December 2011

Determining the Applicability in Costa Rica of Practices & Policies Used in Sustainable Industrial Parks Worldwide

Arten Ahmed-Hussein Esa
Worcester Polytechnic Institute

Martha Onnolee Miller
Worcester Polytechnic Institute

Nathaniel Allan Eames
Worcester Polytechnic Institute

Susan Marie Brennan
Worcester Polytechnic Institute

Assessing Sustainable Industrial Park Models for Costa Rica

Susan Brennan
Nathaniel Eames
Arten Esa
Martha Miller

Date: December 14, 2011

Assessing Sustainable Industrial Park Models for Costa Rica

Determining the Applicability in Costa Rica of Practices & Policies Used in Sustainable Industrial Parks Worldwide

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degrees of Bachelor of Science and Bachelor of Arts

Sponsoring Agency: Cámara de Industrias de Costa Rica

Submitted by:

____
Susan Brennan

____
Nathaniel Eames

____
Arten Esa

____
Martha Miller

Submitted to:

Bernhardt Johst
Cámara de Industrias de Costa Rica

Professors Jeanine Skorinko & James Dempsey
Worcester Polytechnic Institute

Abstract

Costa Rica has the potential for economic growth and environmental accountability in future industrial development. Our research focused on the techniques that can lead to sustainability in industrial parks. Through conducting site assessments and surveys with industrial park managers, we evaluated the potential for sustainability in Costa Rica's industrial parks. We created a database of industrial parks in Costa Rica and a sustainability checklist, and conducted a comparative analysis of international and domestic policies concerning sustainability. Our research revealed that Costa Rica’s industrial parks have the interest and potential to become sustainable, they just need the necessary tools to accomplish this.

Acknowledgments

We would like to extend our thanks to the people and organizations that were invaluable in our research and development of our project.

Firstly, we are immensely grateful to our sponsor, Bernhardt Johst, and Gunther Gust at Cámara de Industrias de Costa Rica (CICR). They have been a very valuable resource for us throughout this process. We would also like to thank the CICR for supporting us and providing us a space to work while we were in Costa Rica.

We are also very appreciative of the people and organizations that took the time out of their busy schedules to meet with us. Their insight and enthusiasm was a crucial component to the success of our project, and we are grateful for their willingness to help us.

We would also like to recognize and thank Professors Jeanine Skorinko and James Dempsey, our project advisors, and Professor Jeanine Plummer, an on-site advisor, for all of their assistance in helping our final product reach its highest potential. We are also very grateful to Professor Ingrid Shockey for her assistance in developing our project proposal. Furthermore, we extend thanks to Worcester Polytechnic Institute for making it possible for us to work on this project in Costa Rica, especially noting our site director Professor Susan Vernon-Gerstenfeld, our site liaisons Jim and Marcela Music in Costa Rica, and for the faculty and staff in the Interdisciplinary and Global Studies Division.

This experience was a very valuable one that provided us with lessons not only in sustainability and industrial operations, but also in culture and crossing borders. We are very grateful for the opportunities we have had here to learn beyond the limits of a classroom.

Executive Summary

As industry becomes a larger part of Costa Rica's economy, minimizing the effects of industry on the environment gains importance. In 2005, industrial processes accounted for 18% of Costa Rica’s greenhouse gas (GHG) emissions, with 1,032,910 metric tonnes of GHGs released into the environment. Since Costa Rica hopes to be carbon neutral by 2021, these emissions need to be reduced. One way to limit industries emissions and affects on the environment is through sustainable industrial parks. A sustainable industrial park (SIP) is a manufacturing area where two or more companies are operating together, minimizing their environmental impact and increasing their financial performance through cross-company cooperation and efficient use of resources, while also having a positive impact on society (Lowe, 2010; Washington State University, 2004; International Chamber of Commerce, 1997). Thus, we set out to investigate the methods for industrial parks to become more sustainable. In particular, we examined how industrial parks can achieve sustainability, how environmental policies in other countries compare to Costa Rica’s policies, and what the potential is in Costa Rica for SIP development.

In order to understand how industrial parks can achieve sustainability, we first examined the types of industries that existed in Costa Rica. From this, we created a database of all of the industrial parks in Costa Rica, which included the companies operating in each park. Since Costa Rica currently has no SIPs, we investigated SIPs in five countries to determine techniques necessary to turn an industrial park into an SIP. In particular, we examined SIPs in Brazil, China, Denmark, Japan and the United States. From this investigation, we ascertained five areas where industrial parks need to focus to become sustainable: (1) Energy Use and Consumption (e.g., energy efficiency, green architecture), (2) Waste Management (e.g., recycling, hazardous waste handling), (3) Water Usage (e.g., water collection, water treatment), (4) Materials (e.g., shipping of goods, storage) and (5) Infrastructure (e.g., transportation of workers, protecting wildlife) These techniques were compiled into a sustainability checklist that could be applied to Costa Rica’s industrial parks in order to see what sustainability techniques they currently have and what they could implement in the future.

In addition, the examination of the international SIPs provided five key guidelines that should be applied to Costa Rica’s SIP development. First, industrial parks need to consider the economic repercussions when implementing environmental improvements. Second, industrial parks need to enforce all environmental policies. Third, industrial parks should aim to cluster similar industries together to reduce the number of techniques required to be sustainable. Fourth, industrial parks should retrofit old buildings in order to save costs and minimize the environmental impact. Fifth, industrial parks need to maintain any outside support they are receiving throughout the SIP development process.

Policies will also be important in supporting SIP development. In order to understand how Costa Rica's policies can be used to promote SIPs, we performed a comparative analysis of legislation regarding sustainability internationally and in Costa Rica. We examined three Costa Rican policies: the Integrated Waste Management Law, the Rational Energy Use Law, and the Organic Law of the Environment, which regulates environmental impact assessments. We investigated similar policies from the five countries that we found example SIPs in to use in our comparison, because we knew those international policies had successfully been used to regulate SIPs in the past. From the comparative analysis of policies, we drew conclusions about what aspects Costa Rica's policies are currently doing well to promote SIPs, and what these policies could change in the future to better regulate SIPs. Currently, Costa Rica has legislation in place that can be successful in promoting SIP development, including greater waste generator responsibility, incentives for utilizing renewable energy techniques, and regulating industrial development with an environmental impact assessment.

Once we had an understanding of what makes an industrial park sustainable and what policies regulate them, we measured the feasibility of implementing those strategies in Costa Rica. To do this, we surveyed industrial parks, investigating which techniques on the sustainability checklist the company already put into operation. In addition, we assessed the industrial parks' interest in becoming sustainable. The survey results revealed that while there are some sustainability techniques being employed in the existing parks, there are many gaps in industrial parks' understanding of how to be sustainable and what the advantages are of becoming a SIP. From the analysis of our survey results, we created a document that CICR can bring to any company or existing industrial park that can educate park officials on the practices necessary for being sustainable and the benefits that come from operating as a SIP.

The purpose of creating the database, the checklist, the survey, and the comparative analysis was to provide CICR with the tools to promote the development of SIPs in Costa Rica. From these tools, we found that there are certain techniques that aid in the transformation of an industrial park into a SIP. We also determined that it will be feasible for Costa Rica to develop SIPs in the future. Future projects can focus on furthering the understanding of what makes an industrial park sustainable, and applying that knowledge specifically to one industrial park to create an example SIP for Costa Rica. Our analysis shows that with adequate support from companies, current industrial parks, and industrial organizations, Costa Rica can successfully develop SIPs in the future.

Table of Contents

Abstract i

Acknowledgments ii

Executive Summary iii

Table of Contents vi

List of Figures viii

List of Tables viii

Chapter 1: Introduction 1

Chapter 2: Background 3

Chapter 3: Methodology 7

Objective 1: Identification of Industrial Parks in Costa Rica 7

Objective 2: Sustainability Techniques from International SIPs 8

Objective 3: Comparative Analysis of Policies 8

Objective 4: Feasibility Study 9

Sustainability Checklist 10

Surveys 10

Chapter 4: Results 12

4.1: Sustainable Industrial Park Development Practices 12

4.2: Techniques 14

Waste Management 15

Energy Use 15

Water Usage 18

Materials 20

Infrastructure 21

4.3: Comparative Analysis of Policies 22

Waste Management Policies 22

Rational Energy Use Policies 25

Environmental Impact Assessment 28

Comparative Analysis Conclusions 30
Potential for SIPs in Costa Rica 31
Database of Industrial Parks 31
Checklist Results 32
Survey Results 33
Chapter 5: Discussion 35
5.1: Achieving sustainability in industrial parks 35
5.2: Significance of Environmental Policies for SIP Development 36
5.3: Potential in Costa Rica for SIP development 37
5.4: Recommendations and Future Research 37
5.5: Conclusion 38
Works Cited 40
Appendix A: In-Depth Description of Example SIPs 44
Kalundborg 44
Devens 45
Fujisawa 46
Tianjin Economic Development Area 48
Xi'an 50
Santa Cruz 51
Appendix B: Chapter IX, Article 38 of Costa Rica's URE Policy 54
Appendix C: Database of Costa Rican Industrial Parks 56
Appendix D: Sustainability Checklist 57
Appendix E: Survey of Industrial Park Managers (English) 59
Appendix F: Survey of Industrial Park Managers (Spanish) 63

List of Figures

Figure 1: Balance of the 3 main areas of sustainability 3
Figure 2: Recyclable Cardboard 32
Figure 3: Storage and Transportation 33
Figure 4: Kalundborg By-Product Synergy Network 45
Figure 5: Sustainable living in Fujisawa 47
Figure 6: Binhai Mass Transit System 49
Figure 7: Public Sector Symbiosis of TEDA 50
Figure 8: Part of Database of Industrial Parks 56

List of Tables

Table 1: Practices Employed by the Example SIPs 14
Table 2: Comparison of Waste Management Policies 25
Table 3: Comparison of Energy Use Policies 28
Table 4: Comparison of Environmental Impact Assessment Policies 30
Table 5: Comparative Analysis of Policies 31
Table 6: Important Technologies Planned at Fujisawa 47
Table 7: Santa Cruz's Initial Goals 52

Chapter 1: Introduction

In 2005, industrial processes accounted for 18% of Costa Rica's greenhouse gas (GHG) emissions, with 1,032,910 metric tonnes of GHGs released into the environment(Araya, Ballestero, & Marín, 2009). In order to prevent negative environmental consequences from these emissions and emissions from other sectors, Costa Rica set the ambitious goal of being carbon neutral by 2021. In a country with such a diverse climate and fragile ecosystem as Costa Rica, maintaining control of emissions is important to avoid environmental consequences from climate change (Instituto Metrológico Nacional; Ministerio del Ambiente, Energia y Telecomunicaciones, 2009). However, with the year 2021 only ten years away, these emissions from industry are an area of concern that needs to be addressed. As Costa Rica's industrial production continues to grow, the amount of GHGs produced from industrial processes will grow as well, unless something can be done (Cordero & Paus, 2008). One method to combat these industrial emissions is to promote sustainable industrial park (SIP) development. SIPs have the potential to not only reduce GHG emissions from industrial processes, but to also increase the competitiveness of Costa Rica's industries, create jobs, and protect Costa Rica's environment.

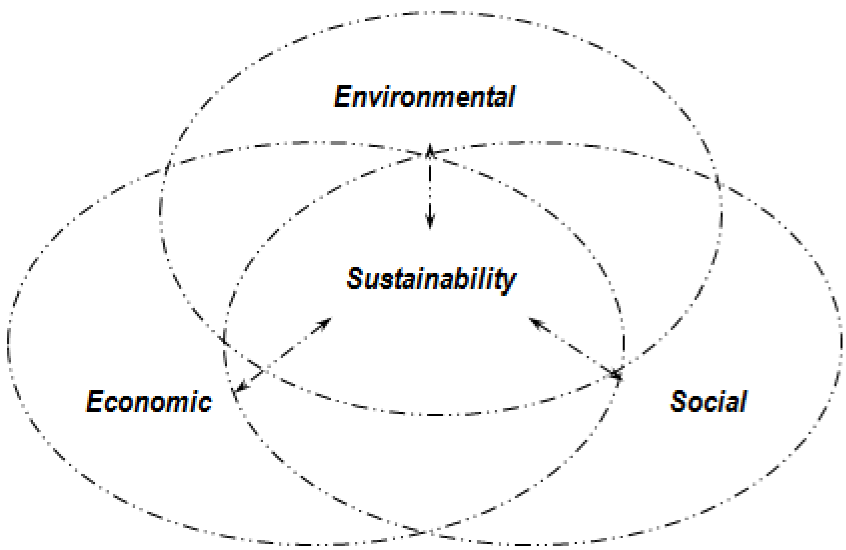
A SIP is a manufacturing area where two or more companies operate together to minimize their environmental impact and increase their financial performance through the efficient use of resources (Lowe, 2010; Washington State University, 2004; International Chamber of Commerce, 1997). The greatest difference between an industrial park and a SIP is that an industrial park is typically only concerned with providing space for companies to operate and making money, while a SIP provides a place for companies to utilize both the most cost-efficient and environmentally friendly practices. (Government of Gujarat, 2011). For a country like Costa Rica, with their commitment to the environment and their recent industrial growth, SIPs could be a way to allow future industrial production without harming their environment.

This project sets out to develop the tools for industrial parks in Costa Rica to utilize when converting to a SIP. We provide significant information about sustainability techniques and regulations that could be used, and offer recommendations on where future development should focus. There are three goals that we address within our project: to provide examples of SIPs in other countries, to conduct a comparative analysis of policies, and to assess the feasibility of implementing sustainability techniques in Costa Rica. Accomplishment of these three goals revealed small, pertinent steps that industrial parks could start implementing with little investment, as well as larger steps that require more investment for industrial parks ready to fully convert to sustainability. Implementing these recommendations in the future in both existing industrial parks and new developments can help Costa Rica reach their goal of carbon neutrality.

Chapter 2: Background

The problem of industry negatively impacting the environment can be addressed through efforts towards sustainability. Sustainability can be defined as accomplishing the goals of the present without hindering those of the future. This can be broken down into three main areas, environment, economy, and society, which all must be considered in order to achieve sustainability. Figure 1 depicts the balance that is necessary to achieve sustainability (Lowe, 2007). When developing sustainable infrastructure, such as that of industry, these three areas are very important. Sustainable industrial development is described as balancing industrial processes with ecological, economical and social interests. For industries, this mix corresponds to the ability to reduce emissions while benefitting financially from production.

Figure 1: Balance of the 3 main areas of sustainability



(Lowe, 2007 modified by Arten Esa 12/13/2011)

At present, sustainable industrial development is not occurring in Costa Rica's industries. The main industries in Costa Rica, which include electronics manufacturers, biopharmaceuticals, and apparel, are meeting the economic and social aspects of sustainability but because of emissions, are not meeting the environmental area of sustainability (Central Intelligence Agency, 2011). Emissions from these include fluoridated green house gases (FGHGs) from the electronics industry and "listed" chemicals from the biopharmaceuticals industries (Barthos, et al., 2006; Environment Australia, 1998; Environmental Protection Agency, 2010; World Bank Group, 1998). While these are the main industries, other ones exist and while the type of emissions they have may differ, they all have some other form of raw material waste that is emitted as a result of their production cycle. Therefore, using this idea of sustainable industrial development to reduce emissions is a good option for Costa Rica, because it would still promote the societal and economical benefits these industries have and address the negative environmental consequences.

With standardized rules for industries to follow, the transition to sustainable industrial parks in Costa Rica can be more effective with "regulatory frameworks" for countries to follow and "major government action" to support this development (Lehtoranta, Nissinen, Mattila, & Melanen, 2011, p. 1866). Organizations such as the United Nations (UN) and the International Chamber of Commerce (ICC) have created guidelines to support countries, like Costa Rica, in developing sustainable industry. In 1997, the International Chamber of Commerce released guidelines for sustainable development. Their policy recommendations were designed to lead countries like Costa Rica in the first steps towards sustainability in industrial production. Their recommendations are based on sixteen principles for industries to consider in sustainable design. The principles cover a range of suggestions from the actual production process and its environmental impacts to align corporate policy and consumer advice with sustainability ideals. These guidelines will assist industries in providing products with a minimal environmental impact on Costa Rica's fragile ecosystems and biodiversity. By following these guidelines, Costa Rica's sustainable industrial park development should be on the right track in the future (International Chamber of Commerce, 1997). Also in 1997, the United Nations Environment Programme (UNEP) met in Paris and authored technical report No. 39, the Environmental Management of Industrial Estates. This document outlined the "performance objectives" that sustainable industrial development should meet, as well as how to design policies to promote that development (Francis & Erkman, 2001). According to the UNEP, these performance objectives that legislation should take into consideration need to be "quantifiable goals" that Costa Rica can feasibly measure the success of during an acceptable time frame (Francis & Erkman, 2001).

Another strategy for sustainable industrial development that the UNEP explains in technical report No. 39 is to focus on creating performance objectives for each industry (Francis & Erkman, 2001). Right now, Costa Rica's strategy for sustainable industrial development, according to a green production representative, is to focus on specific companies rather than industries (Personal communication, 12/7/2011). However, for promoting successful sustainable industrial development, Costa Rica needs to find an approach that combines the UNEP suggestions and their current plan. The new strategy should be to focus on industrial parks rather than companies or industries. By our definition, an industrial park is a manufacturing area where two or more companies are operating. Following this definition, eleven industrial parks comprising over one hundred fifty companies have been identified in Costa Rica (Costa Rican Investment Promotion Agency, 2011; Promotora del Comercio Exterior de Costa Rica, 2011). This large number of companies shows why this strategy is an improvement on the previous one. Rather than reducing each individual company's emissions, working on entire industrial parks would help improve the sustainability of more companies at a time. Also, using the concept of sustainable industrial development, companies within industrial parks can develop synergies through sharing of facilities or responsibilities to increase their performance in all areas of sustainability. This focus on industrial parks, rather than individual companies may expose more opportunities for this synergy. Therefore, this project focuses on converting industrial parks to sustainability.

Sustainable industrial parks (SIPs) have three main intentions. First, companies combine efforts in order to meet their collective needs. These can include treatment of wastewater, disposal of solid waste, and energy generation. Second, all of the companies contribute what they can without straying from their specialties. Depending on the mix of industries, certain companies could provide services to other companies in the park while also continuing to create a profitable product. For example, a biodiesel plant could provide fuel to transportation throughout the park. Third, they take advantage of all possible resources. Beyond using the typical resources, such as oil or coal, SIPs strive to find less conventional resources. An example of an unconventional resource SIPs might use would be waste items that can be used elsewhere, such as agricultural by-products being converted to biodiesel fuel to power processes in the park. These concepts used in SIPs are a recent development that has received attention due to their successful implementation.

The benefits of utilizing SIPs are already visible in international industrial parks. Many countries are employing SIPs to make their industries more environmentally-friendly. However, these countries are using SIPs for advantages beyond reducing industrial emissions, as they also address economic and social interests. Countries such as China and Denmark are using the SIP concept for mostly economic reasons (Tianjin Economic-Technological Development Area, 2011; Kalundborg Symbiosis, 2011). By broadening the understanding of a SIP, from a tool just for addressing environmental concerns to something that can also be utilized to promote economic growth and societal benefits is what makes their application internationally successful.

While there are several international examples of successful SIPs, there are none within Costa Rica for industrial parks to emulate. Thus, industrial parks are hesitant to make any financial commitments towards becoming sustainable. They want to see a proof of concept, and to make sure their investment into this new idea will be advantageous for them. To create that example, this project provides the information to convert industrial parks to SIPs by researching international models. The report is split between three main goals. First, examining the techniques of examples from other countries will determine what practices and techniques make a SIP. Second, knowing the policies that regulate industrial development in countries with SIPs can help to determine where the Costa Rican policies can be improved to promote sustainable development. Finally, assessing the feasibility of implementing the techniques to determine which ones will be important during the development of SIPs. In order to suggest improvements, the strengths and weaknesses of Costa Rica’s industrial parks should be evaluated.

Chapter 3: Methodology

The goal of our project was to research the potential for SIP development in Costa Rica and to find the best practices and policies that could be implemented. To do this, our project focused on finding international examples of SIPs and environmental legislation that Costa Rica could follow to encourage future SIP development. We also examined how sustainable the industrial parks in Costa Rica are, and how interested they would be in becoming more sustainable in the future. Our research and results will ultimately be used by CICR as a document that they can distribute to companies and industrial parks in Costa Rica to educate them on the strategies involved in becoming a SIP. With the guidance of CICR, we have formulated four key objectives to achieve progress toward this goal:

(1) Identify the industrial parks in Costa Rica.

(2) Determine the techniques that make an industrial park sustainable.

(3) Conduct a comparative analysis of policies that promote SIPs in other countries and in Costa Rica.

(4) Measure the feasibility of SIPs in Costa Rica's future.

Objective 1: Identification of Industrial Parks in Costa Rica

In order to understand how an industrial park in Costa Rica can become sustainable, we examined what industries exist in the country. For this examination, we created a database of the industrial parks that are operating in Costa Rica. To develop the database, we located three lists of Costa Rican industrial parks from organizations including the Ministry of Economy, Industry, and Trade (MEIC), Asociación de Empreseas de Zonas Franacas de Costa Rica (AZOFRAS) and the Costa Rica Investment Promotion Agency (CINDE). This database included the name of the park, the number of companies operating within the park, the name of the contact for the park, and contact information including its address and phone number. Creating a database of this information provides a number of benefits for CICR. First, it provides information on the number of industrial parks that exist in Costa Rica, and clear records on them. Second, it can help CICR determine which industrial parks to target for future projects, based on park location or the industries within the park.

Objective 2: Sustainability Techniques from International SIPs

Currently, Costa Rica has no SIPs in the country, so we examined international SIPS to serve as potential models for future development. To do so, we chose international SIPs that have similar industries to Costa Rica, because they would benefit from similar sustainability techniques. We found SIPs with similar industries in Brazil, China, Denmark, Japan, and the United States. For each SIP, we investigated how they became sustainable, and the current techniques they employ. From this, we discerned five key areas important for sustainability: (1) Energy Use and Consumption, (2) Waste Management, (3) Water Usage, (4) Materials and (5) Infrastructure. These key areas are the five categories we organized the sustainability techniques from the international SIPs in to. In addition, we interviewed a world expert on SIP development to ascertain information on important strategies for establishing SIPs, especially in Costa Rica. This, along with the analyses of international example SIPs, contributed to our understanding of what makes an industrial park sustainable.

Objective 3: Comparative Analysis of Policies

In order to learn if Costa Rica's current policies could encourage SIP development, we conducted a comparative analysis examining international and Costa Rican environmental policies. To conduct this analysis, we examined polices in Brazil, China, Denmark, Japan, and the United States, because these countries have similar industries to those of Costa Rica. In particular, we focused on polices dealing with waste management, energy use, and environmental impact.

The first policy area we compared was waste management. All industrial parks produce solid waste, and determining a way to manage the waste so it has the least impact on the environment is an important attribute of SIPs. For our comparative analysis, we chose to compare Costa Rica's Law for the Integrated Management of Waste to the waste management legislation in the five other countries. For our comparison, we specifically focused on if the policy contained extended producer responsibility. This holds the creators of solid waste, like industrial parks, accountable for what happens over the life-time of their products and the solid waste created during production (Personal communication, Dec. 2, 2011). For the comparison, we considered if the policy did include extended producer responsibility and how much of it was placed on the creators of waste. Understanding how industrial parks should manage waste from a legislative point of view can be used to promote cleaner waste management in SIPs.

Similar to waste management, energy use is an area of an industrial park that can promote sustainability and be regulated through policies. For that reason, our second comparison focused on energy use policies. We compared Costa Rica's Regulation for the Rational Use of Energy to the energy use policies from the five other countries on the basis of if they included incentives and what they were. Incentives are rewards set in place by the policy for using certain types of efficient or renewable energy sources. These incentives would encourage industrial parks to use more renewable energy sources, like those found in SIPs.

Our last comparison went beyond specific categories in sustainability and considered legislation that would directly affect new industrial park development in Costa Rica and the environmental impacts it could have. For our third comparison, we investigated policies on environmental impact assessments. The environmental impact assessment is regulated by Costa Rica's Organic Law of the Environment, and we compared that legislation to the legislation in the five other countries. The criteria for the comparison considered if the law directly required industrial parks to file an environmental impact assessment, if it was only implied that industrial parks need to file one, or if industrial parks did not need to file one. Since environmental impact assessments are filed before new development begins, they could be used as a tool to encourage more sustainable development.

To better understand the Costa Rican policies, we also interviewed government officials familiar with the policies. Through the interviews, we learned more about the policies, including what issues the policy aimed to address and whether the officials believed the policy could help regulate SIP development. We also asked them specific questions about how the policy could be used to regulate SIPs, especially about which area of the policy they believed would have the greatest impact on industrial park development. From those answers, we chose the key component from the legislation to focus on in our comparative analysis.

Objective 4: Feasibility Study

Lastly, we assessed the feasibility of developing SIPs in Costa Rica. To do so, we created a sustainability checklist and then conducted surveys with industrial parks to determine the current efforts and interest in becoming sustainable.

Sustainability Checklist

In order to measure the sustainability of industrial parks in Costa Rica, we first created a sustainability checklist. This was used to gather information on energy sources, production methods, and waste handling from the industrial parks that we observed. This information allowed us to gauge the environmental impacts of each industrial park. To develop the checklist, we took the techniques from the international SIPs we had previously researched (Brazil, China, Denmark, Japan, and the United States) and organized them in the previously mentioned five categories (energy use and consumption, waste management, water usage, materials, and infrastructure). Within each of the five categories are sub-categories, to further classify the techniques. For example, within the water usage category there are three subcategories: water treatment, water collection, and water efficiency. Divided into each sub-category are the different techniques that could be implemented to make an industrial park sustainable. The checklist can be seen in Appendix D: Sustainability Checklist. The checklist had two purposes during our study. First, it was designed to be brought to current industrial parks to measure the current sustainability of the park by marking what techniques the park was utilizing on the checklist. The checklist can also be used as a reference when designing a new SIP to see what techniques should be considered for the park. We tested the checklist by visiting a park and applying it there, noting what techniques we actually had access to, and were able to observe. We also used the checklist to gauge the feasibility of new SIPs in Costa Rica, by seeing which criteria on the list parks were lacking in (Stufflebeam, 2000). We were able to make more specific suggestions for future improvements on the sustainability of a park, because we could see which criteria the park was missing, and suggest different techniques from that category for the park to employ in the future.

Surveys

Along with our sustainability checklist, we created a survey for an official at the industrial park, such as a park manager, to complete. The survey supplemented the checklist; it was organized in the same categories as the checklist and included a majority of the sustainability techniques. The park managers had the opportunity to indicate whether or not each technique was being employed. The survey also included an open-answer section in each category where park managers could let us know about any other sustainability techniques they were using in the park that we may not have included on the checklist. In addition, the survey asked questions to gauge the interest of the park managers in turning their industrial park into a SIP. These questions addressed issues of cost, time commitment, available resources, mentality of the companies, and foreseeable benefits. We conducted these surveys over the phone with twenty five percent of the industrial parks in Costa Rica.

Chapter 4: Results

In order to determine what makes an industrial park sustainable, we examined six international SIPs to gain knowledge of their development processes and their sustainable techniques that could be applied to Costa Rica. From this analysis, we discovered five unique practices from the SIPs that made them successful in their conversion to sustainability. In addition to this, we found numerous techniques that could help improve SIPs in five different areas: waste management, energy use, water use and treatment, material usage, and the infrastructure.

4.1: Sustainable Industrial Park Development Practices

We investigated five practices that made the sustainable development processes in the example SIPs successful. The five practices consisted of, 1) considering the economic repercussions when implementing environmental improvements, 2) strictly regulating all environmental policies to ensure all organizations are in compliance, 3) clustering similar industries to reduce number of sustainable techniques required, 4) retrofitting old buildings to reduced costs and effects on the environment, and 5) maintaining any outside support they are receiving throughout the development process.

Economically Responsible Decisions. This is the practice of only employing sustainable techniques that will have a good return on investment for the industrial park. While this practice is employed in each of the industrial parks investigated, it is most prominent in the Kalundborg Symbiosis in Denmark. The Kalundborg Symbiosis was a coalition of companies that, through an unplanned evolution, converted into an SIP. They accomplished this by attempting to improve their efficiency by wasting as few materials as possible. Through this, they benefited themselves economically, but they also reduced the amount of waste and emissions released. The purpose of becoming sustainable is not just to benefit the environment, but also the society and the economics involved in the industrial park. Therefore, sacrificing economics to benefit the environment, while seeming positive, will only hurt the SIP in the long run. (Kalundborg Symbiosis, 2011)

Strict Enforcement of Regulations. The practice of using strict regulations in SIPs was employed by two Chinese SIPs in Xi'an and Tianjin. Through the research gathered on these industrial parks, we found that they are kept up to code by the constant regulations of the parks processes and it is ensured that the companies follow the guidelines. This stops companies from violating policies by using an easier or more financially beneficial method that may be damaging to the environment or society. These policies can be government laws or company policies, but having regulations that encourage good environmental, as well as economic and social practices, produces successful SIPs. (Lowe, Eco-Industrial Park Handbook for Asian Developing Countries, 2001) (Shi, Chertow, & Song, 2010)

Cluster Similar Industries. The main benefit from this practice is that companies of the same industry will require the same sustainability techniques to deal with their pollutants or emissions. This strategy of clustering companies of similar industry is employed in the Xi'an High Tech Industrial Development Zone and the Tianjin Economic Development Area. The Xi'an SIP clusters low emission industries, such as biopharmaceuticals and software development. With no heavy industrial polluters, they do not need to employ advanced technologies that would otherwise be necessary. The Tianjin SIP has heavy industries that require expensive, advanced technologies to reduce their damage to the environment. The benefit of clustering in this case is that the companies are centrally located which means that they can construct one treatment facility to satisfy the many companies in the cluster. This benefits industrial parks both environmentally and economically (Zhong, Xia, & Xu, 2010) (Shi, Chertow, & Song, 2010).

Retrofitting Old Buildings. Another strategy that can improve sustainability in an economic manner is to retrofit old buildings. Three of the six international SIPs, Devens Eco-Industrial Park, Fujisawa Sustainable Industrial Town, and Santa Cruz Industrial Park, took advantage of retrofitting to create their SIPs. The benefits of retrofitting old buildings include the reduction of costs and emissions related to construction. Another advantage of retrofitting is that it has a reduced impact on the society surrounding the industrial park, as it minimizes the obstruction of roadways with construction vehicles and uses less land. (Lowe, 2001)

Ensure Financial Support. To ensure an industrial park's successful conversion to a SIP, they must secure continuous financial support throughout their development process. Five out of the six of the international SIPs had financial support throughout their development phase. The only park that did not gain financial support was the Santa Cruz Industrial Park because its conversion process was being supported by a government program which was discontinued part of the way through its development. This loss of public support caused all progress the industrial park was making to slow dramatically. The Santa Cruz Industrial Park isn't used as an example that aspiring SIPs should follow, but an example that they should learn from. Without proper support from either the private or public sector the chances of an industrial park converting to a SIP drop significantly. (Veiga & Magrini, 2009)

Table 1 below summarizes the lessons learned from the six international SIPs by illustrating which parks use the practices described. As shown, being economically responsible is a main point for each of the SIPs, the strict enforcement of regulations and clustering of similar industries is not as widely practiced, as only 33% of the parks studied are using them. Retrofitting old buildings is a viable technique, employed by half of the parks, and ensuring financial support is very important, as the only park that lost support is also the only park that is struggling to continue development.

Table 1: Practices Employed by the Example SIPs

Practices	Devens	Fujisawa	Kalundborg	Santa Cruz	Tianjin	Xi'an
Economically Responsible Decisions	☑	☑	☑	☑	☑	☑
Strict Enforcement of Regulations					☑	☑
Cluster Similar Industries					☑	☑
Retrofitting Old Buildings	☑	☑		☑		
Ensure Financial Support	☑	☑	☑		☑	☑

4.2: Techniques

While researching the international SIPs, we examined the different technologies and methods that made the industrial parks sustainable. They were broken down into five categories; waste management, energy use, water usage, materials, and infrastructure. The first category, waste management, deals with the reduction of the amount of solid waste an industrial park produces. Energy use pertains to reducing the amount of energy a park uses, as well as acquiring energy from cleaner sources. The category of water usage is concerned with the purification of polluted water, as well as decreasing the amount of water used. The materials section is relevant because it deals with the storage of hazardous materials, the transportation of goods, and the use of recyclable materials. Finally, infrastructure consists of the transportation of workers, the management of the park, and the treatment of the landscape surrounding the industrial park.

Waste Management

Waste management techniques found during research include recycling, by-product synergy, waste-to-energy conversion, and hazardous waste treatment. Recycling centers can receive recyclable waste from the companies to process. Parks can recycle on-site in their own centers or off-site in a municipal center. In some cases, such recyclable waste can be used by another company resulting in by-product synergy. By-product synergy is the re-use of waste from one company by giving it to another company for use. By-product synergy reduces the amount of wasted resources while financially benefitting the companies.

The park in Denmark uses incineration to convert waste into both heat and electricity. Each tonne of incinerated waste generates 2 Megawatt-hour (MWh) of heat and 0.67 MWh of electricity. Approximately twenty percent of the waste remains in the form of ash, of which 98% is recycled. This process emits less than plants that use coal or oil to generate energy. (Ramboll, 2006)

Depending on the type and amount of hazardous waste, each industrial park can decide to either create a treatment center on site, or send their hazardous waste to a nearby facility that will treat or properly dispose of the waste. (United States Environmental Protection Agency, 2011)

Energy Use

The second category of techniques was energy use. The most important energy techniques fell under three subcategories: energy efficiency, green architecture, and on-site power stations. Energy efficiency addresses reducing the amount of power necessary for an industrial park. This is done through techniques such as installing lighting and occupancy sensors, using energy efficient lighting, and acquiring power from renewable energy plants off-site. Lighting sensors work by dimming or shutting off the lights during the daytime when less lighting is needed. Occupancy sensors detect when a room is in use and adjust the lights appropriately. Energy efficient lighting, such as compact fluorescent light bulbs, is a good alternative to traditional light bulbs as they require less electricity and their lifespan is much longer. The electricity required to generate the same amount of light in a standard incandescent light bulb is three to four times more than a compact fluorescent light bulb. In addition, the lifespan of a compact fluorescent light bulb is approximately thirteen times longer than the "long life" standard incandescent bulbs. (U.S. Department of Energy, 2011)

The use of renewable energies does not have to originate inside the industrial park, but instead it is possible to purchase renewable energies off-site. In the United States, this is accomplished through the purchases of Renewable Energy Certificates. For every certificate bought one MWh of renewable energy is produced. The electricity generated by the purchase is not directly used by the purchaser, but is instead added to the public grid. The purchaser, however, is able to claim that the renewable energy covers the electricity they take from the grid. It does not matter where the renewable electricity produced is used, only that it was created to lessen the demand of non-renewable sources. This process can be both beneficial for an industrial park's image as well as being beneficial for the environment.(EPA Green Power Partnership, 2008)

Green architecture is when a building is designed to be energy efficient through both technology and the architectural aspects of the building. Passive solar, or designing a building to take advantage of sunlight, is important in green architecture. The angle that sunlight hits the earth differs during the year in different regions. Passive solar takes advantage of the sun's angle by implementing overhangs, so that during the summer when the sun is higher in the sky it will not shine directly into the building. Then during the winter, when the sun stays lower during the day, it will still be able to shine through the windows. Thus the sun will heat during the winter, when it is needed, but not during the summer when heating is unnecessary. This is the key concept behind passive solar; using the sun to heat or light a building when needed. (Balcomb, 1984)

Another aspect of design is passive cooling which utilizes wind patterns and shade. Using wind to ventilate and cool a building is called cross ventilation. The arrangement of open windows in a certain manner, depending on the wind patterns and the buildings orientation, can help to increase airflow within the building. This reduces cooling costs when air conditioning may otherwise be required. Other aspects of passive cooling include using trees to reduce sun exposure on certain parts of the buildings. Green architecture is not just about design; it also takes advantage of different renewable technologies. (Lowe, 2001)

The use of renewable energies on-site can reduce the emissions of an industrial park as well as be economically beneficial in the long run. The use of clean renewable sources of energy, such as solar power, can replace power generated by un-renewable fossil fuels. Photovoltaic cells are a great source of solar energy that should be looked at for the future. Currently though, electricity generated by photovoltaic cells is more expensive than traditional sources of energy, so the return investment may be longer than desired. For now there are still solar options that can benefit an industrial park. The use of solar energy to heat water is a viable option, for example. The sun heats the water, which can then either be used directly or can be circulated through a building to provide heat. There are many solar options that can reduce an industrial park's burden on the electrical grid, as well as reduce its carbon footprint. Other renewable energies that should be investigated include wind, geothermal, biofuels and hydropower. The more renewable energies used, the less fossil fuels used to pollute the environment.(Qu, Yin, & Archer, 2009)

If fossil fuel plants must be used, there are still techniques that reduce their impact on the environment. The first technique for a power station is co-generation, which is the production of different types of energy from one process. This can be seen in a heat engine, such as a steam-turbine, which produces electricity as well as an excess of steam that can be used to heat a building or heat water for an industrial process. This makes the power station more efficient, but it does not cut back on the damage the gases it releases are doing to the environment. (Kanoglu & Dincer, 2009)

In the Kalundborg symbiosis, a flue gas desulpherization system is utilized to reduce the toxic gases being released from the power station. This flue gas desulpherization process filters out the sulfur dioxide (SO_2) that otherwise would be responsible for acid rain. This system is beneficial in two ways: first, it reduces the toxins released into the environment, and second, it generates opportunities for financial benefit. When it takes the SO_2 out of the air, it can then combine it with calcium carbonate ($CaCO_3$) to create gypsum. This by-product is then sold to a gypsum board manufacturer. This is also an example of the by-product synergy technique mentioned in the waste management section, because it takes waste from the energy process and converts it into a usable resource capable of being sold. Flue gas systems are not only used for power stations, but also waste-to-energy plants. There are other types of flue gas systems which remove different chemicals from the air, including other acidic gases, nitrogen oxides, and heavy metal residues. (Kalundborg Symbiosis, 2011; Ramboll, 2006)

Water Usage

Similar to energy use, water usage focuses on the minimization of resources, as well as the increase in efficiency. The subcategories of water usage are water treatment, water collection, and water efficiency. The treatment of polluted water is important for protecting the environment from damaging chemicals or sewage that may be produced. Water collection and water efficiency are important because they reduce the need for purchasing water. Water is an important resource that many countries take for granted. Approximately one billion people have no access to adequate drinking water and around five million children die every year due to water-borne diseases (Amano, 2011). It is because of this that the preservation and purification of water is important both for the environment and for society.

When looking at water treatment techniques, it was found that each of the six international SIPs used a wastewater treatment system. Wastewater treatment systems include lagoon based systems, land based systems, and mechanical systems. These systems work with varying effectiveness, so because of this, each of them has different effects environmentally, economically, and socially. Lagoon systems use biological or physical treatments to cleanse the water. Land treatment systems use soil and plants to cleanse the water. A mechanical system uses biological, chemical, and physical means to purify water of pathogens, harmful metals, nutrients, and toxic chemicals. Depending on the location of the industrial park, different treatment systems should be used. If the park is in a city, then the lagoon and land treatment systems will be hard to implement, leaving the mechanical system as the optimal choice. In the end it is up to the industrial park to decide which system is best for its wastewater treatment needs. (Muga & Mihelcic, 2007)

Another form of water treatment that is essential for SIPs is drinking water treatment. This is the purification of non-wastewater so that it becomes potable. There are five treatment methods outlined by the United States EPA: flocculation/sedimentation, filtration, ion exchange, absorption, and disinfection. Flocculation/sedimentation is the natural process of combining particles in the water so that they leave the water as sediment. Filtration is the mechanical process of using membranes to separate out particles from the water. These membranes have holes with diameters ranging from 0.01 to 0.1 μm that allow only the smallest of particles to pass

(Walsh & Gagnon, 2006). Ion exchange removes inorganic material from the water through the use of anions, positively charged ions, and cations, negatively charged ions, to attract and remove potentially harmful metals (Neumann & Fatula, 2009). The absorption process is the removal of organic particles from the water. Finally, the disinfection process, also referred to as chlorination, is the practice of sanitizing the water with different chlorine based chemicals. These methods are not used individually; a water treatment plant must employ multiple, if not all, of these processes to ensure safe, uncontaminated drinking water. (United States Environmental Protection Agency, 2004)

In addition to treating water, it is important for industrial parks in both wet and dry climates to attempt to collect water. Industrial parks can do this in two ways, either by collecting storm water or by collecting rainwater. Storm water is water from ponds, creeks or drains, while rainwater is water that runs off of roofs or comes straight from the clouds. There are two types of storage for storm water, on-line and off-line. On-line storage units are constructed on the creek or drain providing the water, while off-line storage units store water elsewhere. As far as rainwater is concerned, it is collected in storage tanks similar to storm water tanks. The water collected in both cases is generally not potable, so it must be treated first. If the water is not treated it can still serve many purposes in an industrial park. There are many industrial processes that require water for cooling or steam creation. Water collection is important because it lessens the need that industrial parks have to purchase water. The collection and storage of water can also be beneficial to companies in case of a drought where a lack of water could cause a stop in production. (Department of Environment and Conservation NSW, 2006)

The last subcategory of water usage is water efficiency. This can be accomplished through techniques such as water reuse and the use of low-flow appliances or systems. Water has different levels of sanitation, more than just drinkable and wastewater. It can be broken down into six different levels: ultra-pure water which is used in the manufacturing of semiconductor chips, de-ionized water which is used for biological or pharmaceutical production, drinking water, wash water which is used for maintenance tasks, irrigation water which is used for landscaping, and wastewater which should be treated. The idea of water reuse is much more effective when these levels of sanitation are considered. Depending on the processes the higher quality water types go through, there is a lot of room for water reuse in the park. For example, the water from the semiconductor manufacturing could be reused for maintenance tasks that need to be accomplished in the industrial park. This can help to significantly cut down on the amount of water the industrial park requires as well as how much water needs to be treated. (Lowe, 2001)

Another option for reducing the water necessary is to employ practices that use less water than normal. The use of low-flow appliances in the industrial park facilities can help to diminish the water usage. In addition, in certain areas of the industrial park, high water pressure may be provided where it is not needed. An industrial park can incorporate a pressure-reducing valve into the water supply lines that run to the area of the park that does not need high water pressure. Other solutions to avoid wasting water include constantly checking for leaks in pipes, as well as conducting water audits to find which parts of the industrial park are using the most water and where it can be reduced. The reduction of the amount of water used does not only benefit the industrial parks financially, but others who are also dependent on the, possibly limited, clean water supply. (Schultz Communications, 1999)

Materials

The materials section can be broken down into three categories: materials, storage, and transportation. The materials category pertains to the use of recycled, recyclable, and non-toxic materials. The storage subcategory illustrates the importance of proper hazardous waste storage and discusses the need to store any by-products produced. Lastly, transport handles the movement of materials both off-site and on-site between companies or organizations. These techniques are important because they can increase the efficiency of an industrial park through more effective storage and transportation systems. They also protect the environment through the use of green, recyclable materials.

There are many types of materials used in industrial parks such as basic office supplies, worker equipment, or vehicle maintenance equipment. Wherever an industrial park can purchase recycled equipment or equipment made from recycled material, it should. If they must buy new equipment, the industrial park should attempt to buy products made out of recyclable materials. Doing so can reduce the park’s effects on the environment and further sustainability.

The materials leftover from production processes are also important for industrial parks to consider. The proper storage of these materials is imperative, particularly any hazardous waste or materials. Without proper storage, hazardous materials can leak into the environment, potentially causing severe damage in the area. The proper storage of non-hazardous by-products is also important, but for economical reasons. The point of storage is to protect the by-product from the elements, which is done to preserve their quality so they can be reused. These techniques of proper storage not only protect the environment but also protect the companies involved from being fined or from losing potential sales of by-products because of inadequate storage.

The final section from the materials category is transportation of materials in and out of the park, and the transportation of materials in the park between companies. A high-efficiency method for transporting materials in and out of an industrial park is the use of a train, because it is able to move more materials than a truck, with lower emissions. As for the transport of materials between companies in the industrial park, the use of conveyor belts, pipes or other systems are good ways to increase efficiency while eliminating emissions from the transportation that would have been needed. (Lowe, 2001)

Infrastructure

The final category of techniques that was looked at is infrastructure. This involves the transportation of workers, the landscape surrounding the industrial park, and the management techniques used by park officials. The transportation of workers is important in reducing vehicular emissions that can be attributed to the industrial park. There are many solutions for this problem including providing public transportation such as buses or trains, installing bike racks, creating carpooling incentives, and creating on-site housing for workers. All these solutions would significantly reduce emissions due to commuting.

In addition to dealing with vehicular emissions, the infrastructure category also includes the environment surrounding the industrial park. The preservation of wildlife is important, as the removal of plants or animals can have a devastating impact on the environment. For example, if trees are removed to make room for buildings, then species, such as bats, living in those trees will move and subsequently the region will experience an increase in the mosquito population. This can cause health problems, due to the diseases that mosquitoes spread, in the industrial park. Affecting an ecosystem in any way can have an adverse affect, thus industrial parks should attempt to have as little an impact on the local ecosystem as possible.

Another technique that can be used to help the local environment is to setup a composting operation for any food by-products that may be produced from food production facilities on-site. The compost could then either be used on-site for landscaping needs or shipped to facilities that need it. This works similar to the by-product synergy technique discussed in the waste management section. This reuse of food by-products leads to less space taken up in landfills and also leads to healthier soil where the compost is used. This technique is a good example of a way to reduce waste while helping the local environment.

The last technique in the infrastructure category involves the management of the industrial park. When looking at the international SIPs, two main types of management techniques were employed to improve an industrial park's sustainability: environmental incentives (e.g., for carpooling), and recruiting companies that can improve the industrial park's by-product synergy. This means identifying new companies that can reuse by-products that are being disposed of when they could be salvaged. Both of these techniques do a lot to improve the industrial park's efficiency while also working to improve the park's environmental friendliness.

4.3: Comparative Analysis of Policies

In order to understand how Costa Rica's policies can be used to promote SIP development, we compared their policies to policies in countries with SIPs. This comparison provided us with a frame of reference to determine where Costa Rica's environmental policies have been successful and where improvements can be made to them. There were three Costa Rican policies that could be significant for SIP development. These policies are the Law for the Integrated Management of Waste (GIRS), the Regulation of the Rational Use of Energy (URE), and the Environmental Impact Assessment (EIA). We looked into what aspects of these policies were similar to international policies regulating the same topics and where differences existed. For this comparative analysis, we looked into policies in Brazil, China, Denmark, Japan, and the United States because they have similar industries.

Waste Management Policies

One important aspect of a SIP is waste management, because waste from an industrial park can have significant effects on the environment if it is not properly regulated. In order to identify the best methods for regulating waste, we compared Costa Rica's waste management regulations to the waste management laws in Brazil, China, Denmark, Japan, and the United States. The GIRS is Costa Rica's legislation overseeing the management of solid and hazardous waste, and it focuses on assigning responsibility for a product throughout its life-cycle, minimizing the environmental impacts of waste disposal, and educational programs for the public (Law for the Integrated Management of Wastes, Costa Rica Law No. 8839, 2010). To investigate the law further, we interviewed a government official who had worked closely with the development of this policy. From the interview, we identified one area the legislation could improve on was in its adaption of a solid waste management plan (Personal communication, Dec. 2, 2011). The legislation called for regulations and placed the Ministry of Health in charge of developing the details for those regulations on waste management, but a year later, those regulations are not yet created, which is delaying the potential improvements this legislation can bring (Personal communication, Dec. 2, 2011). However, according to our interview, one of the greatest areas of strength in the legislation is the extended responsibilities it puts on the generators of waste, such as individual companies (Personal communication, Dec. 2, 2011). For this reason, we focused our comparison specifically on the obligations of waste generators that are set forth in the legislation, since this directly impacts industrial parks.

From this comparison, we discerned two main findings on how the responsibility of waste management is approached. Two countries, China and the United States, place the responsibility on the government and municipalities (Law on Prevention of Environmental Pollution Caused by Solid Waste, China, 1995; Resource Conservation and Recovery Act, 1976). Alternatively, the other finding was that three countries, including Costa Rica, place the responsibility for minimizing environmental impacts of waste on the producers of waste. The policies most similar to Costa Rica's GIRS in this aspect were Brazil's National Policy on Solid Waste and Denmark's Consolidated Environmental Protection Act. Both of these policies included some form of extended responsibilities for the producers of waste, though neither policy included them to the extent that the GIRS does. Each of these laws does state that there is shared responsibility between the manufacturers, importers, distributors, and consumers for the life-cycle of a product, which minimizes the effects of the waste on the environment. There were, however, several important differences in these legislations on the extent of the responsibility on waste producers. In Brazil's National Policy on Solid Waste, the responsibility of the waste producer stops if there are sufficient provisions for the collection and disposal of the waste, whereas in the GIRS, it is always the producer's responsibility, regardless if a third party removes the waste (National Policy on Solid Waste, Brazil Law No. 12.305, 2010). In Denmark's legislation, there are no set guidelines that the waste producer's must follow, which differ from the eight specific guidelines outlined in the GIRS. Denmark's law states the producers are responsible, but does not explain to what extent (Consolidated Environmental Protection Act, Denmark Law No. 698, 1998).

According to this comparative analysis, the GIRS has more responsibilities on waste generators than most countries waste management policies. The newer policies, including the GIRS and Brazil's National Policy on Solid Waste, have included more extended producer responsibility when compared to the older policies from countries like the United States. This focus on not only managing waste, but also on who is accountable for the environmental effects from the waste, could be an important tool for promoting SIPs in Costa Rica. The main component for comparison from the GIRS and the policies from the other five countries are listed in Table 2, below.

Table 2: Comparison of Waste Management Policies

Country	Name of Policy	Year it Became Legislation	Key Component for Comparison Included in Law
Costa Rica	Law for the Integrated Management of Waste (GIRS)	2010	Yes
China	Law on Prevention of Environmental Pollution Caused by Solid Waste	1995 (amended 2004)	No
	*some other recycling provisions in Circular Economy Law (2008) and Cleaner Production Promotion Law to promote recycling (2002)		
Japan	Waste Management Law	1970 (amended in 2000)	No
	Basic Law for Establishing the Recycling-Based Society	2000	
Denmark	Law No. 698 Consolidated Environmental Protection Act	1998	Yes
United States	Resource Conservation and Recovery Act (and Solid Waste Disposal Act Amendments, Hazardous and Solid Waste Amendments, and Federal Facility Compliance Act)	1976 (amended in 1980, 1984, and 1992)	No
Brazil	National Policy on Solid Waste	2010	Yes

Rational Energy Use Policies

SIP development in Costa Rica will also require policies guiding sustainable energy use. In order to understand where Costa Rica's policy is in terms of promoting this aspect of SIPs, we compared their rational energy use legislation to similar legislation from other countries. The Regulation of the Rational Use of Energy (URE) is Costa Rica's guiding policy on energy use, and it develops one plan for Costa Rica to follow in regards to promoting and implementing programs on the rational use of energy, establishes the mechanisms to efficiently use energy, and to update existing mechanisms in order to protect the environment (Regulation of the Rational Use of Energy, Costa Rica, 1994).

In order to further understand the URE and what specifically to focus our comparative analysis on, we interviewed a government official who was knowledgeable on the policy. From the interview, we learned that the area of the policy that would have the greatest impact on SIPs is Chapter IX of the law (Personal communication, Dec. 7, 2011). Chapter IX includes a list of energy technologies that receive exemptions from consumption taxes when they are purchased and used (Appendix B) (Regulation of the Rational Use of Energy, Costa Rica Law No. 7447, 1994). Many of the technologies included in the incentives are also sustainability techniques that SIPs employ to limit their environmental impact, including photovoltaic cells and fluorescent light bulbs (Regulation of the Rational Use of Energy, Costa Rica Law No. 7447, 1994). Because of this, we chose to focus on the inclusion of incentives for the comparative analysis. Brazil's National Policy for the Conservation and Rational Use of Energy, China's Energy Conservation Law, and Japan's Act Concerning the Rational Use of Energy included repercussions for not utilizing efficient energy techniques, but did include incentives for using more efficient technologies does (National Policy for the Conservation and Rational Use of Energy, Brazil Law No. 10.295, 2001; Energy Conservation Law, China, 1997; Act Concerning the Rational Use of Energy, Japan Law No. 49, 1979). The policies promoted the development and implementation of the energy sources with the least environmental impact, but they did not include an explicit list of those technologies or reward those utilizing them, which the URE does (National Policy for the Conservation and Rational Use of Energy, Brazil Law No. 10.295, 2001; Energy Conservation Law, China, 1997; Act Concerning the Rational Use of Energy, Japan Law No. 49, 1979). However, half of the policies did include a list of incentives, including Costa Rica.

The United States, Denmark, and Costa Rica all reward implementing renewable energy sources through incentives in their legislation. Denmark's two legislations on energy use do make mentions of some energy incentives, though their list is not as complete as the one found in the URE. Their incentives include a settlement price for connecting renewable energy fuel sources to the grid and co-operatives for wind turbine ownership to promote public support. They do also have repercussions in place for not meeting efficient energy standards. (Consolidation of the Act on Electricity Supply, Denmark Law No. 286, 2005; Agreement of 21

February 2008, Denmark, 2008) In the United States Energy Independence and Security Act, there are also incentives, but unlike the URE, the US legislation rewards more than just choosing energy sources that are better for the environment. First, in the Energy Independence and Security Act, there are research grants available for research on alternative fuels for transportation and renewable energy (Energy Independence and Security Act, 2007). There are also incentives for producers and consumers of renewable fuel sources and recognition awards and tax incentives for high-performance green buildings and their related technology (Energy Independence and Security Act, 2007). The most significant difference between the URE and the Energy Independence and Security Act is that the specifics for the incentives are not as clear in the Energy Independence and Security Act as they are in the URE (Energy Independence and Security Act, 2007). The United States legislation does, however, include a variety of different incentives, beyond just the tax breaks found in the URE (Energy Independence and Security Act, 2007).

According to the comparative analysis, Costa Rica's includes specific incentives, which can be utilized to promote sustainable industrial park development. However, their legislation does not include incentives for doing more than just choosing the efficient technologies, like in the US policy. Including those in the policy could help to further motivate sustainable energy choices in industrial parks, and are an aspect policy may consider adding in the future. For further information, the policies for the five international countries can be found in Table 3, below.

Table 3: Comparison of Energy Use Policies

Country	Name of Policy	Year it Passed	Key Component for Comparison Included in Law
Costa Rica	Regulation for the Rational Use of Energy (URE)	1994	Yes
China	Energy Conservation Law	1997	No
Japan	Act Concerning the Rational Use of Energy	1979 (most recent amendment in 2005)	No
Denmark	Agreement of 21 February 2008	2008	Yes, but not as complete as the URE
	Law No. 286 Consolidation of the Act on Electricity Supply	2005	
United States	Energy Independence and Security Act	2007	Yes, and beyond what is outlined in the URE
Brazil	National Policy for Conservation and Rational Use of Energy	2001	No

Environmental Impact Assessment

The last policies that we compared in the comparative analysis were policies regulating environmental impact assessments. An environmental impact assessment is used to measure the environmental consequences a new development or project will have on an area. Costa Rica's system for assessing environmental impact is explained in the Organic Law of the Environment and expanded upon in the Biodiversity Law. Generally, policies on environmental impact attempt enable future growth and development without negatively impacting the environment (Organic Law of the Environment, Costa Rica Law No. 7554, 1995; Biodiversity Law, Costa Rica Law No. 7788, 1998). The process of filing an environmental impact assessment differs in all of the countries, as does who is in charge of overseeing the process. In order to gather more information on the process in Costa Rica, we interviewed a government official who was familiar with the assessments. From the interview, we learned that while most new development in Costa Rica requires an environmental impact assessment to be completed, there are concerns that the office that processes the assessments is not strict enough in regards to minimizing environmental impacts (Personal communication, Dec. 7, 2011). Through the interview, we also clarified that in Costa Rica, new industrial parks or SIPs need to follow the procedure of submitting an assessment, because the legislation was not clear about this (Personal communication, Dec. 7, 2011). For the comparative analysis, we decided to focus on whether the policy requires industrial developers to submit an assessment, because this aspect of the policy could directly impact SIP development in the countries. Of the six countries, the only two that do not require an environmental impact assessment be processed before a new industrial park may be built are the United States and Denmark (National Environmental Policy Act, 1969; Danish Ministry of the Environment, 2007).

The remaining four countries, including Costa Rica, do require an environmental impact assessment for projects developing industrial parks. China, Japan, and Brazil directly mention industrial parks or industrial development as projects that require environmental impact assessments in their legislation (Environmental Impact Assessment Law, China, 1994; Environmental Impact Assessment Law, Japan Law No. 81, 1997; Executive Order No. 1, Brazil, 1986). While our interview specified that Costa Rica does require an environmental impact assessment for projects concerning industrial parks, the actual legislation does not make that clear. Therefore, Costa Rica should consider looking to the policies in China, Japan, and Brazil for improvements to make this section of the legislation clearer (Organic Law of the Environment, Costa Rica Law No. 7554, 1995).

According to the comparison, Costa Rica could improve their assessments by becoming more specific about the types of projects that require an assessment, like the other five countries are. Though the United States and Denmark do not require assessments for parks, they did include in their policy a better description of what work does (National Environmental Policy Act, 1969; Danish Ministry of the Environment, 2007). The vagueness of the Costa Rican policy could negatively impact using these assessments for promoting SIPs, because it leaves what projects need one unclear. A table of our comparative analysis findings, including the laws establishing environmental impact assessments in the five other countries can be found in Table 4, below.

Table 4: Comparison of Environmental Impact Assessment Policies

Country	Name of Policy	Year it Passed	Key Component of Comparison Included in the Legislation
Costa Rica	Law No. 7554 Organic Law of the Environment, and expanded with Law No. 7788 Biodiversity Law	1995, expansion in 1998	Yes and No. The law does oversee industrial park projects, but it is not directly stated in the text of the legislation
China	Environmental Impact Assessment Law	1994	Yes
Japan	Environmental Impact Assessment Law	1997	Yes
Denmark	Planning Act with EIA amendment, Statutory Order No. 466	1992, amendment 1999	No
United States	National Environmental Policy Act	1969	No
Brazil	Executive Order No. 1 (Jan. 23, 1986)	1986	Yes

Comparative Analysis Conclusions

These similarities and differences in environmental legislation highlight important points in Costa Rica's legislation that have the potential to affect SIP development in the future. By highlighting these key concepts in Costa Rica's legislation, promoters of SIP development in Costa Rica can understand how to utilize the existing policies to encourage SIPs and where to lobby for future improvements. Our findings from the comparative analysis are summarized in Table 5.

Table 5: Comparative Analysis of Policies

Policy	Key Factor for Comparison	Countries that Include Key Factor
Waste Management	Responsibility of waste producer's over the environmental impacts of their waste	Brazil, Costa Rica, Denmark
Energy Use	Incentives to encourage renewable energy technologies	Costa Rica, Denmark, United States
Environmental Impact Assessment	Whether industrial parks require an assessment be filed before development	Brazil, China, Costa Rica, Japan

Potential for SIPs in Costa Rica

We completed site assessments to determine what techniques the industrial parks in Costa Rica are already implementing with respect to sustainability. We used three tools during our site assessments: the database of industrial parks was used to identify which parks to investigate, the sustainability checklist was used to gauge what exactly each company was doing to be sustainable, and the survey was used to gauge the willingness of parks in Costa Rica to implement sustainable techniques. The following information is the results of all three of these assessment tools.

Database of Industrial Parks

The database of Costa Rican industrial parks supplied us with the contact information and main industries in each of the eleven industrial parks in Costa Rica, which can be seen in Appendix C. In addition, the database provides the locations of each of the industrial parks, as well as how many companies are operating in each park. These parks are comprised of 182 companies in the industries of electronics manufacturing, biopharmaceuticals, communications, equipment manufacturing, and apparel. In the future, CICR can use this database to locate industrial parks that may have the potential to become sustainable. They will also need to maintain and update the list as more parks develop, potentially on an annual basis. CICR will then be able to apply the tools of assessment we created to assess whether or not the parks will be capable of converting to sustainability.

Checklist Results

Applying the checklist (See Appendix D) to an industrial park provided a wealth of information about what techniques the park was using. For our site visit, we were able to visit a company within an industrial park and apply our checklist. For waste management, there is utilization of by-product synergy, but most recycling is still done off-site by the local municipality if it is not dumped into landfills. Proper energy usage is in progress and there is electricity generated from hydropower that comes from the main grid. Efficient energy usage is another aspect that is being addressed through the use of efficient lighting and renewable energy credits. With respect to water usage, there are waste water treatment plants, and there is collection of rainwater but nothing else. There is also consideration of where the materials are coming from, as there was pride that the materials were recycled, recyclable and come from environmentally-friendly companies. Figure 2 shows some cardboard used at the company that was being recycled and re-used. Another example of being environmentally friendly is that the wood used in the production comes from a company that plants five trees for every one they cut down.

Figure 2: Recyclable Cardboard

The transportation of materials involved storing materials in shipping containers and then moving them by truck to the ports. There were no other types of transportation used in the industrial park besides the trucks. Figure 3 depicts the typical storage trailer, which is then attached to a truck and brought elsewhere. Transportation for workers to the park involved the effective use of busses that picked up and dropped off in the towns that surround the park. There were also bike racks at the park, further improving the transportation system at the park.

Figure 3: Storage and Transportation

This amount of techniques marked on the checklist provides evidence that companies within the Costa Rican industrial parks are thinking about their sustainability. Use of by-product synergy, renewable energies and recyclable materials are very important for SIPs, and are already being utilized in some companies and parks. Other smaller techniques such as the use of efficient lighting and collecting rainwater also show that the parks are looking for all possible ways to save money and reduce pollution. From this information, we can see that industrial parks are nearing a sustainable mindset; they just need the right encouragement to make the full transition to sustainability.

Survey Results

The survey was administered over the phone to industrial parks. It contained seven sections: waste management, energy usage, water usage, infrastructure, materials, policy, and the park's interest in becoming sustainable. The sections that the parks were most proficient in were waste management, energy usage and materials. The parks utilize waste management techniques such as recycling and by-product exchange. The energy usage techniques employed are efficient lighting and sensors to adjust the lighting, off-site renewable energy sources, and passive heating and cooling. The materials used during construction were recyclable and local, and some of the buildings were retrofitted with recyclable and non-toxic production materials. While these areas showed an attitude that is friendly to sustainability, there were still key techniques that were not being employed.

The areas that needed improvement were water usage and infrastructure. There are water treatment plants, but no wastewater treatment plants in the parks. Some of the parks collect groundwater, but not rain water, and the water is not cascaded or re-used. They also do not promote the use of low-flow appliances over high-flow appliances. There are bus routes directly to the parks and bike racks on the premises. The parks do not have any composting systems in place. The management of the parks has not created environmental incentives for companies in the industrial park. All this information shows that the industrial park has given thought to certain areas of sustainability, but still needs to focus on other areas.

There were no plans for the installation of waste-to-energy plants or wastewater treatment plants and no plans to recruit a good mix of companies to promote by-product synergy. However, the industrial parks were still willing to invest in their own sustainability if presented with all of the necessary information. The survey shows that that there are select efforts for implementing sustainable techniques, but the motivation to become fully sustainable is not present. There is currently not enough knowledge on the requirements of being a SIP, but there is still potential for progress if the industrial parks are educated properly.

Chapter 5: Discussion

Our project aimed to identify SIP examples and regulations for Costa Rica, and to set the foundation for future projects in developing SIPs in the country. We created a database of Costa Rica's current industrial parks, from which future SIP projects can be chosen. This database was presented to CICR to keep for their records. We chose six international examples of SIPs based on the types of industries in the parks and recommendations from a SIP development professional. From those six parks, we learned sustainability guidelines and techniques that can be applied to future Costa Rican industrial parks to make them sustainable. We took those sustainability techniques and developed a sustainability checklist with them, in order to gauge what an industrial park needs to have to be sustainable. We also compared three Costa Rican environmental regulations to similar policies in other countries that have SIPs, in order to identify strengths and weaknesses within those policies in regulating SIP development. Finally, we looked at how feasible future SIP creation is in Costa Rica through site assessments using the sustainability checklist and surveys. These tools enabled us to locate international models of successful parks that Costa Rican industry can use as a guide for their development as well as understand how Costa Rica's policies can be used to promote SIPs. However, we also ascertained from our surveys that while some companies and parks have begun to apply some sustainability techniques, many current industrial parks are worried about the cost and effort necessary for becoming sustainable. From here, the country's next challenge in developing SIPs will be convincing companies and industrial parks that SIPs can be beneficial for them and are an achievable and affordable goal.

5.1: Achieving sustainability in industrial parks

For an industrial park to become sustainable, there are certain processes that must take place. Each of the working international SIPs followed a path to their success that Costa Rica could mimic in the future. The development and techniques in these international SIP examples exemplify important lessons in SIP development. The five main lessons Costa Rica should take from the international SIPS are:

1) Only make the environmental improvements that are economically sensible.
2) Regulate all environmental policies to ensure all organizations are in compliance.
3) Attract low-emission industries to avoid high industrial pollution.

4) Retrofitting old buildings is less costly and better for the environment.
5) Ensure constant support from organizations during developing process.

When creating SIPs in Costa Rica, there are certain techniques that other SIPs are already employing that will be applicable. It is, however, important to note that even the most successful SIPs do not implement every technique on the checklist. Sustainability is a balance between what is the best environmentally, economically, and socially, and factors from those three categories may affect what techniques should be considered for each park. Some techniques on the checklist are only necessary in some parks, but not all. For example, the checklist checks for a hazardous waste treatment plant in a park. However, if the park is not creating any hazardous waste, then it would not be necessary for this waste treatment solution to be implemented, and the park should not include one. For this reason, the checklist is designed to be administered at industrial parks with our survey for industrial park managers, so that specific information can be collected on the park and recommendations for sustainability can be tailored to the needs of the park. Not all techniques are necessary at every park, but parks are recommended to employ any of the techniques that are applicable to their park and could improve its sustainability.

5.2: Significance of Environmental Policies for SIP Development

We also analyzed the ability of Costa Rica's environmental policies to regulate SIP development. We were able to compare the waste management, rational energy use, and environmental impact assessment legislation in place in Costa Rica to similar pieces of legislation in six other countries. This comparative analysis let us identify significant similarities and differences between those policies and how that affects future SIP development in the country.

Overall, Costa Rica's work to protect the environment becomes more apparent when legislation from the country is compared against other legislation in different countries. Countries with laws from the past twenty years, like Costa Rica, were more likely to include more regulations to promote protecting the environment. Those policies will help to promote SIP development because they are both regulating successful industrial practices and also requiring the environment to be considered during those industrial practices. Costa Rica's waste management, energy use, and environmental impact assessments included the key concept for promoting SIP development that we based our comparison off of each time. The comparison also identified several other policy strategies that Costa Rica could consider adding in the future to further use their environmental policies to promote SIPs. By understanding what regulations Costa Rica has now and knowing where it can improve in the future, SIP development can be promoted through policy. Once organizations like CICR have the techniques and the policies to support the development, it will be up to the industrial parks and companies in Costa Rica to work for further development for SIPs in Costa Rica to be a reality.

5.3: Potential in Costa Rica for SIP development

Once the tools for creating a successful SIP in Costa Rica were identified, the next step was to determine how interested current industrial parks are in becoming SIPs and how feasible the change to sustainability would be for Costa Rica's industrial parks. To discern these results, we conducted surveys of companies and officials in the industrial parks. While administering the surveys, we noticed that park officials had questions on some of the techniques we asked about, because they were unfamiliar with them, and that many parks are already implementing multiple techniques that are sustainable, but do not realize the benefits from them. Also, we often noticed that parks are only implement techniques in order to meet international standards and government regulations, but do not extend beyond what is asked of them in the legislation. All of these observations support the need for an example SIP these parks could look to in Costa Rica. Parks do not know about all of the potential techniques and benefits of being sustainable, because there are no examples nearby to learn from in Costa Rica. Educating these parks on the different sustainability techniques and showing them an example with these techniques in action could help encourage parks to consider making sustainable changes in the future. Also, many industrial parks are worried about the cost of utilizing these sustainability techniques. The parks are a business, and future SIP development in Costa Rica will have to find a way to market SIPs as both beneficial for the environment and for business.

5.4: Recommendations and Future Research

Our work in Costa Rica has set the basis for further work in the development of SIPs. From our work, future research could focus on expanding the sustainability checklist, further application of the survey at other industrial parks, and work addressing the social implications of SIP development. The sustainability checklist has the potential to be a significant resource for Costa Rica's SIP development, as a source that industrial park officials and new park developers could refer to for measuring their current sustainability or when considering methods for improving the sustainability of their production. A future project could develop a weighting system for the checklist that measures how important each technique on the checklist is in terms of sustainability. Also, the scope of our project did not include social aspects to SIP development, including why parks may be apprehensive of future SIP development. Beyond changing the technologies used by industrial parks, SIP development will also affect the workers and the community around new parks, which future research should address.

Our work has also created the opportunity for future projects on SIP development in Costa Rica. One such project could focus on creating one sustainable industrial park to create an example in the country for others to follow. The TEDA is an example of this in China; once there was a SIP to model and compete with industrial parks were more willing to employ sustainability techniques. By focusing on one industrial park, it would also be easier to implement multiple small techniques, creating change in the sustainability of the industrial park faster (Tianjin Economic-Technological Development Area, 2011).

As a recommendation, future projects and research needs to be better documented. Presently, the progress that some parks have made towards sustainability cannot be known without going to the park itself or interviewing someone who was part of the change. This makes it hard for new projects to pick up where old ones might have left off, or even to design new projects on industrial parks in Costa Rica. Company transparency would be helpful in the sense that any interesting use of a technique can be seen and known. There is no progress if it is not visible, therefore every project should be attempting to make their progress known.

Conclusion

The purpose of our project was to provide CICR with the tools to accomplish their goal of developing SIPs in Costa Rica. For our project, we conducted research and studies to meet the objectives of CICR and to help further SIP development to the best of our ability. We focused on answering three main questions through our work:

1) How can an industrial park achieve sustainability?

2) How do the environmental policies in other countries compare to Costa Rica's environmental policies?

3) What is the potential in Costa Rica for SIP development?

Through answering these questions, we were able to meet the objectives set by CICR and provide them with resources that can be used in future SIP development. By answering these research questions, we were able to create tools for CICR to utilize in future work with industrial parks. The database we created and the comparative analysis of environmental policies we conducted can help CICR know where to focus to make improvements in the promotion of SIP development. The sustainability checklist and the surveys can be taken directly to industrial parks to show them what can be done in order to be more sustainable. This research and analysis is a proposal for CICR on how to make industrial parks in Costa Rica more sustainable, and can be used to teach industrial parks currently about SIPs and sustainable production methods. Through modeling environmental techniques and educating industries, SIP development has a great potential in Costa Rica.

Works Cited

Act Concerning the Rational Use of Energy, Japan Law No. 49. (1979). Retrieved from http://www.eccj.or.jp/law/revised/10aug2005.pdf

Agreement of 21 February 2008, Denmark. (2008). Retrieved from http://www.ens.dk/en-US/policy/danish-climate-and-energy-policy/Documents/Energy%20Policy%20Agreement%2021%20Feb%2008_final.pdf

Amano, Y. (2011 16-September). *Why Water Matters*. Retrieved 2011 22-November from International Atomic Energy Agency: http://www.iaea.org/newscenter/news/2011/whywatermatters.html

Araya, A., Ballestero, J., & Marín, J. (2009). *Inventario Nacional de Gases Con Efecto Invernadero y Absorcion de Carbono en Costa Rica.* San José.

Balcomb, J. D. (1984). Passive Solar Research and Practive. *Energy and Buildings* , 281-295.

Biodiversity Law, Costa Rica Law No. 7788. (1998). Retrieved from http://eelink.net/~asilwildlife/costa.pdf

Central Intelligence Agency. (2011, November 15). *The World Factbook.* Retrieved October 2, 2011, from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/cs.html

Consolidated Environmental Protection Act, Denmark Law No. 698. (1998). Retrieved from http://www.elretur.dk/gfx/eng_danish%20environmental%20protection%20act.pdf

Consolidation of the Act on Electricity Supply, Denmark Law No. 286. (2005). Retrieved from http://soeg.ekn.dk/Afgorelser/GB_Lovbekg_286_2005%20elforsyning_ar001003.pdf

Cordero, J., & Paus, E. (2008, April). Foreign Investment and Economic Development in Costa Rica: The Unrealized Potential.

Danish Ministry of the Environment. (2007). *Spatial Planning in Denmark.* Retrieved December 2011, from http://www.ouka.fi/tekninen/innourba/publications/Spatial%20planning%20in%20Denmark.pdf

Department of Environment and Conservation NSW. (2006). *Managing Urban Stormwater: Harvesting and Reuse.* Sydney: Department of Environment and Conservation NSW.

Energy Conservation Law, China. (1997). Retrieved from http://www.unescap.org/esd/publications/energy/compend/ceccpart4chapter4.htm

Energy Independence and Security Act, Pub. L. 110–140, 2 U.S.C. §2162 et seq. (http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf 2007).

Environmental Impact Assessment Law, China. (1994). Retrieved from http://www.chinaenvironmentallaw.com/wp-content/uploads/2008/03/environmental-impact-assessment-law.doc

Environmental Impact Assessment Law, Japan Law No. 81. (1997). Retrieved from http://www.env.go.jp/en/laws/policy/assess/index.html

EPA Green Power Partnership. (2008). *Renewable Energy Certificates.* Washington D.C.: U.S. Environmental Protection Agency.

Executive Order No. 1, Brazil. (1986, January 23). Retrieved from faolex.fao.org/docs/texts/18085ENG.doc

Francis, C., & Erkman, S. (2001). *Environmental Management of Industrial Estates.* Retrieved September 2011, from United Nations Environmental Programme: http://www.unep.fr/shared/publications/pdf/3035-EnvironManagIndusEstates.pdf

Government of Gujarat. (2011). *Industrial Parks*. Retrieved 2011 28-November from Gujarat State Portal: http://www.gujaratindia.com/business/indus-parks.htm

Instituto Metrológico Nacional; Ministerio del Ambiente, Energia y Telecomunicaciones. (2009). *Segunda Communicación Nacional a la Convención de las Naciones Unidas sobre Cambio Climático.* San José.

International Chamber of Commerce. (1997, April 2). *ICC Commitment to Sustainable Development*. Retrieved September 22, 2011, from International Chamber of Commerce Web site: http://www.iccwbo.org/id376/index.html

Kalundborg Symbiosis. (2011, November 17). *A circular ecosystem of economy*. Retrieved November 17, 2011, from Kalundborg Symbiosis: http://www.symbiosis.dk/en/system

Kanoglu, M., & Dincer, I. (2009). Performance assessment of cogeneration plants. *Energy Conversion and Management* , 76.

Law for the Integrated Management of Wastes, Costa Rica Law No. 8839. (2010). Retrieved from http://www.cicr.com/docs/documentos/ley8839.pdf

Law on Prevention of Environmental Pollution Caused by Solid Waste, China. (1995). Retrieved from http://faolex.fao.org/docs/pdf/chn52657E.pdf

Lehtoranta, S., Nissinen, A., Mattila, T., & Melanen, M. (2011). Industrial Symbiosis and the Policy Instruments of Sustainable Consumption and Production. *Journal of Cleaner Production* , 1866.

Lowe, E. (2001). *Eco-Industrial Park Handbook for Asian Developing Countries.* Oakland: Indigo Development.

Muga, H. E., & Mihelcic, J. R. (2007). Sustainability of wastewater treatment technologies. *Journal of Environmental Management* , 438.

National Environmental Policy Act, Pub. L. 91-190, 42 U.S.C §4332 et seq. (http://ceq.hss.doe.gov/nepa/regs/nepa/nepaeqia.htm 1969).

National Policy for the Conservation and Rational Use of Energy, Brazil Law No. 10.295. (2001). Retrieved from http://www.inmetro.gov.br/qualidade/pdf/lei10295.pdf

National Policy on Solid Waste, Brazil Law No. 12.305. (2010). Retrieved from http://faolex.fao.org/cgi-bin/faolex.exe?database=faolex&search_type=query&table=result&query=ID:LEX-FAOC097590&format_name=ERALL&lang=eng

Neumann, S., & Fatula, P. (2009 28-July). *Principles of Ion Exchange in Wastewater Treatment.* Retrieved 2011 1-December from Lanxess Energizing Chemistry: http://www.ionexchange.com/imperia/md/content/ion/presseschau/090316_asian_water_principles_of_ion_exchange_neumann_03_09_.pdf

Organic Law of the Environment, Costa Rica Law No. 7554. (1995). Retrieved from http://www.glin.gov/view.action?glinID=143091

Qu, M., Yin, H., & Archer, D. H. (2009). A solar thermal cooling and heating system for a building: Experimental and model based performance analysis and design. *Solar Energy* , 166-182.

Ramboll. (2006). *Waste-to-Energy in Denmark.* Copenhagen: Reno Sam.

Regulation of the Rational Use of Energy, Costa Rica Law No. 7447. (1994). Retrieved from http://repository.unm.edu/bitstream/handle/1928/12744/L-7447.pdf?sequence=1

Resource Conservation and Recovery Act, Pub. L. 94-580, 42 U.S.C. §6901 et seq. (http://epw.senate.gov/rcra.pdf 1976).

Schultz Communications. (1999). *A Water Conservation Guide for Commercial, Institutional, and Industrial Users.* Albuquerque: New Mexico Office of the State Engineer.

Shaanxi Foreign Affairs Office. (2008 13-December). *Xi'an High-tech Industries Development Zone*. Retrieved 2011 1-December from Shaanxi Foreign Affairs Office: http://www.sxfao.gov.cn/wsbe/econtent.jsp?urltype=news.NewsContentUrl&wbnewsid=89323&wbtreeid=50

Shi, H., Chertow, M., & Song, Y. (2010). Developing country experience with eco-industrial parks: a case study. *Journal of Cleaner Production* .

Tianjin Economic-Technological Development Area. (2011, September 16). *Employment*. Retrieved November 28, 2011, from Tianjin Economic-Technological Development Area: http://en.investteda.org/doingbusiness/employment/humanresource/default.htm

U.S. Department of Energy. (2011, May 11). *Energy Basics*. Retrieved November 21, 2011, from Energy Efficiency and Renewable Energy: http://www.eere.energy.gov/basics/buildings/lighting.html

United States Environmental Protection Agency. (2004 14-December). *Drinking Water Treatment.* Retrieved 2011 1-December from EPA: http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf

United States Environmental Protection Agency. (2011 26-July). *Wastes - Hazardous Waste - Waste Types*. Retrieved 2011 21-November from EPA: http://www.epa.gov/osw/hazard/wastetypes/index.htm

Veiga, L., & Magrini, A. (2009). Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development. *Journal of Cleaner Production* .

Walsh, M., & Gagnon, G. (2006). *Evaluating Membrane Processes for Drinking Water Treatment Design.* Halifax: Association of Environmental Engineering & Science Professors Foundation.

Zhong, P., Xia, W., & Xu, B. (2010). *Study on energy efficiency model in Xi'an High-tech eco-industrial park.* Xi'an: the Humanities and Social Science Foundation of Ministry of Education of China.

Appendix A: In-Depth Description of Example SIPs

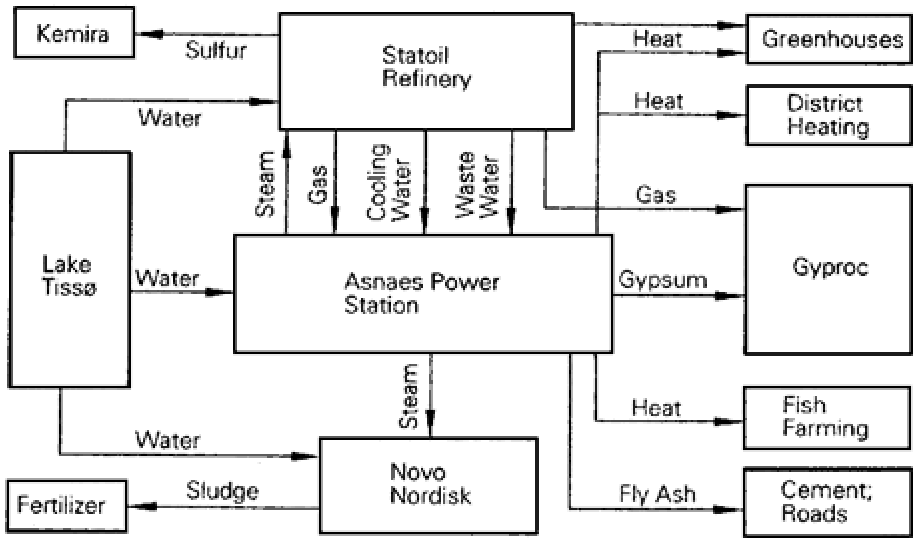
This section goes into detail on the example SIPs in Japan, China, USA, Brazil, and Denmark both on what techniques they use, but also how they developed, the importance of the SIP and even the attitude for development. Japan's Fujisawa Eco-Industrial Park and Brazil's Santa Cruz Industrial Park are both relatively new projects compared to Denmark's Kalundborg Symbiosis and the USA's Devens Eco-Industrial Park.

Kalundborg

As we examined industrial parks around the world we found the Kalundborg Symbiosis. This is the first successfully operating industrial symbiosis facility. The Kalundborg Symbiosis is located in Kalundborg, Denmark, a city that is benefitting from the symbiosis as well. The process of developing this facility was a mere sequence of agreements between businesses and had no formal planning or intention to become an "industrial symbiosis", as this term was not used until 28 years after the first collaboration. The first company to participate in the symbiosis was Statoil, a refinery, in 1961. In 1972 the symbiosis began to grow when the gypsum production company, Gyproc made an agreement with Statoil to use the gas they produced for their own processes. As more companies found they were able to participate in the exchange of by-products the symbiosis grew until in 1989 it was named an industrial symbiosis. (Kalundborg Symbiosis, 2011)

The symbiosis has nine public and private businesses from the pharmaceutical field to the building materials and very large energy production plants as well as a waste management plant. The collaboration is mainly just worked out between companies without any kind of organization through a third party. There is not an individual manager that is in charge of the whole symbiosis. There is a collective board that manages issues that concern the collective. It is not the traditional idea of an industrial park, but it fits the definition we have been working with that there is more than one company present and they are producing and emitting waste that can be used for other processes. There have not been any specific programs developed through this operation because of the absence of an overarching management. The companies involved in the symbiosis need to have a reusable waste that can be used in another application. Figure one shows the path of resources through the many companies involved in the symbiosis. (Kalundborg Symbiosis, 2011)

Figure 4: Kalundborg By-Product Synergy Network



The main techniques in use at in this operation are by-product exchange and cogeneration. There is a pipeline running from a lake near the city to the plant and many of the businesses use the water that flows through this pipeline. The by-products of each production plant are directly transported to another production plant that uses it for whatever processes it can. This can be done by pipeline or even by truck for greater distances.

Devens

One of the most successful examples of installing an eco-industrial park is at the former Fort Devens, an old military base that was no longer in use. The location became useful for businesses to operate out of. In 1994 the Devens reuse plan was created and the military base closed in 1996. Actions were taken by the local community and companies to retrofit the facility to be a useable eco-industrial park in order to help replace the 7,000 jobs lost upon the closing of the base. The town was very involved in the development of this park, which is one of the reasons it was, and has stayed so successful. The relationship between the community and the park is a very close one as the park provides jobs and services to many of the community members. (PWRPT)

Unlike the Kalundborg symbiosis, the plan to make Devens sustainable was very thorough and highly collaborated. The companies operating out of the facility had the devens sustainability indicators applied to them as part of the process of becoming sustainable. The sustainability indicators were one of the two main programs that came out of the development of this facility. The indicators were a way for the community to keep checks and balances on the operation of the park. The three main factors for success of the park were issues concerning the environment, economical issues, and societal issues. The indicators were in place to make sure that the needs of each of these categories were being satisfactorily met. (IQP) The other program that was developed at the Devens eco-industrial park was the Ecostar program. This program is a program centered on economy, ecology, and community. This has very similar goals to those of the sustainability indicators. The Ecostar program is in place for companies to strive to join it. The program sets criteria that needs to be met and the companies that want to be a part of the program have to meet a certain number of these standards. This is a method that allows companies to have the privilege of being a part of a program that has an attractive quality to consumers while keeping them aware of upholding certain environmental standards. Many of the criteria require the companies to use sustainable techniques.

The most successful techniques that are used at Devens eco-industrial park are using green energy sources and monitoring and limiting the output of pollutants during production. There is also effective use of by-product synergy in the park and with the community. Because of the strong relationship between the park and the community there are components of the techniques that involve the community as well. Devens is constantly being reexamined in order to make it as successful as it can be. The future goals of the programs in place are to increase the environmental, economical and societal benefits from the Devens eco-industrial park.

Fujisawa

The industrial park in Fujisawa, Japan was created by EBARA Corporation to address the growing need to move away from end of the pipe technology. The project was supported by the EBARA and a local university with interest in zero-emissions technology. The main idea was to transform the current manufacturing plant owned by EBARA and the area around it to an industrial park and a sustainable living area, where workers would live to easily commute to work. The sustainable community would include homes for workers and each of these homes would be built on the same principle of zero emissions that the rest of the park was founded on, Figure 5 is concept art of the final design, and each house is outfitted with solar panels for energy. This was the vision for the project, going beyond a SIP but to a sustainable community to nullify transportation needs and the emissions that come with those.

Figure 5: Sustainable living in Fujisawa

The progress of the park is unknown, as in 2000 it suffered a setback because of spill that hurt its reputation, and thus the involved entities needed to focus more on managing the crisis and recommended to push the completion date of the park back from 2010. At that point, there had already been significant progress, with multiple technologies put in place, such as a fluidized-bed gasification system, which converts multiple types of waste to usable outputs of chemicals such as ammonia, methane and hydrogen. The rest of the technologies planned could reduce energy consumption by up to 40%, with cuts in carbon emissions and water consumption of 30%. Other important techniques that the park planned to implement, with progress unknown due to their setback, are listed below in Table 6. This park's importance is their focus on technology to amplify their minimization of emissions.

Table 6: Important Technologies Planned at Fujisawa

1.	A fluidized-bed gasification combustion and ash-melting system converts industrial and municipal waste, agricultural waste, sewage, and plastic into commercially viable outputs of ammonia, methane and hydrogen from combustion gases. The combustion provides heat for power generation.
2.	A flue gas treatment system treats the gases to remove nitrogen and sulfur oxides, that are then used as agricultural fertilizers.
3.	Solar photovoltaic cell systems and wind turbine generators are used on rooftops for electric power generation and heating water.

4. Solids are removed from waste water and sent through the sludge treatment process, while the remaining gray water is used to flush toilets and water lawns, gardens, and landscaping. Sludge is treated for composting to be used for agriculture.

5. A sewage water heat exchange pump utilizes the storage capability of sewage water for cooling and heating purposes.

6. A new fuel cell technology converts methane or hydrogen gas generated by the waste gasification and combustion system into electric power through chemical reactions.

7. A direct water supply system consists of a series of rooftop water catchments and storage basins to reduce energy costs associated with pumping of groundwater sources. Water will be stored in the public natural areas.

8. Houses will be designed with high efficiency, insulated building materials, and a vacuum sewage system will be installed for housing units to reduce water consumption.

Besides the impressive technological array of techniques for the development of its sustainability, other aspects are not clear. Since the entire park is owned by EBARA, the by-product exchanges that may occur within facilities are unknown. There is no advertisement of an outstanding management program that may include management of by-product synergy between companies, or management of shared resources such as a waste management plant. Therefore, this park's importance lies only with the technology it is attempting to implement, and the sustainable lifestyle it is attempting to create. (Lowe, 2001)

Tianjin Economic Development Area

The Tianjin Economic-Technological Development Area (TEDA) is one of two example SIPs with a long developing period. The motivation for creating TEDA was simply to boost the economic performance of the area; sustainability was not a factor in creating it. In fact, there was no environmental concern for 4 years after creation. That motivation for an increased economic performance is shown in the amount of foreign investment; TEDA was ranked as the most attractive area for foreign investment. All of this foreign investment led TEDA to a very diverse industry, with similarities to the Costa Rican industry, two of its biggest industries being electronics and biotechnology/pharmaceuticals. As an outcome of its diversity in industries, this park serves as a great example for industrial symbiosis within companies. However, because of the scale of the park, there are significant lessons to be learned from TEDA.

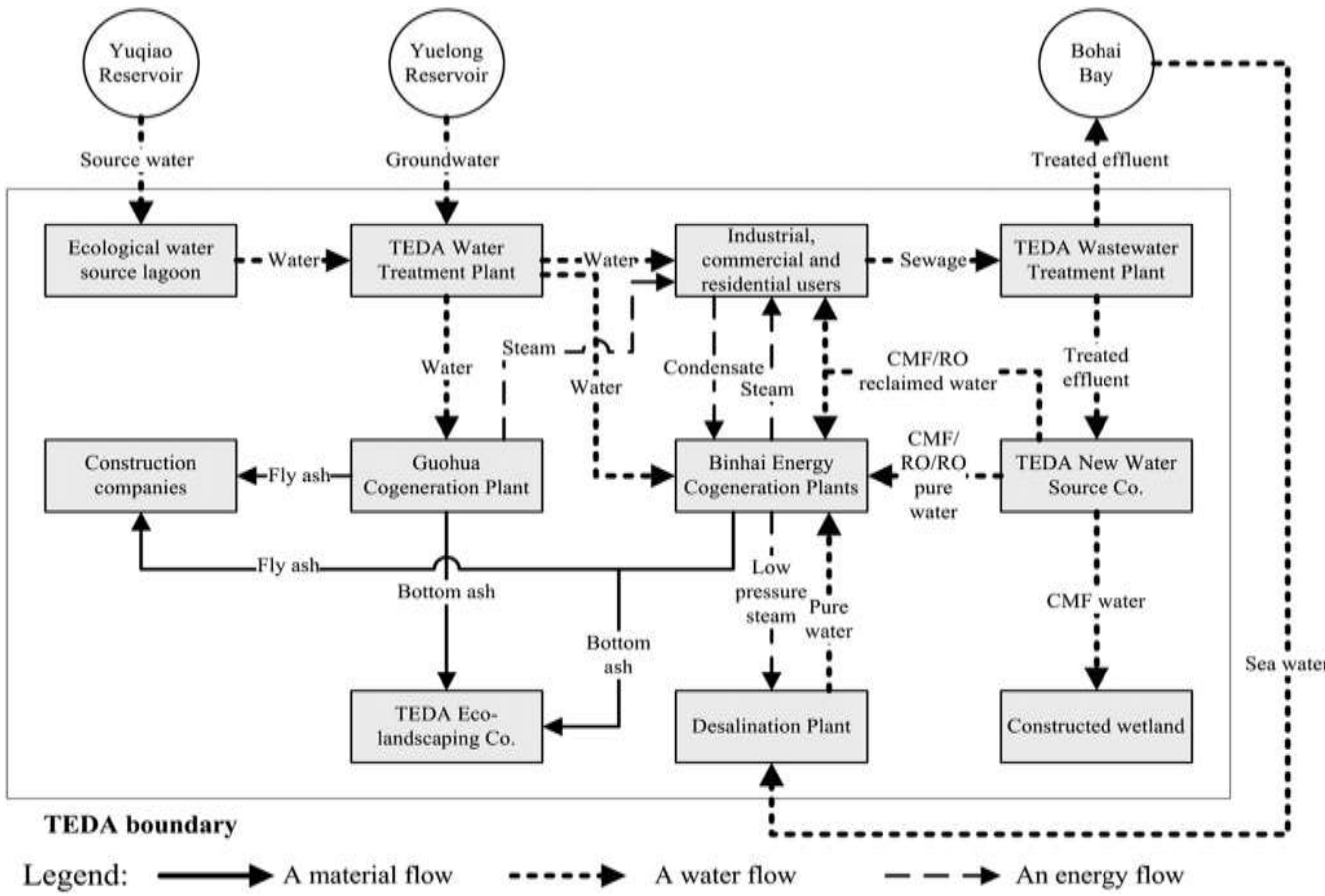
TEDA was started in 1984, and while some activity for the environment was made in the years from 1984-2000, it was not until 2001 that TEDA made becoming a SIP a main goal.

Before this period, a co-generation plant and a waste water treatment plant were built because it was simply the cultural norm in China to share resources such as these. This difference in culture and government structure might be a reason why the SIP is such an easy thing to implement in China. A flue gas desulphurization system was created in 2002, which was the first of many implementations in 2002 and 2003. Multiple systems were implemented that dealt with water usage and treatment. In 2004, a mass transit system was added to address the difficulty of transportation in this growing development area, this mass transit system shown in Figure 6 addressed the need for transportation of workers throughout Tianjin. Not only does it help TEDA, but also the society of Tianjin, by providing quality transportation service. The development of this park was slower than most industrial parks, and even though being an SIP was not a main focus, the attitude that everything does not have to be on your own is of significant importance when developing a SIP.

Figure 6: Binhai Mass Transit System

The symbiosis between public sector utilities is one aspect of TEDA that exemplifies the attitude for creating a SIP. There is significant by-product exchange and co-generation between all of the public sector utilities, the diagram in Figure 7 depicts the exchanges. One significant aspect is the two cogeneration plants that receive water and give steam for use in industrial/commercial/residential users. Another would be the water treatment plant and the wastewater treatment plant that receives water and sewage respectively and is able to provide water for use to multiple places. Not simply accounting for the public sector, there are 81 by-product exchanges that happen at TEDA, and is a really good example for industrial symbiosis in industrial parks and development areas (Shi, Chertow, & Song, 2010)

Figure 7: Public Sector Symbiosis of TEDA



Xi'an

The Xi'an High-Tech Industrial Development Zone is a SIP in the People's Republic of China. As of 2007, nearly 900 companies operate within the industrial park. The industries that are in the Xi'an industrial park are electronic information, equipment manufacturing, and biomedicine. The park is so massive that the industries form clusters within themselves. For example, the electronic information industry is divided into three different clusters; an integrated circuit cluster, a communications cluster, and a software cluster. The park employs approximately 400,000 workers with over half of them having a junior college degree or higher.

Even though the park is located in a major population area it still works to be as environmentally friendly as possible. 41% of the land that the park takes up has some sort of greenery growing on it. In addition to this, there is a lot of effort to keep the air clean. This is regulated by an air pollution monitoring system in the industrial park. Lastly, a significant accomplishment of the Xi'an SIP is that in 2007 approximately 91% of its industrial waste was recycled. It should be noted that this achievement, while impressive, is not particularly difficult for an industrial park whose main industries are electronic information and manufacturing, and biomedicine. These are the industries that Xi'an focuses on attracting as they are all low-emission, low-waste industries. This is one of the methods that Xi'an employs to keep it's affect on the environment down. After this they then work to reduce their already low emissions to even lower levels. This attention to the environment and recruitment of low-emissions companies does a lot to keep the Xi'an High-Tech Industrial Development Zone sustainable. (Zhong, Xia, & Xu, 2010) (Shaanxi Foreign Affairs Office, 2008)

Santa Cruz

The Santa Cruz eco-industrial park in Rio De Janeiro, Brazil, was launched by 14 industries and the state government in 2002 as part of a program called the Eco-Industrial Sustainable Development Program (ECOPOLO). The industries and government were starting to realize that implementing environmentally friendly practices was giving them a significant return on investment and not costing them extra. This park, even though it does not have many similar industries to the industries of Costa Rica, was chosen because in the end it failed for reasons that Costa Rica can avoid.

The park established 13 main goals on creation, and there was a big focus on developing a system to handle byproducts and other waste management techniques. Their initial goals can be seen below in Table 7 which lists techniques that the park would attempt to use as well as broad goals such as number 8. This park began development in 2002 in an existing industrial zone of Brazil, and even now few of these goals have been implemented. As of 2009, no by-product exchanges have occurred even though a complete inventory has been created (Goal #1). There is no support for the people involved who want to continue the project. There is also a lack of knowledge on the subject of SIPs for those still concerned with the initiative. Even though progress of the park has slowed significantly, some lessons can still be learned on this topic. (Zhong, Xia, & Xu, 2010)

Table 7: Santa Cruz's Initial Goals

1.	Byproduct and waste management program: implementation of a central waste and effluent treatment station serving the whole park; development of waste inventory; identification of possible synergies, reuse and recycling possibilities.
2.	Implementation of environmentally sound production practices, instead of end-of-pipe solutions.
3.	Recruitment of new industries, to achieve the right mix to facilitate industrial synergies.
4.	Air quality monitoring system: development of an integrative system to monitor regional air quality, which is a major problem for the industries to get their environmental licenses.
5.	Rainwater and surface runoff monitoring system.
6.	Development of an environmental management plan.
7.	Compensatory measures: planting native species in order to reestablish the site's ecological balance.
8.	Incentives to environmental initiatives in the park's surrounding area.
9.	Ensuring compliance to environmental regulations.
10.	Information, training and service sharing.
11.	Community socio-environmental initiatives: recycling program, social and educational programs.
12	Energy efficiency, water conservation, environmental research and educational programs.

13	Creation of a centralized management association, the Santa Cruz SIP Management Association (AEDIN).

The development of the goal list of Table 7 is a useful tool for the park developers, as in any subject, goals provide significant direction and aid anyone looking to move forward. It also can give a certain hierarchy to what the park is trying to accomplish, as in this example, even though the hierarchy was not followed, creating a successful waste management and byproduct program could be regarded as very important whereas other things such as goal five (Rainwater and surface runoff monitoring system) could be less important. Unfortunately, with the loss of support for the development of this Santa Cruz Park, there is also not much synergy between companies, although it was attempted with the first goal. (Veiga & Magrini, 2009)

Appendix B: Chapter IX, Article 38 of Costa Rica's URE Policy

This is the list of incentives that are included in Chapter 9 article 38 of Costa Rica law No. 7447: Regulation of the Rational Use of Energy (Regulation of the Rational Use of Energy, Costa Rica Law No. 7447, 1994).

URE-Chapter IX
INCENTIVES
Article 38: Exemptions

Are exempted from payment of selective consumption taxes, ad valorem, sales and stipulated in Law No. 6946, of January 14, 1984, the following equipment and materials, both imported and domestic manufacture:

1. Solar water heaters for all use, efficiency certification issued by an accredited laboratory.
2. Water storage tanks for solar heating systems of the type thermosyphon.
3. Photovoltaic power generation panels in any capacity.
4. Control systems for photovoltaic panels, wind generators and hydro-electric direct current.
5. Static converters DC to AC for solar, wind and hydro power generators directly.
6. Lead acid batteries and deep cycle batteries of nickel-cadmium and nickel-iron, with capacities greater than 50 ampere-hours.
7. Heads-saving hot water for showers and sinks, with consumption of less than 9.5 liters / minute.
8. Efficient fluorescent and halogen fixtures.
9. Wind and hydro generators for use unrelated to the generation access to electricity, which points to the Law No. 7200, September 28, 1990.
10. Equipment voltage and frequency control for wind turbines and hydropower.
11. DC appliances for use with panels photovoltaic, wind and hydro generators direct current.
12. Materials to build equipment to take advantage of renewable energy.
13. Tempered glass with less than 0.02% iron content.
14. Thermal insulation for solar collectors as polyisocyanurate and polyurethane, the additives to develop or both.
15. Absorber plate and finned tubes for water heaters.
16. Aluminum profiles specific to build solar water heaters.
17. Thermal insulation for water pipes.

18. Any insulation useful for improving the insulation of tanks heated water storage with solar systems.
19. Apparatus for measuring variables related to renewable energy such as temperature gauges, pressure gauges fluids, anemometers to measure the direction and wind speed and the meter solar radiation.
20. Pumping systems powered with photovoltaic systems and wind.
21. Refrigerators and cookers.
22. Ram pumps.

Appendix C: Database of Costa Rican Industrial Parks

These are four of the eight categories that we included on our database of Costa Rica's Industrial Parks. The database is an Excel file that can be updated by CICR as they learn of new industrial park developments.

Figure 8: Part of Database of Industrial Parks

Name	Companies	Contact	Province
Inversiones Zeta, S.A. (Montecillos)	35	Alejandro Araya Rivera, Alvaro Quiros Coto, Blanca Mesen Fallas	Alajuela
P.I.Z.F Alajuela	13	Miguel Ramirez Steller	Alajuela
P.I.Z.F. Bes	10	Wu Hui-Chen	Alajuela
Coyol	15	Andre Garnier Kruse, Alvaro Carballo Pinto	Alajuela
Inversiones Zeta, S.A. (Cartago)	28	Alvaro Valverde Palavicini	Cartago
Conair Costa Rica, S.A.	2	Fransisco Lopez Trigo	Cartago
CF Free Zone Park S.R.L. (Old Global Park)	19	Carlos Wong	Heredia
Ultra Park	14	Carlos Piedra Jurado	Heredia
Zona Franca Metropolitana, S.A.	36	Priscilla Alvarado Fallas	Heredia
Inversiones Zeta, S.A. (La Valencia)	5	Alvaro Valverde Palavicini	Heredia
P.I.Z.F. Puntarenas	5	Miguel Ramirez Steller	Puntarenas

Appendix D: Sustainability Checklist

Waste Management	☑	**Energy Use**	☑	**Water Usage**	☑	**Materials**	☑	**Infrastructure**	☑
Recycling		**Power station**		**Water Treatment**		**Construction**		**Transportation**	
recycling center	☐	co-generation	☐	waste water treatment facility	☐	recycled materials	☐	bus	☐
by-product synergy	☐	flue gas system	☐	water treatment facility	☐	reuse of old buildings / sites	☐	bike racks	☐
						environmentally friendly materials	☐	train for the transport of personnel	☐
Waste Treatment		**Energy Efficiency**		**Water Collection**		use of local materials	☐	carpooling incentives	☐
waste-to-energy	☐	occupancy sensors	☐	groundwater collection	☐			energy efficient car incentives	☐
hazardous waste treatment	☐	efficient lighting	☐	rainwater collection	☐	**Storage**		on-site housing	☐
		lighting sensors	☐			storage facility for hazardous materials	☐		
		renewable energy source off-site	☐	**Water Efficiency**		storage of by-products before transportation	☐	**Landscaping**	
				use of low-flow appliances	☐			preservation of wildlife	☐
		Green Architecture		water cascading / reuse	☐	**Transport**		unobstructing airflow or water flow in area	☐
		passive solar	☐			train for the transport of materials in/out	☐	composting operation for food by-products	☐
		passive cooling	☐			pipes, conveyers, etc. between plants	☐		

		solar panels / heating	❑					**Management**	
		wind turbines	❑			**On-site Materials**		environmental incentives	❑
		other renewable energies	❑			use of recyclable materials	❑	recruiting companies for by-product synergy	❑
						use of recycled materials	❑		
						use of non-toxic materials	❑		

Appendix E: Survey of Industrial Park Managers (English)

Worcester Polytechnic Institute/Cámara de Industrias
Susan Brennan, Nathaniel Eames
Arten Esa, Martha Miller

Survey of Costa Rican Industrial Parks

This survey is concerning what your park is doing with respect to the environment. It should take about 20-30 minutes. The information collected will be used solely for research and will not be published in any identifiable way. Please follow any instructions and answer all the questions. Thank you for participating.

If you are currently working on implementing any of the questions, but just do not have it built and functional yet, please circle yes if the question asks if you have it.

I. Waste Management

1. Does your industrial park have a recycling center? Yes No
   a. If no, how do you deal with recycling? (Please answer in the box below)
2. Do the companies within your park exchange by-products? Yes No
   a. Do they exchange by-products with companies elsewhere? Yes No
3. Does your industrial park have a waste-to-energy plant? Yes No
   a. If no, is an investment into a waste-to-energy plant something you have planned for the future? If not, might one be considered in the future, why or why not? (Please answer in the box below) Yes No
4. Does your industrial park produce any hazardous waste?
   a. If yes, then do you have a hazardous waste treatment plant? Yes No
      i. If no, what do you do to deal with it? (Please answer in the box below)

II. Energy Usage

1. Does your park have a power station? Yes No
    a. If yes, do you co-generate to reduce the emissions? Yes No
    b. If yes, is it equipped with a flue gas system? Yes No
2. Does your park have occupancy sensors that detect when there are people around for the lighting? Yes No
3. What about lighting sensors that adjust the lights according to the natural light in the room? Yes No
4. Is your park equipped with efficient lighting? Yes No
5. Do you use any off-site renewable energy? Yes No
6. Were any of the buildings constructed using the technique of passive solar generation, where the windows are placed and designed to let the most sunlight in to reduce heating costs? Yes No
7. How about passive cooling, where the building is constructed specifically to allow for more shading? Yes No
8. Does the park have any wind turbines or other renewable energies (Solar energy, biofuels etc.)? Yes No

---

III. Water Usage

1. Is there a waste-water treatment plant in the park? Yes No
    a. If no, would a waste-water treatment plant be worth an investment in the future? Yes No

        Why or why not? (Please answer in the box below)

2. Do you collect ground water? Yes No
3. Do you collect rain water? Yes No
4. Is there a water treatment plant in the park? Yes No
    a. If no, would a water treatment plant be worth an investment in the future? Yes No

        Why or why not? (Please answer in the box below)

5. Is there active promotion of using low-flow appliances over high-flow appliances? Yes No
6. Does the park cascade its water use/re-use water? Yes No

IV. Infrastructure

1. Is there a bus that services your park? Yes No
2. Are there bike racks or biking incentives? Yes No
3. Is there a train that services your park? Yes No
    a. If yes, is it for transportation of goods or people, or both?
       Goods People Both
4. Are there carpooling incentives? Yes No
5. Are there energy efficient car incentives, such as guaranteed parking? Yes No
6. Is there on-site housing for workers? Yes No
7. During construction of the park, was there any obstruction of water-flow or air-flow?
   Yes No
8. Is there any composting for agricultural by-products? Yes No
9. Does the management promote environmental incentives for companies in the park?
   Yes No
10. Is the management actively recruiting a good mix of companies to promote by-product synergy? Yes No
    a. If no, is this a strategy management may pursue later on to reduce costs in recycling and other waste management option? Yes No
       Why or why not? (Please answer in the box below)

V. Materials

1. During construction, does the park use recycled materials? Yes No
2. Were any old/unused buildings retrofitted to be used again? Yes No
3. Did you use local materials when constructing? Yes No
4. Is there a storage facility for hazardous materials? Yes No
5. Are by-products stored before transportation or disposal? Yes No
6. Is there any static transportation for materials in and out of the park? Yes No
7. Are there any pipes/conveyors/transportation for materials within the park? Yes No
8. Are the materials used for productions recycled/recyclable? Yes No
9. Are they non-toxic? Yes No

VI. Policy

1. Are you aware of the Integrated Waste Management legislation? Yes No
2. What is this park doing to comply with the Integrated Waste Management Law? (Please answer in the box below)
3. On a scale of 1 to 5, please rank the ease of compliance this park has had with meeting the requirements of the Integrated Waste Management Law, with 1 being very difficult and 5 being very easy to comply with.
   1 2 3 4 5
4. Are you aware of the Rational Energy Use legislation? Yes No
5. What is this park doing to comply with the Rational Energy Use Law? (Please answer in the box below)
6. On a scale of 1 to 5, please rank the ease of compliance this park has had with meeting the requirements of the Rational Energy Use Law, with 1 being very difficult and 5 being very easy to comply with.
   1 2 3 4 5

VII. Are you willing to invest into your park's sustainability if presented with all the necessary information? Yes No

---

We appreciate the time you have given us, and your answers will help us greatly in our research on industrial parks in Costa Rica. Thanks again for your time.

WORCESTER POLYTECHNIC INSTITUTE 1865 WPI

CICR Cámara de Industrias de Costa Rica

Appendix F: Survey of Industrial Park Managers (Spanish)

Worcester Polytechnic Institute/Cámara de Industrias
Susan Brennan, Nathaniel Eames
Arten Esa, Martha Miller

<u>Encuesta de Parques Industriales</u>

Esta encuesta es sobre lo que su parque está haciendo con respecto al medio ambiente. Se debe tomar alrededor de 20-30 minutos. La información recogida será utilizada exclusivamente para la investigación y no será publicado de ninguna forma de identificación. Por favor, siga las instrucciones y conteste todas las preguntas. Gracias para su participación.

Si usted está trabajando actualmente en la aplicación de alguna de las preguntas, pero simplemente no lo han construido todavía, marque con el círculo Sí, si la pregunta se refiere a si la tiene.

VIII. Gestión de residuos

5. ¿Tiene su parque un centro de reciclaje? Sí No
   a. Si no, ¿cómo lidiar con el reciclaje? (Por favor, conteste en el cuadro a continuación)

6. ¿Las empresas dentro de su parque intercambian sus subproductos? Sí No
   a. ¿Intercambian sus subproductos con empresas afuera del parque? Sí No
7. ¿Tiene su parque una planta de residuo-a-energía? Sí No
   a. Si no, ¿Es una inversión en una planta de residuo-a-energía algo que usted ha planeado para el futuro? Sí No
      i. Si no, ¿puede ser considerado en el futuro? ¿por qué o por qué no? (Por favor, conteste en el cuadro a continuación) Sí No

8. ¿Produzca su parque residuos peligrosos? Sí No
    a. Si sí, ¿Tiene su parque una planta de tratamiento por eso? Sí No
        i. Si no, ¿Qué hacen para lidiar con ese residuo? (Por favor, conteste en el cuadro a continuación)

IX. Uso de Energía

9. ¿Tiene su parque un central eléctrico? Sí No
    a. Si sí, ¿Utiliza la cogeneración para reducir las emisiones? Sí No
    b. ¿Está equipado con un filtro de aire para quitar las emisiones peligrosas? Sí No
10. ¿Tiene su parque sensores de movimiento que detectan cuando hay gente alrededor de la iluminación? Sí No
11. ¿Y sensores de iluminación que se ajustan las luces de acuerdo con la luz natural en la habitación? Sí No
12. ¿Usa iluminación o luces eficientes (fluorescente etc.)? Sí No
13. ¿Utiliza algunas energías renovables fuera del parque? Sí No
14. ¿Algunos de los edificios fueron construidos con la técnica de energía solar pasiva, donde las ventanas se colocan y son diseñados para permitir a más luz solar para reducir los costos de calefacción e iluminación? Sí No
15. ¿Y enfriamiento pasivo, donde el edificio fue construido para permitir más sombre? Sí No
16. ¿Tiene su parque algunas turbinas de viento o otras energías renovables (Solar, biocombustibles etc.)? Sí No

---

X. Uso de Agua

7. ¿Hay una planta de tratamiento de aguas residuales? Sí No
    a. Si no, ¿Valería una inversión en el futuro? Sí No
    ¿Por qué o por qué no? (Por favor, conteste en el cuadro a continuación)

8. ¿Recogen a las aguas subterráneas? Sí No
9. ¿Recogen a las aguas de lluvia? Sí No
10. ¿Hay una planta de tratamiento de agua? Sí No
    a. Si no, ¿Valería una inversión en el futuro? Sí No

11. ¿Por qué o por qué no? (Por favor, conteste en el cuadro a continuación)

12. ¿Hay promoción activa del uso de aparatos de bajo flujo contra aparatos de alto flujo? Sí No
13. ¿Cascadan o re-utilizan el agua? Sí No

XI. Infraestructura

11. ¿Hay un autobús por su parque? Sí No
12. ¿Hay bastidores de bicicletas o incentivos para montar en bicicleta? Sí No
13. ¿Hay un tren por su parque? Sí No
    a. Si sí, ¿Es para la transportación de gente, productos o ambos? Gente Productos Ambos
14. ¿Hay incentivos para compartir los coches? Sí No
15. ¿Existen incentivos para coches eficientes, como estacionamiento garantizado? Sí No
16. ¿Hay un lugar de vivienda para los trabajadores? Sí No
17. ¿Hay compostaje para subproductos agriculturas? Sí No
18. ¿Hay incentivos ambientales para las empresas en el parque de la gestión? Sí No
19. ¿La gestión está reclutando una buena mezcla de empresas para fomentar la sinergia de subproductos? Sí No
    a. Si no, ¿Por qué? (Por favor, conteste en el cuadro a continuación)

XII. Materiales

10. ¿Durante la construcción, utilizan materiales reciclados? Sí No
11. ¿Se han adaptados los edificios antiguos? Sí No
12. ¿Durante la construcción, utilizaban materiales locales? Sí No
13. ¿Hay almacenamiento para materiales peligrosos? Sí No
14. ¿Hay transportación estática para materiales en el parque (cintas transportadoras)? Sí No
15. ¿Los materiales que son usados por la producción están reciclables/reciclados? Sí No
16. ¿Los materiales que son usados por la producción están peligrosos? Sí No

---

XIII. Policy

7. ¿Conoce la ley de Gestión Integral de Residuos? Sí No
8. ¿Qué está haciendo el parque para cumplir con la ley?
   (Por favor, conteste en el cuadro a continuación)

9. En una escala de 1 a 5, por favor clasifique la facilidad de cumplimiento de este parque ha tenido con el cumplimiento de los requisitos de la ley, donde 1 es muy difícil y 5 es muy fáciles para cumplir.
   1 2 3 4 5
10. ¿Conoce la Regulación del Uso Racional de Energía? Sí No
11. ¿Qué está hacienda el parque para cumplir con la ley?
   (Por favor, conteste en el cuadro a continuación)

12. En una escala de 1 a 5, por favor clasifique la facilidad de cumplimiento de este parque ha tenido con el cumplimiento de los requisitos de la ley, donde 1 es muy difícil y 5 es muy fáciles para cumplir.
   1 2 3 4 5

XIV. ¿Está el parque dispuesto a invertir en la sostenibilidad de su parque si se le presenta toda la información necesaria? Sí No

---

Apreciamos el tiempo que nos ha dado, y sus respuestas nos ayudará enormemente en nuestra investigación sobre los parques industriales en Costa Rica. Gracias de nuevo por su tiempo.

WORCESTER POLYTECHNIC INSTITUTE · 1865 · WPI

CICR Cámara de Industrias de Costa Rica