique lo que hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. ¿Su empresa normalmente financia proyectos o programas para las empresas? (Es decir, préstamos)
4. ¿Ha financiado los proyectos de reciclaje en el pasado?
  - a. ¿Con cuáles empresas?
5. ¿Tiene su empresa certificaciones para estos proyectos? (Es decir, certificaciones de ISO)
6. ¿Podría decirnos cuánto dinero su empresa normalmente aporta en estos proyectos?
7. ¿Cuántos otros bancos en Costa Rica participan en proyectos como estos?
8. ¿Es usted consciente de los impactos ambientales de refrigerantes, como los HCFC? (Si no, dile al respecto)
9. ¿Cómo obtener un retorno de la inversión para estos proyectos, es de las empresas que contrata o el gobierno le da créditos para proyectos que son beneficiosos para el medio ambiente?
10. ¿Cree que sería beneficioso para su empresa participar en un programa de implementación de tecnología de reciclaje de refrigerantes?
11. ¿Cuáles son las limitaciones para la realización de proyectos tales como la implementación de un programa de reciclaje?

The bank BAC has offices in Costa Rica, Nicaragua, Panama, El Salvador, and Honduras. We spoke with Sra. Karla Rivera Morales on how BAC could participate in the HCFC phase-out process by providing loans for projects, such as recycling technology or retrofits. Since 2001, BAC has been ISO certified with certification 14001. This certification allows a company to be able to prove their pledge to be environmentally sustainable, and this can manifest itself in many different ways. For BAC, they use this certification to carry out environmental projects such as solar panel installations, retrofits of technology to improve energy efficiencies, and air conditioner exchanges, which includes an exchange of an older, less energy efficient air conditioner with a newer, more energy efficient air conditioner. The BAC has invested from \$37,000-\$100,000 in these air conditioning exchange programs. The overall investment differs for the scale of the project. Although BAC has not been involved in any recycling technology programs, they would be interested in financially supporting such a project. They are aware of the environmental impacts of refrigerants, and said that if the project would be a profitable one, they would be able to participate. The BAC is reimbursed through the companies that they support for environmental projects, and profit off of their interest rates. They also benefit from energy efficiency savings in some cases, and they are aware of the environmental benefits that can be reaped from projects such as these. A program within the BAC called PYMES deals directly with funding environmental projects. PYMES provides consulting for energy efficiency savings, finances, training, and looks for avenues to make a company more environmentally friendly when the company contacts BAC for funding help. Our interviewee and her colleague were not aware of any other bank in Costa Rica that normally participates in the environmental projects that they provide financial help for.



## Appendix B – BCIE/Fundecooperacion Questionnaire and Summary

### Questionnaire from CICR:

**Prompt:** Hello,

We are students of Worcester Polytechnic Institute working as interns of the Camara de Industrias de Costa Rica (CICR) and we want to learn more about your company. We would like your permission to ask questions as part of a questionnaire for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR and will be publishing this information in a research paper. From this questionnaire we hope to learn about how your company could play a role in helping fund recycling programs in the industrial sector. This questionnaire should take around 30 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. Please fill out this questionnaire electronically, and send it back through email.

### Questions:

1. In your own words, please explain what your company does?
2. What role do you play in this company?
3. Does your company usually fund projects or programs for companies? (i.e. loans)
4. Have you funded any projects that involve recycling in the past?
5. Does your company have certifications for these projects? (i.e. ISO certifications)
6. Could you tell us how much money your company usually invests in these projects?
7. How many other companies in Costa Rica participate in the funding of projects like these?
8. Are you aware of the environmental impacts of certain refrigerants, such as HCFCs?
9. How do you get reimbursed for these projects, is it through the companies that hire you or does the government ever give you credits for projects that are environmentally beneficial?
10. Do you think it would benefit your company to be involved in a recycling technology implementation program for refrigerants?
11. What are the limitations to doing projects such as implementing a recycling program?

## **Cuestionario de La Cámara de Industrias de Costa Rica:**

**Prompt:** Hola,

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). La Cámara quisiera aprender más sobre de su empresa. Nos gustaría su permiso para pedir preguntas como parte de un cuestionario para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR y publicaremos la información en nuestra investigación. De este cuestionario esperamos aprender si su empresa podría jugar un papel en ayudar a los programas de reciclaje de fondos en el sector industrial. Este cuestionario debe tomar aproximadamente 30 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Por favor, complete el siguiente cuestionario electrónicamente, y enviarlo por correo electrónico.

### **Preguntas:**

1. En sus palabras, por favor explique lo que hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. ¿Su empresa normalmente financia proyectos o programas para las empresas? (Es decir, préstamos)
4. ¿Ha financiado los proyectos de reciclaje en el pasado?
  - a. ¿Con cuáles empresas?
5. ¿Tiene su empresa certificaciones para estos proyectos? (Es decir, certificaciones de ISO)
6. ¿Podría decirnos cuánto dinero su empresa normalmente aporta en estos proyectos?
7. ¿Cuántas otras empresas en Costa Rica participan en el financiamiento de proyectos como estos?
8. ¿Es usted consciente de los impactos ambientales de refrigerantes, como los HCFC?
9. ¿Cómo obtener un retorno de la inversión para estos proyectos, es de las empresas que contrata o el gobierno le da créditos para proyectos que son beneficiosos para el medio ambiente?
10. ¿Cree que sería beneficioso para su empresa participar en un programa de implementación de tecnología de reciclaje de refrigerantes?
11. ¿Cuáles son las limitaciones para la realización de proyectos tales como la implementación de un programa de reciclaje?

Fundecooperacion is a non-profit organization that works to improve the social and environmental conditions of the Costa Rican population through providing financial services for small and medium sized projects that have a positive impact on these social and environmental conditions. We had correspondence with a credit manager at Fundecooperacion, who directs a team of credit promoters and officers of projects. His team works to offer a credit alternative to the current credit market, in addition to providing support and advice on the presentation of credit proposals. A program called “Credit to your measure” grants funds to people, companies, associations, unions, or federations, for investment ( long term) or for revolving lines of credit (short term), with limits of funding from around \$4,000 to \$150,000. A revolving line of credit is available for an undetermined amount of time, and the entity receiving the credit can repay debt periodically and this credit can be borrowed once again once it has been repaid. The credits are provided for several project themes: sustainable agriculture, sustainable tourism, clean technology (environmentally friendly), renewable energy, culture value and gender.

Fundecooperacion has funded recycling projects with Codiplast (closed), GSS Global Recycler, Ecoway, a pro-environment association, and Development of Z 13 in San Carlos. This last project needs further clarification and correspondence. Fundecooperacion has spent about \$130,000 on the four projects listed above. The organization has spent over \$1 million in the past year on all projects in the areas listed previously. There is no cap on the amount of money they will provide for a recycling project, the issue is more that the company has to have the ability to achieve the goals they seek to reach, while coping with the financial burden that they have to deal with while trying to attain their goals. In 2014, there was only one recycling company that utilized the credit application. However, this project was never realized, since the company couldn't sign the contract for financial reasons.

We were informed through our correspondent that because of the little formality of the companies, the volatility of the market, and lack of guarantees with such projects, virtually no organizations or banks want to bet on the financing being a good option, especially when considering these small businesses and sole proprietorships that Fundecooperacion works with. Large companies such as Ecological Services M.B.B. and Costa Rica Recycling Network are more likely to be able to work with a bank on environmental projects due to the reliability of these companies to be able to pay back their loans and credit.

Our correspondent was familiar with the impacts of refrigerants, like HCFCs, and he explained how such a recycling project with HCFCs would work. The return on the investment of the companies would be established through the joint analysis of credit between the proponent and the Project Officer. Calculations of the return on investment are set according to capacity of production, the market, and costs of production. Upon asking about possible government involvement, our correspondent did not know of any programs where the government provides funding for such projects.

Upon asking whether or not Fundecooperacion would be interested in a refrigerant recycling project, our correspondent responded positively. He said that it would be a part of their environmental component, and it could help them to offer a new financing segment to the market. The limitations of a program like this would be the same as the other recycling programs, mainly financing and the informality of the market.

## Appendix C – Company A Interview Questions and Summary

### Interview April 16th 10:30 am Company A

**Prompt:** Hello Sr.

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and we want to learn more about the refrigerants your company uses. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in your industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization. We are here to help your company to take the next steps to becoming more sustainable in a way that keeps your business competitive. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern, you can ask questions now.

#### Questions:

1. Tell us what your company does.
2. What is your role in this company?
3. Department:
4. Who are your customers (i.e. homeowners, hotels, supermarkets)? Other refrigeration companies?
  - Do your customers buy equipment from you?
  - Do your customers buy refrigerants from you?
5. We know you have made a lot of progress to eliminate HCFCs/CFCs, can you tell us more about this progress? What exactly did you do?
  - What were the challenges?
6. (Say: Thank you very much. Now, we need more information about the refrigerants your company is using.) Which refrigerants do you use?
  - HCFC-22
  - HCFC-123
  - HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Other:

7. Do you use any mixtures of refrigerants?
8. About how much of each type of refrigerant do you use?
9. Do you have any refrigerants stockpiled? If so, can you give us an estimate on the amounts you have?
10. How do you obtain your refrigerants and your refrigeration equipment?
  - What type of equipment (industrial, commercial, domestic)?
  - Is this equipment imported? If so, from who.
  - What about refrigerants? Do you buy refrigerants alone and then add it to your equipment?
11. How helpful are the HCFC regulations that the government has implemented in Costa Rica? How do these regulations compare with those of other countries your company deals with?
12. In your company, what technologies are used to dispose of HCFCs? For example, do you recycle, reclaim, or destroy refrigerants?
13. What are the limitations to using this technology in Costa Rica?
  - Do you use another company or organization for recycling?
  - How do you think the Costa Rican government is doing in trying to help you with disposing of HCFCs?
  - What do you think you need to dispose of HCFCs in the future?
    - i. Do you receive broken refrigeration equipment from customers? If so, what do you do with it?
  - Do you use recycled HCFCs?
  - Would you consider recycling processes?
  - Would you be willing to invest in recycling technology? Why or why not?
  - Do you think it would benefit your company to provide this service to your clients?
14. Is Company A considering alternatives to HCFCs in Costa Rica? If so, what alternatives are most appealing to your company?
  - Are you using these alternatives in other countries? What alternatives are they?
  - What are some of the reasons why your company is not considering some HCFC alternatives in Costa Rica (i.e. ammonia)?
15. Do you think your equipment is energy efficient?
  - How efficient is your equipment in Costa Rica?
  - How do you think the efficiency could be improved?
16. Do your customers usually come to you with their old equipment?
  - If they do, how do you handle the old equipment?
17. Is there required training to handle HCFCs and/or the equipment you use?
  - Has this training been company directed or is this training through the Instituto de Aprendizaje?
19. What do you plan to do in the future to eliminate HCFC use?
20. How helpful has the CICR been for you?

## **Interview April 16th 10:30 am Company A**

**Prompt:** Hello Sr.

Nos gustaría grabar esta entrevista con nuestro teléfono para revisar la información y también tomar notas si usted está de acuerdo.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). Nos gustaría su permiso para pedir preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR y publicaremos la información adquirida anónimamente en nuestra investigación. De esta entrevista esperamos aprender sobre los productos químicos que se utilizan en sus procesos industriales y la forma en la que se manejan. Queríamos informarle que la información proporcionada por Usted no será publicada en su nombre o el nombre de su empresa. Esta entrevista debe tomar aproximadamente 30 a 45 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

### **Preguntas:**

1. ¿Nos puede explicar qué hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. ¿Y su departamento?
4. ¿Quiénes son sus clientes (es decir, los propietarios de viviendas, hoteles, supermercados?) ¿Otras empresas de refrigeración?
  - ¿Sus clientes compran equipos de usted?
  - ¿Sus clientes compran refrigerantes de usted?
5. ¿Sabemos que su empresa ha avanzado mucho con la eliminación de HCFCs/CFCs. ¿Usted puede contarnos más sobre su progreso?
  - ¿Qué fueron los retos para lograr este progreso?
6. (Dice: “Muchas gracias, ahora necesitamos más información sobre los refrigerantes que su empresa está usando.”) ¿Qué refrigerantes utiliza?
  - HCFC-22
  - HCFC-123
  - HCFC-141b
  - HCFC-142b
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Otros:
7. ¿Utiliza mezclas de refrigerantes?
8. ¿Cuánto de cada tipo de refrigerante se utilizan?
9. ¿Tienen refrigerantes almacenados? Si es así, ¿puede darnos una estimación de las cantidades que tiene?
10. ¿Cómo se obtienen sus refrigerantes y su equipo de refrigeración?
  - ¿Qué tipo de equipo (industrial, comercial, doméstico)?



- ¿Se importa este equipo? Si es así, ¿de quién se importa?
  - ¿Qué pasa con los refrigerantes? ¿Compra refrigerantes solo y después lo añade a su equipo?
11. ¿Que tan útil es la normativa de HCFC que el gobierno ha implementado en Costa Rica?  
¿Cómo se comparan estas normas con otros países dónde su empresa tiene sucursales?
12. En su empresa, ¿cuáles tecnologías se utilizan para eliminar los HCFC? Por ejemplo, ¿reciclar, reclamar o destruir refrigerantes?
13. ¿Cuáles son las limitaciones para el uso de esta tecnología en Costa Rica?
- ¿Usted contrata a otra empresa u organización para el reciclaje?
  - ¿Qué opina Usted en cuanto al apoyo del gobierno costarricense acerca de la eliminación de los HCFC?
  - ¿Qué cree Usted que se necesita hacer para eliminar los HCFC en el futuro?
    - i. ¿Recibe equipo de refrigeración roto de clientes? Si es así, ¿qué haces con lo?
  - ¿Utiliza los HCFC reciclados?
  - ¿Usted consideraría los procesos de reciclaje?
  - ¿Estaría dispuesto a invertir en tecnología de reciclaje? ¿Por qué sí o no?
  - ¿Cree que sería beneficioso para su empresa para ofrecer este servicio de reciclaje a sus clientes?
14. ¿Company A está considerando alternativas a los HCFC en Costa Rica? Si es así, ¿qué alternativas son las más atractivas para su empresa?
- ¿Está utilizando alternativas en otros países? ¿Qué alternativas?
  - ¿Cuáles son algunas de las razones por qué su empresa no está considerando algunas alternativas a los HCFC en Costa Rica (es decir, amoníaco)?
15. ¿Cree que su equipo es eficiente con la energía?
- ¿Qué tan eficiente es su equipo en Costa Rica, específicamente?
  - ¿Cómo cree que la eficiencia se puede mejorar?
16. ¿Sus clientes suelen venir a usted con su antiguo equipo?
- Si es así, ¿cómo maneja Usted el equipo viejo?
17. ¿Se requiere capacitación para manejar los HCFC y / o el equipo que se utiliza?
- ¿Esta capacitación ha sido dirigida por la empresa o por una institución como el Instituto de Aprendizaje?
19. ¿Qué es lo que piensa hacer en el futuro para eliminar el uso de HCFC?
20. ¿Qué tan útil ha sido el CICR para usted?

Company A is one of the leading refrigeration companies in Costa Rica and Central America. They provide a variety of refrigerants and refrigeration equipment options for industrial, commercial, and domestic refrigeration use. For the commercial and domestic market they provide not only the refrigeration equipment, such as refrigerators and coolers, but also accessories including panels and compressors. For the industrial refrigeration market they have much bigger projects where they are responsible for building the equipment to suit a major industrial refrigeration process for a company. Another major part of their business is the selling of refrigerants to their clients and to independent technicians.

Within this refrigeration equipment that Company A supplies, they have a large variety of refrigerant options. By 2006 Company A had phased out CFCs, since then they have begun to expand their range of refrigerant options past HCFCs and into HFCs and natural refrigerants. However, their main import of refrigerants is still in HCFCs, where they use these types: R-22, R-402, R-406, R-407, R-409. Their main refrigerant is still R-22 but they have begun to replace it with HFCs like R-134A, R-410A, R-404A, and R-507 for air conditioning and refrigeration purposes. This is a slow process as the majority of the imported equipment the company brings in is using HCFCs and would need to be changed to use HFCs. The two major refrigerants that are used in Company A are R-22 and R-134A. Looking at the new developments and interest in the natural refrigerant market, Company A has begun to test natural refrigerants to see their potential. They have two natural refrigerant projects currently running to test the use of butane, R-600, and propane, R-290, in their systems and see if they are a viable option to switch to. This is an important step for a leading refrigeration company like Company A to show the push for new developments and implementation of natural refrigerants in the market.

The recycling process for refrigerants at Company A is another factor to consider because it is a unique situation in the industrial sector. Company A actually sells refrigerant recycling equipment to their clients but they do not use the equipment for their own facilities. This is because the recycling equipment that they sell is mostly used for servicing and maintenance work in refrigeration where the refrigerant needs to be removed and cleaned slightly to improve the output of the system. Beyond this simple cleaning purpose the recycling machines are not useful for the major industrial refrigeration processes and equipment. The major factor here is the refrigeration technology for industry needs a highly pure refrigerant to operate at its full potential and the recycling equipment cannot provide this. The recycling equipment is a small unit that is imported from the US and is solely used for this purpose. Overall, the use of this small recycling equipment is a step in the right direction but has limited functionality in the scale of recycling needed in Costa Rica.

The training of refrigeration technicians is an important part of reducing the emissions from these refrigerant gases and Company A, along with many other companies, has decided to train their own technicians. The reason that a company would do this is because it claims that its training is better than that offered by the technician training institutions in Costa Rica, such as INA. The main factor for this is that the technicians that are trained on site will be trained on the same equipment used in the company they work for and the technology is sometimes more advanced. However, there are still some companies that will send their technicians to attend seminars that are held by MINAE or CICR to update them on new policies.

The overall management of refrigerants at Company A is an extremely unique situation in Costa Rica at the moment. Currently, Company A has an agreement with MINAE where Company A is

stockpiling their refrigerants and then after they reach a certain limit the government will collect these refrigerants and take them away to be destroyed. This is the only company in Costa Rica that is in this agreement to our knowledge. The stockpiled refrigerants are mostly HCFCs, and Company A is only importing enough to meet their quota limit. The difference is that all of the other companies in Costa Rica are holding on to these used refrigerants waiting for the Ministry of Health to approve a destruction method that is safe to use. But currently it seems like Company A is almost like a trial company to test this destruction method for the Ministry of Health. This allows Company A to use their full quota of refrigerants and then stockpiling them until the government takes them away for destruction at no cost to Company A. The current destruction system is the cement kiln operation at a company called Holcim, which is located in Costa Rica. The government had promised the private sector a plan like this to be incorporated for the disposal of CFCs during their phase-out, but it never occurred due to the lack of infrastructure in Costa Rica for destruction. This is an ideal method of handling the large amount of stockpiled HCFCs that are present in Costa Rica. It would allow the companies to begin the transition to other refrigerant types while preventing the need for venting HCFCs to the atmosphere. However, it seems as though this plan has been moving along slowly and the public sector needs to speak up about its progress because the majority of companies in Costa Rica are not up to date on its progress.

## Appendix D – Company B Interview Questions and Summary

### Interview March 23rd 9:00 am

**Prompt:** Hello Sr.

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about your organization and its role in training technicians to service HCFCs. Any additional information you are able to provide regarding HCFC use in the private sector or regulations on HCFC use and training will also be of great help. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR for inspection and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization, should we obtain information that will jeopardize a business' reputation. We will take your responses and combine them with other information. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern you can feel free to ask questions now.

#### Questions:

1. Tell us what your company does.
2. What is your role in this company?
3. Department:
4. Does your organization use any of the following products (Check as many as needed):
  - Refrigerant Chemicals (including air conditioning)
  - Cleaning Solvents
  - Aerosol Propellants
  - Foam Blowing Agents
  - Other:
5. What are they used for?
  - Involved in cooling technology
  - Removes oil, grease, solder flux, and other contaminants
  - Involved in vapor degreasing
  - Involved in cold batch cleaning
  - Involved in automated cleaning equipment
  - Involved in metal cleaning
  - Involved in electronics/industrial machinery cleaning
  - Other:
6. Which chemicals are used for this process?
  - HCFC-22
  - HCFC-123

- HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Other:
7. Is it a specific blend?
- If so what does the blend consist of?
8. How much of this chemical is used annually by your company?
9. How much money does your company spend on this product?
10. Does your company sell, buy or service equipment that uses these chemicals? Do you install the equipment?
11. How efficient is your equipment?
- If you service this equipment, how often does this equipment require servicing?
  - Do you service the equipment for other companies, organizations, or homes?
    - i. If yes, can you tell us which companies you service?
    - ii. If you can't tell us which companies you service, can you tell us how many companies you service?
12. Is there required orientation/training to handle HCFCs and/or the equipment you use?
- a. As part of the orientation/training, are workers informed of current HCFC regulations?
  - b. Has this training been company directed or is this training through the Instituto de Aprendizaje?
13. Recovery Technology:
- a. Does this organization have/use technology to recover HCFCs? If so, where did you acquire this technology?
  - b. Where is the recovery technology located, in your facility, or elsewhere?
  - c. If not, does your company know of a program to recover HCFCs from consumer products that this organization sells? If so, please explain how it is done.
14. Disposal and Recycling Procedures:
- a. Are these chemicals recycled? If so:
    - i. Are they recycled in-house or outsourced?
    - ii. Where did you acquire the recycling technology?
  - b. If these chemicals are not recycled, are they disposed of or removed?
    - i. If so, how?
  - c. Are these chemicals or their waste being stockpiled?
  - d. What recycling technology do you think would be best for your company?
  - e. Do you think you could partner with another company to recycle HCFCs?
  - f. Do you think your company could support an in-house recycling facility?
  - g. How much do you think your company would be willing to spend on a recycling program? Or could you receive governmental funds for a project to implement a recycling program?
15. Is this organization considering alternatives to HCFCs? If so, what alternatives are most appealing to your company?

- a. What are some of the reasons why your company is not considering HCFC alternatives (i.e. ammonia)?
16. What HCFC regulations apply to your industry/manufacturing processes?
17. How helpful are these regulations?
18. How do you feel about your company's actions to become sustainable?
  - If good: Was there something that your company did to get where they are today?
  - If bad: What is something you feel your company should strive to do/achieve?
19. Is there anything you would recommend that other companies do to become sustainable?
20. Do you have anything to say that we have not asked you?

## Entrevista 26 de marzo 9:00 am

**Prompt:** Hola Sr.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). La Cámara quisiera aprender más sobre de su empresa y que los procesos y los productos químicos que utiliza. Nos gustaría su permiso para pedir preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Esto no sólo beneficiará al medio ambiente, pero su empresa también. Propondremos este plan a la CICR y publicaremos la información adquirida anónimamente en nuestra investigación. De esta entrevista esperamos aprender sobre los productos químicos que se utilizan en sus procesos industriales y la forma en la que se manejan. Queríamos informarle que la información proporcionada por Usted no será publicada en su nombre o el nombre de su empresa. Tomaremos sus respuestas y las combinaremos con otra información de múltiples empresas para nuestro plan de reciclaje. Sólo vamos a notar el nombre de su empresa para nuestro documento inicial y un documento guardado por el CICR para ayudar a su progreso futuro. Esta entrevista debe tomar aproximadamente 30 a 45 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

Nos gustaría grabar esta entrevista con nuestro teléfono para revisar la información y también tomar notas si usted está de acuerdo.

### Preguntas:

1. Primero que nada, ¿nos puede explicar qué hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. Su departamento:
4. ¿Cuáles de los siguientes productos usa su organización? (Marque todos los que aplican)
  - Refrigerantes químicos (inclusive aire acondicionado)
  - Disolventes de limpieza
  - Aerosol propelente
  - Agentes espumantes
  - Otros:
5. ¿Cuál es la función de los productos?
  - Involucrados en la tecnología de enfriamiento
  - QUITAN el aceite, la grasa, el flujo de la soldadura y otros contaminantes
  - Involucrados en el desengrasado de vapor
  - Participan en la limpieza de metales



- Participan en lotes fríos para limpiar de metales
  - Participan en máquinas de limpieza automatizado
  - Participan en la electrónica / maquinaria industrial de limpieza
  - Otros:
6. ¿Cuáles sustancias químicas se utilizan para esta función? (Marque todas que aplican)
- HCFC-22
  - HCFC-123
  - HCFC-141b
  - HCFC-142b
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Otros:
7. ¿Es una mezcla específica?
- Si es así, ¿en qué consiste la mezcla?
8. ¿Cuánto de este producto químico su empresa utiliza anualmente?
9. ¿Cuánto dinero gastan en este producto anualmente, en general?
10. ¿Su empresa vende, compra o sirve equipo que utiliza estas sustancias químicas? ¿Instala el equipo?
- Si se da servicio a este equipo, ¿con qué frecuencia lo requiere?
  - ¿Repara el equipo para otras compañías, organizaciones o casas?
    - i. En caso afirmativo, ¿puede decirnos cuáles son las empresas que reciben este servicio?
    - ii. Si no se puede darnos tal información, ¿quizás pueda decirnos cuántas empresas reciben el servicio?
11. ¿Qué tan eficiente es su equipo?
12. ¿Es necesario tener capacitación para manejar los HCFC y/o el equipo que se usa?
- a. Como parte de la capacitación, ¿los trabajadores son informados de las regulaciones actuales de HCFC?
  - b. ¿Esta capacitación es dirigida por la empresa o por el Instituto de Aprendizaje?
13. La tecnología de recuperación:
- a. ¿Esta organización tiene/usa tecnologías para recuperar los HCFCs? Si es así, ¿dónde adquirió esta tecnología?
  - b. ¿Dónde se encuentra la tecnología de recuperación: en sus instalaciones o en otro lugar?
  - c. Si no, ¿Su empresa sabe de un programa para recuperar los HCFC? Si es así, por favor explique cómo se hace.
14. Procedimientos de eliminación y reciclaje:
- a. ¿Se reciclan estos productos químicos? Si es así:
    - i. ¿Son reciclados en su empresa o en otra empresa?
    - ii. ¿Dónde se ha adquirido la tecnología de reciclaje?
  - b. Si estos productos químicos no se reciclan, ¿son eliminados o removidos? Si es así, ¿cómo?
  - c. ¿Estos productos químicos o sus residuos se almacenan?
  - d. ¿Qué tecnología de reciclaje cree que sería la mejor para su empresa?
  - e. ¿Cree que podría asociarse con otra empresa para reciclar los HCFC?

- f. ¿Usted cree que su empresa podría apoyar una planta de reciclaje en sitio?
  - g. ¿Cuánto dinero su empresa estaría dispuesta a gastar en un programa de reciclaje? O podrías recibir fondos gubernamentales para un proyecto para implementar un programa de reciclaje?
15. ¿Su organización está considerando alternativas a los HCFCs? Si es así, ¿cuáles alternativas son las más atractivas para su empresa?
- a. ¿Cuáles son algunas de las razones por qué su empresa no está considerando alternativas a HCFC? (i.e. amoníaco)
16. ¿Qué reglamentos de HCFC se aplican a los procesos / fabricación de la industria?
17. ¿Qué tan útiles son estas regulaciones?
18. ¿Cómo se siente Ud. sobre las acciones de su empresa para ser más sostenible?
- Si positivo: ¿Hay algo específico que su compañía hizo para llegar a donde está hoy?
- Si negativo: ¿Hay algo específico que su empresa debe esforzarse por hacer / lograr?
19. ¿Hay algo que usted recomendaría que otras empresas hagan para ser sostenibles?
20. ¿Tiene algún otro comentario aparte de lo que le hemos preguntado?

In order to gain some information about the smaller companies in Costa Rica, we spoke with a representative from Company B, a small sized air conditioning company that employs 35 people. The purpose of interviewing this company was to gain insight about the smaller companies in Costa Rica, and their status. Thus, this information serves to represent the smaller companies in Costa Rica utilizing refrigerants. It is important to note that this company only deals with air conditioning, and as such, they may not be an excellent representation of smaller refrigeration companies. However, due to the refrigeration market being dominated by larger companies, we believe this is not a large issue, since many smaller companies using refrigerants in Costa Rica are most likely air conditioning and servicing companies. This company also had close contact with the Chamber of Industry, so scheduling an interview was not difficult.

This company buys, installs, services, maintains, and accepts old equipment for domestic, commercial, and industrial air conditioning. The company is rather young, in operation for less than 20 years and their customers consist of banks, universities, supermarkets, and property owners. The company uses mainly HCFC-22 for servicing equipment, which consists of 20-40% of the refrigerants that they use. Around 80% of the refrigerant they use consists of R-410A, which is a mixture of two hydrofluorocarbons used to replace R-22 in air conditioning equipment, due to its higher energy efficiency rating. They also use R-107 and R-134a for domestic appliances, and R-124. They have been stockpiling canisters of ozone-depleting gases, especially HCFCs. Whether or not they have CFC stockpiles is unknown, however, due to the lack of technology available in Costa Rica, it is likely they also have stockpiles of CFCs. About two or three years ago, this company had 150 canisters of ODS. The representative from this company told us that the amount of stockpiling has decreased about 30-40% in the past two or three years. These 150 canisters consist of about 30 lbs (or 13.6 kg) each, and have been stockpiled since around the start of the company 15 years ago. Thus, over 2,000 kg of ODS are currently stockpiled by this small company, and they do not know what to do with it. They were going through a company called Fogel in Cartago, to recycle HCFC-22. However, the process became too expensive, and thus they stopped recycling altogether and moved on instead to other refrigerants and stockpiling the ODS.

Currently, all companies have a quota of how much HCFC-22 a company can have. The quota controls how much refrigerant enters the market, and after that, it is a free market. When buying between companies, the price is higher than importing due to the free market, at least for this company. Furthermore, according to this source, it is not mandatory for technicians to be certified. The technicians at this company are, but it hurts business when a technician at another company can offer a cheaper price to their customer because they are not hiring a certified professional. Furthermore, although the National Institute of Learning incorporates training for natural refrigerants, this company representative was not aware of this program. It also became apparent during this interview that there is a clear lack of communication between the private and public sector, as well as the public sector and the people of Costa Rica. About 15 years ago, a professor at the University of Costa Rica did a study on natural refrigerants in appliances and published this study saying that the natural refrigerants were much too dangerous because they were explosive. When asked about the explosive ability of natural refrigerants and whether or not it was a problem, this representative began to explain that the explosiveness of the natural

refrigerants is much too dangerous. This sentiment has some merit of course, but false in that individual appliances are prone to explosion. Oftentimes, appliances have very little refrigerant in them, and at most are no more dangerous than the canisters of propane many Costa Ricans have in their home, which have a much higher content than that of an air conditioner. This topic is explained further in the general technology section.

After some more questioning, we discovered that the real issue was with the clientele in Costa Rica. It is they who are worried about the explosive capabilities of natural refrigerants, and must be convinced that it is not a great risk in order for this company to be able to begin to use natural refrigerants in their air conditioning appliances. The positive side of our interview with this representative is that they do realize that using natural refrigerant would be a good alternative, and are willing to make the switch, but the funding and the negative sentiment of their clients is holding them back. They also know about the cement kiln operation available to them through the government, but it is much too expensive for them to use it.

## Appendix E – DIGECA-OTO Interview Questions and Summary

**Interview March 25th 8:00 am Ozone, Sra. Alfaro and Sr. Elizondo**

**Location: DIGECA-OTO- Avenida 18, calle 9 y 9 bis edificio color celeste #935, segundo piso. (Costado Norte del Liceo Costa Rica, contiguo a Autos Mío)**

**Prompt:** Hello Sra. Alfaro and Sr. Elizondo,

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about your organization and its role in training technicians to service HCFCs. Any additional information you are able to provide regarding HCFC use in the private sector or regulations on HCFC use and training will also be of great help. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR for inspection and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization, should we obtain information that will jeopardize a business' reputation. We will take your responses and combine them with other information. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern you can feel free to ask questions now.

### Questions:

1. Tell us about your organization.
2. What is your role in this organization?
3. What regulations apply to businesses using HCFCs? For example, do they have caps on their use, import, or emission based on sector or some other criteria?
  - a. How helpful are these regulations?
  - b. Are these regulations enforced? If so, how?
4. With the implementation of new natural refrigerants, are you including regulations on the safety risks involved in using these refrigerants?
5. Is there a domestic certification process for the servicing and handling of HCFCs, HFCs, and/or natural refrigerants?
6. Has there been any changes to the customs techniques for equipment importation. For example, such as the lowest possible value of equipment efficiency?
  - a. What exactly do the efficiency values signify?
7. Are there any financial incentives, or any other form of incentives, in place to support the elimination of HCFCs?

8. In your words, why have some companies been so resistant to using alternatives to HCFCs?
9. What are the barriers to using natural refrigerants with respect to the job market?
10. Are there companies that have set a good example of handling HCFCs that you believe we should interview, in order to see how a successful sustainability plan works?
11. Can you give us information on the percentage of HCFCs imported by each importer?
12. Can you also give us this information divided by each industrial sector?
13. Can you tell us which importers sell HCFCs to other companies, like Company C?
14. If you can, could you send us a summary of the data you were unable to publish in the HPMP to maintain anonymity of the importers?
15. Can you explain how HCFC emissions are offset with the domestic carbon market, if at all?
16. Are there companies that are already taking part in the offset with HCFCs?
17. Can you give us information about recycling infrastructure or technology in place that could be used for recycling HCFCs? Such as facilities previously used for CFCs?
18. Can you direct us to the companies used to purchase these recycling technologies?
19. How did you measure HCFC emissions for the HPMP report? Was it with economic data or atmospheric data?
20. Can you give us an idea of the percentage of greenhouse gas emissions that HCFCs constitute in Costa Rica?
21. Has Costa Rica reached target reduction goals for the first phase of the plan? (i.e 2015-10%)
22. Can you give us some of the main details about the second and third phases of the HPMP?
23. Which organizations are involved in the development of these phases; are they the same as those that completed development of the first phase?
24. Do you have any suggestions for companies, in the private sector that would be helpful to interview, to gather data about HCFC use in Costa Rica?

**Entrevista 25 de marzo 8:00 a.m. Ozono, Sra. Alfaro y Sr. Elizondo**  
**Ubicación: DIGECA-OTO- Avenida 18, calle 9 y 9 bis Edificio color celeste# 935, Segundo Piso. (Costado Norte del Liceo Costa Rica, contiguo una Autos Mío)**

**Prompt:** Hola Sra. Alfaro y Sr. Elizondo,  
Nos gustaría grabar esta entrevista para revisar la información si usted está de acuerdo.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). Cualquier información adicional que podrían proporcionar con respecto al uso de HCFC en el sector privado o los reglamentos sobre el uso de HCFC y su capacitación también será de gran ayuda. Nos gustaría su permiso para hacer preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR y publicaremos la información adquirida de forma anónima en un trabajo de investigación. De esta entrevista esperamos aprender acerca de los productos químicos refrigerantes que se utilizan en la industria y la forma en la que se manejan. Queremos informarle que la información proporcionada por Usted **no** será publicada en su nombre o el nombre de su organización si obtenemos información que pondrá en peligro la reputación de negocio. Tomaremos sus respuestas y las combinaremos con información de otros entrevistados. Esta entrevista debe tomar alrededor de 30 a 40 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

**Preguntas:**

1. ¿Podrían contarnos de su organización, especialmente a que se dedica?
2. ¿Cuál es su papel en esta organización?
3. ¿Qué regulaciones son aplicables a las empresas que utilizan HCFC? ¿Por ejemplo, tienen límites de uso, importación, o de emisión por sector u otro criterio?
  - a. ¿Qué tan útiles son estos reglamentos?
  - b. Se hacen cumplir estas normas? ¿Si es así, cómo?
4. Esta un miembro de la Comisión Interinstitucional para la Eliminación de HCFCs?
  - a. ¿Qué está ocurriendo con este comisión?
  - b. ¿Cuándo fue la última reunión?
  - c. ¿Qué planes tiene esta comisión en el futuro?
5. Con la implementación de nuevos refrigerantes naturales, ¿se incluye los riesgos de seguridad involucrados en el uso de los refrigerantes?
6. ¿Hay un proceso de certificación nacional para el mantenimiento y el manejo de los HCFC, HFC y / o refrigerantes naturales?
7. ¿Ha habido un cambio en las regulaciones para la importación de equipo usando HCFCs? ¿Por ejemplo, hay un valor de eficiencia mínima para el equipo que se importe?
  - a. ¿Qué es exactamente lo que los valores de eficiencia significan y cómo se miden? Por ejemplo, cuál es la diferencia entre 8% y 12%?

- b. ¿Sabe sobre la etiqueta de la energía que los estudiantes de WPI crearon el año pasado? ¿Lo usan las compañías?
8. ¿Existen incentivos financieros, u otra forma de incentivos, para apoyar la eliminación de los HCFC?
  9. ¿Por qué algunas empresas han sido tan resistentes a la utilización de otras alternativas a los HCFC?
  10. ¿Cuáles son las barreras para el uso de refrigerantes naturales en relación con el mercado de trabajo?
  11. ¿Hay empresas que han establecido un buen ejemplo de manejo de los HCFC que usted cree que podamos entrevistar con el fin de ver cómo un plan de sostenibilidad exitoso funciona? (Buenas Practicas)
  12. ¿Ha llegado Costa Rica a las metas de reducción para la primera etapa del plan? (Es decir, desde 2015 hasta 10%)?
  13. ¿Puede darnos algunos de los principales detalles de la segunda y tercera etapas del HPMP?
  14. De estas organizaciones involucradas en la segunda y tercera etapas, ¿cuáles también completaron el desarrollo de la primera etapa?
  15. “A diciembre del 2015 se haya suscrito dos acuerdos voluntarios de compra de equipos y refrigerantes ecoeficientes y para el año 2020, se espera, que al menos el 25% de los equipos que se comercialicen en el país sean ecoeficientes.” (HPMP) ¿Ha habido algún progreso con esto?
  16. ¿Puede darnos información sobre el porcentaje de los HCFC importados por cada importador? (Potentially will not get an answer)
  17. ¿Puede usted también darnos esta información dividida por cada sector industrial?
  18. ¿Nos puede decir que los importadores venden los HCFC a otras empresas, ejemplo Company C?
  19. Si se puede, ¿Ud. podría enviarnos un resumen de los datos que no pudo publicar en dicho plan para mantener el anonimato de los importadores?
  20. ¿Puede explicar cómo las emisiones de HCFC se compensan con el mercado de carbono nacional?
  21. ¿Existen empresas que ya están participando en el reemplazo con los HCFC?
  22. ¿Nos puede dirigir a las empresas utilizadas para la compra de estas tecnologías de reciclaje?
  23. ¿Fueron datos económicos la principal forma de medir las emisiones de HCFC para el informe HPMP; en lugar de incorporar datos atmosféricos?
  24. ¿Puede darnos una idea del porcentaje de las emisiones de gases de efecto invernadero que los HCFC constituyen en Costa Rica?
  25. ¿Tiene alguna sugerencia sobre empresas privadas que sería útil para entrevistar para así recoger datos sobre el consumo de HCFC en Costa Rica?



The Dirección de Gestión de Calidad Ambiental (DIGECA: Directorate of Environmental Quality Management) is a branch of the Ministry of Environment and Energy in charge of the “agenda café” and is responsible for promoting awareness and preventing environmental issues, such as pollution, deforestation, ozone depletion and the greenhouse gas effect. Furthermore, DIGECA is responsible for promoting “environmental management” which entails designing strategies and public policies that mitigate and reverse the degradation of water, air, and soil through conceptual tools and techniques. They also establish means for monitoring and compliance of these tools and techniques.

Additionally, DIGECA features a sub-branch called the Oficina Técnica del Ozono (OTO: Ozone Technical Office), which is the link between the Ozone Secretariat, the Multilateral Fund for the Implementation of the Montreal Protocol and the Costa Rican Government, that uses resources provided by the United Nations Program for Development (UNDP) in order to complete several projects. Some of which include: defining governmental policies and programs aimed at ozone conservation and protection; research and encouragement of replacing harmful ozone-depleting substances (ODS) with safer alternatives; complying to import quotas and export of ODS as well as equipment and technologies that use and contain the reported ODS; and, collaborate with education training programs like the Instituto Nacional de Aprendizaje (INA: National Institute for Learning) for the handling of ODS, and their alternatives, recovery and recycling techniques.

Because DIGECA prioritizes on the laws, regulations, and implementations of ODS management, we initially spoke with Sr. Ing. Rodolfo Elizondo Hernández, the HCFC Phaseout Management Plan (HPMP) Coordinator and learned of the current progress of the HPMP in Costa Rica.

Through Elizondo, we learned more on the equipment certification process that goes through the Instituto Costarricense de Electricidad (ICE: Costa Rican Institute of Electricity) in order to test the efficiency of the SEER (Seasonal Energy Efficiency Ratio) and the EER (Energy Efficiency Ratio) of air conditioners. As well as the fact that, ICE follows an equipment quota set by both the government (through DIGECA) and the Montreal Protocol (through UNEP & OTO). If ICE were to certify more equipment than was allowed, the equipment would be stored and banned from use. Furthermore, we also learned of the technician certification regulations currently in conversation that would require all industrial institutions using ODS reported in the Montreal Protocol to hire nationally certified refrigerant technicians.

Elizondo also spoke of the Institutional Committee for the Elimination of HCFCs and how infrequently they meet each year (1 to 2 times with the committee per year), as well as how each individual sector within the industrial sector meets to further their implementation plans and compare progress. The Institutional Committee for the Elimination of HCFCs began discussions in 2010. However, because of cultural customs meetings are mostly all-talk and no-action.

HCFC substance importation was banned in 2010 aside from amounts necessary to service existing HCFC equipment, and HCFC equipment importation will be banned later in 2020. Presently, in order to use and buy HCFC equipment legally, companies are required to hold a Tech-Note 38 permit when purchasing further HCFC refrigerants or HCFC equipment. Unfortunately, DIGECA only knows how much of the HCFC substances and equipment are being imported, but where the gases are shipped to is another lingering and unanswered question.

Natural refrigerants were also discussed: the supposed risks and fear that many Costa Ricans believe about natural refrigerants are a large obstacle to overcome for the HPMP. For example, many believe a small amount of propane is capable of exploding whereas it is simply flammable. There are also rumors that refrigerators or other home equipment using propane, butane or other natural refrigerants will destroy homes when only a little amount of the substances in pure liquid form are used in the appliances. Because of this misinformation, many of the smaller companies refuse to support the change towards natural refrigerants and some of the problems for change includes lack of support as well as lack of available environmental efficient technology due to most of the equipment being developed overseas. There was also discussion on how to change is viewpoint that included implementing tax breaks on the companies that purchase equipment or just substances. Also, there needs to be a promotion implementation to showcase the benefits of using eco-efficient equipment.

The DIGECA representative also briefly discussed Costa Rica's progress regarding the HPMP. The country has met their proposed 10% reduction rate at the beginning of 2015. However, there has been absolutely no development for the second and third phase of the HPMP and developing these phases will follow after the completion of the first phase sometime in 2015. Furthermore, Costa Rica wants to completely skip the transitioning of substances from HCFCs right to natural refrigerants and prevent the use and import of HFCs and HPOs. There was also talk that no destruction technology is formally in place but Costa Rica is currently working on this issue.

## Appendix F – ENER-G Interview Questions and Summary

**Interview: Sr. Music**

**Location: Esacazú, Ener-G**

**Prompt:**

Can we record this interview to review the information we talked about?

We are students of WPI working as interns for “La Camara de Industrias de Costa Rica (CICR)” and we want to learn more about your business and the help it can provide to the industrial sector. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. This will not only benefit the environment but hopefully your business as well. We will be proposing this plan to CICR for inspection which will be published in our research paper. This interview should take around 30-40 minutes and is completely voluntary. If you do not want to participate or answer any questions you do not have to. We consider this information of great importance to our project and your help would be greatly appreciated. If there is any confusion or concern you can feel free to ask questions now.

1. Tell us about what your business does exactly.
2. How many other businesses are like yours in Costa Rica?
3. Are you aware of the environmental impacts of certain refrigerants, such as HCFCs? (If not, tell him about it)
4. Have you done projects involving refrigeration technology in the past?
5. How do you get paid for these projects, is it through the companies that hire you or does the government ever give you credits for projects that are environmentally beneficial?
6. Do you think it would benefit your company to be involved in a recycling technology implementation program for refrigerants?
7. What are the limitations to doing projects such as implementing a recycling program?

We interviewed Engineer and owner of the Energy Servicing Company ENER-G, Christopher Music, to inquire about his interest and ability in involving ENER-G in a project for implementing recycling technology or other technology to phase-out HCFCs and other environmentally harmful refrigerants in Costa Rica. ENER-G is an energy service company that does not distribute equipment. It avoids this model due to the bias the company would have in choosing equipment for each project. Instead, when a company comes to them with a project, they look at their economic data, perform an audit on their energy costs, they then design a solution that they submit to a cost-benefit analysis, and they find and install the equipment necessary to complete the project. ENER-G does not charge the company that has hired them anything for this service. Instead, they sign a contract with the company which includes an agreement that ENER-G receives a share of the costs saved from energy efficiency increases for a certain number of years, so that ENER-G can make a profit. The company that hires ENER-G pays them nothing until they receive savings. In the past 15 years that ENER-G has been in business, they have completed 760 projects. About 35% of their projects are in the industrial sector, with service and retail companies making up the bulk of the rest. They have done very little work with the government, due to the convoluted process of doing so. Often times, there are many contracts to be signed, and many delays. Thus, they work primarily with the private sector.

ENER-G is the only known company in Costa Rica to have their type of business model. The major issue with using a model like this is that companies are reluctant to pay and abide by their contract. There is a feeling in Costa Rica that “either you win and I lose, or I win and you lose”. There is a lack of a win-win mentality, and that makes it difficult for ENER-G to make a profit. What we failed to find out from this company is exactly how much of the energy savings and for how long they ask for compensation. Regardless, even if ENER-G was asking for 90% energy efficiency savings for 10 years, the company that “hired” ENER-G would at the very least see almost no difference in costs. The only problem with an agreement such as this would be the time off of the market that a company would have to spend, which would cost the company. In this case, there would be more impetus to ensure that the company receives an adequate share of the energy efficiency savings, at least to compensate for the costs incurred while the project is ongoing.

ENER-G typically receives loans from smaller banks within Costa Rica, although they have pursued loans from international, larger banks to do larger projects. The issue that the larger banks have is that ENER-G is a small company itself, and are not very familiar with their business model, which seems unstable to a loan officer that does not understand the success of such a model. Our interviewee explained to us that these banks prefer larger, more stable companies, and although the business model works successfully, it is very foreign to many of these larger banks and it is perceived as unstable. The majority of their investments are within \$25,000-\$75,000, but there is no real maximum on the amount that they would invest, given the right profit margin on energy savings.

ENER-G has yet to do any significant recycling projects. They have done a retrofitting project to make the switch from HCFCs to natural refrigerants in a refrigeration system within Costa Rica. Our interviewee informed us that his company would be willing to be a part of a recycling technology program, given a solid idea of the project. He would like to know how much savings are to be had from the project, how much more efficient the equipment will be and what it will take to achieve higher efficiencies, and what would the cost be for the project. He stated that limitations include availability of technology, convincing partners that they need to share the energy efficiency savings, and financing the projects-- getting the loans to carry out the project at hand.

## Appendix G – Company C Interview Questions and Summary

**Interview April 10th, 3:00pm, Sr. Miranda**

**Location: CICR**

**Prompt:** Hello Sr. Miranda,

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more your company and the refrigerants your company uses. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica.

This will not only benefit the environment but your business as well. We will be proposing this plan to CICR for inspection and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in your industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization. We are here to help your company to take the next steps to becoming more sustainable in a way that keeps your business competitive. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern you can feel free to ask questions now.

### Questions:

1. Tell us what your company does.
2. We have heard from CICR that your company has begun taking steps towards carbon neutrality. What are these steps specifically? How has the process been?
  - What challenges did you face in this process?
3. What type of refrigerants do you use in your cooling systems (both stationary and for transport)?
  - HCFC-22
  - HCFC-123
  - HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Other:
    - Do you use mixed refrigerant blends?
      - i. What does it consist of?
4. How efficient is your refrigeration equipment?

5. Is there required orientation/training to handle the equipment you use?
  - As part of the orientation/training, are workers informed of current refrigeration regulations like HCFCs?
6. Disposal and Recycling Procedures:
  - Are these chemicals recycled? If so:
    - i. Are they recycled in your facilities or transported to another company for recycling?
  - Are these chemicals or their waste being stockpiled? Why?
  - Do you think your company could support an in-house recycling facility?
  - How much do you think your company would be willing to spend on a recycling program?
7. Is this organization considering alternatives to HCFCs? If so, what alternatives are most appealing to your company?
  - Do you have an ammonia based refrigeration system?
    - i. How long have you had it?
    - ii. Did your company design it or import it?
    - iii. Is it only for industrial refrigeration?
    - iv. Do you think it would be possible for other companies to use this technology?
8. How helpful are these regulations?
9. How do you feel about your company's actions to become sustainable?
  - If good: Was there something that your company did to get where they are today?
  - If bad: What is something you feel your company should strive to do/achieve?
10. Did working with GIZ help you at all?
11. Plans for the future involving refrigerant use and C-Neutrality?

## Entrevista 10 de abril, 3:00pm, Sr. Miranda

### Ubicación: CICR

Nos gustaría grabar esta entrevista para revisar la información si usted está de acuerdo.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). Cualquier información adicional que podría proporcionar con respecto al uso de HCFC o los reglamentos sobre el uso de HCFC y su capacitación también será de gran ayuda. Nos gustaría su permiso para hacer preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR y publicaremos la información adquirida de forma anónima en un trabajo de investigación. De esta entrevista esperamos aprender acerca de los productos químicos refrigerantes que se utilizan en la industria y la forma en la que se manejan. Queremos informarle que la información proporcionada por Usted **no** será publicada en su nombre o el nombre de su organización si obtenemos información que pondrá en peligro la reputación de su empresa. Tomaremos sus respuestas y las combinaremos con información de otros entrevistados. Esta entrevista debe tomar alrededor de 30 a 40 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

### Preguntas:

1. Por favor, explica lo que hace la compañía
2. La Cámara de Industrias nos dijo que su compañía ha empezado a trabajar el proceso de convertirse en carbono neutral. Exactamente, ¿que hacía?
  - ¿Que obstáculos ha enfrentado?
3. ¿Cuales refrigerantes usa Usted en los sistemas de refrigeración?
  - HCFC-22
  - HCFC-123
  - HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Otra:
    - Usa mezclas de refrigerantes Usted?
      - i. ¿Que consiste en estas mezclas?
4. ¿Que tan eficiente los equipos de refrigeración?
5. ¿Hay capacitación que es necesario competir para operar los equipos que usan HCFC?
  - Durante la capacitación, ¿los trabajadores estan informado de las regulaciones sobre HCFC?
6. Destrucción y reciclaje:
  - ¿Los refrigerantes estan reciclados?



- i. ¿Tiene las facilidades para reciclar los refrigerantes o están transportados a otra compañía?
    - ¿Los refrigerantes están acumulados? ¿Por qué?
    - ¿Cree que su empresa podría apoyar una planta de reciclaje en casa?
    - ¿Cuánto cree que su empresa estaría dispuesta a gastar en un programa de reciclaje?
- 7. ¿Su compañía está considerando los alternativos a HCFC, como refrigerantes naturales?  
¿Cuáles alternativos ha considerado?
  - ¿La compañía tiene un sistema de refrigeración de amoníaco?
    - i. ¿Cuántos años ha lo tenido?
    - ii. ¿Su compañía lo diseña o lo importa?
    - iii. ¿Solamente es para refrigeración industrial?
    - iv. ¿Usted cree que es posible que otras compañías utilicen esta tecnología?
- 8. ¿Qué tan útiles son las regulaciones?
- 9. ¿Cómo se siente sobre las acciones de su empresa para ser sostenible?
  - Si bueno: ¿Hubo algo que hizo su empresa para llegar a donde están hoy?
  - Si malo: ¿Hay algo que siente su empresa debe esforzarse por hacer?
- 10. ¿Trabajando con GIZ ayudó a su empresa?
- 11. ¿Cuáles son los planes futuros de su empresa que involucran en el uso de refrigerantes y C-neutralidad?

Company C is a Costa Rican company that produces and distributes food and beverages to Central America, the Caribbean, and North America. They also provide capital investments and run real estate in Guanacaste, Costa Rica. Their operations are in Costa Rica, El Salvador, Guatemala, and the United States. Company C has around 5,700 employees and is one of the largest international companies based out of Costa Rica. They have four major manufacturing plants here in Costa Rica and eleven distribution centers. Therefore Company C is one of the largest player in the refrigeration market in Costa Rica.

Company C is one of the leading companies that is pushing towards Costa Rica's goal of carbon neutrality. An ambitious goal was set in 2010 for the company to reach carbon neutrality by the year 2017 and Company C has made great strides towards that. The breakdown of their emission report is that 74% of emissions are from fossil fuels (34,111 tons of CO<sub>2</sub>), 11.1% are from refrigerant gases (5100 tons of CO<sub>2</sub>), and 11.1% are from electricity (5167 tons of CO<sub>2</sub>). Company C has been working towards the incorporation of renewable energy sources for their main energy costs and have begun to reduce their emissions from refrigerant gases by using alternatives. The main obstacles they have run into during their transition to being carbon neutral is the lack of funding, technology and incentives to follow through in this process. The first problem Company C ran into was the lack of funding sources for this recycling technology or for the alternative refrigerant technology. There is very little technology here in Costa Rica that is commonly used for these purposes, but internationally there are many options. The problem is this technology is not only expensive but needs to be shipped around the world just to get to Costa Rica, as the majority of the technology is from Europe or the United States. On top of the initial cost of the new equipment the company would lose profits from shutting down its facilities for the exchange and, depending on the equipment efficiency, would have to pay higher energy costs. One of the last obstacles is the lack of incentives in providing government aid to these projects. Alongside this, the use of natural refrigerants is considered dangerous in the local market and its advertisement could hurt company sales. However, Company C is able to withstand the initial disadvantages of some of these obstacles as they are a large company and are using this advantage to take small steps in pursuing their carbon neutrality.

The refrigerant use at Company C has improved over the years as they have phased out CFCs and have begun to phase out HCFCs. Company C currently uses these HCFCs: R-22, R-24A, R-401 and R-402B. They have begun to phase them out with these HFCs: R-134A and R-404A. Company C has also begun to run tests on using the natural refrigerant propane in their commercial cooling equipment. The main issue with the management of refrigerants at Company C is that they have been stockpiling them while they wait for the Ministry of Health to force a regulation of these stockpiles and then supply the companies with a destruction solution. This destruction solution is looking into the cement company Holcim, where they use their incinerator to destroy the refrigerant gases. Company C had actually used their services in the past but has stopped because it was too expensive. However, in 2012 Company C purchased a piece of recycling technology and has been using it to test the efficiency of the recycled refrigerants in their equipment. This is mostly being used to clean refrigerants during equipment maintenance, after which the recycled refrigerant is put back into the same equipment. This recycling technology was purchased for \$10,000 from a Central American refrigeration company called

Fogel. This technology seems to be a reasonable solution for part of the stockpiling problem in Costa Rica, but it will need to be tested to see how effective the recycled refrigerant is and what scale the technology can be used on.

Company C is among a majority of large companies in Costa Rica that train their own refrigeration technicians instead of using the national training centers in Costa Rica, such as INA. This is a common practice among larger companies because they have very specific equipment for the refrigeration processes that they use and teaching their own technicians on it is more beneficial for them. This is regardless of the fact that the training at government sponsored organizations like INA is free of cost to the company. The fact remains that the training at INA requires an admissions process that is lengthy and they actual training take around two and half years to complete. In order to make the training at institutions like INA viable, these institutions need to cater to the needs of the companies that would send their technicians there so that both parties benefit. In the end the government has begun to register the company based and independent refrigeration technicians in Costa Rica and may mandate a nationalized certification program for them in the future.

In relation to the CICR, Company C has not worked with them on many projects and cannot speak in any depth about how helpful they have been. However, Company C has worked on projects with the GIZ's 4E program to improve their company's green policy. The GIZ's 4E program help countries in Central America to use renewable energies and increase their energy efficiency. This is how Company C has begun to combat their energy uses in fossil fuels by looking towards renewable solutions and purchasing more energy efficient equipment.

## Appendix H – INA Interview Questions and Summary

**Interview March 24rd 9:30 am Instituto Nacional de Aprendizaje, Sr. Alvarado, Location: INA office across from National Amusement Park**

**Prompt:** Hello Sr. Alvarado,

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about your organization and its role in training technicians to service HCFCs. Any additional information you are able to provide regarding HCFC use in the private sector or regulations on HCFC use and training will also be of great help. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR for inspection and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization, should we obtain information that will jeopardize a business' reputation. We will take your responses and combine them with other information. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern you can feel free to ask questions now.

### Questions:

1. Please name the organization:
2. Your department:
3. Your position:
4. What training programs do you have in place for refrigerant technicians?
5. Do companies that use refrigerants send their technicians to you, or are these technicians usually from third parties?
  - a. Do you have a list, or do you know of the companies that have sent technicians to you in the past? If you do have a list, we would like it if you are authorized to give us a copy.
6. Do you have a program for HCFC refrigerants?
  - a. If not, please explain why.
7. What equipment are they trained to service?
8. How long is this program?
9. What information must they need to know to properly service HCFC containing equipment?
  - a. Do they have any knowledge on how to prevent emissions while servicing?
10. Do you have a program for natural refrigerants?
  - a. If not, please explain why.
11. Does this program educate the technicians about the same equipment?

12. How much of your budget do each of these programs use?
  - a. How are these programs funded? Government funding or do companies fund their technicians to be trained?
  - b. What is a common cost of training a technician to handle HCFCs?
13. Who teaches these programs?
  - a. Where were they trained?
  - b. Who were they trained by?
14. What regulations apply to training technicians for natural refrigerants or HCFCs?
15. How helpful are these regulations?
16. What qualifications does an educator need to be able to teach these training programs?
  - a. What type of evaluations are used for the training programs?
17. Does this training include recovery, recycling and disposal of refrigerants?
  - a. Do you know what technology they are trained to use for recovery, recycling, and disposal?

**Entrevista 24 de marzo 09:30 am Instituto Nacional de Aprendizaje, Sr. Alvarado,  
Ubicación: oficina INA frente a Nacional de Parque de Atracciones**

**Prompt:** Buenos días Sr. Alvarado,

Somos estudiantes de WPI que trabajan como pasantes de la Cámara de Industrias de Costa Rica (CICR ) y queremos aprender más sobre de su organización y su papel en la formación de técnicos a los HCFC servicio. Cualquier información adicional disponible con respecto al uso de HCFC en el sector privado o los reglamentos sobre el uso de HCFC y la formación también será de gran ayuda. Nos gustaría su permiso para preguntarle como parte de una entrevista para nuestro investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Propondremos este plan a la CICR para la inspección y publicaremos esta información de forma anónima en un reporte. De esta entrevista esperamos aprender sobre de los refrigerantes químicos que se utilizan en la industria y la forma en que se manejan. Queremos informarle de que la información que aprendemos no será publicada en su nombre o el nombre de su organización. Tomaremos sus respuestas y los combinaremos con otra información. Esta entrevista debe durar entre 30 a 40 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y no tiene que contestar cualquier pregunta que no quiera. Consideramos que esta información de gran importancia para nuestro proyecto. Su ayuda sería muy apreciada. Si hay alguna confusión o preocupación que usted puede sentirse libre de hacer preguntas ahora

**Preguntas:.**

1. ¿Cómo se llama su organización?
2. ¿Y cómo se llama su departamento?
3. ¿Y su posición?
4. ¿Podría describir la capacitación para los técnicos de refrigeración, por favor?
5. ¿Las empresas que utilizan los refrigerantes le envían sus técnicos a usted, o estos técnicos son generalmente de terceros?
  - a. ¿Tiene una lista (en papel o en digital) de las empresas que le han enviado técnicos en el pasado? Si usted tiene una lista en papel, nos encantaría una copia si le es posible.
6. ¿Tiene un programa para refrigerantes HCFC?
  - a. Si no es así, por favor explique por qué.
7. ¿Cuáles equipos son entrenados para dar servicio?
8. ¿Cuánto tiempo dura este programa?
9. ¿Qué información se necesita para operar correctamente [en equipos de HCFC que contiene]
  - a. ¿Tienen algún conocimiento sobre cómo prevenir las emisiones durante el servicio?
10. ¿Tiene un programa para refrigerantes naturales?
  - a. Si no es así, por favor explique por qué.
11. ¿Este programa de educar a los técnicos sobre el mismo equipo?
12. ¿Es este programa, siempre y cuando el programa refrigerante HCFC?
13. ¿Cuánto de su presupuesto se usa para cada uno de estos programas?
  - a. ¿Cómo se financian estos programas? ¿Es financiamiento del gobierno o lo hacen las mismísimas empresas?

- b. ¿Cuánto cuesta la capacitación de un técnico para manejar los HCFC?
- 14. ¿Quién enseña estos programas?
  - a. ¿Dónde estaban entrenados?
  - b. ¿Quién los entrena a los entrenadores?
- 14. ¿Qué regulaciones se aplican a la capacitación de técnicos en refrigerantes naturales o HCFC?
- 15. ¿Qué tan útiles son estos reglamentos?
- 16. ¿Qué calificaciones necesita un educador para dar estos programas de capacitación?
  - a. ¿Qué tipo de evaluaciones se utilizan para los programas de capacitación?
- 17. ¿Esta capacitación incluirá la recuperación, reciclaje y eliminación de refrigerantes?
  - a. ¿Te saben lo que la tecnología que están capacitados para utilizar para la recuperación, el reciclaje y la eliminación?

The Instituto Nacional de Aprendizaje (INA: National Training Institute) is one of four governmentally-funded organizations that provides vocational educational programs for nationalized Costa Ricans. The other three are the Fundación Samuel en Calle Blancos, CEDES Don Bosco: Colegio Técnico Don Bosco, and the Colegio Técnico Profesional de Calle Blancos. INA first took root after the implementation of regulation No. 3506 on May 21<sup>st</sup>, 1965. INA provides free vocational training for citizens over the age of 15, in all sectors of the economy. This aids in INA's mission in promoting economic and social development, as well as improving living and work conditions. The institute aims to achieve their life bettering mission by providing quality training, skill development, certification, and accreditation for sustainable, equitable and productive high-quality work. In 2013, INA had a record 57 centers throughout Costa Rica and its training programs have educated over 135,000 students.

As part of HCFC Phaseout Management Plan (HPMP), Costa Rica implemented regulations that required companies utilizing HCFCs or other dangerous substances as per mandated by the Montreal Protocol, to certify all refrigerant-handling technicians employed in the companies. Because of this reason, we looked to further understand the process and what INA's refrigerant training entailed.

We spoke with Sr. Ing. Wilberth Alvarado Marín, a researcher and former instructor in the Process Technology Management department of the Nucleo Electronio. A former instructor in INA's Guanacaste and Puerto Limon centers, Alvarado has worked in the field for 16 years and currently works as a researcher for INA to discover new technology and training procedures regarding electronics, telecommunications, and refrigeration and air conditioners. He explained that in the Nucleo Electronico branch of INA provides a general training for all types of current systems that utilize refrigerant chemicals like HCFCs (R-22), HFCs (R-134a), and even natural refrigerants. Training includes topics such as the risks and safety issues regarding each refrigerant, as well as soldering, detecting, testing, repairing, thermodynamics, electrical engineering, theoretical issues, and recovery using refrigerant equipment. The training program lasts a minimum of 2 ½ years, in which after technicians undergo supervised employment for an additional 4 months. This is followed by a cumulative exam to determine if the student passes or fails the program and whether they receive a certificate.

Alvarado also briefly explained exactly where the funding for the program comes from. Approximately 1.5% of the taxes from the government is utilized by INA, which pays for the small salary, technology, supplies, tuition and everything in between for both students and employees. He also explained that participating companies may also apply for grants to fund the training of their employees even providing room and board.



## Appendix I – COMPANY D Interview Questions and Summary

### Interview April 8th 9:00 am COMPANY D

**Prompt:** Hello Sr.

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about the refrigerants your company uses. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization. We are here to help your company to take the next steps to becoming more sustainable in a way that keeps your business competitive. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern, you can ask questions now.

#### Questions:

1. Tell us what your company does.
2. What is your role in this company?
3. Department:
4. What is your relationship with Atlas and GE?
5. Who are your customers (i.e. homeowners, hotels, supermarkets)? Other refrigeration companies?
  - Do your customers buy equipment from you?
  - Do your customers buy refrigerants from you?
6. We know you have made a lot of progress to eliminate HCFCs, can you tell us more about this progress? What exactly did you do?
  - What were the challenges?
7. (Say: Thank you very much. Now, we need more information about the refrigerants your company is using.) Which refrigerants do you use?
  - HCFC-22

- HCFC-123
  - HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Other:
8. Do you use any mixtures of refrigerants?
  9. About how much of each type of refrigerant do you use?
  10. Do you have any refrigerants stockpiled? If so, can you give us an estimate on the amounts you have?
  11. How do you obtain your refrigerants and your refrigeration equipment?
    - What type of equipment (industrial, commercial, domestic)?
    - Is this equipment imported? If so, from who.
    - What about refrigerants? Do you buy refrigerants alone and then add it to your equipment?
  12. How helpful are the HCFC regulations that the government has implemented in Costa Rica? How do these regulations compare with those of other countries your company deals with?
  13. In your company, what technologies are used to dispose of HCFCs? For example, do you recycle, reclaim, or destroy refrigerants?
  14. Does your company use this technology in Costa Rica? Or, are they only used in countries outside of Costa Rica?
    - What are the limitations to using this technology in Costa Rica?
    - Do you use another company or organization for recycling?
    - How do you think the Costa Rican government is doing in trying to help you with disposing of HCFCs?
    - What do you think you need to dispose of HCFCs in the future?
    - Do you use recycled HCFCs?
    - Would you consider recycling processes?
    - Would you be willing to invest in recycling technology? Why or why not?
    - Do you think it would benefit your company to provide this service to your clients?
  15. Is COMPANY D considering alternatives to HCFCs in Costa Rica? If so, what alternatives are most appealing to your company?
    - Are you using these alternatives in other countries? What alternatives are they?
    - What are some of the reasons why your company is not considering some HCFC alternatives in Costa Rica (i.e. ammonia)?
  16. Do you think your equipment is energy efficient?
    - How efficient is your equipment in Costa Rica?
    - How do you think the efficiency could be improved?
  17. Do your customers usually come to you with their old equipment?
    - If they do, how do you handle the old equipment?
  18. Is there required training to handle HCFCs and/or the equipment you use?
    - Has this training been company directed or is this training through the Instituto de Aprendizaje?

19. What do you plan to do in the future to eliminate HCFC use?
20. How helpful has the CICR been for you?

## Entrevista 08 de abril 09 a.m. COMPANY D

**Prompt:** Hola Sr.

Nos gustaría grabar esta entrevista con nuestro teléfono para revisar la información y también tomar notas si usted está de acuerdo.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). La Cámara quisiera aprender más sobre de su empresa y que los procesos y los productos químicos que utiliza. Nos gustaría su permiso para pedir preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Esto no sólo beneficiará al medio ambiente, pero su empresa también. Propondremos este plan a la CICR y publicaremos la información adquirida anónimamente en nuestra investigación. De esta entrevista esperamos aprender sobre los productos químicos que se utilizan en sus procesos industriales y la forma en la que se manejan. Queríamos informarle que la información proporcionada por Usted no será publicada en su nombre o el nombre de su empresa. Tomaremos sus respuestas y las combinaremos con otra información de múltiples empresas para nuestro plan de reciclaje. Sólo vamos a notar el nombre de su empresa para nuestro documento inicial y un documento guardado por el CICR para ayudar a su progreso futuro. Esta entrevista debe tomar aproximadamente 30 a 45 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

### Preguntas:

1. ¿Nos puede explicar qué hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. ¿Y su departamento?
4. ¿Cuál es su relación con Atlas y GE?
5. ¿Quiénes son sus clientes (es decir, los propietarios de viviendas, hoteles, supermercados?) ¿Otras empresas de refrigeración?
  - ¿Sus clientes compran equipos de usted?
  - ¿Sus clientes compran refrigerantes de usted?
6. ¿Sabemos que su empresa ha avanzado mucho con la eliminación de HCFCs. ¿Usted puede contarnos más sobre su progreso?
  - ¿Qué fueron los retos para lograr este progreso?
7. (Dice: “Muchas gracias, ahora necesitamos más información sobre los refrigerantes que su empresa está usando.”) ¿Qué refrigerantes utiliza?
  - HCFC-22
  - HCFC-123
  - HCFC-141b
  - HCFC-142b
  - HCFC-123

- HCFC-124
  - HCFC-225
  - Otros:
8. ¿Utiliza mezclas de refrigerantes?
  9. ¿Cuánto de cada tipo de refrigerante se utilizan?
  10. ¿Tienen refrigerantes almacenados? Si es así, ¿puede darnos una estimación de las cantidades que tiene?
  11. ¿Cómo se obtienen sus refrigerantes y su equipo de refrigeración?
    - ¿Qué tipo de equipo (industrial, comercial, doméstico)?
    - ¿Se importa este equipo? Si es así, ¿de quién se importa?
    - ¿Qué pasa con los refrigerantes? ¿Compra refrigerantes solo y después lo añade a su equipo?
  12. ¿Que tan útil es la normativa de HCFC que el gobierno ha implementado en Costa Rica? ¿Cómo se comparan estas normas con otros países dónde su empresa tiene sucursales?
  13. En su empresa, ¿cuáles tecnologías se utilizan para eliminar los HCFC? Por ejemplo, ¿reciclar, reclamar o destruir refrigerantes?
  14. ¿Su empresa utiliza esta tecnología en Costa Rica? O, ¿son sólo utilizados en los países afuera de Costa Rica?
    - ¿Cuáles son las limitaciones para el uso de esta tecnología en Costa Rica?
    - ¿Usted contrata a otra empresa u organización para el reciclaje?
    - ¿Qué opina Usted en cuanto al apoyo del gobierno costarricense acerca de la eliminación de los HCFC?
    - ¿Qué cree Usted que se necesita hacer para eliminar los HCFC en el futuro?
    - ¿Utiliza los HCFC reciclados?
    - ¿Usted consideraría los procesos de reciclaje?
    - ¿Estaría dispuesto a invertir en tecnología de reciclaje? ¿Por qué sí o no?
    - ¿Cree que sería beneficioso para su empresa para ofrecer este servicio de reciclaje a sus clientes?
  15. ¿COMPANY D está considerando alternativas a los HCFC en Costa Rica? Si es así, ¿qué alternativas son las más atractivas para su empresa?
    - ¿Está utilizando alternativas en otros países? ¿Qué alternativas?
    - ¿Cuáles son algunas de las razones por qué su empresa no está considerando algunas alternativas a los HCFC en Costa Rica (es decir, amoníaco)?
  16. ¿Cree que su equipo es eficiente con la energía?
    - ¿Qué tan eficiente es su equipo en Costa Rica, específicamente?
    - ¿Cómo cree que la eficiencia se puede mejorar?
  17. ¿Sus clientes suelen venir a usted con su antiguo equipo?
    - Si es así, ¿cómo maneja Usted el equipo viejo?
  18. ¿Se requiere capacitación para manejar los HCFC y / o el equipo que se utiliza?
    - ¿Esta capacitación ha sido dirigida por la empresa o por una institución como el Instituto de Aprendizaje?
  19. ¿Qué es lo que piensa hacer en el futuro para eliminar el uso de HCFC?
  20. ¿Qué tan útil ha sido el CICR para usted?

We spoke with a representative from Company D who is essentially the CEO of Company D in Costa Rica. Company D is a major domestic refrigeration company, which started its facility in Costa Rica in 2008 and currently provides over 70% of the domestic refrigeration market in Costa Rica. Thus, Company D is a major player in HCFC phase-out and responsible refrigerant use. In addition to domestic refrigerators, the company also sells ranges, stoves, and other electrical appliances. Company D bought Atlas in 2008, and Atlas is now a subsidiary of Company D. GE owns 48% of Company D's shares, and began investing in Company D in the 1980s. Company D is a Mexican company, but has offices in Mexico, Colombia, and Argentina. Less than 1.0% of Company D's company shares are independently owned, mostly by old shareholders of Atlas. Company D is responsible for 120,000 appliances sold in Costa Rica annually. Despite the large market presence in Costa Rica, they export 90% of the products manufactured in Costa Rica to other countries in Central America, the Dominican Republic, the United States and the Caribbean. The other 10% that actually stays within Costa Rica is sold to four major companies: Grupo Monge, Collo, Casa Blanca, and Artelec. These 4 companies make up 70% of the appliances sold in Costa Rica by Company D, while the other 30% are sold to through retail stores which makes up over 150 clients. Company D also imports from Mexico, China, and the USA to sell in Costa Rica.

Company D imports equipment from Mexico, but they also manufacture equipment in Costa Rica. They do not sell refrigerants, since most of the products they sell are already charged. Company D does not currently use HCFCs at all. In 1998, Company D began using HFC-134a instead of CFC-12 as part of the CFC phase-out. They import about 20 metric tons of HFC-134a annually from a company called Oxford in China. In 2013, they replaced all foam blowing agents using HCFC-141b with cyclopentane, a natural refrigerant. This switch was funded in part by the Multilateral Fund (50%) and Company D (50%). Due to their switch to cyclopentane, they can no longer import mixed polyol with the blowing agent, since cyclopentane is not normally pre-mixed. In addition, they are able to report the exact amount of cyclopentane imported, whereas prior to this, the amount of HCFC imported needed to be calculated since it was premixed.

When asked what the limitations are to using natural refrigerants, cost was the main issue, but this is changing quickly. For example, butane used to be more expensive than using HCFCs, but now it has become cheaper to use. There are also technical limitations. The gas is flammable, which poses risks when using it in the manufacturing facilities. It isn't a problem in their appliances, but when they are dealing with large quantities of the natural gas, the process becomes more complex due to the additional risks. In addition, making the switch requires the facility to shut down so that they can go through with the project. As far as other limitations, some of the alternative refrigerants can only be used in certain processes. For example, ammonia is not a compression type gas, it is only used in absorption cycles that Company D does not use or produce. Furthermore, we were told that ammonia is not very useful for large scale refrigeration equipment. The same limitations apply to propane. In addition, many people still believe that there is significant danger of explosion in smaller products like domestic refrigerators. This is a rumor that has perpetuated itself for some time in Costa Rica. Furthermore, the company is not certain as to whether or not natural refrigerants actually have a

GWP of lesser value than the HFC-134a. For demanufacturing projects, the reverse logistics are an issue. It is a highly costly process, since you have to dismantle the entire refrigerator without releasing any of the gas. Then there is the foam component, which contains more chemical than the cooling system itself that must be degassed. Company D currently has no recycling technology for refrigerants or managing the end life of HCFCs or the appliances that they sell. Our interviewee was not aware of much technology available, aside from technology in Holland that utilizes a completely sealed building structure, presumably to prevent emissions during dismantling.

As far as training is concerned, Company D trains their own technicians. They believe that their training is more suited to their technology and processes, and that training elsewhere, such as at publicly funded institutions is inadequate. Many technicians service the appliances they sell, which usually costs \$100-\$150 to service, accounting for only refrigerant cost.

When asked about the government and whether or not their regulations are helping this company, we were told that the government wants them to move to natural refrigerants but is not giving them a possible avenue to do so. The program they did to phase-out HCFCs in foams was done through MINAE and the OTO (although funded by the Multilateral Fund). When asked about CICR's relationship, they believed this relationship to be irrelevant, especially for previous projects.

## Appendix J – Company E Interview Questions and Summary

### Interview April 14th 10:00 am COMPANY E

**Prompt:** Hello Sr.

We would like to record this interview to review information if you agree.

We are students of WPI working as interns of the Camara de Industrias de Costa Rica (CICR) and want to learn more about the refrigerants your company uses. We would like your permission to ask questions as part of an interview for our research project. The purpose of our research is to develop an HCFC management plan for the industrial sector of Costa Rica. We will be proposing this plan to CICR and will be publishing this information anonymously in a research paper. From this interview we hope to learn about the refrigerant chemicals that are used in industry and how they are handled. We want to inform you that the information that we gather from you will **not** be published in your name or the name of your organization. We are here to help your company to take the next steps to becoming more sustainable in a way that keeps your business competitive. This interview should take around 30-40 minutes and is completely voluntary. You do not need to participate if you do not wish to and you can skip any question that you do not want to answer. We consider this information of great importance to our project. Your help would be greatly appreciated. If there is any confusion or concern, you can ask questions now.

#### Questions:

1. Tell us what your company does.
2. What is your role in this company?
3. Department:
4. Who are your customers (i.e. homeowners, hotels, supermarkets)? Other refrigeration companies?
  - Do your customers buy equipment from you?
  - Do your customers buy refrigerants from you?
5. We know you have made a lot of progress to eliminate CFCs, can you tell us more about this progress? What exactly did you do?
  - What were the challenges?
6. (Say: Thank you very much. Now, we need more information about the refrigerants your company is using.) Which refrigerants do you use?
  - HCFC-22
  - HCFC-123
  - HCFC-141B
  - HCFC-142B
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Other:
7. Do you use any mixtures of refrigerants?
8. About how much of each type of refrigerant do you use?



9. Do you have any refrigerants stockpiled? If so, can you give us an estimate on the amounts you have?
10. How do you obtain your refrigerants and your refrigeration equipment?
  - What type of equipment (industrial, commercial, domestic)?
  - Is this equipment imported? If so, from who.
  - What about refrigerants? Do you buy refrigerants alone and then add it to your equipment?
11. How helpful are the HCFC regulations that the government has implemented in Costa Rica? How do these regulations compare with those of other countries your company deals with?
12. In your company, what technologies are used to dispose of HCFCs? For example, do you recycle, reclaim, or destroy refrigerants?
13. What are the limitations to using this technology in Costa Rica?
  - Do you use another company or organization for recycling?
  - How do you think the Costa Rican government is doing in trying to help you with disposing of HCFCs?
  - What do you think you need to dispose of HCFCs in the future?
    - i. Do you receive broken refrigeration equipment from customers? If so, what do you do with it?
  - Do you use recycled HCFCs?
  - Would you consider recycling processes?
  - Would you be willing to invest in recycling technology? Why or why not?
  - Do you think it would benefit your company to provide this service to your clients?
14. Is COMPANY E considering alternatives to HCFCs in Costa Rica? If so, what alternatives are most appealing to your company?
  - Are you using these alternatives in other countries? What alternatives are they?
  - What are some of the reasons why your company is not considering some HCFC alternatives in Costa Rica (i.e. ammonia)?
15. Do you think your equipment is energy efficient?
  - How efficient is your equipment in Costa Rica?
  - How do you think the efficiency could be improved?
16. Do your customers usually come to you with their old equipment?
  - If they do, how do you handle the old equipment?
17. Is there required training to handle HCFCs and/or the equipment you use?
  - Has this training been company directed or is this training through the Instituto de Aprendizaje?
19. What do you plan to do in the future to eliminate HCFC use?
20. How helpful has the CICR been for you?

## **Entrevista: April 14th 10:00 am COMPANY E**

**Prompt:** Hola Sr.

Nos gustaría grabar esta entrevista con nuestro teléfono para revisar la información y también tomar notas si usted está de acuerdo.

Somos estudiantes estadounidenses de Worcester Polytechnic Institute de Massachusetts, y actualmente estamos trabajando como pasantes en la Cámara de Industrias de Costa Rica (CICR). La Cámara quisiera aprender más sobre de su empresa y que los procesos y los productos químicos que utiliza. Nos gustaría su permiso para pedir preguntas como parte de una entrevista para nuestro proyecto de investigación. El objetivo de nuestra investigación es desarrollar un plan de gestión de HCFC para el sector industrial de Costa Rica. Esto no sólo beneficiará al medio ambiente, pero su empresa también. Propondremos este plan a la CICR y publicaremos la información adquirida anónimamente en nuestra investigación. De esta entrevista esperamos aprender sobre los productos químicos que se utilizan en sus procesos industriales y la forma en la que se manejan. Queríamos informarle que la información proporcionada por Usted no será publicada en su nombre o el nombre de su empresa. Tomaremos sus respuestas y las combinaremos con otra información de múltiples empresas para nuestro plan de reciclaje. Sólo vamos a notar el nombre de su empresa para nuestro documento inicial y un documento guardado por el CICR para ayudar a su progreso futuro. Esta entrevista debe tomar aproximadamente 30 a 45 minutos y es completamente voluntaria. Usted no tiene que participar si usted no desea y puede saltar cualquier pregunta que no quiera contestar. Consideramos esta información de gran importancia para nuestro proyecto y esperamos beneficiar la sostenibilidad ambiental de su empresa con la información. Su ayuda sería muy apreciada. Si tienen alguna confusión o preocupación, por favor no duden en hacernos preguntas ahora.

### **Preguntas:**

1. ¿Nos puede explicar qué hace su empresa?
2. ¿Cuál es su papel en esta empresa?
3. ¿Y su departamento?
4. ¿Quiénes son sus clientes (es decir, los propietarios de viviendas, hoteles, supermercados?) ¿Otras empresas de refrigeración?
  - ¿Sus clientes compran equipos de usted?
  - ¿Sus clientes compran refrigerantes de usted?
5. ¿Sabemos que su empresa ha avanzado mucho con la eliminación de CFCs. ¿Usted puede contarnos más sobre su progreso?
  - ¿Qué fueron los retos para lograr este progreso?
6. (Dice: “Muchas gracias, ahora necesitamos más información sobre los refrigerantes que su empresa está usando.”) ¿Qué refrigerantes utiliza?
  - HCFC-22
  - HCFC-123
  - HCFC-141b
  - HCFC-142b
  - HCFC-123
  - HCFC-124
  - HCFC-225
  - Otros:
7. ¿Utiliza mezclas de refrigerantes?

8. ¿Cuánto de cada tipo de refrigerante se utilizan?
9. ¿Tienen refrigerantes almacenados? Si es así, ¿puede darnos una estimación de las cantidades que tiene?
10. ¿Cómo se obtienen sus refrigerantes y su equipo de refrigeración?
  - ¿Qué tipo de equipo (industrial, comercial, doméstico)?
  - ¿Se importa este equipo? Si es así, ¿de quién se importa?
  - ¿Qué pasa con los refrigerantes? ¿Compra refrigerantes solo y después lo añade a su equipo?
11. ¿Que tan útil es la normativa de HCFC que el gobierno ha implementado en Costa Rica? ¿Cómo se comparan estas normas con otros países dónde su empresa tiene sucursales?
12. En su empresa, ¿cuáles tecnologías se utilizan para eliminar los HCFC? Por ejemplo, ¿reciclar, reclamar o destruir refrigerantes?
13. ¿Cuáles son las limitaciones para el uso de esta tecnología en Costa Rica?
  - ¿Usted contrata a otra empresa u organización para el reciclaje?
  - ¿Qué opina Usted en cuanto al apoyo del gobierno costarricense acerca de la eliminación de los HCFC?
  - ¿Qué cree Usted que se necesita hacer para eliminar los HCFC en el futuro?
    - i. ¿Recibe equipo de refrigeración roto de clientes? Si es así, ¿qué haces con lo?
      - ¿Utiliza los HCFC reciclados?
      - ¿Usted consideraría los procesos de reciclaje?
      - ¿Estaría dispuesto a invertir en tecnología de reciclaje? ¿Por qué sí o no?
      - ¿Cree que sería beneficioso para su empresa para ofrecer este servicio de reciclaje a sus clientes?
14. ¿COMPANY E está considerando alternativas a los HCFC en Costa Rica? Si es así, ¿qué alternativas son las más atractivas para su empresa?
  - ¿Está utilizando alternativas en otros países? ¿Qué alternativas?
  - ¿Cuáles son algunas de las razones por qué su empresa no está considerando algunas alternativas a los HCFC en Costa Rica (es decir, amoníaco)?
15. ¿Cree que su equipo es eficiente con la energía?
  - ¿Qué tan eficiente es su equipo en Costa Rica, específicamente?
  - ¿Cómo cree que la eficiencia se puede mejorar?
16. ¿Sus clientes suelen venir a usted con su antiguo equipo?
  - Si es así, ¿cómo maneja Usted el equipo viejo?
17. ¿Se requiere capacitación para manejar los HCFC y / o el equipo que se utiliza?
  - ¿Esta capacitación ha sido dirigida por la empresa o por una institución como el Instituto de Aprendizaje?
19. ¿Qué es lo que piensa hacer en el futuro para eliminar el uso de HCFC?
20. ¿Qué tan útil ha sido el CICR para usted?

Company E is a company that manufactures commercial refrigeration equipment for Costa Rica and other Central American countries. We interviewed them, because they represent the commercial refrigeration sector of Costa Rica. We wanted to obtain more information on the current state of the efforts of commercial refrigeration companies as it relates to eliminating

HCFCs. We spoke with Sra. Alpizar and a co-worker, who is an engineer. Company E's clients include restaurants, supermarkets, sodas, hospitals, the government, hotels, and other companies. Unlike other companies, Company E does not provide servicing to their products after selling. It is up for the buyers to find technicians to service the equipment.

Company E uses a large variety of refrigerants in their products. These refrigerants include R-22, R-404a, R-507, R-134a, R-410a, R-600a. All of the refrigerants that Company E buys is imported from countries like China and the US. 50% of the refrigerants used is R-134a, and the next most used is R-507. Because of the quota system in Costa Rica that limits the amount of HCFCs that can be imported, they are forced to use refrigerants like R-134a, which is an HFC. Presently, Company E is running trial runs to see if they can use R-600 (butane) in any of their equipment, but without aid with funding these projects, they may never be implemented fully.

Company E's in-house technicians are trained and certified through INA. This was surprising, since all of the other companies we interviewed did their own internal training. Company E believes that all technicians that handle refrigerants and refrigeration system should be certified. According to Company E, there is a problem with uncertified 'street' technicians, who don't use proper techniques and end up venting refrigerants into the atmosphere. Company E believes that other companies should require their technicians to obtain certifications, so that the entire industry uses better practices.

Currently, Company E has no recycling or destruction technology. After recovering refrigerant that has been used and needs to be replaced, it is simply stored in a canister and put into a warehouse. They are waiting for disposal technologies to become available to them, so that they won't have to keep all of the impure, dangerous refrigerant. The biggest limitation keeping them from purchasing this tech themselves is that it is far too expensive for them to buy and operate alone. They are waiting on the Ministry of Health to enact legislation and a system of disposal for companies that have these refrigerants stockpiled. Currently, Company E has little to no contact with the CICR regarding these issues, but they are utilizing INA for their training.

## Appendix K – Private Sector Information Chart

This table shows the most important information that we gathered about each of the refrigeration/air condition companies that we contacted.

Example Clients:	Company A	Company E	Company C	Company D	Company B
<b>Refrigeration Sector:</b>	Industrial, Domestic, Commercial	Commercial	Industrial	Domestic	Air Conditioning
<b>Corporation Size:</b>	Large	Medium	Large	Large	Small
<b>Regional market:</b>	Costa Rica and Central America	Costa Rica	Costa Rica, Central America, United States, Caribbean	Costa Rica, Central America, North America, South America	Costa Rica
<b>Example Clients:</b>	Convenience stores, supermarkets, restaurants, etc.	Restaurants, Supermarkets, Sodas, Hospitals, Government Buildings, Hotels, etc.	Restaurants, Supermarkets, Sodas, Hospitals, Government Buildings, Hotels, etc.	Consumers, Grupo Monge, Collo, Casa Blanca, Artelec	Consumers, businesses
<b>HCFC use/types:</b>	R-22, R-402B, R-406, R-407, R-409	R-22	R-22, R-24A, R-401 and R-402B	N/A	R-22, R-124
<b>HFC use/types:</b>	R-134A, R-410A, R-404A, and R-507	R-404a, R-507, R-134a, R-410a	R-134A and R-404A	R-134a	R-410A, R-134A
<b>Natural Refrigerant use/types:</b>	R-600A, R-290	R-600A	R-290	Cyclopentane	N/A
<b>Use of Mixed Substances:</b>	Yes	Yes	Yes	N/A	Yes
<b>Stockpiling:</b>	Yes	Yes	Yes	N/A	Yes
<b>Technician Training:</b>	In-House	INA	In-House	In-House	No formal training
<b>Provides Servicing:</b>	No	Yes	No	No	Yes
<b>Recycling Technology:</b>	Yes: Selling recycling tech for servicing but not reclamation use	No	Purchased recycling tech from Fogel in 2010: \$10,000	No	No
<b>Waiting for destruction technology from the Public Sector:</b>	No: Currently using destruction tech at Holcim as part of MINAE contract	Yes	Yes	N/A	Yes
<b>CICR Relevancy:</b>	Irrelevant	Irrelevant	Irrelevant	Irrelevant	Irrelevant

<b>Current Progress:</b>	Have two projects testing the use of R-600A and R-290 in their systems.	Testing butane in their refrigeration units	Have a trial test of propane in refrigeration units	Phased out CFCs and HCFCs using Multilateral Fund	Currently have stockpiled over 2,000kg of ODSs
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## Appendix L – Funding Companies Information Chart

This table shows the most important information that we gathered about each of the funding companies/organizations that we contacted. It

Organization/Company	Fundacorporación	ENER-G	BAC
<b>Brief Description</b>	Non-Profit Investment Organization: Works to improve the social and environmental conditions of the Costa Rican population	Energy Servicing Company: Funds entire project outright and collects a return based off of the energy savings the company generates	National Costa Rican bank: Collects a return on support for environmental projects through interest rates
<b>Organization Type</b>	Non-Profit Organization	Esco	Bank
<b>Possible Projects</b>	Small and medium-sized projects; topics include: impacting social and environmental conditions, sustainable agriculture and tourism, clean technology, renewable energy	Energy efficiency projects	Recycling technology, renewable energy and energy efficiency
<b>Previous Projects</b>	Codiplast', 'GSS Global Recycler', 'Ecoway', and 'Development of Z 13' in San Carlos	760 projects completed (~35% industrial sector based)	Solar panel installations, retrofits of technology to improve energy efficiencies, and air conditioner exchanges
<b>Funding Origin</b>	"Credit To Your Measure": Provides credit market (\$4,000 to \$150,000)	Loans from smaller Costa Rican banks; self-investments	Self-investments (PYMES)
<b>Funding Range</b>	No Cap: based on feasibility	No Cap: based on feasibility; typically around \$25,000 to \$75,000	No Cap: based on feasibility; \$37,000-100,000
<b>Projects We Recommend Funding</b>	Recycling technology projects: Decentralized HCFC recycling and reclaiming technology	Recycling technology projects: Decentralized HCFC recycling and reclaiming technology, Natural refrigerant technology	Recycling technology projects: Decentralized HCFC recycling and reclaiming technology
<b>Interest</b>	Positive	Positive	Positive
<b>Limitations</b>	Finance and Informality of the Market	Finance and Return on Investment	Finance and Return on Investment

provides a quick reference sheet so the reader can determine which company/organization would best fit their needs.





## Appendix M – Refrigerant Blend Properties Chart

We have included this table to provide the physical properties of different categories of refrigerant blends. These properties can be used to determine which refrigeration/recycling/reclaiming/destruction system is best for the corresponding refrigerant.

### Carbon Dioxide Blends

	Reporting Units	R-744
<i>CHARACTERISTICS:</i>		
Sublimation Point <sup>1</sup>	°C at 101.3 kPa	-78.4
Sublimation Point Range <sup>1</sup>	K	± 0.3
<i>VAPOR PHASE<sup>2</sup>:</i>		
Air and other non-condensables, Maximum	% by volume at 10°C below the critical temperature and measure non-condensable directly	1.5
<i>LIQUID PHASE<sup>3</sup>:</i>		
Water, Maximum	ppm by weight	10
High Boiling Residue, Maximum	% by weight	0.0005
Particulates/Solids	Pass or Fail	Visually clean
Minimum Purity	% by weight	99.9
Notes: 1. Sublimation point, sublimation point range, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1. 2. Sample taken from vapor phase. 3. Sample vaporized from liquid phase.		

(AHRI Standard 700, 2015)

## Single Component Hydrocarbon Blends

	Reporting Units	R-50	R-170	R-E170	R-290	R-600	R-600a	R-601	R-601a	R-610	R-1150	R-1270
<b>Characteristics</b>												
Boiling Point <sup>1</sup>	°C at 101.3 kPa	-161.5	-88.6	-24.8	-42.1	-0.5	-11.8	36.1	27.8	34.6	-103.8	-47.6
Boiling Point range <sup>1</sup>	K	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5
Nominal composition	% weight	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5	≥ 99.5
Other Allowable Impurities	% weight	NA	NA	NA	22	22	22	0-1 R-601a	0-1 R-601	NA	NA	0-1 R-290
<b>Vapor phase<sup>3</sup></b>												
Air and other non-condensable	% by volume @ 25.0°C	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5
<b>Liquid phase<sup>4</sup></b>												
Sulfur Odor	Pass or Fail	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor	No sulfur odor
High boiling residue	% weight	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
Particulates/solids	Pass or Fail	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity	ppm by weight (as HCl)	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
Water	mg kg <sup>-1</sup>	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10
All Other Volatile Impurities	% weight	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total C <sub>3</sub> , C <sub>4</sub> and C <sub>5</sub> Polyolefins	% weight	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
Notes:												
1. Boiling points, boiling point ranges, although not required, are provided for informational purposes.												
2. 2% of other C <sub>3</sub> and C <sub>4</sub> saturated hydrocarbons are allowed												
3. Taken from vapor phase												
4. Vaporized from liquid phase												

(AHRI Standard 700, 2015)

## Single Component Fluorocarbon Blends

	Reporting Units	Reference Section	R-115	R-116	R-123	R-124	R-125	R-134a	R-141b
<i>CHARACTERISTICS :</i>									
Boiling Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-38.9	-78.2	27.8	-12	-48.1	-26.1	32
Boiling Point Range <sup>1</sup>	K	N/A	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3
Critical Temperature <sup>1</sup>	°C	N/A	80	19.9	183.7	122.3	66	101.1	206.8
Isomer Content Isomer	% by weight	N/A	N/A	N/A	0-8 R-123a+ R-123b	0-5 R-124a	N/A	0-0.5 R-134	0-0.1ea R-141, R-141a
<i>VAPOR PHASE CONTAMINANTS :</i>									
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	1.5	1.5	N/A <sup>2</sup>	1.5	1.5	1.5	N/A <sup>2</sup>
<i>LIQUID PHASE CONTAMINANTS:</i>									
Water, Maximum	ppm by weight	5.4	10	10	20	10	10	10	100
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.9
Halogenated Unsaturated Volatile Impurities, Maximum	ppm by weight	5.11.2 .1	40	40	40	40	40	See footnote <sup>4</sup>	40
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight (as HCl)	5.7	1	1	1	1	1	1	1
Chloride <sup>3</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity
<p>Notes:</p> <p>1. Boiling points, boiling point ranges and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1.</p> <p>2. Since R-11, R-113, R-123, R-141b, R-245fa, and R-1233zd(E) have normal boiling points near or above room temperature, non-condensable determinations are not required for these refrigerants.</p> <p>3. Recognized chloride level for pass/fail is about 3 ppm.</p> <p>4. Up to 5000 ppm R-1234yf is acceptable as a halogenated unsaturated volatile impurity in R-134a.</p> <p>N/A Not Applicable</p>									

(AHRI Standard 700, 2015)

	Reporting Units	Reference Section	R-142b	R-143a	R-152a	R-218	R-227ea	R-236fa	R-245fa	R-1233zd(E)	R-1234yf	R-1234ze(E)
<i>CHARACTERISTICS :</i>												
Boiling Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-9.2	-47.2	-24	-36.8	-16.5	-1.4	14.9	18.3	-29.4	-19
Boiling Point Range <sup>1</sup>	K	N/A	--	± 0.3	± 0.3	± 0.3	--	± 0.3	± 0.3	--	N/A	N/A
Critical Temperature <sup>1</sup>	°C	N/A	137.1	72.7	113.3	72	101.7	124.9	154.1	165.6	94.8	109.4
Isomer Content Isomer	% by weight	N/A	0-0.1ea R-142, R-142a	0-0.01 R-143	N/A	--	--	--	0-0.1ea R-245ca, R-245cb, R-245ea, R-245eb	--	N/A	0.3 R- 1234ze(Z)
<i>VAPOR PHASE CONTAMINANTS :</i>												
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	2	1.5	1.5	1.5	1.5	1.5	N/A <sup>2</sup>	N/A <sup>2</sup>	1.5	1.5
<i>LIQUID PHASE CONTAMINANTS:</i>												
Water, Maximum	ppm by weight	5.4	15	10	10	10	10	10	20	20	10	10
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Halogenated Unsaturated Volatile Impurities, Maximum	ppm by weight	5.11.2.1	40	40	40	40	40	40	40	N/A	N/A	N/A
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight (as HCl)	5.7	3	1	1	1	1	1	1	1	1	1
Chloride <sup>3</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity
Notes: 1. Boiling points, boiling point ranges and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1. 2. Since R-11, R-113, R-123, R-141b, R-245fa, and R-1233zd(E) have normal boiling points near or above room temperature, non-condensable determinations are not required for these refrigerants. 3. Recognized chloride level for pass/fail is about 3 ppm. N/A Not Applicable -- Data Not Available												

(AHRI Standard 700, 2015)

	Reporting Units	Reference Section	R-11	R-12	R-13	R-22	R-23	R-32	R-113	R-114
<i>CHARACTERISTICS :</i>										
Boiling Point <sup>1</sup>	°C @ 101.3 kPa	N/A	23.7	-29.8	-81.5	-40.8	-82	-51.7	47.6	3.6
Boiling Point Range <sup>1</sup>	K	N/A	± 0.3	± 0.3	± 0.5	± 0.3	± 0.5	± 0.3	± 0.3	± 0.3
Critical Temperature <sup>1</sup>	°C	N/A	198	112	28.9	96.2	26.1	78.1	214.1	145.7
Isomer Content Isomer	% by weight	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0-1 R-133a	0-30 R-144a
<i>VAPOR PHASE CONTAMINANTS :</i>										
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	N/A <sup>2</sup>	1.5	1.5	1.5	1.5	1.5	N/A <sup>2</sup>	1.5
<i>LIQUID PHASE CONTAMINANTS:</i>										
Water, Maximum	ppm by weight	5.4	20	10	10	10	10	10	20	10
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Halogenated Unsaturated Volatile Impurities, Maximum	ppm by weight	5.11.2.1	40	40	40	40	40	40	40	40
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight (as HCl)	5.7	1	1	1	1	1	1	1	1
Chloride <sup>3</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity
Notes:										
1. Boiling points, boiling point ranges and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1.										
2. Since R-11, R-113, R-123, R-141b, R-245fa, and R-1233zd(E) have normal boiling points near or above room temperature, non-condensable determinations are not required for these refrigerants.										
3. Recognized chloride level for pass/fail is about 3 ppm.										
N/A Not Applicable										

(AHRI Standard 700, 2015)

## Zeotropic Blends

	Reporting Units	Reference Section	R-401A	R-401B	R-402A	R-402B	R-403A	R-403B	R-404A
<i>CHARACTERISTICS :</i>									
Refrigerant Components	N/A	N/A	R-22/ 152a/124	R-22/ 152a/124	R-125/ 290/22	R-125/ 290/22	R-290/ 22/218	R-290/ 22/218	R-125/ 143a/134a
Nominal Composition	% by weight	N/A	53/13/34	61/11/28	60.0/2.0 /38.0	38.0/2.0 /60.0	5/75/20	5/56/39	44/52/4
Allowable Composition	% by weight	N/A	51-55 /11.5-13.5 /33-35	59-63 /9.5-11.5 /27-29	58.0-62.0 /1.0-2.1 /36.0-40.0	36.0-40.0 /1.0-2.1/ 58.0-62.0	3-5.2 /73-77 /18-22	3-5.2 /54-58 /37-41	42-46 /51-53 /2-6
Bubble Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-33.3	-34.9	-49	-47	-47.8	-49.2	-46.2
Dew Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-26.4	-28.8	-46.9	-44.7	-44.3	-46.8	-45.5
Critical Temperature <sup>1</sup>	°C	N/A	105.3	103.5	76	83	87	79.7	72.1
<i>VAPOR PHASE CONTAMINANTS :</i>									
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	1.5	1.5	1.5	1.5	1.5	1.5	1.5
<i>LIQUID PHASE CONTAMINANTS:</i>									
Water, Maximum	ppm by weight	5.4	10	10	10	10	10	10	10
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.5
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight (as HCl)	5.7	1	1	1	1	1	1	1
Chloride <sup>2</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity
Notes: 1. Bubble points, dew points and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1. 2. Recognized chloride level for pass/fail is about 3 ppm. N/A Not Applicable									

(AHRI Standard 700, 2015)

	Reporting Units	Reference Section	R-405A	R-406A	R-407A	R-407B	R-407C	R-407D	R-407E	R-407F
<i>CHARACTERISTICS :</i>										
Refrigerant Components	N/A	N/A	R-22/152a /142b/C318	R-22/600a /142b	R-32 /125/134a	R-32 /125/134a	R-32 /125/134a	R-32 /125/134a	R-32 /125/134a	R-32 /125/134a
Nominal Composition	% by weight	N/A	45/7/5.5 /42.5	55/4/41	20/40/40	10/70/20	23/25/52	15/15/70	25/15/60	30.0/30.0 /40.0
Allowable Composition	% by weight	N/A	43-47 /6-8/4.5-6.5 /40.5-44.5	53-57 /3-5 /40-42	18-22 /38-42 /38-42	8-12 /68-72 /18-22	21-25 /23-27 /50-54	13-17 /13-17 /68-72	23-27 /13-17 /58-62	28.0-32.0 /28.0-32.0 /38.0-42.0
Bubble Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-32.9	-32.7	-45.3	-46.8	-43.6	-39.5	-42.9	-46.1
Dew Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-24.5	-23.5	-38.9	-42.5	-36.6	-32.9	-35.8	-39.7
Critical Temperature <sup>1</sup>	°C	N/A	106	116.5	82.3	75	86	91.4	88.5	83
<i>VAPOR PHASE</i>										
<i>CONTAMINANTS :</i>										
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
<i>LIQUID PHASE</i>										
<i>CONTAMINANTS:</i>										
Water, Maximum	ppm by weight	5.4	10	10	10	10	10	10	10	10
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight	5.7	1	1	1	1	1	1	1	1
Chloride <sup>2</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity

Notes:

1. Bubble points, dew points and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1.

2. Recognized chloride level for pass/fail is about 3 ppm.

N/A Not Applicable

(AHRI Standard 700, 2015)



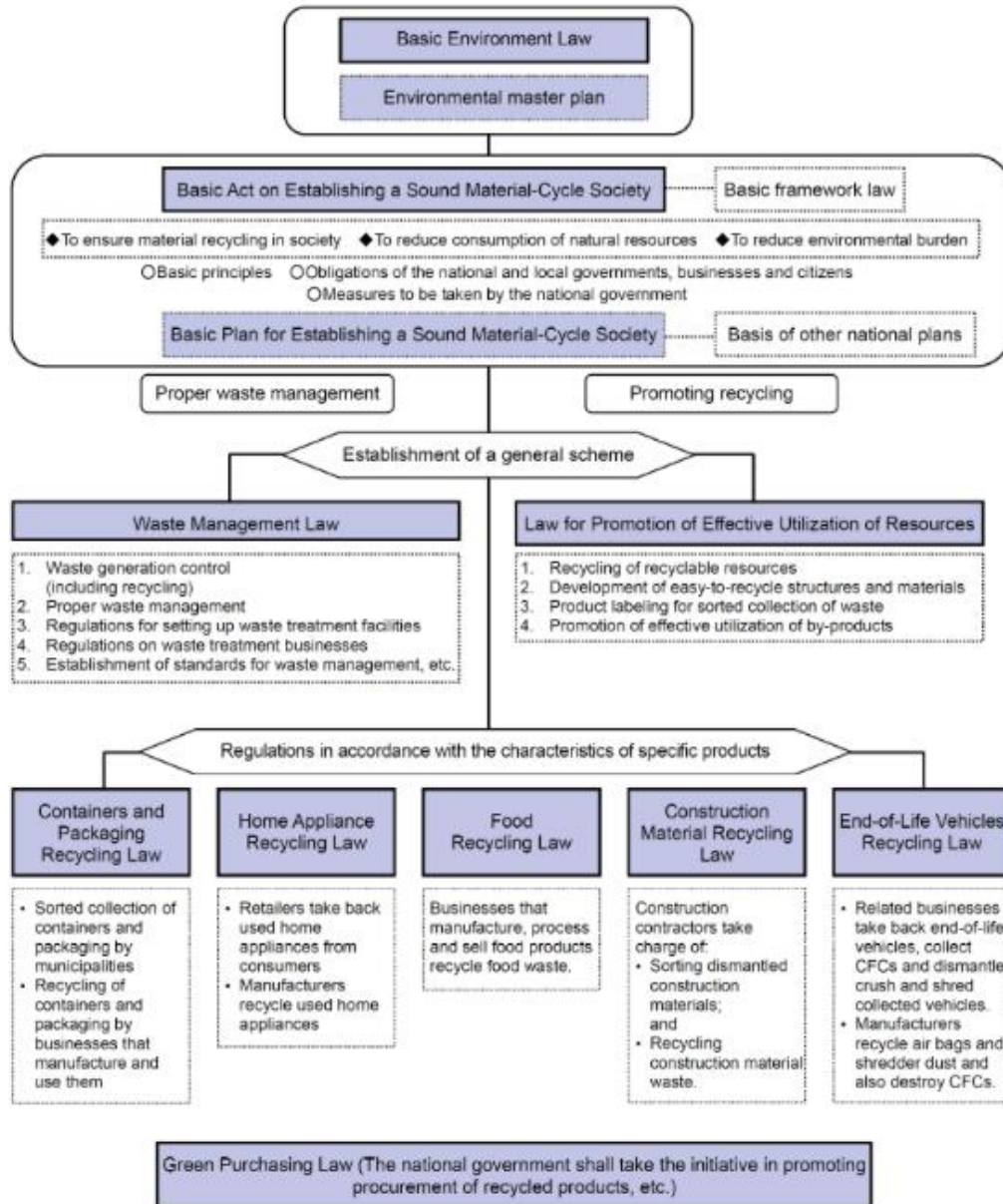
	Reporting Units	Reference Section	R-408A	R-409A	R-409B	R-410A	R-410B	R-411A	R-411B
<i>CHARACTERISTICS :</i>									
Refrigerant Components	N/A	N/A	R-125/ 143a/22	R-22/ 124/142b	R-22/ 124/142b	R-32/125	R-32/125	R-1270/ 22/152a	R-1270/ 22/152a
Nominal Composition	% by weight	N/A	7/46/47	60/25/15	65/25/10	50/50	45/55	1.5/87.5 /11.0	3/94/3
Allowable Composition	% by weight	N/A	5-9 /45-47 /45-49	58-62 /23-27 /14-16	63-67 /23-27 /9-11	48.5-50.5 /49.5-51.5	44-46 /54-56	0.5-1.5 /87.5-89.5 /10-11	2-3/94-96 /2-3
Bubble Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-44.6	-34.7	-35.6	-51.4	-51.3	-39.5	-41.6
Dew Point <sup>1</sup>	°C @ 101.3 kPa	N/A	-44.1	-26.4	-27.9	-51.4	-51.6	-36.6	-40
Critical Temperature <sup>1</sup>	°C	N/A	83.1	106.9	106.9	71.4	70.8	99.1	96
<i>VAPOR PHASE CONTAMINANTS :</i>									
Air and Other Non-condensables, Maximum	% by volume @ 25.0°C	5.10	1.5	1.5	1.5	1.5	1.5	1.5	1.5
<i>LIQUID PHASE CONTAMINANTS:</i>									
Water, Maximum	ppm by weight	5.4	10	10	10	10	10	10	10
All Other Volatile Impurities, Maximum	% by weight	5.11	0.5	0.5	0.5	0.5	0.5	0.5	0.5
High Boiling Residue, Maximum	% by volume or % by weight	5.8	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particulates/Solids	Pass or Fail	5.9	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean	Visually clean
Acidity, Maximum	ppm by weight (as HCl)	5.7	1	1	1	1	1	1	1
Chloride <sup>2</sup>	Pass or Fail	5.6	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity	No visible turbidity
Notes: 1. Bubble points, dew points and critical temperatures, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1. 2. Recognized chloride level for pass/fail is about 3 ppm. N/A Not Applicable									

(AHRI Standard 700, 2015)



## Appendix N – Japan Environmental Law Chart

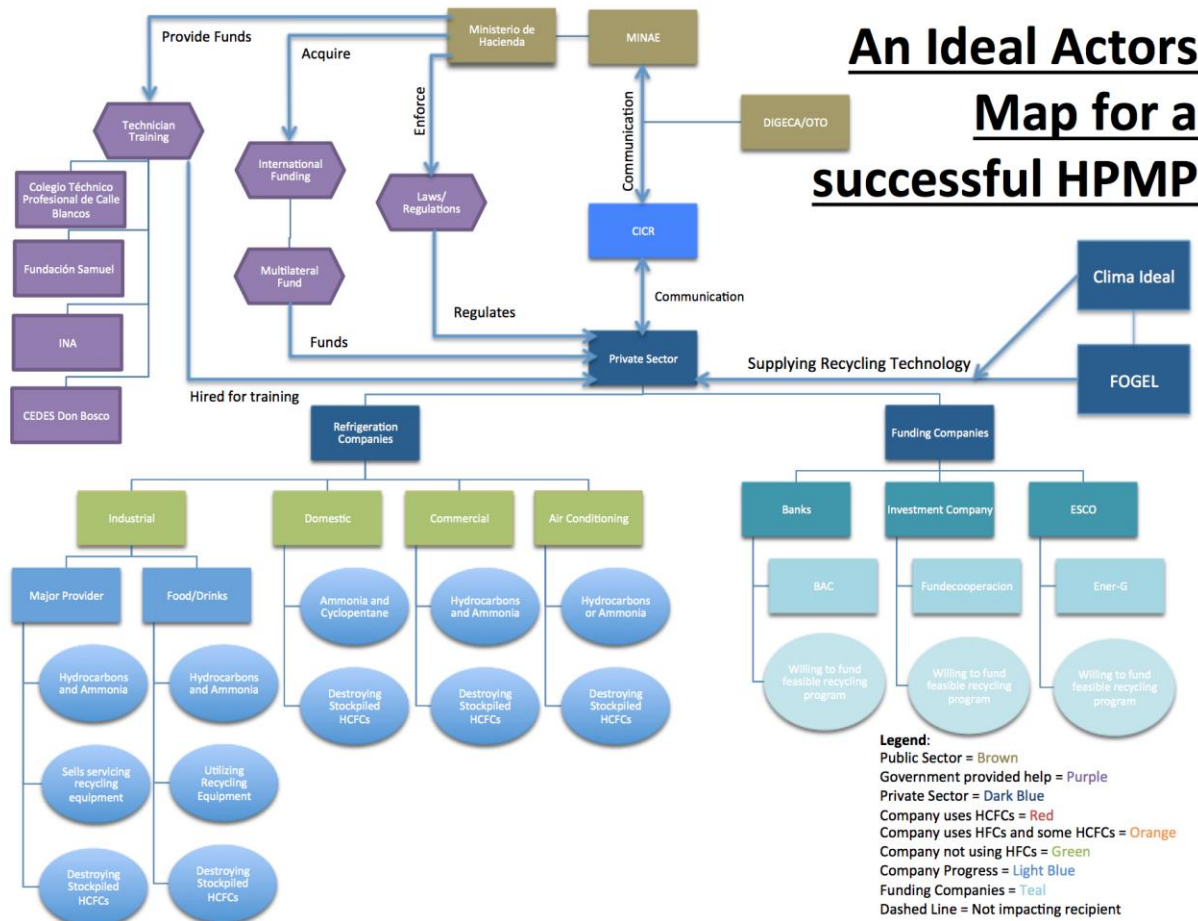
This chart provides a quick overview of Japan’s comprehensive environmental law as it pertains to waste management, including refrigerants.



(Ministry of Economy, Trade and Industry, 2000).

## Appendix O – An Ideal Actors Map for a Successful HPMP

This is what the Actors Map for refrigerant players in Costa Rica should look like after implementing our recommendations.



## Appendix P – Example Meeting Schedules

This is an example of how frequent the companies should meet throughout the span of one year with consideration for Costa Rican and religious holidays. Conferences between network representatives and CICR should meet after CICR's largest event usually in April, the EXPO. Ideal months for conferences between CICR and the private sector are May and November on the third or fourth Friday. Reason for this is most holidays in May and November are the first two weeks. Additionally, May and November are 6 months apart. Meetings have the option of being either once every month or once every two months. They should be on the second Tuesday of the month. Reason for this is most holidays are on Mondays and are generally the first two weeks or last week of the month.

## Sample Schedule 2016

JANUARY						
M	T	W	T	F	S	S
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

FEBRUARY						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	1	2	3	4	5	6

MARCH						
M	T	W	T	F	S	S
29	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3

APRIL						
M	T	W	T	F	S	S
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	1

MAY						
M	T	W	T	F	S	S
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30	24/31	25	26	27	28	29

JUNE						
M	T	W	T	F	S	S
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	1	2	3

  = Once a month    
   = Once every two months    
   = Twice a year

JULY						
M	T	W	T	F	S	S
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

AUGUST						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

SEPTEMBER						
M	T	W	T	F	S	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2

OCTOBER						
M	T	W	T	F	S	S
26	27	28	29	30	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24/31	25	26	27	28	29	30

NOVEMBER						
M	T	W	T	F	S	S
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	1	2	3	4

DECEMBER						
M	T	W	T	F	S	S
28	29	30	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

## Appendix Q – Refrigerant Destruction Trial Schedule

Gas / Fecha:	Periodo de medición	Tipo de operación:	Combustible utilizado:		Flujo de alimentación de gas refrigerante:
HCFC 22 (R22) 09/06/2014	11:15 - 15:35 horas.	Compuesta del horno y molino.	Coke	7,0 Ton/hr.	25,33 kg/hr.
			AFR líquido	No hay	
			AFR sólido	4.0 Ton/hr.	
			Cámara de humos	No hay.	
HFC 134a (R134a) 11/06/2014	09:00 - 13:00 horas.	Compuesta del horno y molino.	Bunker	9,5 Ton/hr	22,80 kg/hr.
			AFR líquido	No hay	
			AFR sólido	No hay.	
			Cámara de humos	No hay.	
CFC 12 (R12) 13/06/2014	09:00 - 13:00 horas.	Compuesta del horno y molino.	Bunker + Coke (08:00-12:00 MD)	1,5 Ton/hr. + 7,9 Ton/hr	22,08 kg/hr.
			Bunker (12:00 MD – 13:00 hrs)	6,0 Ton/hr.	
			AFR líquido	No hay	
			AFR sólido	3,5 Ton/hr.	
			Cámara de humos	No hay.	

(Ministerio de Ambiente y Energía [MINAE], 2014)

## Appendix R – Analytical Results of Refrigerant Gases in a Cement Kiln

Gases	Resultado promedio			
	Para HCFC 22	Para HFC134a	Para CFC12	Norma de Costa Rica
HCL (mg/m <sup>3</sup> )	0.19 ± 0.01	0.20 ± 0.01	0.24 ± 0.01	70 (mg/m <sup>3</sup> )
HF (mg/m <sup>3</sup> )	<0.01	<0.01	<0.01	-----
NH3 (mg/m <sup>3</sup> )	0.9 ± 0.2	0.8 ± 0.2	1.3 ± 0.2	-----
HCT's Expresados como metano. (mg/m <sup>3</sup> )	<0.2	<0.2	<0.2	70 (mg/m <sup>3</sup> )
Refrigerante residual (mg/m <sup>3</sup> )	<0.01	<0.01	<0.01	-----
O <sub>2</sub> de referencia* (%)	7.0	7.0	7.0	

(Ministerio de Ambiente y Energía [MINAE], 2014)

## Appendix S – Analysis of Refrigerant Samples Compared to the Standard in Costa Rica

Parámetros	Resultados Promedio			Norma en Costa Rica
	HCFC22 (R-22)	HFC134a (R-134a)	CFC12 (R-12)	
Partículas en suspensión totales (isocinético)* (mg/m <sup>3</sup> )	57 ± 2	5 ± 2	75 ± 2	30 mg/m <sup>3</sup>
SO <sub>2</sub> * (mg/m <sup>3</sup> )	35 ± 2	77 ± 2	228 ± 6	700 mg/m <sup>3</sup>
NO <sub>x</sub> (como NO)* (mg/m <sup>3</sup> )	451 ± 11	381 ± 9	402 ± 10	800 mg/m <sup>3</sup>
CO <sub>2</sub> * (%)	18.2 ± 0.18	17.6 ± 0.18	18.3 ± 0.18	-----
O <sub>2</sub> * (%)	9.6 ± 0.1	10 ± 0.1	9.7 ± 0.1	
CO* (mg/m <sup>3</sup> )	137 ± 3	138 ± 3	104 ± 2	630 mg/m <sup>3</sup>
Cobalto (Co) (mg/m <sup>3</sup> )	<0.0005	<0.0005	<0.0005	-----
Manganeso (Mn) (mg/m <sup>3</sup> )	0.016 ± 0.001	0.211 ± 0.001	0.022 ± 0.001	-----
Cobre (Cu) (mg/m <sup>3</sup> )	0.0044 ± 0.001	0.0047 ± 0.001	0.0029 ± 0.001	-----
Antimonio (Sb) (mg/m <sup>3</sup> )	0.0054 ± 0.001	0.0053 ± 0.001	0.0058 ± 0.001	-----
Cadmio + Mercurio (mg/m <sup>3</sup> )	<0.0002	<0.0002	<0.0002	0.28 mg/m <sup>3</sup>
Arsénico + Estaño + Selenio + Níquel (mg/m <sup>3</sup> )	0.221 ± 0.005	0.649 ± 0.005	0.123 ± 0.005	1.4 mg/m <sup>3</sup>
Plomo + Cromo + Zinc (mg/m <sup>3</sup> )	1.45 ± 0.010	4.39 ± 0.010	1.575 ± 0.010	7 mg/m <sup>3</sup>
Humedad del gas* (mg/m <sup>3</sup> )	12.9 ± 0.4	12.6 ± 0.4	(12.8 ± 0.4)	-----
O <sub>2</sub> de referencia* (%)	7	7	7	-----



## Appendix T - Analysis of Dioxins and Furans in Cement Kiln

Analito	Concentración Total (ng/m <sup>3</sup> )			Equivalente tóxico (ng/m <sup>3</sup> ) (EQT)	Norma en Costa Rica (ng/m <sup>3</sup> ) (EQT)
	Para HCFC22	Para HFC134 <sup>a</sup>	Para CFC12		
2,3,7,8-TCDF	<0.0004	<0.0004	<0.0004	<0.0002	0.2
2,3,7,8-TCDD	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,7,8-PCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,7,8-PCDD	<0.0009	<0.0012	<0.0004	<0.0002	
2,3,4,7,8-PCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,6,7,8-HxCDF	<0.0008	<0.0008	<0.0004	<0.0002	
1,2,3,6,7,8-HxCDD	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,,7,8,9-HxCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,7,8,9-HxCDD	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,4,7,8-HxCDF	<0.0010	<0.0008	<0.0004	<0.0002	
1,2,3,4,7,8-HxCDD	<0.0004	<0.0004	<0.0004	<0.0002	
2,3,4,6,7,8-HxCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,4,6,7,8-HpCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,4,7,8,9-HpCDF	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,4,6,7,8-HpCDD	<0.0004	<0.0004	<0.0004	<0.0002	0,2
1,2,3,4,7,8,9-OCDD	<0.0004	<0.0004	<0.0004	<0.0002	
1,2,3,4,7,8,9-OCDF	<0.0004	<0.0004	<0.0004	<0.0002	

(Ministerio de Ambiente y Energía [MINAE], 2014)



## Appendix U – Analysis of Refrigerant Gases Fed into the Kiln during Injection Trials

Análisis	Resultado Promedio			Norma de Costa Rica
	Para HCFC22	Para HFC134a	Para CFC12	
Poder calórico	No detectable			2500 Kcal/Kg (min)
Cromo VI (Cr vi)	No detectable (Menor a 0.02 mg/L)			100 mg/L
Arsénico (As)	No detectable (Menor a 0.1 mg/L)			4000 mg/L
Plomo (Pb)	No detectable (Menor a 0.1 mg/L)			50 mg/L
Mercurio (Hg)	No detectable (Menor a 0.05 mg/L)			100 mg/L
Plata (Ag)	No detectable (Menor a 0.05 mg/L)			100 mg/L
Selenio (Se)	No detectable (Menor a 0.1 mg/L)			100 mg/L
Cadmio (Cd)	No detectable (Menor a 0.1 mg/L)			500 mg/L
Sulfuros (S=)	No detectable (Menor a 0.1%)			1000 mg/L
Cloruros (Cl-)	No detectable (Menor a 0.02 %)			2 %
Bario (Ba)	No detectable (Menor a 0.1 mg/L)			6000 mg/L
Compuestos Orgánicos Halogenados Totales (Exp. como Cl)	No detectable (Menor a 0.05 mg/L)			2 %
Bifenilos Policlorados (PCB's)	No detectable (Menor a 1 mg/L)			50 mg/L
Plaguicidas Organoclorados	No detectable (Menor a 1 mg/L)			5 mg/L
Plaguicidas Organofosforados	No detectable (Menor a 1 mg/L)			5 mg/L

(Ministerio de Ambiente y Energía [MINAE], 2014)

## Appendix V – Destruction and Removal Efficiency Rating of Refrigerants during Injection

Gas refrigerante alimentado	HCFC22	HFC134a	CFC12
DRE alcanzado (%)	99.98351362	99.98151087	99.98209474

(Ministerio de Ambiente y Energía [MINAE], 2014)

## Appendix W – Analysis of Refrigerants Used in the Trial

	Componentes	%
Refrigerante HCFC 22 (R-22)	R-22	91.60
	R-125	5.70
	R-143a	2.70
	Total	100%
Refrigerante HFC 134a (R-134a)	R-134a	98.50
	R-152a	1.50
	Total	100%
Refrigerante CFC12 (R-12)	R-12	88.30
	R-134a	2.80
	R-22	4.30
	R-143a	4.60
	Total	100%

(Ministerio de Ambiente y Energía [MINAE], 2014)

## Appendix X – Country Demographics and Refrigeration Plans

### United States

With Costa Rica in need of an example to follow for future regulations and development in infrastructure for the elimination of HCFC, the United States is able to provide a wealth of examples to learn from. The United States is a developed, or Non-Article 5 country according to the Montreal Protocol. The population of the United States is around 300 million and covers approximately 9,826,630 square kilometers. Shipments of refrigerators, both domestically and exported, in 2002 were worth approximately \$5.5 billion USD (ICF International, 2008, p. 133). The demographics of the United States, as well as the scale of the refrigeration market are much different from that of Costa Rica. The United States is much larger, has a populace of about 75 times that of Costa Rica and the refrigeration market in Costa Rica is dominated by very few companies, the largest of which has its major operations outside of Central America. Thus, when considering the implementation of HCFC phase-out in the United States, we had to be very aware differences in demographics.

These differences are especially applicable to the recycling and recovery model in the US, because its geographic size is much different. Also, from a cultural perspective, the United States is a much faster paced country, especially in government. This cultural difference has been gleaned from communication with those in the private sector, and is generally common knowledge throughout Costa Rica. Because of this, major changes that the United States has made may be more difficult to implement in Costa Rica by the deadlines of the Montreal Protocol. The fact remains though that major changes are necessary and whether or not they are difficult to implement should not stop Costa Rica from pursuing them. In addition, the United States has adopted alternatives that Costa Rican officials do not find effective as alternatives due to the Carbon Neutrality Goals and their ratification of the Kyoto Protocol, which the U.S. has not ratified. These alternatives include hydrofluorocarbons (HFCs), which are non-ozone-depleting, but have global warming potentials of notable concern. That said, because some Costa Rican refrigeration companies are not manufacturing refrigeration units solely for Costa Rica, some of these companies have begun using HFCs as cheaper and more efficient replacements for HCFCs. With that in mind, the recycling procedures applied in the United States are applicable to Costa Rican companies utilizing HFCs. Furthermore, because the U.S. had a ten year jumpstart on the HCFC phase-out, due to its developed status as a Non-Article 5 country, technology implementation, laws and regulations, and the challenges with carrying out the HCFC phase-out process is highly advanced compared to developing countries, like Costa Rica. The U.S. stands as an example for Costa Rica, mainly because of their advanced phase-out plan.

The continued effectiveness of a successful phase-out plan requires a set of regulations that are continually enforced and do not allow companies to ignore them. Costa Rica is in dire need of this type of enforcement and regulation change, as evidenced by our interviews with the private sector. The United States has a set of regulations that would provide meaningful change in the Costa Rican HCFC phase-out plan. The beginning of these regulations starts with the national

certification of refrigerant technicians. In the United States, the Environmental Protection Agency (EPA) has a certification test that all technicians must pass and is the first step in regulating these technicians for good practices in servicing this refrigeration equipment (U.S. EPA, 2014). The United States EPA then requires technicians to register in a national database of all of the certified technicians. They use this database mainly as a method of restricting the sale of refrigerants to these registered technicians. The main gap in this process is the restriction on refrigerant sale does not include those refrigerants that are used in wholly assembled refrigerant circuits, which includes household refrigerators and air conditioners. Thus there is no restriction on the sale of the appliances that contain the refrigerant, although import of any equipment containing HCFC-22 has been banned since January, 2010 (U.S. EPA, 2012). Costa Rica has actually just begun the process of registering its certified technicians, but it has only just started and will take some time to build an accurate database, and the U.S. can provide a model for the process of registering technicians. The problem with implementing these policies in Costa Rica is the fact that most of the companies we talked to expressed the opinion that the training schools, such as INA, did not teach as well as learning directly from the industry would. With resistance from most companies to certify their technicians, Costa Rica is going to have to implement some enforcement regulations on top of these new policies. One of the methods that the United States has used to deal with this issue is by using costly fines that force all companies to follow their regulations. By using these regulations in the Costa Rican market, they would be able to cut back on the emissions from bad practices in the servicing sector of Costa Rica. Emissions from bad practices, such as uncertified technicians, which is a part of the HPMP plan to be completed by 2025 (Gobierno de Costa Rica, 2011). To begin these regulations now would be extremely beneficial to the Costa Rican national strategy and would create a solid foundation to regulate refrigerants in the industrial sector, however, we are aware that the Costa Rican government does not usually impose such fines.

Costa Rica has been relying on the MINAE's Ozone Technical Office and DIGECA for the enforcement of regulations on refrigerants, and with all of the other tasks that these offices have to consider there is not enough effort being put into the management of refrigerants. In addition, considering the nature of Costa Rican government to avoid the imposition of taxes, a voluntary program may be more suited to promote responsible handling of refrigerants and the appliances that they are in. The United States developed a specific program for Responsible Appliance Disposal (RAD), a voluntary partnership program that recovers ozone-depleting chemicals from appliances (U.S. EPA, 2015). This program is mainly a collection program for household appliances. As we have already discussed the approach the U.S. has taken with the beginning life cycle of refrigerants, it is appropriate now to discuss the actions taken to reduce environmental impact at the end of the life cycle of these refrigerants. The RAD program has saved over one hundred million dollars for consumers and one million metric ton equivalents of CO<sub>2</sub>. In addition, hundreds of thousands of pounds of HCFC-22, and HCFC-141b have been reclaimed or destroyed by RAD partners. In 2012 alone, 886, 677 units, including a/c units, stand-alone freezers, and refrigerators have been processed by RAD partners (RAD Partner Meeting, 2014). Through this program, the EPA performs random inspections of solid waste landfills and metal recycling facilities. Fines then enforce both of these actions where violators of EPA regulations can be charged up to \$37,500 per day for breaches of ethical conduct (U.S. EPA, 2014). These consequences may seem severe and if implemented in Costa Rica would have to be changed to

fit the anti-penalization tax culture, but it is true that severe consequences are sometimes an efficient way to create change and these consequences have to be enforced. Should this program be applied to Costa Rica, we recommend a program that rewards recycling facilities with a label of environmental stewardship on their company website or place of business, or something along these lines.

Along with this voluntary program to promote proper disposal of home appliances, the United States also imposes an end-of-life regulation on refrigerants that would also be applicable in Costa Rica once they begin to advance their regulations on refrigerants themselves. This mainly applies to recyclers and reclaimers of refrigerant. The refrigerant end-of life regulations require the last person in the refrigerant disposal chain to be identified with a signed statement including the date the refrigerant was recovered as well as information necessary to contact this person. Stickers are not usually used as a form of verification, unless it includes the date of recovery as well as the name and address of the signee (U.S. EPA, 2014). The development of a program to enforce responsible disposal of refrigerants would provide Costa Rican companies and the government with a way of data reporting and recordkeeping to ensure compliance with regulations. In the end, Costa Rica is going to have to create stronger regulations that have real consequences for these companies. Should Costa Rica do this, we predict that they will see a large reduction of emissions from their industrial sector as a result of better measures to prevent illicit emitting.

Though we have used the United States as an example of future regulations that can be implemented in Costa Rica, it should also be noted that the U.S. also has some failures to learn from. The US has already invested, through their RAD program, in a large amount of recycling infrastructure for refrigeration equipment and refrigerants, with very little results to show for it. The most recent RAD update reported that an estimated 11.1 million refrigerators and freezers were disposed of in the U.S., yet less than 900,000 were recovered and disposed of properly through the RAD program (Responsible Appliance Disposal Program & Environmental Protection Agency, 2013). There are 34 RAD facilities, with 48 reclamation facilities and less than 10 destruction facilities throughout the United States, and less than half of the states in the U.S. participate in the RAD program (ICF International, 2008; Responsible Appliance Disposal Program & Environmental Protection Agency, 2013). There are just not enough facilities spread out across the country and transportation costs are likely high because of this. The RAD program in the US has been improving over the years but has had a lack of participation in its recycling program because it is based off a state-by-state participation (Program & Environmental Protection Agency, 2013). The states that do not participate in the program are failing to give their consumers a reachable avenue for recycling their old refrigerant using units. This is where there are advantages with the implementation of a program such as RAD for Costa Rica. Costa Rica is less than 1% the size of the United States and this is the basis for this infrastructure difference (Central Intelligence Agency, 2015). Because Costa Rica is significantly smaller in size and population it would be easier to obtain higher participation rates in such a program and the transportation costs would be much less. Costa Rica would also not require the scale of infrastructure that the United States must utilize, thus Costa Rica would be able to accomplish this task, likely with one centralized facility for the entire country. Overall, the implementation of consumer based collection programs and regulations on technician servicing and certification,

that mimic those in the United States, would strengthen both the government's role in phasing out HCFCs and the private sector's ability to be environmentally responsible without competition from irresponsible businesses.

## United Kingdom

As a member state of the European Union (EU), the United Kingdom is a part of a unique economic and political partnership between 28 European countries. The partnering countries have developed an economic interdependency that extends to policy-making. Because of this relationship, the United Kingdom, must follow guidelines set by the EU's standardized system of regulations ranging from education to the environment. Towards the end of 2014, requirements of the EU's fluorinated greenhouse gas (F-gas) regulations expanded and included more details focused on the beginning phase-down of HFCs, including annual sales and import quotas. Researching the United Kingdom and its partnership between other EU member states can be utilized in terms of possible team working templates in Costa Rica between companies, especially when discussing the Waste Electrical and Electronic Equipment Directive's compliance scheme later in this evaluation.

The United Kingdom is a Non-Article-5 country under the Montreal Protocol and so like other developed countries, has closer HCFC phase-out deadlines than that of Costa Rica. However, the United Kingdom and most of the EU has reached their deadlines ahead of schedule. As a result, many new enacted regulations are focused on F-gases such as HFCs and their proper handling while promoting natural refrigerant technologies (Department of Environment, Food & Rural Affairs, 2014). This is important for Costa Rica to study because of the country's desire to switch straight to natural refrigerants and skip HFCs in its entirety. The availability of HFCs in the EU market is projected to decrease by 79% between 2015 and 2030. Now only companies with EU quotas are able to supply HFCs to the EU market and F-gases, especially those with higher GWPs, are becoming increasingly expensive as a result of the quotas (Department of Environment, Food & Rural Affairs, 2014). Costa Rica has implemented a similar strategy for HCFCs, and should do the same for HFCs, like the United Kingdom. This will strengthen Costa Rica's program to significantly greenhouse gas emissions. Furthermore, the EU has set up an HFC registry to monitor the phase-down. This requires any producer or importer with an existing total or partial quota to supply HFCs to the EU market to register, including organizations exempt from quotas as well as HFCs imported from outside of the EU to assure that no novel HFCs are imported. This HFC registry is a potential monitoring solution that could easily be implemented in Costa Rica, for both HCFCs and HFCs. Not only will this allow the government to determine which entities are importing and how much refrigerant a company utilizes, but it will also provide registered quotas to compare to the value of imported substances from customs to ensure compliance, preventing smuggling (Department of Environment, Food & Rural Affairs, 2014).

Aside from regulations, we analyzed the United Kingdom due to its unique funding mechanisms for ODS and HFC recycling and disposing operations that have successfully been implemented in some developing countries similar to Costa Rica. Some of the existing funding mechanisms require producers to "take responsibility for their products, or implement elements of the *polluter-pays* principle" (Touchdown Consulting, 2012). The Waste Electrical and Electronic



Equipment (WEEE) Directive in the EU establishes this producer responsibility for waste household refrigeration and air conditioning appliances, medical freezers, automatic dispensers, and other specified equipment. Equipment producers are required to pay for the collection, recovery, treatment and disposal processes of this equipment. This includes hazardous ODS and any substance with a GWP greater than 15 (Touchdown Consulting, 2012). Furthermore, consumers are obliged to pay a recycling fee when new appliances are purchased. These fees contribute to the cost of transportation, collection, and recycling of end-of-life equipment. A limitation Costa Rica may face if adopting the EU model for end-of-life equipment management is that consumer fees are always a disincentive and enforcing these fees may be difficult. However, if the fees are tacked on to the purchase price of new appliances, funds are already reserved for the eventual equipment collection and enforcement is less of an issue since consumers pay the fee during their purchasing process (Touchdown Consulting, 2012). These compliance schemes simply make product producers (manufacturers and importers) responsible and one of the enforcing regulations includes setting an annual 'cap' on equipment. The companies are allowed to purchase as many supplies as long as it remains under their established quotas, and must collect and destroy the same amount of supplies they purchased for the year. By instituting a 'cap' and some form of a penalty, companies in Costa Rica and the government will be able to actively monitor the popularity of the equipment, including market trends, and witness the movement of legally recorded equipment that has reached the disposal stage in its life cycle.

## Japan

The Cámara de Industrias de Costa Rica has been searching for refrigerant alternatives to replace HCFCs, most notably natural refrigerants like that of ammonia and propane. As such, our team chose to research Japan due to its expansive refrigerant technology as well as its successfully implemented HPMP and environmental policies. Japan is a developed Non-Article-5 country with a population size of approximately 127.3 million people covering around 378 thousand square km (Central Intelligence Agency, 2015). Despite its size, understanding Japan's waste management infrastructure could essentially be reproduced in an efficient and smaller scale for Costa Rica. Japan possesses some of the most state-of-the-art equipment utilizing HFCs and natural refrigerants. There are also over 200 refrigerant manufacturing companies throughout the country, yet their waste management system for refrigerants and appliances is orderly despite being so distant from one another. The country has also witnessed a myriad of effective HFC and natural refrigerant implementation projects in their domestic, commercial and industrial homes and buildings. Japan's success in switching the majority refrigerant from CFCs to HCFCs and now from HFCs to natural refrigerants is impressive. Because Japan has had success with equipment implementation projects and strong penalization policies, an evaluation of Japan's actions to make their refrigeration and air conditioning sector more sustainable, this evaluation provides useful applications to advance Costa Rica's transitioning from fluorinated refrigerants to natural refrigerants.

Many of the world's eco-friendly refrigerant manufacturers and importers are of Japanese origin and much of their technology available in the market is completely reliant on HFCs (such as R-134a and R-407) and natural refrigerants (such as ammonia, propane, and carbon dioxide). Much of the technologies available in the market for refrigerant equipment are of Japanese origin. The equipment also utilizes many of the refrigerants Costa Rica wishes to implement in its industrial refrigerant sector. One equipment of possible use in for commercial freezers is REI-TECH's AHT Cooling Systems Showcases that utilizes R-290 and contains a variable speed compressor reducing high electrical consumption, pollution and is user friendly. Additionally, there has been over 530 thousand energy-saving units sold all over the world. And, since 2014, sales amount for these Plug-in hydrocarbon showcases have increased by 35% annually depicting its rise in popularity (Tatewaki, 2015).

Besides dominating the world's HFC and natural refrigerant market, Japan has introduced several regulations that are possible to apply with particular ease in Costa Rica. The *Basic Act of Establishing a Sound Material-Cycle Society* works to “promote comprehensively and systematically the policies for the establishment of a 'Sound Material-Cycle Society' and thereby helps to ensure healthy and cultured living for both the present and future generations of the nation” (Ministry of Economy, Trade and Industry, 2000). A ‘Sound Material-Cycle Society’ represents a society in which the consumption of natural resources is conserved and the environmental load is reduced to the greatest possible extent. This is covered by establishing proper sharing of roles among the State, local government, business operators, and citizens as

well as establishing fair costs as part of developing a waste management system for appliances. By doing so, Japan places more responsibility and raises awareness for recycling refrigerants on its citizens. This would be easy to promote in Costa Rica due to its already established national environmentally responsible culture. This act also provided the footwork for Japan's second major policy implementation, the *Home Appliance Recycling Law*. This law provides context for a national recycling scheme in which the principle imposes obligations on home appliance manufacturers and retailers in order “to ensure proper waste treatment and efficient use of resources by reducing wastes and making full use of recyclable materials” (Ministry of Economy, Trade and Industry, 2000). Briefly, there are three tiers of responsibility depicted under this law. First, the disposal is the responsibility of the consumers. Appropriate disposal is financed through additional collection and recycling fees where the equipment is either collected through retailers who have either sold the equipment or are replacing discarded appliances (trade-ins), and can be transported through municipalities funded by taxes. Retailers, municipalities or the consumers are obligated to deliver discarded appliances to a designated take-back site. This would be one of the project shortcomings for Costa Rica to overcome as it would require additional funding and man-power to implement and manage a separate storage facility where collected equipment would be sorted according to manufacturer and type. After the collection process, discarded appliances are then taken back by manufacturers or importers and subsequently recycled of materials and destruction or reclamation of refrigerants. The distance of the take-back site from consumers and retailers must also be considered when determining transportation costs and feasibility, although because Costa Rica is so small, this is likely to be a large problem. Anticipating this logistical problem, one of Japan’s biggest transport companies, Nippon Express, is on the forefront in the recycling collection and transport business, and may have interest in entering the international business and establishing projects. Utilizing the resources of Nippon Express may be of interest to Costa Rica. Limitations of applying the *Home Appliance Recycling Law* in Costa Rica is surveying capability, enforcement, and funding for both collection sites and refrigerant technologies as well as determining a reasonable price to pass on to consumers. Even so, Japan’s regulations provide examples that can be modified and applied to Costa Rica to promote the success of Costa Rica’s refrigerant management plan (Ministry of Economy, Trade and Industry, 2000). A visual overview of Japan’s Laws and Support System for Promoting Waste Recycling can be found in Appendix N.

## Brazil

Costa Rica is lacking recycling infrastructure and funding for their HCFC elimination plan and Brazil has previous projects in these areas that could help. Brazil is an Article-5 country located in South America. With approximately 202 million people, it covers around 8.5 million square km. When comparing Costa Rica and Brazil, their major differences of size and population should be considered, as they are important in why Brazil's past projects could work in Costa Rica. But when comparing the HCFC regulations, economy, and industrial problems of both of these countries, they share some similarities. Since the HCFC regulations of these two countries are fairly similar, it makes Brazil a great example for comparison even though Costa Rica has little to learn from Brazil's policy enforcement. Both countries are also rebuilding their economic systems, which are heavily dependent on the health of the environment. Their economies are reliant on the agriculture and ecotourism sectors of their countries and this influences Brazil and Costa Rica to protect the environment as much as possible (Central Intelligence Agency, 2015). The similarities in the industrial sector come from both countries acting to reduce carbon emissions and implement regulations for good practices in industrial processes. These similarities in regulations, economy, and the industrial sector provide a good basis for using Brazil's solutions in Costa Rica.

With Costa Rica's lack of recycling technology for their refrigeration equipment, they should look towards Brazil for an example of where to acquire this type of infrastructure. Brazil acquired recycling technology that can recycle refrigeration equipment and refrigerant gases in response to their large quantity of refrigerator units that needed to be recycled. In 2008, Brazil had over 50 million old household refrigerators that were inefficient and contained CFCs. This caused the Brazilian government to focus on the recycling of domestic refrigeration equipment in their country. As Brazil began to take on this problem, they realized that they needed to look for outside help to fix it. The GIZ, a German organization that aids in international projects, stepped in and developed a plan in 2008 to create a pilot plant in Brazil for the recycling and recovering of CFCs from approximately 350,000 refrigerators annually. The annual reduction of CFC-11 was then calculated to prevent 138 ODP tons and 890,000 tons of carbon dioxide (GIZ, n.d.) (Fischer V., 2011). The established recycling infrastructure was the Querstromzerspaner (QZ) machine from a German company called ANDRITZ-MeWa (Roberts T., n.d.). This is technology that could have a similar impact on the current problem in Costa Rica. Costa Rica has a large amount of old refrigerators that need to be recycled, but there is no method of accomplishing this. However, one of the major faults that occurred in Brazil, when they tried to fix this same problem, was they did not consider the time it would take to transport the old refrigerators to the recycling plant. It could take up to three days by truck to only move approximately 15-30 refrigerator units (Fischer V., 2011). This slow transportation time did not provide the recycling facility with enough units to be economically viable. The benefit of implementing a project like this in Costa Rica is that this issue of transportation would not cause the same problem. Costa Rica is less than 1% the size of Brazil, so it would be highly possible to find success in this type of recycling infrastructure (Central Intelligence Agency, 2015). If Costa Rica sought out a funding organization to invest in technology for the recycling of refrigeration equipment, then it would significantly reduce its refrigerant emissions.

There were two main methods that Brazilian companies used to fund these recycling projects, and Costa Rica has the potential to use either of them. Even if Costa Rica had a plan for implementing recycling infrastructure, it would not be able to happen without proper funding. There are two different cases in Brazil where the funding for the Querstromzerspaner (QZ) machine was provided. The first case, as mentioned above, was a GIZ sponsored project that had a budget of €5,000,000, approximately 5.4 million USD (GIZ, n.d.). The German Federal Ministry funded this project for the Environment, Nature Conservation, and Nuclear Safety as a part of Germany's International Climate Initiative to help countries reduce their environmental impact. When analyzing this budget it is unclear what the cost of the recycling technology is because the €5,000,000 covers the entire cost of the whole project. This budget is split up into different areas such as the refrigerator exchange program and the building of the recycling facility, as well as buying the refrigerator recycling equipment. Unfortunately, we were not able to determine how much of the budget was spent in certain areas, so the limitation here is that the cost of the recycling technology is lost in all of the other expenses that would accrue. However, because Brazil is an Article-5 country in need of help to properly recycle its refrigeration units, it was able to receive the majority of the funding for this project from Germany. This provides a good outlook for Costa Rica when they begin to tackle this same problem and they begin to reach out to countries like Germany for help. The second case in Brazil is another refrigerator recycling plant with international funding. The recycling plant is run by a company called Industria Fox and is funded through a Swiss organization called Fair Recycling. Fair Recycling sells carbon credits in the Swiss industrial sector and repurposes the profits directly into Industria Fox, to recycle refrigerators in Brazil. Both of these methods of funding rely on a problem in the country causing the need for assistance from foreign countries to interject and provide support. Costa Rica has the need for such help, and if the government reaches out to another country for this purpose, it could be possible to receive funding for a recycling infrastructure project (Fair Recycling, n.d.).

These are just a couple of the successful refrigerant recycling programs that have been developed in Brazil. These programs have some important ideas that Costa Rica can use to develop their own recycling program that is specific to old refrigerators containing not only HCFCs but CFCs as well. The first important idea is the technology used in these examples is proven to work for efficiently recycling refrigeration equipment and would give the industrial sector of Costa Rica an option to recycle this obsolete equipment. However, it is important to look into the results of these programs and learn from the mistakes that were made. Even though Costa Rica is not as big of a country as Brazil, they still have large mountain ranges that could impede the transportation of equipment to a centralized recycling hub. This type of consideration needs to be taken into account to successfully implement a large scale-recycling program in Costa Rica. The major problem for Costa Rica at the moment is the lack of funding for recycling programs and equipment, but both of these examples show alternative ways of funding. These options are feasible for Costa Rica as the CICR has direct ties to the GIZ and Costa Rica is beginning to develop their carbon market. Solving the important initial issue of funding for these programs is a big step and should be focused on in order to make advancements towards HCFC reduction and elimination. These types of recycling programs would not only help the environment, as these

examples have shown, but also create jobs and a new source of revenue for companies that participate.