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Industrial Ecology Prosperity Game™

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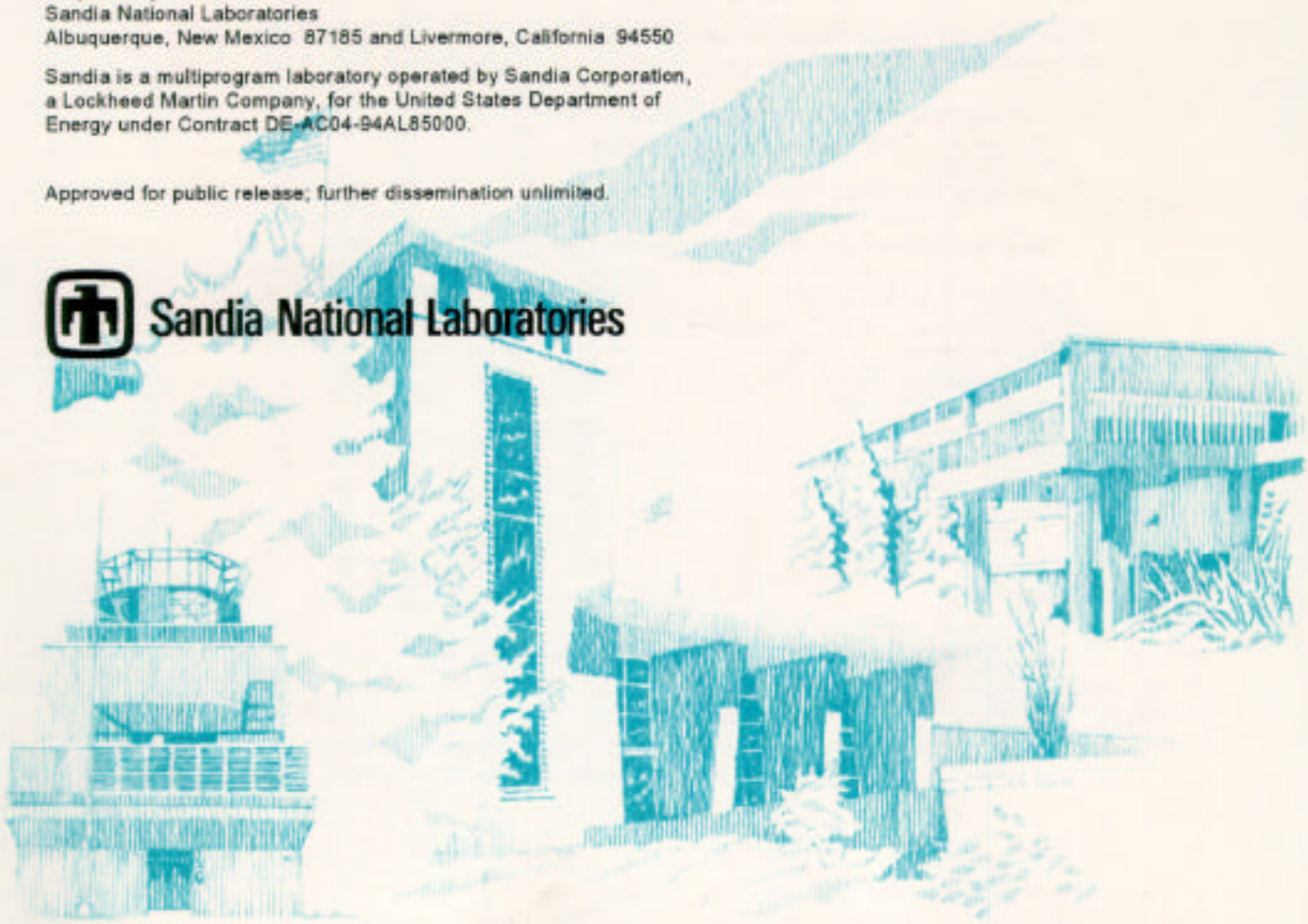

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INDUSTRIAL ECOLOGY PROSPERITY GAME™

May 20-22, 1997
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Herndon, Virginia

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ABSTRACT

Sandia conducted its seventeenth Prosperity Game™ on May 23-25, 1997, at the Hyatt Dulles Hotel in Herndon, Virginia. The primary sponsors of the event were Sandia National Laboratories and Los Alamos National Laboratory, who were interested in using the format of a Prosperity Game to address some of the issues surrounding Industrial Ecology. Honorary game sponsors were: The National Science Foundation; the Committee on Environmental Improvement, American Chemical Society; the Industrial & Engineering Chemistry Division, American Chemical Society; the U.S. EPA–The Smart Growth Network, Office of Policy Development; and the U.S. DOE–Center of Excellence for Sustainable Development.

ACKNOWLEDGEMENTS

A complex event such as a Prosperity Game™ requires the efforts and encouragement of many people. Kathleen Schulz was the initiator of this project, and a strong supporter throughout the design, prototyping and execution of the game. She contributed to the game content, to sponsor solicitation, and to attracting players and experts. Without her contributions and expertise, this game would never have taken place.

Gary Sycalik and Ernest Lowe provided their expertise throughout the design and execution of the games, as well as significantly improving the content of the pre-game materials.

Staff from Los Alamos and Lawrence Livermore Laboratories also provided funding and support for the game. We especially thank the Industrial Ecology experts who came to the game, and contributed their ideas and suggestions. Gladys Shaw, as always, did a wonderful job in arranging for facilities and equipment and ensuring that all went smoothly.

Eighty-five players and thirty-four staff committed themselves to the success of this game, and their efforts are greatly appreciated. The sixty-five players and twenty-seven staff participating in the prototype game were also helpful to the successful outcome of the final game. Special thanks to those players from industry, labs, academia, and the government who took time out from their busy schedules to contribute to this effort. Thanks also to the staff who provided outstanding facilitation for the game and analyses of the results.

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EXECUTIVE SUMMARY

The growth of the human population and the industrial base required to support it are placing an ever-increasing burden on the life-support systems of the planet. The desire for higher quality of life is further taxing the capacity of all natural resources. We are only beginning to understand the full range of these impacts. There are some areas of concern, such as food supplies, energy resources, and environmental impacts that imply a bleak future. And yet, there are many signs of activities that are expressing our inherent human creativity in overcoming problems that give hope for a bright and prosperous future.

We do understand enough about these changes to have mobilized innovative forces in all sectors of society. Corporations and government agencies around the world are defining the goals of sustainable development. Thousands of researchers are studying the ecological impacts of human activities and designing methods and tools for overcoming them. Industrial ecology (IE) is an emerging scientific field growing out of this endeavor that views industrial activities and the environment as an interactive whole. Industrial Ecology provides a dynamic, systems-based framework that has the potential to enable corporations and governments to scientifically manage human activity to meet their goals. The sponsors and players of this Prosperity Game™ on industrial ecology joined together because they see both sets of signs. They came together to understand and promote the development of this still new field of research and practice. They came with the hope that perhaps their efforts will increase the prospects of a bright and prosperous future for all.

This was the seventeenth Prosperity Game™ that has been conducted. The game was sponsored by Los Alamos National Laboratory and Sandia National Laboratories. Honorary Sponsors included The National Science Foundation; Committee on Environmental Improvement, American Chemical Society; Industrial & Engineering Chemistry Division, American Chemical Society; U.S. EPA—The Smart Growth Network, Office of Policy Development; and U.S. DOE—Center of Excellence for Sustainable Development.

This Prosperity Game™ was designed to accomplish the following objectives:

- Develop an understanding of what industrial ecology is.
- Develop an understanding of how industrial ecology can help meet the needs of the stakeholders and the nation.
- Explore the role of government in an integrated industrial ecology effort.
- Identify and initiate follow-on activities to promote findings and policies generated in the game.

The game incorporated thirteen basic teams. U.S. government interests were allocated among four teams: Congress; Local and State Governments; Federal Advisory and Regulatory Agencies; and Federal Industrial Agencies (representing the nuclear weapons complex of the DOE, the bases, equipment, logistics, and production systems of the DOD, and the Space Transportation System of NASA). Industry was split into three teams: Finance, Insurance, and International Programs; Resource provider firms; and Manufacturing firms. Each industry team contained appropriate elements of the service industry. Research and development activities were simulated in the game by three teams: Universities; DOE Labs; and Think Tank, Inc. (representing the wide spectrum of R&D resources not covered by the other two R&D teams). The public stakeholders were represented by the Public Team, which was tasked to represent the full gamut of interests from the "haves" to the "have nots," to the activist groups. Non-commercial foreign interests were held by the Foreign Countries Team, which was tasked to represent the governments and the public of both developed and developing nations. The last team, Control, was primarily responsible for conducting the game, including polling, game play support simulations, agreement evaluations, publications, etc.

The teams themselves were composed of a mix of executive-level players that differed greatly in their background in IE. The original intent was to "seed" each team with at least one player that had a strong background in some

aspect of IE in order to help keep IE in the game play. The active game sessions successfully kept the players engaged in the IE arena. Team plans and most team agreements were in keeping with the desired IE focus, although they often paid little attention to the challenges posed in the Players' Handbook.

This Prosperity Game™ also included (for the first time) two plenary sessions. The first session occurred prior to the start of active play. It was organized around a series of presentations by IE experts in an effort to educate the players about IE and to "kick start" them into thinking along IE lines. The second session occurred midway through the game, and was organized as a summit meeting with elected members from each team. Historically, and for this game, it has been found that a summit meeting helps focus and motivate the players during the second half of the game. As evidenced by the post-game reports, both sessions served their intended role, although there were complaints that the experts spent too much time preaching the virtues of IE rather than teaching IE concepts.

The first specific objective of the game was to "develop [in the players] an understanding of what industrial ecology is." The second objective, "develop an understanding of how industrial ecology can help meet the needs of the stakeholders and the nation," was also related to the players' knowledge about IE and its benefits. Performance against these objectives was best measured by polling the players both pre- and post-game. The players were asked to rate their knowledge of industrial ecology (IE) on a scale of one (very little) to five (very much); the response was a dramatic shift from a mean of 3.15 pre-game to 3.89 post-game. Post-game written evaluations from the players were consistent with the polling responses. Most players felt that the game was a "great learning experience." On the basis of the player feedback, this can be attributed to both the pre-game written materials as well as to the intra- and inter-team discussions that took place during the game. In addition to their exposure to IE concepts, on the basis of play during the game some players were able to draw several general conclusions about IE that were supported by post-game analysis (see below):

- IE is not recognized as an important endeavor by a sufficiently large part of society.
- IE has no focused sponsorship.

Additional learning was reported in the areas of achieving consensus, team dynamics, and partnering.

The third game objective sought to "explore the role of government in an integrated industrial ecology effort." Responses indicate that most people feel that government should be involved in promoting and directing IE efforts (score = 4). However, another question might have been used to ask how or in what way? Post-game analysis made an attempt to capture this by analyzing the actual moves made during the game (interpreted as reflecting the players' areas of interest and the perceived importance). Moves were evaluated by topic from the standpoint of total resource investments, the number of agreements drafted, the number of participants, and the duration of the interest. The results indicated that players were most concerned with how to actually support and implement IE rather than use it to solve problems. (A subjective interpretation is that the players perceived that IE provided an appropriate framework to solve issues like sustainability, but that there is inadequate support to effectively implement it.) This was also in keeping with the player feedback mentioned above. Game play focused on developing the education, programs, incentives and other funding means, and the cooperation necessary to implement IE. In most of these areas government involvement will be required for success. From a DOE Labs perspective (the paying sponsors), there is clearly a potential role in the high-focus areas identified, such as conducting systems analyses in industrial ecology, serving in an advisory capacity (e.g., the "honest broker" role), and as an information provider.

The fourth game objective was to "identify and initiate follow-on activities to promote findings and policies generated in the game." Polling responses indicate that many people would be willing to participate in the follow-on efforts (score = 4). Capturing ideas for potential follow-on activities was accomplished in the game through player evaluation forms and staff reports. The major categories included:

- establish online (Internet) resources to facilitate discussions and provide access to the extensive data required to conduct IE-type studies

- conduct follow-on IE Prosperity Games™ both for educating additional audiences as well as for further development of IE concepts in specific areas
- develop partnerships or consortia to further promote IE
- develop IE-oriented educational tools and programs
- further develop certain innovative ideas that were played out in the game

By the measures and results available so far, the Industrial Ecology Prosperity Game™ was a resounding success. Players' responses to polling questions indicate that the majority of players felt that their time had been well spent (score = 3.94) and that the game's objectives had been met (score = 3.58). Although it seems that in any setting there are a few people who complain about everything (e.g., "too noisy," "insufficient time," "the introduction from the 'experts' ... [had] little practical discussion," "be more careful in choosing participants," "...[was] the game focus ... IE or socialism[?]"), most of the people were pleased with their experience.

- The games were very good.
- Game was good and appeared to be true to life.
- Interesting, interactive, educational event.
- Helped me appreciate other people's positions.
- Very stimulating in paradigm-changing thinking about the future.
- Very enjoyable experience.

INTRODUCTION

Industrial ecology (IE) is an emerging scientific field that views industrial activities and the environment as an interactive whole. The IE approach simultaneously optimizes activities with respect to cost, performance, and environmental impact.

Industrial Ecology provides a dynamic systems-based framework that enables management of human activity on a sustainable basis by: minimizing energy and materials usage; insuring acceptable quality of life for people; minimizing the ecological impact of human activity to levels that natural systems can sustain; and maintaining the economic viability of systems for industry, trade and commerce.

Industrial ecology applies systems science to industrial systems, defining the system boundary to incorporate the natural world. Its overall goal is to optimize industrial activities within the constraints imposed by ecological viability, globally and locally. In this context, “Industrial systems” applies not just to private sector manufacturing and services but also to government operations, including provision of infrastructure.

Industrial ecology integrates a broad range of disciplines, ranging from basic sciences to engineering, economics, and other social sciences. IE seeks to provide the scientific framework required for discovering the path to sustainability.

IE seeks a shift from linear resource flows in the economy toward closed-loop systems. Through its methods of analysis, it assesses the long-term impacts of sustained material and energy flows on the quality of human life and ecological systems. IE design methods seek to reduce the amount of energy and materials flowing through a process or embodied in a product, while providing the same or improved output.

Industrial ecology also seeks to minimize waste and pollution of process outputs. This often is achieved by tailoring former "waste" streams so that they become input streams for other processes. A related concern is replacing non-renewable resources with renewable ones.

Applying industrial ecology promises benefits to all sectors of society:

- Companies may gain increased efficiencies, reduced waste, and lower environmental costs and liabilities (thereby achieving higher profit margins).
- Investors and insurance companies may lessen exposure to environmental risk.
- Communities and individuals can reduce environmental damage and health risks while seizing new opportunities for local economic development and job creation.
- Government can benefit by replacing one-size-fits-all regulations with a focus on the results achieved.
- And finally, the world community can benefit from the renewed hope of a sustainable, economically viable future for all.

GAME CONCEPT AND DESCRIPTION

The Game

Prosperity Games™ were adapted from strategic war games to simulate current realities and possible alternative futures as influenced by executive-level decisions. Prosperity Games™ are about leadership and strategy development. Prosperity Games™ provide a high-level interactive simulation that models the complex world of values, propositions, and persuasion. They are not people playing against a computer.

The environment engendered in every Prosperity Game™ serves to meet a set of general objectives simply by participation in the simulation process itself. These objectives include:

GENERAL OBJECTIVES:

- Develop partnerships, teamwork, and a spirit of cooperation among industry, government, university, and public stakeholders.
- Increase awareness of the needs, desires and motivations of the different stakeholders.
- Bring conflict into the open and manage it productively.
- Explore long-term strategies and policies.
- Provide input for possible future legislation.
- Stimulate thinking.
- Provide a major learning experience.

The players involved in a Prosperity Games™ simulation represent a wide range of different interests and often have different views on key issues. Each participant is responsible for representing his or her team's "real life" constituency. The format of the Prosperity Games™ allows the viewpoints of the different teams' constituencies to be understood in small groups and synthesized into a working consensus – one which all parties can support, even if it is not the optimum for a particular interest group.

Game play takes place in an open environment. Prosperity Games™ feature the processes of planning and negotiation. Players control the content of the games and generate their own strategies and goals or objectives, which are one of the major outputs of the game. High-level players create new insights and options that often develop into post-game opportunities. Teams are designed to provide sufficient knowledge and judgment necessary to make decisions as well as to contain the diversity needed to create stimulating and engaging interactions.

Prosperity Games™ are viscerally engaging. This serves to generate enthusiasm and commitment, and to bring conflict into the open in a safe environment where it can be managed productively. The Prosperity Game™ simulation explores empathic and learning experiences, collaborative and competitive interactions, experimentation, decision making, and innovation. Players who fully engage in the process of creating a constructed reality and in testing each other's ideas benefit the most. The games are so interactive, fast paced, and complex that the few players who try to "game the game" are usually unsuccessful and disappointed.

A final debriefing allows the teams to share their experiences. The game experiences of the players are then collected, discussed, prioritized, and documented in a final report. This experiential process develops the relationships and provides the inputs and innovative thinking that will be used for follow-on activities and planning.

Industrial Ecology Prosperity Game™ Objectives

The sponsors of this game are seeking to promote interaction among the various players who have a stake in industrial ecology and related fields of endeavor. The interactions within the simulation will provide participants with a chance to understand the

broad applicability of industrial ecology principles in solving sustainability problems at many levels of concern. It will be an invaluable learning experience that can create exciting *alternative* futures as well as explore the current *real* world.

This Prosperity Game™ is designed to accomplish the following specific objectives:

SPECIFIC OBJECTIVES:

- Develop an understanding of what industrial ecology is.
- Develop an understanding of how industrial ecology can help meet the needs of the stakeholders and the nation.
- Explore the role of government in an integrated industrial ecology effort.
- Identify and initiate follow-on activities to promote findings and policies generated in the game.

These objectives will be met by the players and teams acting separately and in concert to explore the future through the development and implementation of their own strategies.

Industrial Ecology Game Concept

Scenario:

This game begins in the present and extends over the next decade. The setting is real life. The burgeoning world population is placing severe demands on dwindling resources. Further details on the state-of-the-world for selected global, national (U.S.), and regional (Rio Grande Border) settings can be found in the appendices.

Groups in all walks of life have begun to pursue "sustainability." One outcome of such pursuits is a call for population control. However, such social issues are ***not*** part of this game. Projected population growth will drive resource demands, but limiting population size is not an acceptable solution in the game. (Besides, current projections include consideration of planned and ongoing population control programs.) Rather, the challenge is to determine how to use the power of technology to confront the power of population. For the purpose of the Industrial Ecology Prosperity Game, the stakeholders in this issue have been categorized into five groups:

STAKEHOLDER GROUPS:

- Government
- Industry
- R&D providers
- Public
- Rest of the World

The central theme of the game, as in real life, is the relationship among all the stakeholders in the competition for scarce public and private resources and how they can be used to achieve a sustainable culture. The public is concerned about the percentage of national income that is taken by the government, and the allocation of that money to competing needs. Industry is also concerned about the allocation of resources to fund ongoing company operations versus allocation for future investments. All stakeholders would like to have metrics to evaluate the success or failure of previous decisions and to help guide future decisions.

In order for this simulation to adequately represent the wide range of different interests and to stimulate interaction, the five stakeholder groups have been further subdivided into 13 teams. Team designations within these groups are illustrated in Figure 1 and are discussed below.

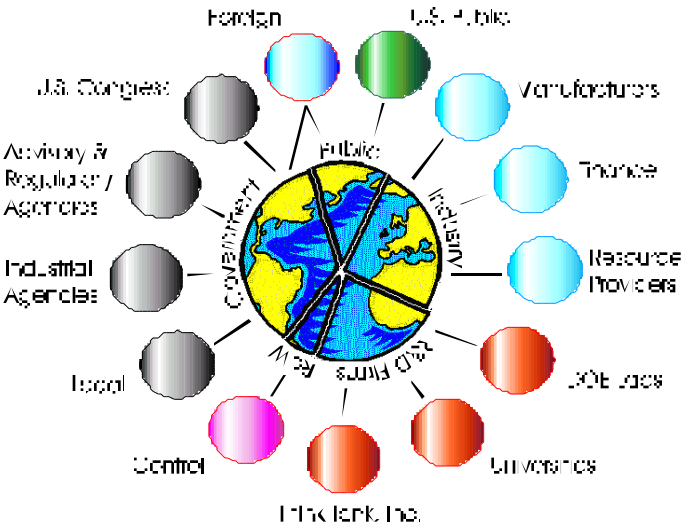


Figure 1. Industrial Ecology Prosperity Game Team Designations.

Organization and role assignments within the teams to accomplish the tasks "at hand" are the responsibility of the players assigned to each team (e.g., leaders, voting, recorders, advocates, "watch dogs," etc.). Each team can assume it has the necessary "in-house" legal, technical and fiscal management resources that would be found in real life (e.g., lawyers). Each team will also be assigned process managers (game staff) to facilitate team interactions, provide process guidance, capture information, and flag upcoming deadlines.

The government interests have been allocated among four teams:

U.S. GOVERNMENT TEAMS:

- Congress
- Local and State Governments (may represent any city, county, state, or regional authorities)
- Federal Advisory and Regulatory Agencies (e.g., EPA, NRC, certain parts of DOE, Department of Agriculture, Bureau of Mines, etc.)
- Federal Industrial Agencies (represents the nuclear weapons complex of the DOE, the bases, equipment, logistics, and production systems of the DOD, and the Space Transportation System of NASA)

Industry has been split into three teams. It should be noted that although there is not an explicit service industry, components of it are implicitly contained within the three teams defined below. For example, the Resource Providers can address transportation service issues (e.g., rental cars). Or, as another example, the Manufacturers Team can address leasing, buyback, or other service-oriented marketing policies and plans.

INDUSTRIAL TEAMS:

- <u>Finance, Insurance, and International Programs firms</u> – includes constituents from investment bankers, venture capitalists, the World Bank, insurance firms, and other similar funding groups
- <u>Resource provider firms</u> – represents extractive industries that provide raw materials such as metal and mineral mines, oil companies, water companies, logging companies, and agriculture; energy companies (power plants of all types); and transportation companies (trucking, railroad, airline, barge and ocean shipping), and any distribution networks such as power lines and pipe lines
- <u>Manufacturing firms</u> – represents all industry that uses outputs of the Resource Providers Team (energy, materials, and distribution) to produce and sell finished goods (e.g., chemicals, electronics, cars, clothes, houses, etc.)

The R&D providers group is organized into three teams:

R&D PROVIDERS TEAMS:

- Universities Team –represents the wide range of basic science and technology research capabilities found in higher educational institutions
- DOE Labs Team – represents the broad range of expertise specific to industrial ecology resident in the DOE National Laboratories
- Think Tank, Inc. – represents the wide spectrum of R&D resources that can be found outside of the universities and DOE labs.

The public stakeholders are represented by the Public Team, and they may have the most difficult job. This team must represent the general public including the "haves" and the "have nots" (who want to be "haves"), and the educated and uneducated. It must also represent activist groups from the Humane Society to extreme eco-system rights movements. The Public Team represents workers, consumers, voters, and perhaps even future generations. The team can also choose to designate one of its members as a journalist.

Non-commercial foreign interests are held by the Foreign Countries Team. This team is intended to represent the government and the public of both developed and developing nations.

Finally, the Control Team is primarily responsible for conducting the game, including polling, game play support simulations, agreement evaluations, publications, etc. It is also responsible for resolving all disputes, and for playing all other roles (the "Rest of the World" stakeholders group) and functions not otherwise assigned that may arise during the game.

Team players are expected to remain faithful to their assigned roles by protecting the interests of their constituents. In addition to the selected global, national, and local data sets related to sustainability already mentioned, further team descriptions have also been provided (see appendices) to help stimulate thinking and provide a common but non-exclusive setting for players to base their planning on. This information, coupled with the experience and expertise of the players, launches them into the real-world simulation of the game. Teams are encouraged to draw upon their own resources (players) to enrich their understanding of their own situation.

Players:

Players are assigned to one of the stakeholder teams. This exploration requires highly skilled players with a strong knowledge of sustainability issues of a technical nature (social issues such as population control are not being addressed), and the confidence to make decisions, observe their consequences, and alter their decisions accordingly. The players should also be self-starters who are highly motivated to work toward perceived goals. Their creativity and commitment to the simulation determine the success of the game. A list of the players and their team assignments is provided Appendix A.

Game Play

Planning – Every Prosperity Game™ is unique because the outcomes depend upon the players. In Prosperity Games™, the players own the final content of the game. Thus, the most critical element in any game is for each team to clearly decide upon a course of action and document it in a plan. Background information on the state-of-the-world and on the various teams has been provided in the appendices, and includes some potential challenges that might be pursued. However, after a review of the data and challenges, ***the players are responsible for developing team strategies for the game*** that, based upon their expertise, will best meet the interests of their constituents. These strategies may include a selected and modified subset of the given challenges, or they may be based on something different. The actual strategies selected and pursued by the players during the game will determine the game outcome. The breadth of the constituents represented by the teams makes it likely that local, national, and global issues will be brought into play. The interplay of the different teams (through the options and agreements that they develop or support) will then serve as a selection process to reduce the many issues to a selected few deemed important by most of the players. A copy of all strategic plans, including challenges, goals, and objectives, is a deliverable to the Control Team at the close of planning sessions.

Basic moves – The game has few rules. Team members play their roles by negotiating and interacting with each other and with other teams. Players develop plans to further their team goals, solicit and obtain co-sponsors with funding from other teams, invest in new technologies, and implement new policies.

Game play utilizes two types of “moves” which players use as a means to pursue their strategies and objectives, and alter the future accordingly. In the context of the game, most long-duration events (such as building new facilities) can be assumed to have already been accomplished in the event of a successful move.

One move involves making investments in “Toolkit” options, which can only be executed during Toolkit sessions. The Toolkit contains an extensive inventory of technology and policy options, some of which can be activated through team investments. This move is defined to be the allocation of team resources (money) to selected Toolkit options. Resources assigned to teams for use in a Toolkit session can not be carried over into other sessions.

The second type of move is referred to as an “agreement.” The agreement move replicates real-life activities, including negotiations, consensus building, resource allocation, and contracting, between stakeholders. This move is defined to be the creation and execution of a document that reflects the outcome of such activities within the game. Agreements are primarily used during Open Negotiation sessions, but they sometimes prove useful during Toolkit sessions as well.

Toolkit options – These are a list of some of the many types of technologies, methodologies and policies that might be selected and pursued in the interest of promoting the use of industrial ecology and in achieving sustainability. The primary purpose of the list is to serve as a “jump start” to the creative abilities of the players due to the limited game time available.

The players may select and invest in some of the Toolkit options that are important to their strategies. Players may also create new Toolkit options (see Toolkit section of appendices). Solicitation of support for selected options from other teams may be important to their success. Toolkit investments must be completed prior to the end of the designated session. The Toolkit session results will also be used as a metric to evaluate team interests. These interests are assumed to be aligned with the stakeholders represented by each team. The Toolkit budget for each team, which can only be used during the Toolkit session, is proportional to a qualitative estimate of the discretionary funds available within the organizations represented by the team in real life.

Each Toolkit item listed in the Handbook has been assigned a "price," which is the designated amount that will provide a 50% probability of being activated. No option has a 100% chance of success (activation). A variable is introduced into the process of Toolkit option enactment by the use of a computer probability program (electronic "dice"). This is used to introduce an element of speculation and chance into the game, and to represent real-life uncertainties. A cumulative, minimum investment of one half of the listed price is required (total of all teams). Teams can enhance the probability of activation of any selected Toolkit item by increasing the amount of money allocated to it.

Teams should invest in areas important to their goals or strategies (negotiation allowed).

Agreements – The “agreement” move in the game is a completed contract which represents investment decisions and inter-team agreements. These decisions or agreements are recorded on standard agreement forms. In general, agreement moves are made during the open negotiation sessions. However, they may also be used during Toolkit sessions in order to document player-generated Toolkit options (other than those listed in the Handbook), or for documenting inter-team agreements (relative to Toolkit items) concluded during Toolkit investment portions of the game.

Agreements between multiple teams must describe the value received, include any required “resources” (e.g., chits), and be approved and signed by each negotiating party. Agreements must also be submitted to the Control Team for final acceptance and approval. The most important test for any move (action, agreement, contract, partnership) is its reasonableness evaluated from the perspective of the real world. This test does not discriminate against creative or innovative thinking, but is intended to discriminate against fantasy. Open negotiation sessions should produce agreements that are based on quality, valid negotiations, and partnering or strategic alliances.

The concept of resource scarcity will be modeled by introducing a limited number of "chits" into each session, but with each team receiving a different selection of “colored” money. The color-coded chits will be used to represent not only money, but other intangibles like technology and political influence. Agreements will generally require the use of a variety of chit-types in order to be successful. Since the colors and quantities are not distributed equally, but rather in a semi-quantitative manner that reflects real life, partnering will be required to execute most agreements. Teams unwilling to pursue alliances or partnering to create agreements will find themselves isolated and generally ineffective in making any progress toward their strategic objectives.

Team money – Team resources are allocated in two categories. One category, called money, is designated to be used only in a Toolkit session. The second category is a mix of "chits" that may represent money, technology, political influence, and regulatory/legislative action. Chits are for use during the Open Negotiation sessions.

Other moves – disputes and lawsuits. All disputes will be resolved by the Control team, whose decisions are binding. Lawsuits can be filed at any time by any team. An odd number (at least 3) of judges must hear the case. After both sides have presented their arguments, the judges decide by majority rule. Judges' decisions are final and binding. Litigants must appear before the judges at their scheduled times. If one litigant is one minute late, a judgment will be immediately rendered in favor of the litigant who is present. If both litigants are five minutes late, the case will be dismissed; the litigants will need to reschedule their court times.

Schedules and appointments – It is essential that all players strictly follow the agenda and be on time for their appointments. Penalties can be assessed for players or teams that are late.

Winning the game – The game is "won" by successfully meeting the challenges and objectives embraced by one's team. Circumventing or "gaming the game" is not winning, desirable, or of benefit to the other players. Players should seek to accomplish their goals by following the most realistic alternatives available within the constraints of the simulation. The most successful moves will be those that are consistent with the established team strategy.

Strong feelings are a natural product of stakeholder interests and perceptions or paradigms and is, therefore, an important ingredient of the game. Emotions fuel and motivate players. The game process can elicit deep emotions. The surfacing of deep-seated stakeholder agendas and key areas of stakeholder protection into game play – wherein they can be further articulated and discussed in a safe environment – can result in a new consensus where all stakeholders benefit from newly formulated strategies relevant to real world situations. **This constitutes the real win.**

Game Scoring and Metrics:

Several forms of assessment will occur during the game. The players will assess completed agreements, selecting a "winner" after every Open Negotiation session. The teams will assess themselves against how well they met their stated objectives and the perceived impact they made on the future. And finally, they will be assessed by the Prosperity Game™ staff on the basis of investment impacts on selected global, national, and local sustainability indicators. In general, "winners" are those teams whose actions and decisions have benefited future generations and the teams' constituencies. However, some specific awards will be presented to the winning team(s) on the basis of the peer voting.

Industrial Ecology Game Schedule

This Prosperity Game™ is organized around an orientation followed by six sessions that define the play. A summary of the play is provided in Table 1. A detailed game schedule is provided in Appendix B, Part 3. The play runs from the present to the end of 2006. On the basis of play times, this represents a compression ratio in excess of 4000:1 (1 game minute ~ 1 week). This naturally means that many aspects and issues will be treated very approximately.

Session 1: Planning session.

This session focuses on strategic planning and organizing your team to best deal with the coming events. The session activities will be initiated with a panel discussion which will help focus players on industrial ecology issues that should be considered during game play. Teams will decide on ground rules for making decisions, decide who will play what roles on the team, assign responsibilities, and initiate processes for accountability and correcting errors. Outstanding questions about the game should be resolved. Teams will review their current states and decide where they would like to be in the year 2006. Players will discuss the challenges provided in this handbook and modify or supplement them with others of their choosing and prioritize the list. Team members will review the detailed descriptions of their team and other teams. Team strategies, objectives, and final, prioritized team-specific challenges must be submitted to the Control Team at the close of this session.

Session 2: Toolkit session.

The session will start with allocation of team specific Toolkit resources. Teams focus on the list of Toolkit technology and policy options, and determine how to invest their limited resources. Most Toolkit options will require partnering among teams in order to yield higher probabilities of success. All Toolkit investments using allocated Session 2 resources must be made by the close of the session.

Teams are responsible only for their own Toolkit investments. However, they are encouraged to discuss pooling their resources with other teams to increase the likelihood of success. Those discussions can be informal or formalized by an agreement between two or more teams. However, the Control Team will only acknowledge each team's individual Toolkit submission.

After Toolkit investments are made, teams must use realistic processes for developing and marketing desired technologies and policies. No Toolkit resources can be carried over for use in executing agreements. Agreements may be drafted from scratch, or they can be further development of Toolkit options that were unfunded or previously unsuccessful.

Session 3: Open negotiation session.

This session will begin with the announcement of successful Toolkit options and distribution of team resources (resource carryover to Session 4 NOT allowed). New agreements can build on the successful Toolkit options (e.g., technology developments). Policy changes that impact play will also be incorporated into the game. Champions of particular technologies and policies should pursue the agreements necessary to bring their ideas to fruition.

Session 4: Open negotiation session.

This session will begin with the allocation of new resources. Teams should continue to pursue their strategies by executing and partnering in agreements.

Session 5: Open negotiation session (w/ plan update).

This session will be preceded by a summit meeting that will focus on selected IE issues as they arose in the previous day's play. Active play will begin with the allocation of new resources. Each team should briefly review its planning document for possible revision based on previous play and the results of the summit. All updates are to be submitted to the Control Team by the close of this session. Play should continue as in sessions 3 and 4 though the use of agreements that build on all earlier successes.

Session 6: Debriefing session.

Facilitators will debrief each team, and deliver the results to the Control Team. The debriefing should address: (1) how well the team met its specific challenges and strategic objectives; (2) what impact the team had on general challenges; (3) speculation on the future state of the world based on overall game play; and (4), discussion of potential follow-on activities. Following the team debriefings, the teams will vote on how well all of the other teams did in embodying the principles of IE, with results to be used in making team awards. The session will conclude with final game evaluations through use of electronic polling and written responses, and a town meeting (each team is responsible for selecting a primary spokesperson).

Note: For further discussion of the game, see Appendix B, Part 1, Players' Handbook.

Table 1. Game Session Summary

	Phases of the Game				
Terms of Play	**Session 1: Planning**	**Session 2: Toolkit**	**Session 3: Open negotiations**	**Sessions 4-5: Repeat sessions 3**	**Session 6: Debriefing**
Definitions and staging information	Play begins with briefing materials (players should have read the handbook), perceived constituent interests, and player's expertise and knowledge, setting the stage.	"Toolkit" options are technologies and policies that help teams meet their objectives. Toolkit resources are based on relative stakeholder influences.	Agreements are records of negotiations, contracts, and investments among the stakeholders. Agreement resources are limited.	Play resumes after the Control Team updates the state-of-the-world based on the play in previous sessions.	Composite outcome of all game planning and moves is important for final assessment.
Team actions	Teams agree on team's vision, constituent interests, and posture vis-a-vis other teams. Develop decision-making processes and define roles and responsibilities for team members. Develop team challenges, strategies and objectives to meet teams vision for the year 2006. Copies of these plans are submitted to the Control Team.	Control team assigns resources to teams (which must be invested in this session). Teams assess provided toolkit options and generate alternatives, as needed, to pursue plans. Teams prioritize investments and turn in a Tookit Spreadsheet with final allocations.	Control issues new resources (to be used only in Session 3). Teams conduct negotiations and invest in agreements to build initially on all successful Toolkit options, and then on successful agreements, in order to advance their cause. Agreements may be submitted at any time during this session.	Session 5 planning: Each team updates its plan and submits revision. Negotiation sessions proceed in the same manner as in Session 3. New resources will be provided by the Control Team.	Each team undergoes a final debriefing. The debriefing addresses: 1) how well team met its plan; 2) impact of team on the general challenges; 3) speculation of impact of game play on the future state of the game world; 4) possible real-world follow-on activities.
Relationship to other teams	Team strategies and objectives may be synergistic or antagonistic.	Teams may partner with other teams to increase total investment in their preferred options. (Each still invests separately.)	Teams may partner with other teams to increase their influence in what agreements are pursued.	As in previous sessions	Vote assessing teams' performance. Final game evaluations through electronic polling and written responses.
Impact on Game	Play in the pursuit of team strategies and objectives determines the game outcome.	The success and failure of Toolkit investments determines the extent to which team objectives are met by the players.	The agreements funded determine the extent to which team objectives are met by the players.	As in previous sessions	Important for final assessment and report, and for initiating follow-on activities.

RESULTS AND OBSERVATIONS

Game Play

In order to help summarize and interpret the 101 game moves (TKOs and agreements) made during the IE Prosperity Game™ they were grouped into eighteen different topical areas. The topics themselves arose from an evaluation of the moves, and did not represent any set of preconceived ideas. The topics were then further grouped into four primary topical headings. Different analysts with a different mind set could generate a variation on the resulting list. It should also be recognized that there is crossover between topics by many of the broader agreements (both in terms of content and support). However, all of the moves were forced into a single topic for the purpose of this summary. An outline based on the resulting categorization follows, along with applicable data in Table 2.

1. Economics
   - *advisory*–evaluation and rating of corporations, projects, investments, grants, and policies with respect to environmental performance and sustainability using IE principles.
   - *financial* programs & incentives–promote IE through revised procurement regulations, expanding the scope of existing funds and establishing new ones, creating a voucher system, risk reduction legislation, environmental accounting, full-cost pricing, and consortia work to improve performance. (Additional incentives not included here were contained within the scope of some of the tax legislation.)
   - *taxes*–reduce environmental harm by encouraging such things as: reduced wastes, energy consumption, use of virgin materials, and carbon fuels; and investment in alternative fuels, pollution-reduction technologies, and IE.
   - *other economic*–develop a new economic indicator and establish an environmentally conscious economy.

2. Programs
   - *waste reduction*, including reuse and recycling—organizational, policy and regulatory reform; R&D including exploration of the use of nano-technology.
   - *infrastructure*–a complete restructuring of the nation's transportation, communications, power, and public utility systems including the necessary R&D.
   - *biology*–food production and toxicology studies.
   - *ecosystems*–implementation of ecosystem ideas primarily at the community rather than industry level.
   - *energy*–other government Acts and technology initiatives to reduce use of carbon-based fuels (see also *financial* and *taxes*).
   - *industrial ecology*–"Let's do IE." IE related R&D, including exchange programs, endowed chairs, virtual systems, and consortia.
   - *standards*–updating and implementing ISO 9000 and 14000 standards to include IE principles and methods.

3. Education
   - *information* dissemination–use of data collection, databases, Internet, exchange agreements, and World Conferences to exchange IE-related information.
   - *consumer* education–use of seals, labels and advertising to inform the general public on the life-cycle impact of products.
   - *formal* education–teaching IE concepts in schools and organizations.

4. Civics
   - *regulations*–reorganization and reform to promote better environmental performance using participatory decision making, compliance through voluntary programs, and IE tools. Compliance elevated to global rather than national level.
   - *security*–national security paradigm modified to include environmental threats.
   - *society*–programs to protect minorities, women, cultural diversity, and displaced workers.
   - *environmental*–habitat restoration and greenhouse gas reduction.

Table 2: Game move summary data by topic

Topic	No. moves	No. successes	Credits invested	Chits invested	Participants	Sessions
Economics						
advisory	9	8	200	21	11	2,3,4,5
financial	15	12	605	48	12	2,3,4,5
taxes	10	3	210	9	4	2,3,4,5
other economic	2	2	195	6	4	2,4
Programs						
waste reduction	6	3	230	10	9	2,3,4,5
infrastructure	3	2	110	9	6	2,3,5
biology	3	2	0	12	7	3,5
ecosystems	6	5	0	32	9	3,4,5
energy	4	2	0	12	5	5
industrial ecology	9	7	330	25	10	2,3,4,5
standards	3	2	10	4	4	2,4
Education						
information	7	5	335	15	8	2,3,4
consumer	5	4	0	14	8	4,5
formal	8	6	380	13	10	2,3,4,5
Civics						
regulations	5	3	265	10	5	2,3,5
security	1	1	0	6	5	4
society	3	2	0	8	6	3,4
environmental	2	0	30	0	2	2,5

To assess the **relative** degree of importance of these different topics to the players of the IE game, a means of scoring the moves in each area is required. (Don't place too much interpretation on the absolute values of the scores.) For this purpose, the importance of any one topic may be estimated by:

1. investment of "money" ("i" represents both chits and credits)

$$\alpha_i = \frac{invested}{total}$$

2. number of moves (investment of time and "energy")

$$\beta = \frac{moves}{total}$$

3. number of teams participating

$$\gamma = \frac{teams}{total}$$

4. number of sessions or duration of the interest

$$\delta = \frac{sessions}{total}$$

The final score for any one topic is then given by:

$$\sigma = \alpha\beta\gamma\delta$$

The results of this scoring are provided in Figure 2. The topics have been sorted by score for comparison purposes. (Using a final score that is the sum, rather than the product, of the individual terms retains the same "quartile" ranking; individual topics may shift places with a neighboring category.)

Comparison of the scores between topics clearly indicates that the most prevalent concern among the teams was how to fund and make IE pay (*financial* with a score of 0.055). This concern was further bolstered by some of moves in the *taxes* category.

Second on the list appeared to be a concern over implementing IE through widespread use of integrated R&D (*industrial ecology*--0.015), decision-making (*advisory*--0.011), and educational (*formal*--0.011) programs.

All other areas had a score of one or more magnitudes lower than the *financial* category.

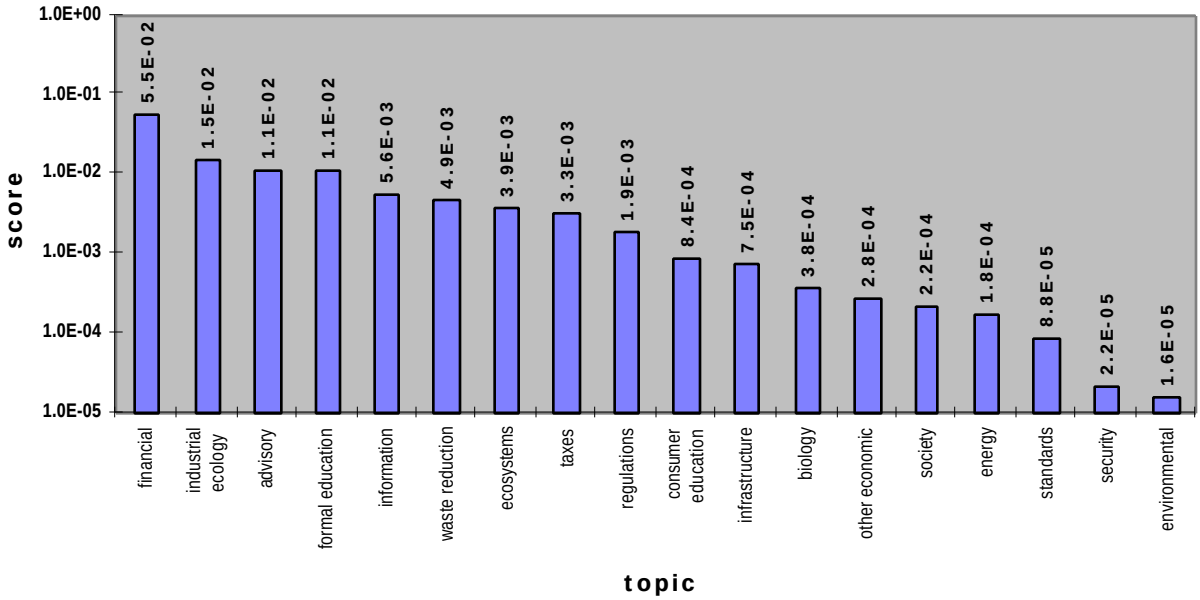


Figure 2. Scoring results for game moves by topical area.

Note that, in general, the low-scoring topics primarily represented the challenges posed in the "State-of-the-..." appendices of the Players' *Handbook;* they received little explicit attention. As it was, much of this effort also took place in the last session after the players were chided by the game director for not having made any significant impact on these problems.

One way to interpret the focus of these moves is that the players were more interested in how to do industrial ecology (IE) than on actually solving problems with IE. Although not captured by the categorizing and scoring, it is also notable that one-third of the move descriptions explicitly called for formation of consortia, coalitions, joint programs or ventures, or similar entities. (Other moves clearly required it.) Although perhaps reading between the lines, this implies that the players also felt that partnering is a must if IE is to move forward.

FOLLOW-ON IDEAS

Suggested Follow-on Activities

Computer networking (36% of the individual responses)

- E-mail conference or ongoing facilitated seminars.
- Chat room for IE game participants.
- Post game status and results on web page. Include all game documents. Add links to other IE sites.
- Conduct a virtual game without meeting in one spot.
- Establish a computer internet connection with a discussion list focused as an IE resource.
- Set up list of information sources for current federal studies.

Follow-on IE-related Prosperity Games

- PG focused on implementing IE in a business setting.
- Adapt the game for University students to stimulate their ideas in IE (e.g., conduct an IE game among various disciplines at MIT).
- Conduct a game on "sustainable development" incorporating economic, social, agriculture, and pollution-prevention issues.
- Conduct a one-day seminar or game at the 1 year anniversary to assess how well the IE message, concept, and practice has moved beyond the game.
- Have a PG graduate follow-up game at which participants come prepared with real-deal proposals for group evaluation and development.
- Replay the game with Congress freshmen, manufacturing association representatives, etc.
- Devise a version of the IEPG for emerging or third-world countries.
- Run them in high schools (Set up dungeon master) using local issues. May have to limit to specific class (e.g., chemistry).
- Mainstream it. Get local kids and parents involved to deal with an issue. Perhaps a series of short games rather than one long one.
- I will explore the use of games within my company with Managers.

Partnering

- Lots of networking and bonding occurred with some players - a number of teams stated that they will maintain their contacts
- Work some of this info into NREL interaction
- Will try to work consortia concept; should tie to existing consortia
- Will implement concepts with current Federal clients (e.g., DoD)
- "I will rethink the role of the Labs in our company."
- I will encourage EPA to broaden the stakeholder group
- I have more respect for the individual values in the international community to be used in my global business decision-making.
- I will bring the Yale team into my business as a resource for system training.
- Pursue more partnerships

Education

- Teach “Green” cost-accounting at Universities
- Develop IE curriculum for Universities
- Develop IE science tools to involve students at an early age (DARE as an example)
- Build public and government awareness and support for IE. Create stakeholder awareness through dispersed conferences and workshops involving all elements of society. These would grow to national and then international conferences.
- Consumer awareness with a Madonna tour called "Re-Use Material Girl."
- Develop materials so that businesses can educate their customers.
- Develop materials that can be used at home with family.

Develop follow-ons from the major or significant agreements completed in the game.

- Information system [FIA-02], T-1, [metrics] P-12, and Joint Pricing concepts. Analysis will set priority.
- Get some of the game's laws/acts refined and passed by the real Congress.
- "Green" cost accounting
- Voucher scheme follow up
- Biotechnology partnering agreement and other initiatives to enhance biotechnologies
- Sustainable communities project
- PNGV
- Bioremediation
- Agriculture

Other

- Network the technical community with real community sustainability programs to formulate an IE R&D agenda.
- Form an IE association based in Washington to promote IE with the federal government.
- Prepare and distribute IE presentation material which could be used at associations and business meetings, economic forums, etc.
- Want to bring the DC-based people together that are looking at materials flows to look at IE.
- Finding a private company to drive the construction of a model Eco Park
- Factor IE considerations into federal R&D.
- Host a Washington area meeting of the players for a briefing on "real" efforts -- President's Council on Sustainable Development, Interagency working groups, etc.
- Support an IE Institute (non-profit, educational).
- The Allenby quote "Ignorance is profound." I will share with my clients the humility of experts and hope to prepare a paper with my clients on the difficulty of incorporating these concepts.
- Someone is needed to nurture follow-on activities and avoid the IE knowledge vacuum.
- Have a follow-up meeting with respect to an R&D consortium.
- Define, document, and distribute the IE market advantage for real life businesses.
- Share what we learned here with industry sponsors that work with the labs.

GAME EVALUATIONS BY PLAYERS

Specific Objectives

The Industrial Ecology Prosperity Game was designed around four specific objectives; these were to:

- "develop [in the players] an understanding of what industrial ecology is"
- "develop an understanding of how industrial ecology can help meet the needs of the stakeholders and the nation"
- "explore the role of government in an integrated industrial ecology effort"
- "identify and initiate follow-on activities to promote findings and policies generated in the game"

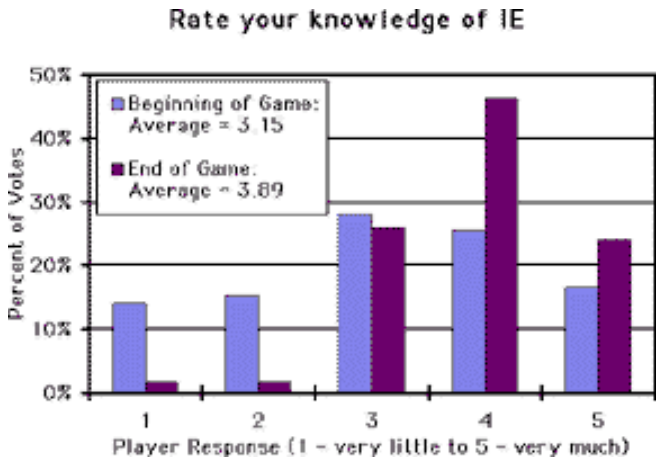
Players' responses to polling questions indicated that the majority of players felt that their time had been well spent and that these game objectives had been met. Game participants were polled for their responses to several questions both before and after the game as a way to help evaluate how the game met certain objectives, and to measure their attitudes and any change that might have occurred over the course of the game. The scale used for each of these questions was from 1 = very little to 3 = neutral to 5 = very much. These questions, along with the mean pre- and post-game responses, are given in the table below (only the changes in questions 1 and 4 have much statistical significance).

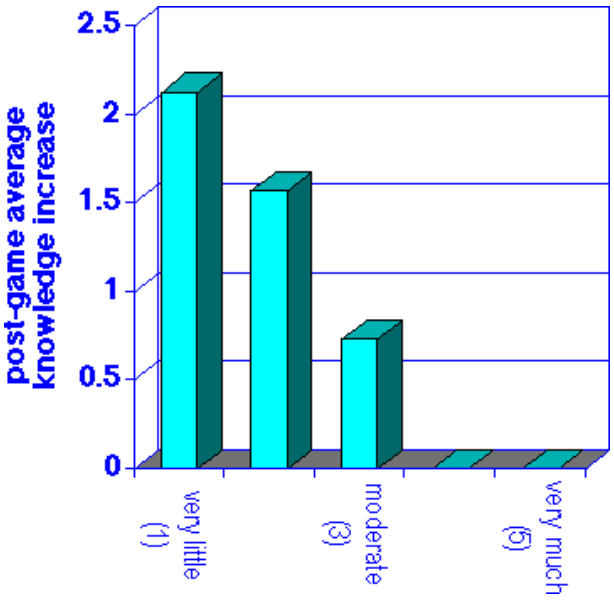
Pre- and Post-game Responses to Selected Questions

	Question	Mean (pre-)	Mean (post-)	Difference
1	Rate your knowledge of Industrial Ecology.	3.15	3.89	+0.74
2	Rate the importance of IE to your professional life.	3.67	3.64	-0.03
3	Rate the importance of IE to your personal life.	3.49	3.39	-0.10
4	How much should the government be involved in promoting an integrated IE effort?	3.73	3.89	+0.16
5	How much would you personally be willing to do to promote IE concepts?	3.97	3.88	-0.09

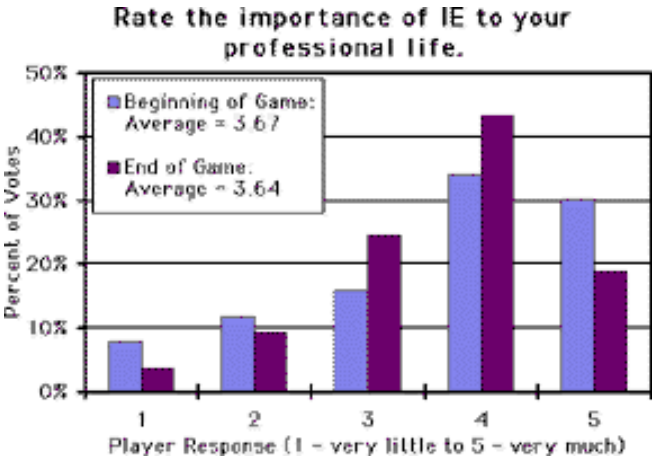
Additional details of the responses to these questions are provided below.

1. Rate your knowledge of Industrial Ecology. The responses to Question 1 regarding the players' knowledge of IE is of particular note (see the first graph). The combination of game preparation and play served to provide a large boost in the players' knowledge of IE. (A similar shift was observed in the prototype game.) The change is even more impressive when it is realized that the upper-half of the population (votes of 3, 4 and 5) did not change their vote; the dramatic shift in mean population knowledge came about because the lower-half of the population (votes of 1, 2, and 3) felt they had learned a lot about IE in the game. (The "lower-half" population, considered on their own, exhibited a shift of almost 2 points; see the second graph.)

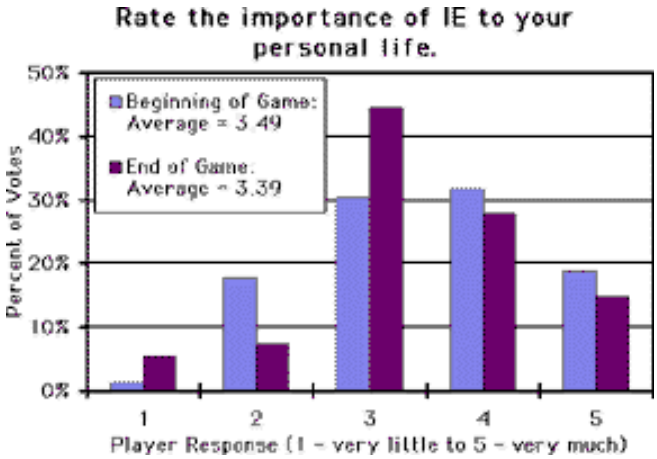




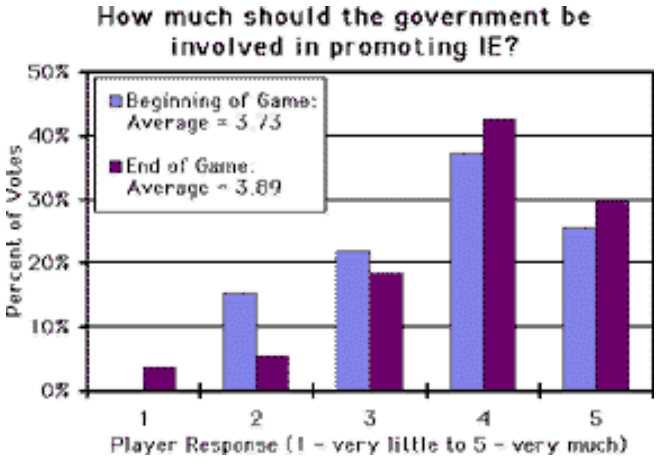
2. Rate the importance of IE to your professional life. The observations made for Question 1 are supported by the results of Question 2, where just over 60% of the players stated that Industrial Ecology was important (voted 4 or 5) to their job. It would be expected that if something is important to your career, you would learn what you could about it. (The small change in the average score from pre- to post-game is not statistically significant.)



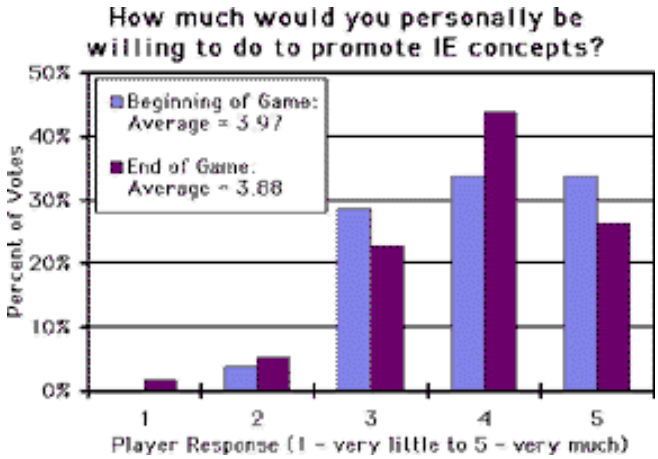
3. Rate the importance of IE to your personal life. It was interesting to note that almost as many people felt that IE was important to their personal life as those that said it was important to their professional life.



4. How much should the government be involved in promoting an integrated IE effort? The third game objective sought to "explore the role of government in an integrated industrial ecology effort." Responses indicate that most people feel that government should be involved in promoting and directing IE efforts (score = 4). Additional information on how or in what way can only be suggested by post-game analysis of the actual moves made during the game (interpreted as reflecting the players' areas of interest and the perceived importance).

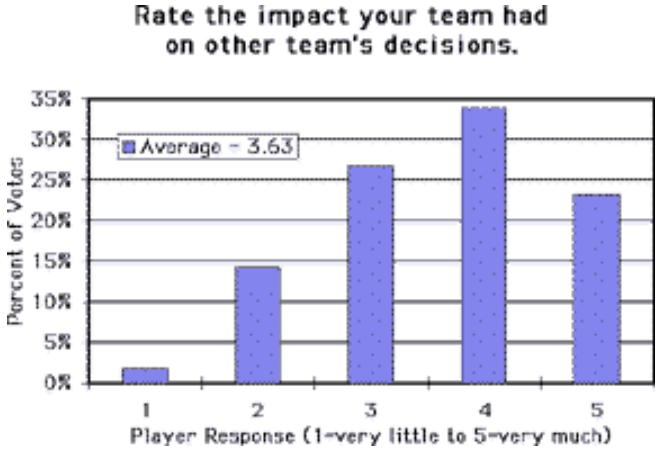


5. How much would you personally be willing to do to promote IE concepts? The fourth game objective was to "identify and initiate follow-on activities to promote findings and policies generated in the game." Capturing ideas for potential follow-on activities was accomplished in the game through player evaluation forms and staff reports. However, polling responses indicate that many people would be willing to participate in the follow-on efforts (score = 4).

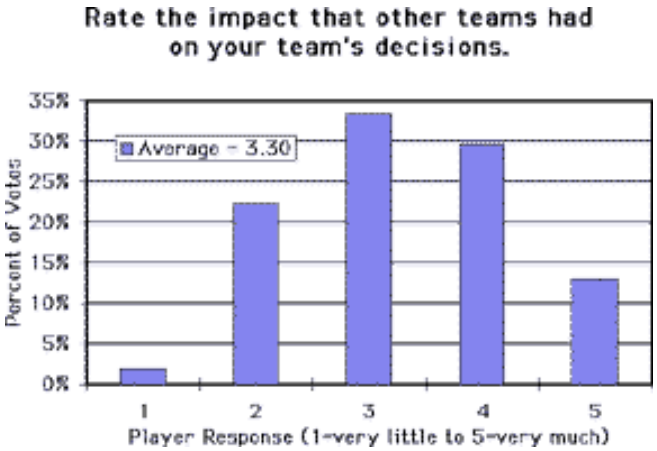


Other Specific Game Play Questions

6. Rate the impact that your team had on other teams' decisions. Most players felt that they had a definite impact on the decisions made by other teams (score = 3.6).



7. Rate the impact that other teams had on your team's decisions. At the same time, they did not think that they were as heavily influenced by the actions of other teams (score = 3.3).



Results for Standard Prosperity Game Polling Questions

A standard set of questions used to assess Prosperity Games was answered by the participants during the last session of the game. These have been useful in assessing both game design and conduct, as well as the attitudes of the players. Mean responses for these questions are compared to those from previous games in the table below. The scale used for each of these questions was from 1 = very little to 3 = neutral to 5 = very much.

Noteworthy among the results for the IE game (last column on the right) is the response to the fourth question: How well did the game accomplish the sponsors' objectives? The mean response of 3.58 is the highest that has been received when compared to other 'final' games with comparable scope (the University game was very different in design and scope), and indicates that the players felt the sponsors' objectives were sufficiently met by the game. A relatively high score was also received with regard to the game stimulating thinking on future technology and policy. High scores were also given regarding the game maintaining enthusiasm and being worth the time spent, indicating that the players felt that their involvement was worthwhile and in harmony with the objectives.

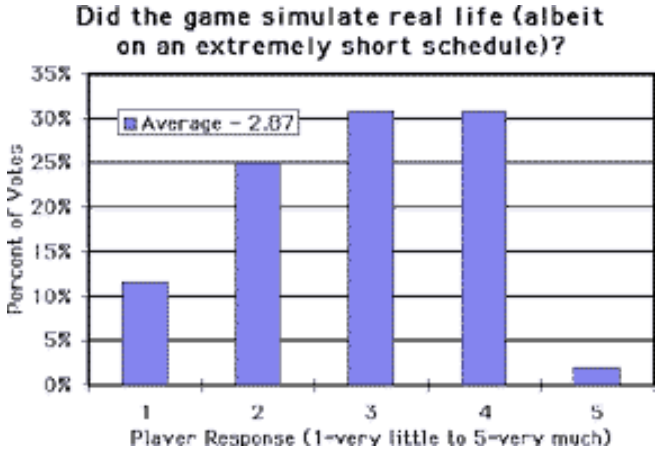
Comparison of Prosperity Game™ Evaluation Polling Results

Question and average responses by game	EIA	AEA	Adv. Mfg.	NEMI		ENV		Univ	BIO MED		DOE Labs		IE	
				prot	final	prot	final		prot	final	p2	final	prot	final
Rewarding experience?						3.91	4.17	4.32	4.18	4.40	3.86	3.87	3.92	4.06
Simulate real life?						3.49	3.63	3.94	3.57	3.40	3.21	3.33	3.12	2.87
Broaden perspective/new ideas?						3.85	3.38	4.19	3.79	4.42	3.65	3.53	3.46	3.93
Accomplish sponsors' objectives?						3.51	3.43	3.80	3.58	3.49	3.12	3.33	3.09	3.58
Meet your objectives?						3.57	3.61	3.77	3.93	4.02	3.60	3.58	3.40	3.62
Maintain interest and enthusiasm?			4.29	4.61		4.02	4.02	4.27	4.24	4.28	3.89	3.96	3.98	3.93
Stimulated thinking on future technology and policy?	4.07	3.68	4.29	4.64	3.83	3.56	3.37	3.84	4.14	4.43	3.56	3.73	3.80	3.85
Facilitated understanding of roles and relationships (develop relationships among players)	(3.33)	(3.05)	3.53	3.46	(3.94)		3.64	3.93	3.76	3.95	3.68	3.51	3.46	3.56
Long-term thinking and planning?	4.02	3.68	3.59		3.89	3.02	2.69	3.52	3.57	3.55	3.34	2.87	3.02	3.26
Laid foundation for industry to make tech road map (How valuable would a road map be?)	3.70	2.42			3.38				(4.30)	(3.79)				
Would you play a full 2-day game with peers?	3.74	3.95	3.82			3.78			3.80					
Worth the time spent?							3.71	4.32		4.00	3.91	3.70	3.98	3.94
Recommend that others play full 2-day game	4.31	4.16			4.36	4.13	3.86		3.90	4.30	3.77	3.69	3.80	3.91
Played assigned role effectively?	2.96	3.11	3.82			3.89	3.93	4.00	4.10	3.93	3.60	4.08	3.83	3.81
Players controlled the content?	4.38	4.42			4.59	3.66	3.66	3.94	3.75	3.46	3.76	3.89	3.89	3.76
Expert Panel discussion														3.67
In-game feedback														2.63
Format of the games	3.31	2.68		3.61	4.25	3.72	3.73	3.29	3.76	3.71	3.56	3.65	3.48	3.84
Innovator decision aid	4.12	4.05			3.38									
Players' Handbook	2.87	3.00			4.29	3.73	3.91	3.03	3.37	3.64	3.07	3.77	3.55	4.31
Prosperity Games staff helpfulness/effectiveness?	4.09	4.53			4.79	4.49	4.88	3.94	4.67	4.86	4.31	4.64	4.38	4.72

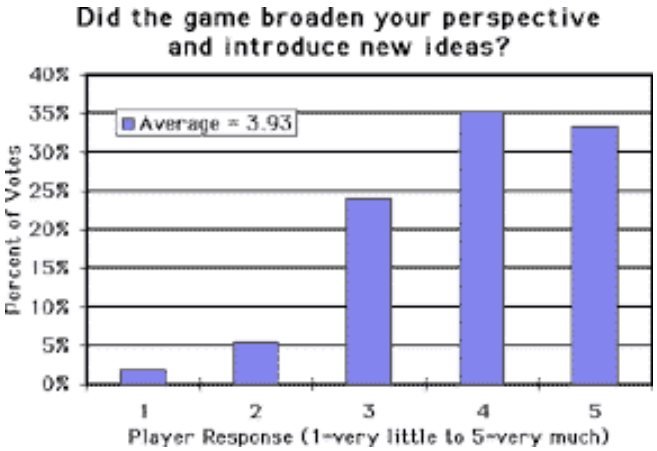
Additional details of the responses to these and several other questions are provided below (note that the numbering scheme used in the game restarts at one for this question set).

1. Did you have a rewarding experience? Almost all players had a rewarding experience, with 80% voting a 4 or 5. With an average score of 4.06, the IE game was average in this area compared with the other games played to date. Three people were evidently dissatisfied with the game, and voted a 1 or a 2.

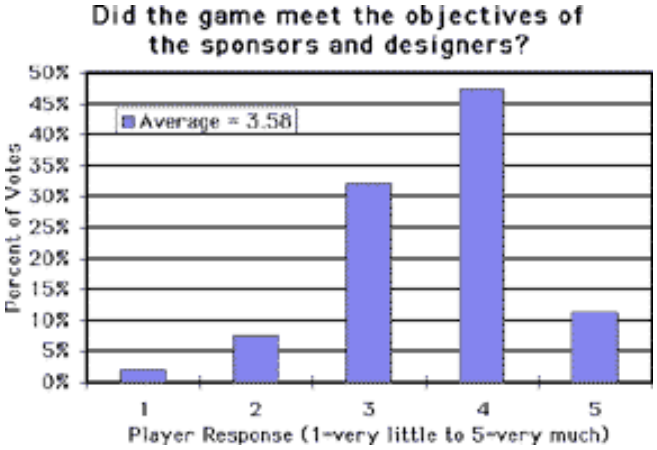
2. Did the game simulate real life (albeit on an extremely short schedule)? Although it is not clear from the written comments as to why, this polling question clearly indicates that the players did not think that the IE game succeeded very well at conducting a simulation of real life. The average score of 2.87 was the lowest score received in this category for any game.



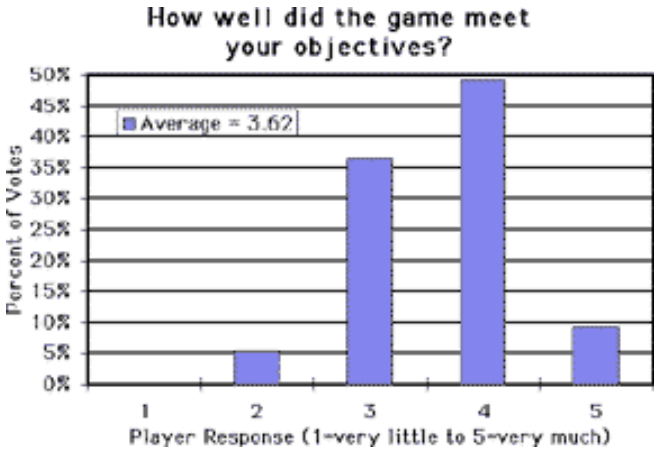
3. **Did the game broaden your perspective and introduce new ideas?** 60% of the players felt that the game broadened their perspectives much or very much (4 and 5). The average score of 3.93 places this game into the top third in this category.



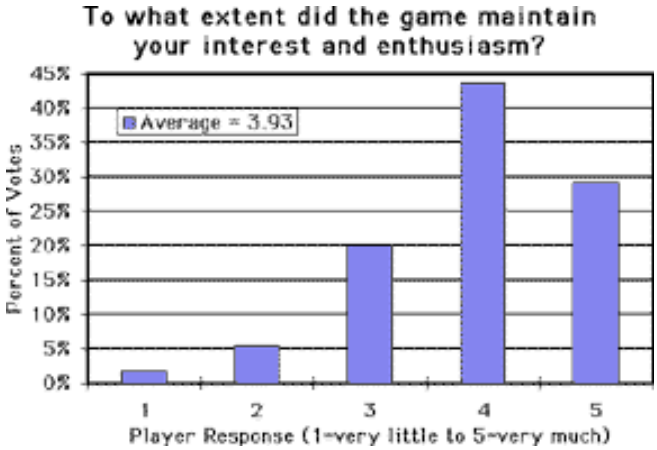
4. How well did the game accomplish the objectives of the sponsors and designers? 60% of the players felt the game accomplished the sponsors' objectives well or very well (4 or 5). One person felt that the objectives were very poorly met. The average score of 3.58 was very high for this category, being exceeded by only one other game.



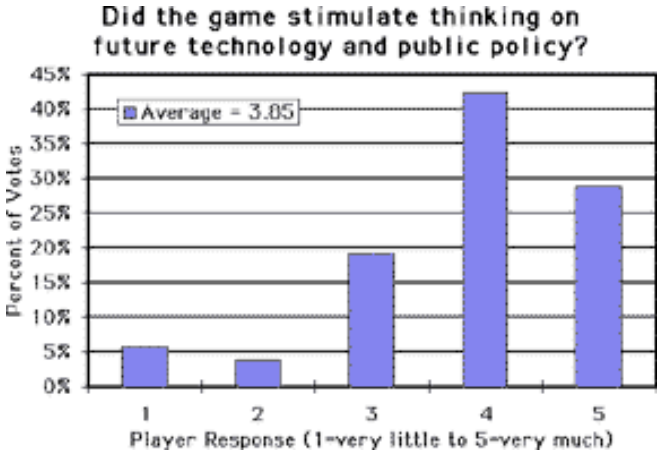
5. How well did the game meet your objectives? The results for this question are very comparable to the answers received for meeting the sponsors objectives. This is not always the case.



6. To what extent did the game maintain your interest and enthusiasm? 74% of the players felt the game maintained their enthusiasm well or very well (4 or 5).

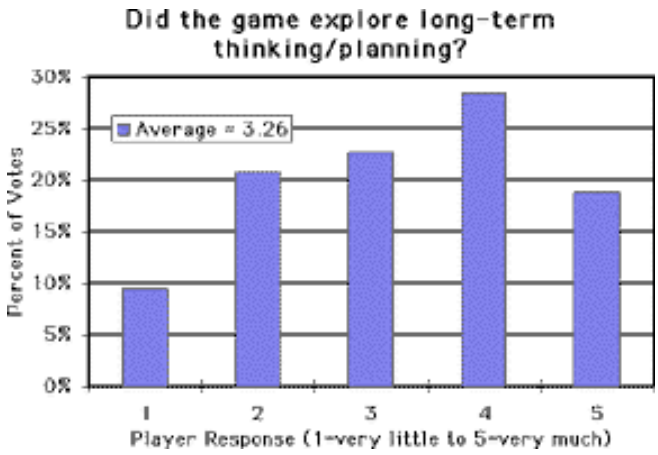


7. Did the game stimulate thinking on future technology and public policy? The game was effective at stimulating thinking on future technology and public policy; with an average of 3.85, this game placed in the top third of previous game scores.



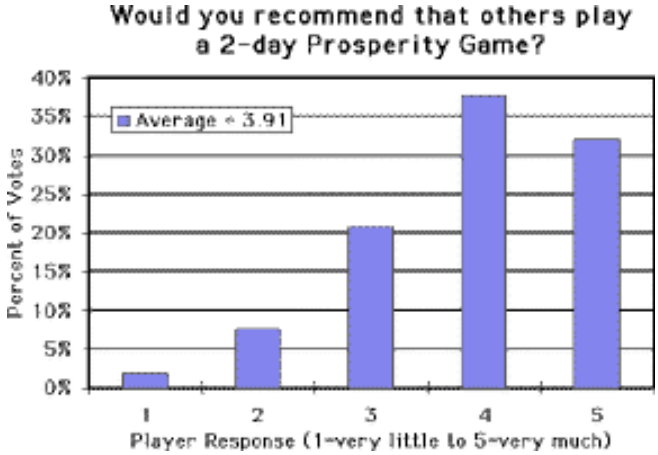
8. Did the game help you understand the roles and relationships among players? Understanding of the roles and relationships of the many stakeholders was improved as a consequence of the game, with an average score of 3.56.

9. Did the game explore long-term thinking/planning? Long-term planning was explored well or very well for 47% of the players. 30% felt that this exploration was poor or very poor.

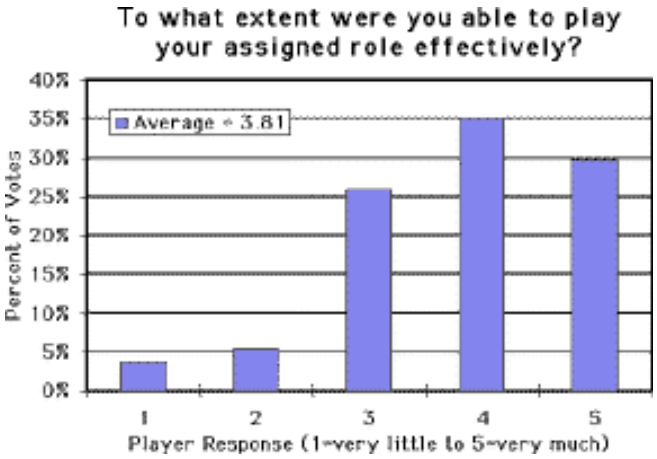


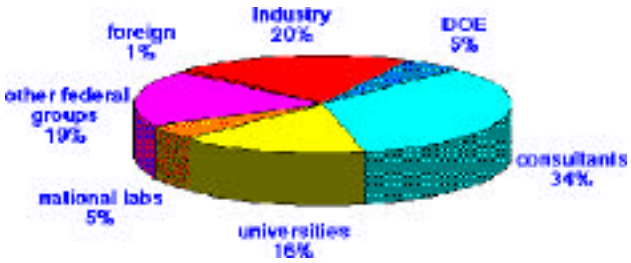
10. Was the Prosperity Game event worth the time spent? 75% of the players believed that the event was well worth the time spent (4 or 5).

11. Would you recommend that others play a 2-day Prosperity Game? The majority of all the players would recommend a similar game to others, with an average score of 3.91.

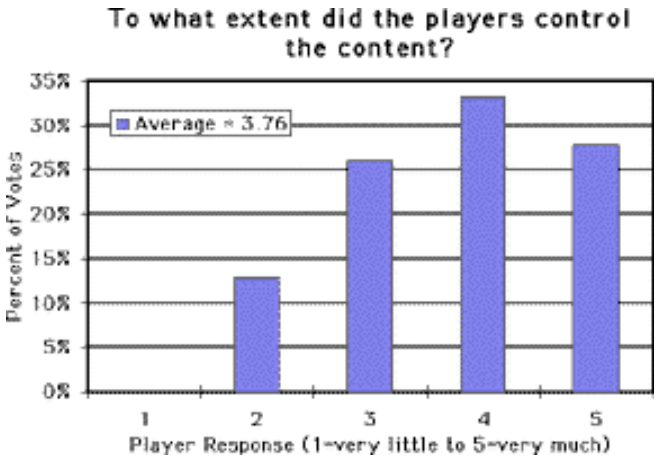


12. To what extent were you able to play your assigned role effectively? Most players felt that they were able to play their assigned roles adequately (see first graph). 9.4% said that they had some difficulty. The average score of 3.81 places this game next to the bottom quartile in this category. Part of the problem may have been due to the preponderance of players that were consultants (34%; see second figure), which was unlike any other Prosperity Game.





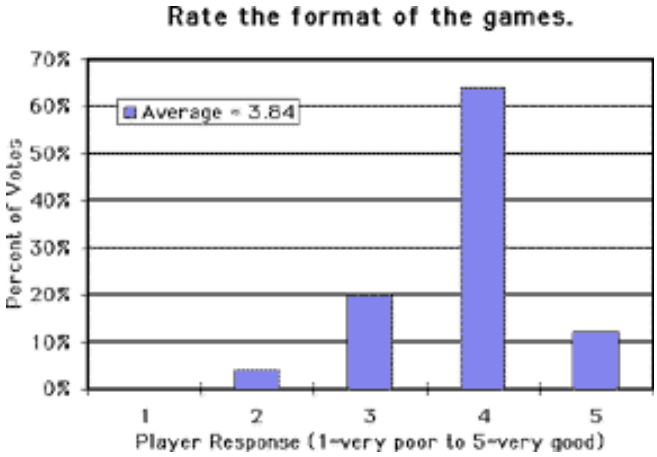
13. To what extent did the players control the content? Most players felt that they controlled the content; however, 7 players felt that their control was little.



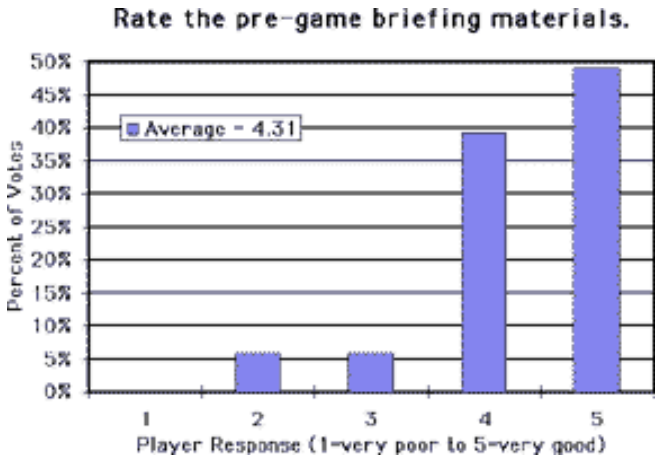
14. How useful was the expert panel discussion? The Industrial Ecology Prosperity Game was the first time that an expert panel was convened at the start in order to help provide an initial focus for the players. 57% of the players believed that the event was useful (4 or 5), while 11% did not (1 or 2). This response may reflect the pre-game IE knowledge level of the players (see Specific Objectives Question 1).

15. How useful was the in-game real-time feedback? This was the first game in which this question was explicitly asked, so there is no basis for comparison. However, in previous games written responses often complained of inadequate feedback. The road map, mind map, computer network, state-of-the world simulation, and mid-game assessments were all new efforts used in this game for the first time in an attempt to answer some of this criticism. The score of 2.6 for this question would seem to strongly indicate that this is still (and maybe always will be) an issue.

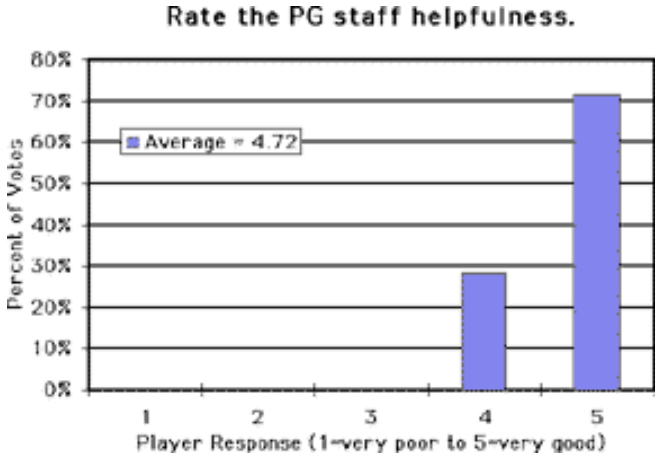
16. Rate the format of the games. 76% of the players rated the game format from good to very good (4 or 5). Two players rated the format as poor. The score of 3.84 is the second highest ever received in this category.



17. Rate the pregame briefing materials. 88% rated the pregame materials as good or very good. Three players rated the materials as poor. The score of 4.31 is the highest ever received in this category.



18. Rate the PG staff helpfulness. The players rated the staff very highly, with an average score of 4.72.



In summary, based on these player evaluations, this game was among the very best games conducted so far in the areas of: meeting the sponsors' objectives; broadening the players' perspectives; and in the overall game format. It was also ranked first in terms of pregame briefing materials. When all categories are considered and averaged together, this game was eighth out of fifteen with a score of 3.74 (all-game average of 3.78).

LESSONS LEARNED

General Game Comments

- The games were very good.
- Game was good and appeared to be true to life.
- Interesting, interactive, educational event.
- Helped me appreciate other people's positions.
- Very stimulating in paradigm-changing thinking about the future.
- Very enjoyable experience.
- An interesting method for conducting a focused workshop exercise, although it took some time to adjust to the method.
- This was a great experience. Interesting, fun, and got me thinking expansively about the subject.
- I was honored to have been invited to participate. It was a first-class operation all around.
- I couldn't help dwelling on the exercise as a purely academic experience -- implementation requires people in a position of influence.
- I did enjoy the game. The 1st day was difficult for me. The second day improved greatly.
- Excellent resource.
- Excellent personal experience.
- Great program!
- Very well managed.
- OVERALL RATING OUTSTANDING!
- Great game, lots of fun!
- It doesn't feel that the "war game" strategy lends itself well to topics that are so new and undefined.
- This was fun! I'm glad I could participate.
- Generally very positive.
- Enjoyed the experience very much. Networking happened on a large scale for me.
- I enjoyed the game. We got better (and were more effective) as time went on -- last day best.
- GREAT.

IE In the Game Context

- At times wasn't sure whether the game focus was IE or socialism.
- A pretty good consensus about what IE is about.
- I learned a lot about IE.
- This was a great learning experience -- from learning what everyone brings to the table to the dynamics of how agreements are made -- as well as how to apply IE in my field.
- I learned a great deal about IE from the written materials and the discussion with the team and game members.
- Positive - good learning experience regarding IE.
- The major problem with this game was a general lack of understanding of the IE field. This did not improve as much as it should have.
- I sense the underlying problem for IE is no focused sponsorship.
- The subject is interesting but perhaps not yet recognized by major elements of our society as an issue yet.
- IE an awfully large amorphous concept to game.
- In general, it was a very good learning experience. It has provided me with suggested ideas for: further reading; potential course development; and the possibility of incorporating "green accounting" concepts into the offerings provided by my business.
- Tremendous amount of learning.

Players

- Met some neat, smart people.
- Team-mate quality was very good and enhanced learning experience.
- A great opportunity to meet and interact with an interesting group of people.
- Very interesting folks -- a privilege to participate.
- Be more selective in choosing participants.
- Some teams did not have people with necessary experience.
- Excellent quality of team members.
- Enjoyable interaction with other players.

Stakeholders (Teams)

- Manufacturing should have had stronger representation (or more chit power) because they are both the problem and the solution to IE-related problems.
- It would have been better to have only one manufacturing group -- coordination between two added a degree of complication we had trouble dealing with in the time available.
- There was an over representation and over emphasis on consortia.
- Give more opportunities for formation of inter-group alliances.
- Needed more business teams. Game biased toward government entities.
- Problem solution set was rather constrained by game parameters -- that is, government, agencies and DOE labs were assumed and mandated to be players.
- Weighted toward research focus -- needed environmental groups to put pressure on FAR and others. Public group too diverse to focus on this.
- Consider including the NGO community for both US and Global communities.
- There seemed to be a weighting towards government employees and academics -- consider having a game with 60% private sector.
- Reduce the number of government groups and add a media group.
- The stakeholders need to be changed. The groups should be more international and other groups such as environmental groups, UN, etc., should be represented.
- DOE labs and Think Tank didn't need their own groups. Universities are NOT PRIMARILY technology providers, they're educators. Environmental advocates should have had their own group (not merged into Public).
- Universities' role in society was badly configured. Roles are perhaps less technology but more in influence (education, advice, service). The team quickly forgot who they represented and what their objectives were and focused only on the agreement.
- Need more teams representing regions/countries.
- Need to have more extreme groups represented (e.g., Green Peace). This would force more "out-of-the-box" thinking.
- Make sure the groups truly represent the designated constituents.
- Non-North Americans were particularly under represented.
- Cross-fertilization of ideas needed. Would suggest some mixing of groups.

Game Scenario/Focus

- The exercise was structured more around a technology/research agenda than I thought was appropriate. Not enough focus on the social/political aspects of actually implementing IE concepts in the real world as it will ultimately require ...
- Most issues facing implementation of IE at the community and local government level require social, economic and institutional change. Technology push will not drive it. The game was very biased toward S&T research.
- Needed "step function" wild cards in the games. For example: breakthrough in technology; war; successful cleanup of a city; etc.
- Use situation cards that reflect the "unknown" forces that shape the future: drought, climate change, war, etc.
- Once or twice a major event should occur -- global warming induced floods for example. This could be a "news flash."

Game Pace And Time Constraints

- Biggest problems are chaotic 11th-hour trading but may also add to game excitement.
- The hectic pace was not conducive to organized thinking, but that was OK.
- Needed more time to debate agreements. There should be less emphasis on new agreements and more on refining good ones.
- Insufficient time to discuss details -- that may defeat, however, the purpose of the GAME.
- Insufficient time allotted to really examine the IE posters.
- Need to optimize utilization of "common time" (e.g., plenaries, summit, mind mapping, etc.) -- not always efficient and effective use of time.
- The two sessions on Wednesday P.M. were too short to accomplish much. This raised a level of frustration with the game play.
- Inadequate time/opportunity to review all agreements (work of other teams).
- The frantic pace is both a plus and a minus. It forces generation and consideration of innovative ideas without getting mired in details, but doesn't capture the full effect of different stakeholder views because critical stakeholders don't have to agree to many agreements (e.g., the carbon/waste tax passed without real input or debate from the industrial group). In reality this can't happen.
- Some aspect needs to be added to address this. Maybe the pricing of agreements should require chits from specific stakeholder groups.
- Too many short time periods or steps interrupt significant strategy development and deal making.
- Consider a break during the first day to regroup and discuss relevant IE topics.

Summit And Plenary Sessions

- Morning plenaries were most interesting.
- The plenary sessions were stimulating.
- Additional summit meeting in PM of first day.
- Panel sessions were the most useful.
- The introduction from the "experts" was highly theoretical and little practical discussion.
- The "World Council" session was VERY good.

Chits, Pricing and Agreements

Chits were useful .

- Improve on pricing to add more realism; generally agreements came too cheaply.
- In general, agreements were priced too low. As a result, our team rarely had to make hard choices.
- Besides chits given to entire team, give each team member some to reflect the heterogeneity in group.
- Penalize teams for not spending all of their resources, or let them carry it over subject to outcome of "roll of the dice" (reflects chance that influential champion may die of a heart attack, Congressman's failure to be re-elected, government downsizes, etc.).
- Add a formal press corps that controls a large part of the influence chits.
- There seemed to be too few influence and too many technology chits in the whole ensemble.
- Material needs simplifying explanations of chits -- who has what and what their approximate value is -- that players can read before the sessions start.
- The agreements seemed easier that would otherwise be in real life.
- Some teams weren't believable as to what they agreed to versus what could be expected in the real world.
- Need more of a focus on innovation rather than negotiation. Too much time wasted on the game and not enough on the topic.
- Speed up approval process for agreements. Integrate intranet into the process.

Toolkit Options

- Toolkits stifled creativity rather than sparked it -- groups need no preconceived notions of solution.
- TKOs restricted creativity -- should have focused on a specific IE project.
- No formal connection between toolkit options, the success in getting them, and the rest of the game.
- Game would work better with a more free-thinking development of the game path. The toolkit options obstructed people from creative thinking.
- The toolkit session was unnecessary.
- Need to rethink how toolkits concept is explained to the players and its impact in the game. For this game, its importance was not stressed enough.
- Significant disconnect between TKOs and agreements -- don't need TKOs.

In-Game (Real-Time) Feedback

- A measure of the impact of agreements needs to be part of the game.
- Need to reflect in game information revealed in real time.
- Little awareness of what happened due to agreements. Need more dependence on outcomes.
- Use Innovator during the game to poll results/feedback.
- Recap reports should be issued.
- Need more feedback on the impact of agreements that have passed as part of the game process.
- Improve real-time feedback.
- Give more feedback on how well objectives are being met.
- The purpose of the data on the flow chart was unclear.
- Need better electronic interaction. Need metronome for indicating elapsed time.
- The game needs to include mechanisms for feedback to players, mid-stream and final, from a fictional world upon which our actions had influence.
- Use of information from the web required too much time to extract. Need a display board categorized for easy reading. Having agreements typed was very helpful.
- Solutions (toolkits and agreements) should have an impact on the scenario in the next session. This is a quick response task for Control.
- Need more feedback in terms of changing baselines.
- Need state-of-world update after each session to show consequences of previous play.
- No sense of what effect actions (toolkits, agreements) we took had (example -- what effect did the energy tax we imposed made on energy consumption and the health of the economy).
- Not enough feedback on the effects of the bills passed.
- The use of computers was not effective in enhancing idea flows.

Game Materials

- Excellent quality of preparation materials.
- I wish it was more clear as to the requirement of having to read all of the background material -- which I could have done in two or three chunks rather than all at once.
- Need better instruction and definition going into the game, description of agreement roadmap.
- Moving from game to reality is difficult. It might be useful to introduce or layout what game playing is. After all, for many adults the value of game playing may exist only as a distant memory.
- Could benefit from more practical tutorial on game mechanics (e.g., funding process for agreements) to improve efficiency.
- Provide better context for rules of play (e.g., relative value of chits).

Environment

- Loud speakers were an annoying distraction from time to time.
- How about a chat room for participants?
- Central location for Control.
- Too noisy and confusing to develop real content.
- Use recycled photocopy paper in games -- walk the walk!!
- The walls seemed to inhibit exchange of ideas/cross talk between teams. The noise problem is preferable to seclusion/isolationism.
- Do the meeting virtually without meeting in one spot.

APPENDIX A: Game Play

PART 1: Expert Panel discussion

5/21/97 (Transcribed from video)

Panel Members:

Mak Dehejia, former Vice President of the World Bank Group
John Elter, Vice President, Strategic Programs-Office Document Products Group, Xerox
Brad Allenby, Vice President, Environment, Health and Safety, AT&T
David Rejeski, Executive Director, Environmental Technology Task Force
Marian Chertow, Director, Next Generation Project, Yale Center for Environmental Law and Policy
John Ehrenfeld, Senior Research Associate, MIT Center for Technology, Policy and Industrial Development

Questions:

Why are you interested in industrial ecology? Are you actively working in IE?
What areas of application do you see as the most valuable?

8:00 a.m. Introduction/Opening Comments by Kathleen Schulz

We will ask everyone to address something in the spirit of Q 1, which is really an introduction question.

1. Why are you interested in industrial ecology? Are you actively working in IE?

The purpose of this panel discussion is to get us on the IE wavelength, hear points from various sectors.

Mak Dehejia said he is recent convert. How come?

Mak Dehejia: Thank you Kathleen. You preempted my statement and I really don't belong to this distinguished panel, but I am a recent convert and, like all converts, have the passion and missionary zeal to want to change the world. I'll make some confessions here, but first I'd like to say how fortunate we are to be living in this age because if you look back in history, throughout human history we have tried to protect human beings against the environment, but it is now the reverse and we are trying to protect the environment against human beings. I think it's a marvelous time to be in and to be a convert. Asked the question what lead me to IE, and I hadn't really thought about it, but presume it's been all the past influences I've had during my professional career. And, thinking about it Kathleen, I can discern three factors. I first began my professional career some 40 years ago as a design engineer designing power plants, and machinery for power stations in England. Second, my first job happened to be in Manchester the city that considers itself the birth place of the industrial revolution. And third, in the various spots in the world where I have lived I noticed two trends, obviously the deterioration of the environment, and I also saw over my lifetime the reversal of environmental pollution by small actions. For instance, Washington used to have smog every August, but thanks to the catalytic converter and other minor things, the air is fairly cleaned up. On the contrary, New Delhi in India is a city where you have to duck into an oxygen tent just to survive. So I've seen these kind of trends.

Now, let me elaborate, why design? Looking at my job as a young engineer in Manchester, I was to evaluate American designs and European designs and come up with a better design for the British company to be competitive. Basically trying to optimize between the American design, which was material intensive, but very efficient on labor, and the Europeans who were very careful about the use of material, but did not mind spending a lot more time and energy on the production/process side. So this optimization was a classic industrial optimization, dollars and cents, product quality, and so on. Manchester--one saw in Manchester the effects of IE in the 50's (black city, a calypso song - city of the night in the middle of the day), and so on.

This transformation that I have seen--when I went back to Manchester in the 70's, I was delighted to see a cleaned up city. Thanks to the banning of coal fires. So those kinds of pollution solutions got me convinced that something could be done. Now the jump from pollution prevention to IE--how did that happen? Back to my design days. As I retired from active service in the World Bank, I said, what should I do now? Why don't we use some of these principles in the design of products, such as

minimize materials and energy use, maximize recyclability. In talking to a friend about it, he said, you are talking about DFE. About the same time I was introduced to Ernie Lowe and Ernie sent me a book called "The Source of Value." I call it the "Handbook on IE," and that did it, that convinced me that that is my mission for the rest of my life.

Brad Allenby, AT&T: What I'd like to do is tell you the kinds of things I'm interested in for two reasons, one is if you can look at this stuff and not be fascinated, it probably means you have some serious medical problems. The second is that that explains why I am interested. I'd like to give you an idea of some of the potential impacts of beginning to think in terms of IE because they are very profound and have significant employment, economic, capital, and investment implications. I think that's why I'm interested. I want to give you a couple of scenarios, because that is easier to think about if you are thinking in terms of a project or an issue. Think about dry cleaning. A major problem because it releases a chlorinated solution contributing to air quality problems. Now, the first thing you do if you are working in dry cleaning is to do a study, so Massachusetts did a study and found that half of the reasons people were sending clothes to dry cleaners is that they wanted their clothes *pressed.* They didn't care about the cleaning part. So a simple process change in the way clothes were handled would cut emissions by x percent. So then you start thinking in terms of fundamental changes to the technology. You replace the process equipment, go to an aqueous-based cleaning system that is robust and that can handle all the clothes we wear that require dry cleaning. Now that gets into some serious changes. You obsolete a certain amount of capital, need new technologies, look at the design of fabrics and clothing. The third step--why are we still making clothes that need to be dry cleaned? Somebody is going to say we don't need to and design fabrics that can be made into clothes that don't need to be dry cleaned. The implications are substantial--you knock out a whole sector of small business in many towns, obsolete capital equipment, and you increase unemployment. That kind of economic impact is the kind of thing you get into when you talk about industrial ecology. It behooves us to remember this is going to have significant impacts on a number of people, which is our responsibility to think about as well. Another scenario is doable. Technology is relatively trivial. Take a central server. When a new CD is out, you just put it on the central server and when you want it you just call it down. Impacts: it dematerializes the CD and tape industries, factories go away, transportation goes away, employment is impacted. Not an environmental technology.

Ten-, twenty-, thirty-year kind of example. Let's think about one of the givens: fossil fuels are bad. However, we can give a strong argument that with existing and foreseeable technology, you could turn the fossil fuel industry into the governor for the carbon cycle over the next century. How do you do that? We now have the ability to capture carbon dioxide at the plant stack and sequester it. The idea then is to develop a system on carbon-based power plants which have varying input of fossil fuels and biomass, and varying output of carbon dioxide emissions and carbon sequestration. You can then begin to develop a system where a human energy production capability becomes a governor on the carbon cycle. Do we know enough to do that yet? Absolutely not. Is it foreseeable over the next decades? Sure. May we have to do it? Yes. Because what we're doing is not saying we are trying to move toward a risk-free world. What we are saying, is there are risks to doing it this way, there's risks to global climate change. How do you do this? Considering that about 50% of petroleum products go to mobile sources. Carbon-based power plants, pump electricity into the grid, or produce hydrogen for mobile uses. One big problem in going to hydrogen-based or electric automobiles is that somehow you have to buy-off the petroleum companies. They are very powerful political interests, and powerful political interests don't die quietly. So you get them to run the hydrogen distribution system. Give them an opportunity to play in a new energy structure. Unless you have a graceful pathway to develop technology, you are not going to go anywhere.

Let me give you an idea of things you need to look at if you are going to talk about IE. You need to begin to think in terms of a very different set of systems which can be treated somewhat separately for analytical purposes. You can't look at the whole world all at once. The importance is looking at the network around the piece you are working with. You have to understand materials, have to understand energy. Sustainable energy is now the policy of the United States. I don't know what that means. You've got to understand products--simple products; complex products. Very different kinds of methodologies to understand those. Sectors--who is going to win, who is going to lose. The wisdom now is fossil fuel is going to lose. That's not necessarily set in stone. We also need to understand scales systems, from family, community, national, regional, international economies. You can't make a community sustainable by shipping everything downstream. Our knowledge is extremely sporadic, primitive and unsystematic. This is a huge research agenda and unless we begin to put some answers in here, we are blowing smoke. Unless we are willing to do research to understand what it really means, we are making a religious, not scientific statement. That's not necessarily bad, but we need to understand that.

And that is why I'm interested in IE.

John Ehrenfeld: You have all heard of the new Journal of Industrial Ecology. The National Academy has been holding summer workshops on Cape Cod every couple of years and I get to go to the workshops. I can do some things that absolutely none of my MIT colleagues have any interest in at all. IE has actually chased me all my life; I'm a techie, I was trained at MIT as a chemical engineer. I've gone back there after a non-academic career to join the MIT community in the environmental policy area. In many ways, IE has come to be, through my teaching as much as anything else, and searching for a sane environmental policy. I've mucked around in government and other parts, but always in environment. Ten years ago, things weren't working, tested here and tested there, most of the solutions weren't solutions, but solutions that hadn't become problems yet. Here I was at the bastion of technology, positivism, etc. IE to me is a way of thinking in that it is a paradigm. I truly do believe that things are broke out there, but our problems are not problems in the world. But the crises which is missing, is not the crisis in the world, but the crisis which is in ourselves, in that we are no longer able to work out our problems. I mean, does anybody in this room really believe that we're going to balance the budget in the United States? Does anybody here believe we are going to solve the problem of political corruption and contributions? I would love to have that conversation in the hall. And part of that is not that politicians are, in fact, corrupt or that the budget isn't balanceable, it's the way we've come to think about the world doesn't lead us to the right solutions. I see IE as a recasting of our human beingness putting it back in nature, using observations of nature as science has always done to solve problems. So I think that this is a monumental new idea more than a set of tools. I think the type of things Brad talks about are absolutely essential. That out of this will come the tools, but without a new way of thinking, we'll be creating the world over and over again.

Dave Rejeski: I was actually converted in October 1970. I almost remember the exact date. I began as an industrial designer and in that month I had my first design problem. I had to design a small hand tool and I spent three weeks doing it. I brought this in to my mentor and he said "that's interesting, but how would nature do it?" I could never really answer that question, but I would maintain that that is the fundamental question behind IE. The thing that attracted me to it then, and still does today, it is essentially a very powerful metaphor in a world that is dominated by piecemeal problem solving and end-of-pipe solutions. We are inherently attracted to elegant solutions, even if we can't reproduce them. That's why people go every month to Kalundborg to look at this industrial park. So my actual interest started a long, long time ago. About three years later, after I was constantly grappling with this question, I found I couldn't answer the question, "would nature *even* do it?" In other words, do we need four new cell phones every week? And I think unless you're able to answer that question, and that bothered me for a long time, basically the paradigm will never have any credibility south of the equator. Fundamentally, we are kidding ourselves if we believe most of the developing world is going to think we can tinker with the system at the edges without touching fundamental problems of consumption. So, that's kind of my journey. I came back into industrial ecology because I also was fascinated by Brad's hats and boots at a number of National Academy events.

One of the interesting thing was in looking around and realizing that I was the only public policy person in the room. And I don't believe in any way shape or form you can actually have those kinds of transformations without the government involved. So, even though it's partially corrupt, it's the government that's going to have a role in the R&D investments that you need to get you there, the incentives, and the social displacements - taking care of those dry cleaners that are out of work. So I'm totally convinced there's an enormous role for the government here, and that the government has to get actively involved. And that's essentially what I am trying to do in my position now, which is to think about the R&D, incentives, how to get the agencies involved, the right data collected, the right metrics, which is an enormous job. I can use a lot of help, and some of the people who are helping are here today.

Kathleen Schulz: With regard to Dave's comments about getting government involved, I would like to recognize our honorary sponsors from NSF, EPA and DOE. I think that's a promising development.

Marian Chertow: As you've discovered by now, everyone comes to IE from somewhere else. I was in a very respected academic discipline known as 'garbology." I had been a solid waste practitioner for seven years and also worked additional years in government, then came to Yale. For five years I taught a course in solid waste management and it was very exciting. Then I found out after many years of thought that I was only at the extreme end of product life cycle. That there was all this stuff--and there was all this stuff happening upstream--from extraction, manufacturing, distribution, and use of product. Fortunately, this field came along called 'industrial ecology' that looked at the whole thing and I thought this would be the thing for me. I felt I couldn't even teach waste management anymore, because that was just a small part of the problem. And, as soon as you adopt a systems view, you don't want to just stick yourself at one end, you've got to think about the whole issue. So, I guess I did my own little paradigm shift. At Yale I had the industrial environmental management program even before we had IE. Today the

intellectual core of our program is IE. We have the world's first professor of industrial ecology in our program; the Journal of Industrial Ecology, the first such journal, led by Reid Lifset is published there. We are also getting more jobs for students in IE. So how from 'garbology' I came to IE. What am I working on? Since I am not a scientist, my specific interest is, "how do we use this new scientific knowledge in public policy," and that's what I've been writing on.

John Elter: I wrote an article in a magazine, "Essays in Radical Agriculture" in 1971 and it said "formerly a scientist at Xerox." I was unhappy at Xerox and was going to leave, and I think I'm still unhappy and may still leave. When I was a kid, we would walk to the stream, turn rocks over, catch minnows, and had lots of fun. I think I'm interested in industrial ecology because of the habitat. I think there's a direct relationship between habitat and our quality of life. What am I working on now? Right now we have a production line at Xerox, building its 400th machine, I think. It's manufacturing a product that's about 97% totally recyclable. That started with about four engineers in 1991. We took as our goal that we would take a completely new perspective on product development and put a goal like 'zero landfill' in front of ourselves. We constantly asked questions, what is an integrated design, manufacturing, and service strategy? How will we know that how we design, manufacture, and service the product is integrated? We ended up taking about 280 people to a vision-quest kind of thing to the Catskills, Adirondacks, and to New Mexico. People had to draw a circle in the sand and sit there for one sunset and one sunrise and contemplate their relationship to the environment, so when we got back to work we didn't have to beat on people as to what it meant to be environmentally conscious. So now we have the whole organization. pretty much attuned to the fact that they have to think of the supplier, the factory, the end user, and the end-of-life of the product in terms of design. So we have a product that instead of having 2000 spare parts has 180 spare parts. Instead of sending a service tech out at $50/hr., we have the customer repair the machine for practically nothing. The suppliers are involved in the economic benefit of recycling, because all the spare parts go back to the initial supplier for remanufacture. So they participate in the economic advantage of reducing their raw materials. And, we've changed the entire customer experience with this product. The name of the product is 'Lakes.' We thought there were a lot of lakes, so we could have a lot of product variance. Our conference rooms are called Cuyahoga, etc., (named after the Finger Lakes). We think we've completely changed the customer's experience of what Xerox is going to offer in the future. We're redesigning our logistics systems, our order systems, to take advantage of the product design, supplier based system. The entire food chain is being influenced by this idea of an integrated design and manufacturing, and service strategy. Next month we'll be about 98% recyclable and our objective is to get to 100%. We'll have a few things to deal with yet. That's why I'm interested in industrial ecology.

Kathleen Schulz: Questions?

Question from the floor (Steve): Didn't hear any 'fire and brimstone' speeches. My question is, "Are we going to go to hell in the next 25-50 years if we don't make substantial progress in industrial ecology"?

John Ehrenfeld: Yes, I think we're probably already there. That's a question everyone has to look at. I really do believe if we are looking for the world to end in "hell-fire and damnation," it's probably not going to happen. My view is really inside ourselves. You have to one day wake up and say I'm sort of fixing things, but are not satisfied. I believe nature can teach us something about ourselves, about how we value things, and how we value ourselves. We have had three very interesting notions woven together. One is environmental security. That's the one we're talking about today. The other two are about social justice, equity today, and taking care of the future. Some people say these are disparate notions, one based in science and the other about human beings. I say, when you begin to value nature and put yourself back in nature, you start to value yourself. Everybody is going to have to decide for themselves. What really got me here today is not to learn about industrial ecology, but to learn to see whether some exercise like this workshop can do exactly what you asked, Steve, and that is wake up and begin to see that the problems we're trying to work on are real problems, but the solutions we are trying to construct are built on a house of cards. You have to wake up one morning and see things differently. Nature is a wonderful teacher to bring you there.

Brad Allenby: A very interesting question, an objective question. Data do not yet permit us to say where we're going to end up. There clearly will be some loss of biodiversity. Not definitive yet, probably won't be until too late to do anything about it. In the broad view, we're not talking about the destruction of the globe, the destruction of life, even the destruction of the species, but significant socio-economic disruption and a greatly increased rate of mortality. The second point, is a question of values. 'Hell' is a value term. There is not a sustainable world, there are many different worlds that could be sustained over some

reasonable period of time. We could easily end up with a world where developed countries maintained some kind of quality of life, and there is extremely high and variable mortality in underdeveloped countries which maintains the global system. In fact, that's a reasonably likely scenario. That would be unfortunate, immoral. The things we can't avoid are choice and responsibility. The impact of our species on the world is so significant. We have failed to accept the responsibility. The question now is, what kind of world are we going to choose to have. And that has a number of very difficult dimensions to it, only one of which is scientific.

Question from floor: "How much money does Xerox save?"

John Elter: About $800M per year, bottom line, on recycling. They found out that doing what's right for the environment is also good for business. I think that's a fundamental tenet that's true.

Q from the floor: What's the impact on morale?

After the first trip funny things happened, people got attuned to the environment in a different way, each person had a personal experience, all made a vow of secrecy to each other, so there was a team thing going on. So there are now 280 people who have sort of a subculture because they all had the same experiences. When we came back, we adopted what we call the "employee bill of rights." The first one is "even though you don't agree with me, don't make me feel wrong,"--humanistic kinds of statements. It's not only a 'green' product, but a 'green' process, so we started to think about each other. In our conference rooms, we have props "talking pieces" we picked up from American Indian culture, so whoever has the 'talking piece' can speak indefinitely and people listen. We have been working 12-14 hours a day without overtime for five years, so people are now stressed out.

Q: "Using nature as a guiding reference point - is that a good idea?"

Dave Rejeski: How many people in the room are "practicing" ecologists?--basically do ecology on a daily basis? This is a meeting about IE. One of the things that has struck me over the years, even though we use the term industrial ecologists, the ecologists really aren't there and the ecologists are the ones that can answer the questions, or least have more intelligent answers. They are the ones that have the skills to talk about population dynamics, caring capacity, scale and diversity issues. And to answer the questions, how is nature working, where is it working efficiently? we need to bring in the ecologists, looking at the other side of the interface between industrial systems and ecological systems; otherwise, it is not intellectually honest.

John Ehrenfeld: Just looking at ecology is not enough. This idea of industrial ecology actually lives in a larger concern about sustainability, about prolonging the human society we know to get the benefits of the things that make us uniquely human as a species. Ecology in the natural world offers some examples of sustainability. And there are all kinds of ecological systems, forests and old growth systems are very sustainable. Many of the ideas that I operate from in the design world--loop closing, dematerialization, protecting the metabolism, all come out of looking at more stable ecological systems. The example you have given is a good one, when bacteria go through that self-death cycle, it's because they have appeared at the wrong place at the wrong time and haven't become part of the system. And maybe that's where we are in society today, we're doing exactly what the bacteria is doing, looking at the world as an infinite source.

Brad Allenby: Two points: I think one of the connections between natural systems and industrial systems is that they are both complex and I think if you push the analogy too far, you can make some very serious mistakes. I think the underlying conceptual basis is that of complex systems. Most engineers, on the other hand, tend to work with systems where they can identify causality, and tend to be more traditional, simple systems. A good exercise for this group might be to think about what capabilities would you want in a laboratory in the 21st century. The lab of the 20th century clearly has been a physics lab. I think that's not going to be the case for all the labs in the 21st century. What capabilities would you want? I suggest at least one of them have the capability to study and understand biological systems at varying levels of complexity, because I think a lot of that knowledge of complex systems would be transferable to industrial ecology.

Kathleen Schulz: We'll take one more question, then will ask you to vote on which question you would like to hear about next--2, 3, or 4.

Q from the floor: "John from MIT, can you confirm or deny that you are opening a school of philosophy sponsored by Xerox and moving to the Hopi nation?"

John Ehrenfeld: Am I trying to install a new philosophy in places like MIT? Yes.

Marian Chertow: I am going to interpret your question a little bit, because this is one of the things that people who have converted to industrial ecology have to deal with. Is IE some sort of flaky futurism, and does it just represent some form of nostalgia or sentimentality about playing with minnows when you were a boy or this sort of thing?. I think these are very basic and important questions that we have to answer. If that's all that it is, then we have to say there isn't enough analytic basis here. Because industrial ecology is so new, we haven't created a lot of the analytic components that will be needed, and we will be able to think about that question and what IE really is much more ten years from now. When we really start to employ the tools that were described in the Tutorial, that's when we really start to pin down what we are and where we are.

Q from the floor: " I would challenge the room to say, are we taking a look at the wrong thing?" There has been no question to the panel yet about habitat and food sources, which are probably some of the largest waste streams that there are. So although I laud Xerox's efforts on making a totally recyclable piece of machinery, when we are looking at community development as a totally recyclable habitat, then perhaps we are addressing the entire system, which is why I brought up Hopi nation.

Marion Chertow: I am less sanguine to pointing to nature and saying it holds the right answers. We have a program at our school called "Urban Resources Initiative." I note that some of my colleagues on the Regulatory team must work in this area based on their descriptions. What we find out when go in to the Inner City, when we go into Baltimore and New Haven and we are looking at quite dysfunctional neighborhoods and families, is that to these high school kids nature is something that is scary--trees are something that muggers hide behind, parks are something that you must avoid, and you cannot just be outside because you might get shot. This is not the kind of nature that we want to replicate. Clearly a huge disjuncture has occurred. How can we even talk about the same sorts of policies, goals and objectives when we don't even agree that a park is beautiful? I think there's a lot of places that we need to come from before we get to the ultimate question of sustainability.

Kathleen Schulz: One more question before we move on.

Q from the floor: "In thinking through all the things that you have learned, and all the things you have gathered about IE--and this is a new subject to me--what do you see as the points of highest leverage for change, and of those points, how would you rank-order them?"

Brad Allenby: That's an interesting question, but I think the question presupposes a degree of control and understanding of the evolution of the future, which we don't have. If you look at the almost explosion of different initiatives that could fall under an IE definition in very different sectors: agriculture, forestry, paper, manufacturing in virtually all sectors, packaging. it's not possible to say there are leverage points which could impact all those in the sense it implies a degree of control. What I think is possible, and I think this is why the government is important as Dave says, is there are policies which can be adopted which are more sympathetic to the evolution to environmentally and economically intelligent systems. Policies like appropriate government procurement policies. If DoD were to green milspecs and milstandards, you'd have an enormous change in behavior, which would ripple across the world, because those specs and standards are embedded in a number of procurement documents. The keys to being sophisticated is discovering those levers and making sure we do less harm by changing them than by leaving them alone, because we always have to remember that our ignorance in this is profound. I once went in to a group of people who were designing a 'green' telephone, and one of the first questions was "what materials should be used?" And, you can't answer it. If you can't answer a question that fundamental, you can't answer which one has less embedded environmental impact in a particular application. Then it tells you how far you are from beginning to have a firm foundation for moving forward too rapidly, does not argue against experimentation, does not argue that you have to stop doing LC or DFE, but that you have to augment it. What it does say is that you always need to have a profound respect for your ignorance in this area. There are much more intelligent policies we could adopt.

John Ehrenfeld: I am going to answer in a very different way. I think what Brad said is very relevant, but I think the importance of IE is the ecology part of it, industry follows. It's a way of thinking, and at the heart of my sense, the most powerful metaphor in IE. We have talked about nature, this is not nature as a romantic notion, this is nature as in the world. As human beings, certainly in the west, have come to be, we have a very intriguing view of who we are. The model of what it is to be human in the last 150 years in the west has evolved to be autonomous-self. It's a Cartesian (Descartes?- not clear) world out there. It leads to a notion of how I live in the world by myself, and it's a very lonely world for everybody. Modernity is a lonely time, because we are alone, not only against nature, but all those other technical things called other 'people.' The notion of an ecology in which looking at the way it works, as the 'system' that Brad keeps coming to is one of the powerful things, but it's not just the system; that's a 'techie' term. It's that every species literally relies on every other species. And that no one is defined alone. Every human being is part of every other human being. That shifting of notions of the independence of humans and the autonomy of humans, which is where we've come by taking ourselves out of this natural system, and to begin to put us back in that and reconstruct the world in harmony with those natural species and other people, I think is absolutely the most powerful part of thinking about an ecology as the basis for reconstructing the humanness of societies.

Dave Rejeski: One of the areas where I think there could be a lot of leverage is the idea of actually looking at an analytical model to look across facilities and sectors. If you look at what the government does, a lot of the programs we put in and a lot of regulations, they tend to be sector specific. The interesting thing about IE is it begins to get you to look across sectors, the whole idea of synergy, byproducts, etc. I think this is a basic ecology principle of supporting diversity. And, looking at the optimization of diverse systems. It does provide an opening, potentially an analytical model, for beginning to look at how you would optimize across sectors. The one thing that I'd add that you have to put in it is, you can't have a viable model that leaves out 80% of the economy, which is the service sector. Service ecology doesn't sound good, it doesn't have a ring to it; but 80% of the GDP, 75% of all employment is in services. If you don't think services have an impact on the environment, take a look at a hospital. Take a look at any restaurant. McDonald's is buying two million pounds of potatoes every single day. They have one of the most complex logistics systems in the world. The ability of IE to get people to think across sectors is an enormous leverage point that remains largely unexplored and has some real interesting program and policy applications for state and local governments also.

John Elter: When we had the idea and put this program in place, we went out and hired a consulting organization; they didn't call themselves the 'complex systems' or the 'ecological systems'; they called themselves 'living systems.' The big idea in my mind is that we think of what we're doing as everything being connected. Therefore, there isn't the notion of what's the number one priority; what's the maximum leverage point doesn't fit into that idea. What we taught our engineers is that everything's connected. And said, think about it as a 'living system.'

Kathleen Schulz: Let's vote on which question to consider next?
We will go with Q3: **What areas of application do you see as the most valuable?**

Mak Dehejia: In listening to the comments of my colleagues on the panel, I feel that the bandwidth of the comments is so wide, I'm getting quite depressed and pessimistic. What I think everyone is saying is the definition of an 'expert' -- "we know more and more about less and less, so we are totally ignorant." Coming from the other side of the totally ignorant person in this business, but from a point of view of the rest of the world, this is America, a self-sufficient nation, showing signs of isolationism, generally, and the types of comments I've heard so far are typically sort of within the U.S. context. If you just step outside into the real world and see what's happening, GM invested $2B in Thailand to create an auto industry. What's going to happen to Asia with the motorization of that part of the world? They'll have the same kind of problems that we face here, and so on. Therefore, I see some very useful common sense applications of what is known as IE, or parts of IE, right away. One of the leverage points, I would say, is the ISO 14,000, which is already having an impact on international trade. Good or bad is a value judgment, but it has an impact. I would like to see more progress on recognition of total cost accounting, or 'green' accounting; now that is going to make a lot of difference to our way of thinking and operating. In the subsets of IE--industrial metabolism, mapping of flows--leads directly to very practical advantages and solutions: energy conservation, conservation of material, and so on. In a conversation with a group of businessmen in Indonesia recently, I said, "would you be prepared to pay us if we came to your enterprise and showed you how you could save 30% of your energy consumption?" And, of course, they were totally willing; but, "will you come to a seminar on IE?" They just yawn. So there are practical applications within the confines of our present methods of measurement. Energy conservation is one of them; design for environment; the need for new kinds of packaging, or of doing without packaging; the example of transporting polyethylene resin in polyethylene bags instead of drums.

Those kinds of applications will take off quite rapidly and will have an impact on the whole world. They may not be intellectually or academically very exciting, but I think, as a practical business matter, they have quite a lot of promise.

Brad Allenby: I'm reminded of a story when the NAE had a meeting with the Japanese on IE in Irvine, CA. We all sat down and talked for a day and a half, and the Japanese were very polite. So it was a day and a half before they said, "look we came in with people form the cement industry, the steel industry, the auto industry, and sitting across from us--as industrial representatives--we have Apple, IBM, AT&T, and Xerox." There is something wrong with this picture. It was obvious that they wondered where the rest of the economy was. I think that there's a couple of points from that. When you're starting something like IE, you have to be a little bit like a virus. Your desire is to infect the whole thing, but you have to be opportunistic. The electronics industry was the one that picked up on a lot of these things initially. The thing that is necessary is for the government and academic institutions to begin look at questions which private industry will not because they cannot capture the benefits of it. There's a lot of work going on in the design for life cycle assessment in private firms. That's good, but that's not going to get you where you need to go, because it's only one level of the system. There's another higher level which involves the government answering questions like, in say 10 to 20 years there will be a whole new energy infrastructure built for Asia. That's going to imbed a lot of technology in that system. That technology has an average life of somewhere around 50 years. So unless we do something fairly soon to understand things like the carbon governance cycle, we're going to imbed 50 years of lag into our technological systems. There's no private firm that's going to look at that, they're going to respond to the short-term incentives. One of the things we have to do is get the government and academic effort up to the same intensity as the private firm effort. And that, frankly, is not happening.

John Ehrenfeld: There are applications anywhere you want to look; there are applications in my institution. To begin to use the notion of connectedness. One application is simply to design curriculum around it. Another application is to begin to design policy. This presidency has tried to do this in a number of areas to begin to get away from the 'one size fits all' approach to develop a framework for a much more holistic view. Dave Rejeski has been a key player in that; it hasn't worked very well, because the forces of stovepipes are very strong in this country. There is a certainly critical opportunity for the use of the ideas, not the specific analytics. The most advanced applications of IE are the ones Brad talks about. There are an increasing number of companies that are using these principles to design their products. In Europe, IE really does live in the policy area. Much of their policy has shifted in ten years to product policy--something we lag in the U.S. And that policy is driven by notions of chain management. The Dutch national policy, in essence, is driven by IE. The Germans have adopted a recycle policy and have installed a political theory called 'extended responsibility'--that means that companies that make things are basically responsible for them through their life cycle. That's transformed design of products. There are indeed applications already out there. Many of the analytic notions are not new, we are beginning to relax the boundaries a lot more. The leverage is really everywhere, but particularly in designing policies from a broad systems point of view. And, re-thinking how we educate ourselves at all levels.

Marian Chertow: I'm of the school that industrial ecology isn't everything, that there are a few other things left in the world. In terms of applications, orientation, and leverage, there is extreme and incredible power in the notion of design for environment, both at the level of the firm, but also in just thinking about the environment at the start of your process. It is building-in environment early. Yesterday, I felt all the examples in the presentation were about transportation and automobiles. Suppose we did really did design a fuel-efficient car, or a hydrogen car, intelligent roads, I believe we would still need pricing signals to enable the implementation. So, I think there's a dual strategy here: get designers thinking (everyone), but also get price signals right by using the right tools, full-cost accounting, etc., so that we can get there even faster.

Dave Rejeski: One other opportunity is supply-chain management. I think the trend you see is to reduce number of suppliers so that there is an existing set of relationships.

Kathleen Schulz: We have 5 minutes.

Q from the floor: I believe anything that would move this along faster would be good in general, and certainly, one kind of force would be to identify opportunities along the lines of what entrepreneurs could do. I'm wondering if any of the panelists might have some thoughts where that might fit in.

Brad Allenby: There is an interesting dilemma which you raise. If you think about what a lot of 'design for environment' does, it extends the scope and scale of the firm to cover the scope and scale of the environmental impact of the products or material that is under consideration. That goes contrary to the idea if you want rapid technological evolution, you want to encourage precisely the type of entrepreneurial activity that you are talking about. So there are some internal contradictions in thinking about a theory of the role of the firm in IE. Not a lot of work done on that - some research would be very useful.

Q from the floor: This is a very intellectual and technological approach and almost all of the ways we are looking at it is supply-side driven. We're going to get engineers to make better products, we're going to get designers to design better products. How are we going to create the demand for these better products? A lot of the changes that will need to come about will need to be made by consumers. A lot of stuff ending up in municipal waste dumps is stuff the consumers throw out. The 2 million pounds of potatoes that McDonald's uses each day were developed in the 30's and are very pesticide intensive. The reasons farmers grow them is that McDonald's requires them because of their size and uniformity and make nice french fries. So, how are we going to deal with these issues?

John Ehrenfeld: I think your observations are right-on, that sustainability has created an opening for thinking in an industrial ecological sense. Concern about the levels of consumption and production have driven our attention toward this. Somehow, we have focused largely on the production side. I think it's an immensely difficult problem to think about how to begin change on the consumption side. Some of the speakers mentioned early about what is it we need? Do we really need another cell phone? The origin of needs is a very important one--do needs arise from some sense of individual experience or of a sense of a world of a constant barrage of commercials. A lot of people describe this as the era of commercialism, that human beings, especially in the west, buy things because they're told they are good for them. If that is indeed true, we're in a vicious cycle. And the answer to your question is somewhere in introducing notions of connectedness into the educational system. If we don't probe the question of consumption deeply, find out what you and I, in this room, use when we buy things, we aren't going to be able to answer it. We see these as independent notions; neo-classic economics sees the market place as a set of isolated marginal decisions; that my decision has absolutely nothing to do with yours, except as the goods become scarce. Somehow in our education system, we need to introduce a new idea of scarcity. There are a number of ways to do that, but we haven't done that and I'm not sure that IE holds the answer to that.

Mak Dehejia: One other thing that has fascinated me has been a cultural change in the concept of ownership. Today we are so geared to owning things, because of the commercial environment, but if we give up the concept of ownership, what would happen? Do we want a hulk of steel and electric wires sitting outside our houses and apartments to add to the cool air in the apartment? Probably not, what we want is the service of cooling. If we don't buy air conditioners that the GEs and Carriers of the world sell for the service of cooling, what would happen to the general system? It would lead to longer product life, different use of materials, and so on, which would all be beneficial. I believe some kind of cultural shift as to ownership questions would help.

Marshall Berman: Stephen Covey says "all things are created twice, once in the mind by planning and second in the real world." We are going to give you an opportunity to create it three times. First in your mind, in terms of the planning session that's coming up, then in the game, and hopefully in the real world. Let's do some serious thinking and thank the panelists for a very stimulating discussion.

PART 2: Team Reports

U.S. Congress

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Vision

Increased economical strength, improved quality of life, & ecologically sound use of resources for U.S. citizens & industries.

Challenges

1. Regulation Reform
2. Financial Incentives
3. Public Acceptance
4. International lead and influence
5. Technology Innovation - Continue & enhance

Objectives (What)

- Regulations: Provide flexibility for innovative solution, providing incentives and opportunity
- Financial: Accounting (Fed) systems capture benefits of ecological operations (tax incentives)
- Public: Demonstrate benefits to constituents (communication)
- International: Fast track and other trade negotiations include ecological improvement. Improve US industry's competitive advantage.
- Technology: Encourage ecologically sensitive technologies, (i.e., fossil fuels, agriculture innovations)

Strategies (How & When)

- **Regulations:**
  *Change existing environmental statutes or modify to allow exceptions that address/enhance ecology
  *Incorporate market-based flexibility (e.g. pollution trading)
  *Consolidate data bases to provide ecological metrics & directions

- **Financial**
  *Create programs to initiate efforts in private sectors not using federal $ (e.g., DOE & Chicago Schools, other agencies)
  *Finance demo and scale-up technology

*Tax credits for new ecological protective initiatives by industry, others

- **Public**
  *Hearings
  *Press Releases
  *Media
  *Town Meetings
  *Generate interactions at "home" in DC

- **International**
  *Incorporate ecological requirements into fast track & other trade agreements
  *Demonstrate/advertise US commitment and lead

- **Technology**
  *Support R&D at University and Fed Agencies
  *Gov't agencies prime/first users of ecologically produced products

Team Composition/Preparedness:

The team members seemed to have knowledge about how congress works and proceeded accordingly. Many of the team members were working in ecology areas and knew the concerns, actions, politics, etc., in detail; two were on a federal interagency team addressing this issue, so they had a good sense of the issues and barriers.

Description of Planning Session:

Lots of energy. Asked a lot of questions about procedures, dos and don'ts.

Ground Rules:

- Be a conference committee, must sell to both houses
- Hear some liberal views. Conservative vs. liberal - members will try to represent both views whenever possible.
- Vote as a Congress when issues are defined.
- Consensus Vote
- Quorum - (Core from each committee, minimum of 4)

Role Assignments:

Congress assigned members to committees according to their personal expertise. The 4 areas were as follows:

- Regulation (Deborah, Tom, Dave G., Dave B.)
- Appropriations/ R&D (Paul B., Alan, Paul, Dave G., Lee)
- Tax & Trade (Alan, Tom, Deborah)
- National Security (Deborah, Paul B., Dave B., Lee)

It was decided that members would be assigned to visitors according to their issue.

Final Plan

The final plan did not reflect several issues that came up in the game. Nuclear power plant issues came up several times during the game, but they did not progress beyond a draft agreement. They also wanted to go on an education campaign late in the game, but realized that there was not enough time. New directions taken as a result of Congressional hearings were also not put into the plan.

Plan Focus:

Global 5% National 90% Regional 5%

How Strategies Implemented

Empowerment:

The team recognized they needed a leader/coordinator. Elected David Berry as "Whip." David jumped right in as an enthusiastic Whip. The early split of issues to members continued to work well. David would bring them all back to the main core and those assignments. All players were clearly involved in the game and each had a role as stated above. The last session was the only session when some team members made agreements without the consent of others. During the heated discussion over such actions, a few Congressmen were cut off time and time again. During this session, chits were traded for influence with the promise of backing in other agreements.

Were Moves in Concert with Strategies?

Congress was good at referring to their original goals and negotiating agreements accordingly until the last session. Following the state-of-the-world address, everyone started thinking a little differently about things. To help guide their future actions, Congress set up a hearing. David Berry was Chair for the hearings and Deborah Wince-Smith was present. Industry demanded tax relief so they could invest in new technologies and people. Citizens were outspoken about big industry ripping them off and demanded that continuing education and support be provided to those being laid off by big industry. All sectors were heard from. The Chair agreed to work with each sector to assure their concerns were addressed. Congress seems to place public opinion high on their list of priorities whether it be Joe Shmoe or Manufacturing Cos. The hearing was a proactive approach that clearly spelled out their intentions as a sympathetic Congress.

A summary of the moves pursued by Congress indicates that while they supported the team's objectives, many of them were not in explicit pursuit of team strategies, leaving many of them unfulfilled.

Long-Term/Short-Term thinking

Congress generally exhibited short-term thinking until the last session.

Ability to Partner

From the very beginning, Congress stated a desire to please all and work on benefits for everyone. They had a true heart for a win/win situation. They quickly realized they had to partner because they did not have all of the chits they would need, and so worked diligently to partnered with public.

Recognizing that Influence chits were critical, one Congressional member spent full time trying to trade for the Influence chits. They set up a hearing (see above) that generated support from all constituents of the game.

Broad vs. Narrow Agreements
All agreements made were broad thinking because they considered the impact to all (i.e., Public, industry).

Team Debriefing

Greatest Successes

- Press conference with public support and manufacturing standing side by side.
- Thought more about longer term in last session.
- Bonding occurred with some team members. Suggested that the D.C. area people get together later.

Lessons learned

- Planning and strategy early is important.

Didn't work

- Unstructured in congress. Didn't always know what was going on with commitments. Behind the scenes changes and deals. (Note: This is real world!)
- No willingness on the part of tax payers and public to make changes.

Implement in real life/Follow-on Activities

- Information system [FIA-02], T-1, [metrics] P-12, and Joint Pricing concepts. Analysis will set priority.
- Bonding occurred with some team members. Suggested that the D.C. area people get together later.
- Want to bring the DC based people together that are looking at materials flows to look at IE.
- Want to take bills introduced in Congress and maybe refine and work on.
- Set up list of information sources for current federal studies.
- Other game ideas: Run them in high schools (Set up dungeon master). May have to limit to high school chemistry. Mainstream it. Get local kids and parents involved to deal with an issue.

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Vision

"We are a national resource for research and development, ... and services for Industrial Ecology and serve as systems integrators across all sectors and disciplines."

Challenges

1. Systems-Research institutions are highly compartmentalized, whereas industrial ecology demands a highly transdisciplinary approach. Industrial Ecology work is fragmented, and many efforts remain narrowly focused.
2. Methods-The non-linearity of many systems of concern in IE presents unique challenges to researchers accustomed to working in a linear mode. IE methods, such as industrial metabolism and design for environment, depend upon data on developing and improving ecological and health impacts of substances and processes. The data are now available for only a fraction of chemicals.
3. Data-The diverse economic, environmental, and technical data bases required for IE analyses are often not available. Basic data on materials and energy flows and toxicity is incomplete and scattered across many data sources.

Objectives and Strategies

Systems Challenge:
Objective: Identify the pieces of the IE system and tie them together. Strategy: Create a Virtual Lab System.
Objective: Systematically develop partnerships with four entities (universities, the public, laboratories and industry). Strategy: Create a Four-Entity Partnership, or Co-Laboratory.

Methods Challenge:
Objective: Create a robust set of IE solutions for implementing IE. Strategy: Really define what I.E. is by doing it: case studies.
Objective: Defining parameters of the IE universe: social, cultural, economic, political, and technological issues.
Objective: Develop models, decision tools, and information to reduce data gaps. Strategy: Demonstrate IE tenets by solving a specific problem.

Data Challenge:
Objective: Identify and fill the data gaps. Strategy: Create a clearing house for data.
Objective: Define the role of the labs. Strategy: Verify, validate, and merge existing data systems

In a matrix format, these objective-strategy pairings are:

Objectives "Whats"	**Strategies "Hows" (Use www for all)**
Systems challenge 1. Identify pieces of I.E. system and tie them together 2. Systematically develop partnerships with 4 entities	*Systems challenge* Create virtual lab system 2. Create 4-entity (lab, public, university, industry) partnership (co-laboratory)
Methods challenge 1. Develop robust set of I.E. solution methods 2. Define parameters of the I.E. universe (include soft sciences–social, cultural) as well as technology 3. Develop models, decision tools and information	*Methods challenge* 1. Demonstrate I.E. tenets and really define what I.E. is by doing case studies
Data challenge 1. Identify and fill data gaps 2. Define role of labs	*Data challenge* 1. Develop a data clearing house 2. Work with private sector's data bases: verify/validate/purge/merge

Team Composition/Preparedness:

All of the players had read their Player's Handbook and were looking forward to the Prosperity Game experience. While there were a number of questions about the Game (at various stages of the Game), team members didn't seem to "fight the game," seemed to learn pretty quickly, and were willing to become an active part of the Game with only a little encouragement. Every player except one came from a national laboratory setting. All have extensive experience in promoting laboratory programs and technologies. Each player demonstrated adequate familiarity with the technologies that the DOE labs as a whole can offer industry, universities, and other entities.

Planning Session:
The team decided that those who were present at the time decisions were made would make decisions for the whole group. Voting was done using a thumbs-up, thumbs-down gesture. Discussion was to continue until everyone could live with the decision. We agreed to be a system of labs for this game.

Final Plan

How Strategies were implemented

This team was faithful to their vision, objectives, strategies and challenges even though some were frustrated by a lack of ability to get support for large strategic initiatives: During the tool kit session, it became evident that major issues would be difficult to address effectively. [The team supported TKO (T6) to address greenhouse gas reductions but could not get anyone else's support.] During Session 5, the team had fun but was unsuccessful getting funding for a national test bed. Several comments were made that indicated that others "could not understand systems or non-linear thinking and that it was too hard to explain these concepts to the resource providers." While most of our team members understood that the lack of support for large strategic initiatives was a high-fidelity reflection of reality, it was a difficult pill to swallow - especially after Marshall's pep talk regarding the need to be strategic.

Empowerment:
Our team members empowered each other to make decisions that were consistent with the vision, objectives, and strategies. Several times our team members were empowered to bring deals to a close. For example, one team member was given full authorization to commit 2-3 of our six technology chits to make a deal with the Resource Providers Team.

Were moves in concert with strategies, or carpe diem?
The team was aligned to the three major focus areas: systems, methods, and data. We also sought to integrate methods strategies. All of the agreements we worked on were true to our vision and strategies. The team had the long-term interest of the world at heart much of the time. When actually making moves in the game, we supported those agreements which offered long-term improvement through testing and implementation of new technologies and biotechnology. The team was comprised of strategic thinkers who followed through during every session when they planned. Yet when it came to actually committing chits, the players gave quite freely, in some cases without much thought. Our group also tried to think outside the box. For example, we looked at the ethical questions of sustaining life on this planet: Should we consider continuing to prop up the culture with our technological stilts and gimmicks? What really is the definition of sustainability?

Long-term or short-term thinking?
While we were strategic most of the time, it also seemed that there was some lack of resolve to force strategic issues. For example, the group was frustrated that others did not support the greenhouse gas emissions tool kit option and yet no one would take up the challenge to write such an agreement and try to get support for it in the general sessions.

Competition vs. collaboration; ability to partner?
The agreements we wrote were energizing for the team, and the team members had a lot of fun trying to garner the requisite chits to get them supported. On the other hand, the team occasionally lost its drive because it appeared that our efforts were not being supported by other teams we had targeted. Early on, for example, we determined that working with the University Team would be strategically ideal for us. When approached, the University Team didn't agree that a partnership with the DOE Labs Team was crucial to them. (In retrospect we asked: "Why didn't we have a good partnership with universities? There was no need. They had worthless technology chits and so did we.")

Broad vs. narrow agreements/vision?
Our team's vision was broad, as were our agreements. We consistently took a systems approach to meeting the I.E. challenge, and it helped us stay broadly focused. Our agreements were aligned with our strategies, and we lent our support to a number of other agreements which advanced our vision and goals. Thanks to our partnering focus and ability, we made strong links with other agreements and teams. We count our working with six other teams to get a Biotech agreement through as one of our greatest successes.

Information that was not listed on the agreement forms?
At times it seemed like our team was too concerned about form (word-smithing) rather than function (number of good agreements). One of the reasons we may have fallen into this mode is that we only had technology to offer and most teams seemed to value things other than technology more. In spite of this, the team kept a strong spirit of cooperation, were engaged, and had fun.

Team dynamics and decision making process as game progressed:
The team valued minority views and tended to address them responsively. For example, one of our players asked: "What is I.E. for each of us? I feel I am talking to one Chinese, one German, and one French, and none of us understands each other." We addressed this question by each listing our anticipated customers, suppliers and products. Our customers in the year 2006 were listed as the nation, manufacturing sector, and users of energy systems. Our suppliers were given as the manufacturing sector and our product was stated to be technology and the invention of energy systems for the future (including behavior changes). All opinions were treated respectfully by all the team members.

Team successes, failures, and other highlights:
Given the small size of the team and the distractions that many of the players had, the team was successful and all of the players seemed satisfied with their experience. However, performance could have been improved by having more players and having the players spend more time involved in the Game as opposed to their other pressing commitments.

The team was split regarding their view of how well our vision was attained. (The people that spent the most time in the game were the most positive and those spending the least were most negative.) Our best ideas were the Biotechnology agreement, then the test bed, then the vision. The team believed that we worked well together, were not bureaucratic, had few soliloquies, and were empowered in negotiations - all felt that deals could be made that would be supported by the others. The greatest success during the game was felt to be getting the Biotechnology agreement through, in cooperation with six other groups. We were also proud of the first agreement approved, the multi-entity co-laboratory agreement.

Chits:
Our team felt that the chit business ended up distracting from the in-depth discussions. "We had to spend more time than anyone else explaining because we put ourselves down as integrators." The chit pricing paradigm made it difficult to construct long-term strategic deals (also the lack of chit carryover and short times for the sessions exacerbated this). There were many comments that the DOE Labs Team had too little influence and that our chit allocation was inadequate to allow us to put deals through on our own. All agreed this was a realistic situation, given the labs' influence in present culture. The multi-colored chits were a good idea because they provided both realism and limited influence. "I personally think the Resource Providers did the best job. They also had the best set of chits. The best mix of each category. They could get whole agreements through just on their own [without partnering]."

What impacts did the panel discussion and summit meeting have on your team and their play?
One of our team members thought that the expert panel went too much to the religious / philosophical side. The team enjoyed the summit and were pleasantly surprised at how well versed each "ambassador" was. Each ambassador faithfully spoke on behalf of the constituency she or he represented. They thought on their feet and adjusted to the issues raised - all of which were relevant. The summit was a big success - a chance for everyone to see the big picture of I.E.

Did players experience the value of IE to their stakeholder group?

With regard to lessons learned by the team, it seems clear that: We have a long way to go in terms of definition of I.E.; technology is not a big part of the problem (that is, there is a need for much more than technology to solve the I.E. problem); systemic, strategic solutions are very hard to explain and sell; and a lab system might contribute to a cultural change in which I.E. technologies and principles are made more central.

Follow-on Ideas:
Regarding follow-on activities, we are going to pursue the biotechnology partnering agreement and working with our stakeholder communities to pursue more agreements. We will also share what we learned here with industry sponsors that work with the labs. The team also expressed a desire to pursue initiatives to enhance biotechnologies, contribute to the sustainable communities project, PNGV, bioremediation, and agriculture.

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Vision/Mission

To act as an enabler of sustainability by offering a floor of strictly enforced minimum requirements and lots of incentive paths to the sky. We will develop and establish methods and tools to collect, measure, and disseminate information toward progress on sustainability.

Final Challenges

1. Current cultural, institutional, legal, and regulatory structure inhibits a systems approach.
2. The technical complexity of environmental issues and their long-term effects makes understanding by the public and obtaining their support difficult.
3. Globalization of the economy and environmental security issues present a different context for viewing sustainable development.
4. Dealing with hundreds of thousands of small businesses and hundreds of millions of individuals in a global economy is a much different problem than dealing with hundreds of point sources.
5. The current fiscal and regulatory structure encourages once-through industrial use of resources.

Objectives

1. Develop a legal system to encourage experimentation and innovation.
2. Develop or foster mechanisms to communicate the impacts of consumer choices.
3. Develop a decision making methodology that includes consideration of the positive and negative aspects of globalization of the economy and environmental security issues.
4. Support participatory processes that move decision making to the level where the connectiveness is best understood and appreciated (e.g., state, watershed, global, etc.)
5. Encourage Industrial Ecology

Strategies

1. Pass legislation to move from command and control to command and covenant through the use of the coordinated exemption process from current law.
2. Foster information (including labeling, certification, and right-to-know) and price (market mechanisms and full cost accounting) strategies to communicate the impact of consumer choices.
3. Re-examine corporate charters.

4. Implement SEC "social" and environmental reporting by all companies doing business in the US.
5. Target critical emerging economies for assistance and exchange of information on regulatory frameworks that embrace Industrial Ecology.
6. Develop, analyze, and disseminate information so that individuals understand connectiveness.
7. End virgin materials subsidies, amend depreciation laws, modify price mechanisms, develop tax credits for technology innovation, and facilitate lease trading

Description of Planning Session
The team met for a couple of hours as a group in the evening after the opening session of the Prosperity game. During this evening session the personality of the group and its dominant members began to emerge. This evening's discussion also enabled the group to quickly develop consensus on ground rules, decision processes, vision, mission, and challenges Wednesday morning. The team's self-vision was that they needed to be an "iron fist in an evangelist's glove."

Ground Rules
- One person talks at a time.
- No filibustering.
- Every opinion is valuable (no right or wrong).
- Can revisit the ground rules at any time.
- Decision Process: A consensus where everyone may not agree, but one that everyone can live with.
- Can't commit the group without talking to the group. Should depend on how serious the decision is, i.e., allow initiative to be taken.

Final Plan

How Strategies Implemented

Were Moves in Concert with Strategies
The group had a clear picture of its identity, and initiated or participated in agreements that reflected that identity.

A summary of the moves pursued by the FAR indicates that while they supported the team's objectives, many of the team strategies were not explicitly pursued, leaving them unfulfilled.

Broad vs. Narrow Agreements
Agreements originated in the earlier sessions tended to fit into a single category, those originated later in the game or by other groups tended to embrace multiple categories. Agreements seem to be sequenced logically, e.g., demonstrations occur after R&D phases, policy changes tend to become grander in later years. Partnerships become more complex in the later phases of the game.

Team Debriefing

1. **What was your team's greatest success?** Defining who FAR was and where FAR needed to go in the future. As noted above, the impromptu evening session on the first day greatly facilitated achieving this success.
2. **What worked best in the game (i.e., for all teams)?** The Tool Kit -- priced right.
3. **What did not work?** Tool Kit -- did not provide far-out options. The team should have had to negotiate harder. It was very easy to just go for the sample Tool Kit Options. Encourage teams more strongly to not just vote on the list provided. In later sessions it was felt that the agreements were priced too cheaply.
4. **What were the key learnings?**
   - Players should have a mechanism before the game to input to tool kit.
   - Send out agreements after game for player critique: How difficult are these to achieve? At what cost? What are barriers?
   - Some teams were not realistic, especially Congress and the Public.
   - Add e-mail to Players list.
   - Congress--should be aware of what FAR is doing and not veto FAR agreements. Perhaps sign off on the agreements. There may be other pairings, e.g., business and finance. Perhaps FAR should also know about what Congress is doing.

5. What ideas and initiatives will you try to implement in real life? Do-able within 5 yrs.:
- FAR-02 Title: Shift Industrial Policy to Reuse and Recycling of Primary Resources via Statute
- FAR-01: Performance beyond Compliance (a modified Tool Kit Option P-2)
- Tool Kit Option T17: "Green" Cost Accounting
- Tool Kit Option T1: Integrated Databases

Do-able in 10 yrs.:
- FAR-08 Title: Implementing Full Cost Pricing
- TTI-05 Title: Industrial Ecology Education Program
- FIN - 2 Title: Lender Liability Responsibility

6. Follow-On Activities:
Sponsors:
- need to find a way to maintain a "critical mass" of interest/participation in IE activities (WEB site).

Universities:
- Teach "Green" cost accounting
- Develop IE curriculum
- Run IE games at universities.

Financial Community:
- Adopt "Green" cost accounting.

K-12:
- Develop science tools to involve students at an early age (DARE as an example)

- IE Game for students using local issues. Perhaps a series of short games rather than one long one.

7. Would you participate in an internet news group/list server established after the game? A resounding YES.

8. Other Comments and Suggestions?

- Time constraints do not allow for out-of-the-box thinking.
- There is a "tension" between playing the game and developing new tool kit options. There are 7 or 8 pages of tool kit options, but only 1/3 of a page devoted to developing new options. Tool kits too explicit, and do not foster "out-of-the-box" thinking.
- Perhaps there could be a two-phase game, a "miniature" one conducted electronically to develop tool kit options, followed by the full game to play.
- Reward teams for using all resources.
- Voting--teach the use of the machines by asking right handed people to press 1, left handed ones to press 5. Should eliminate some of the initial confusion.
- There was not enough realistic disagreement, between team members and between teams. Require as part of the game.
- Adopt realistic pricing.
- Why the chit secrecy? May take too much time from the game to determine.

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Vision

We represent those Federal agencies that support a large industrial base and economic development systems, through manufacturing, procurement, and R&D. To achieve our missions in the most environmentally sound ways, we will provide leadership and tools to advance environmentally sound practices.

Challenges (Rank Ordered)

1. Insufficient knowledge base and analytical tools for IE.
2. A need to develop policies reflecting IE within federal agencies and in the larger community.
    - Examples of new policies would include changes in procurement and the alteration of military specifications and standards to further IE.

    "Procurement regs don't allow the use of procurement power."
3. Resource constraints: natural resources, budgets, human resources, environmental, public support, and educational.

Objectives/Strategies (Strategies bulleted)

1. Inventory and analyze existing IE practices, applications, analytical tools, and research.
    - Develop partnerships to identify: best practices, knowledge gaps, education requirements, and future R&D requirements.
    - Addresses the challenge of lack of knowledge and analytical tools.
2. Develop and implement new policies to advance IE.
    - Make procurement and standardization more friendly to IE.
    - Require suppliers to use IE in all their business (not just products and services sold to Federal agencies).
    - Addresses the challenge of lack of policies reflecting IE.
3. Expand public support for IE and increase budget for IE.
    - Partner with consumers and educational institutions.
    - Develop a shared vision with industry.
    - Work with congress and state governments.
    - Explore and integrate broad cultural diversity.
    - Addresses the challenge of resource constraints.
4. Better utilize dollars, people and feedstocks.
    - Develop accounting systems that price resources more accurately.
    - Educate people in IE .
    - Addresses the challenge of resource constraints.

Team Composition/Preparedness

None of the players demonstrated a great deal of familiarity with the handbook or the game rules. Several players said that this was their first exposure to the concept/field of industrial ecology. Only one player showed up on the first full day of play with independently prepared written notes of ideas for the game. One player was a last-minute substitute.

Description of the Planning Session
The team had problems with the term 'industrial ecology,' and felt it didn't really capture what was being addressed. Playing the role of FIAs as outlined in the manual clearly did not resonate with the team, and they chose to expand its scope to reflect economic development concerns (characteristic of HUD and DOT activities). There were also significant differences within the group about what sort of goal should be expressed in the vision statement.

Ground Rules
The team discussed but did not assign roles or ground rules in the planning session. Instead, they let the rules develop as they went along. This became problematic later when one team member promised second-round chits to another team in exchange for support for a first-round project. Because of a lack of communication within the team the player who struck the deal did not know that the needed support had already been found by another player from a different source. The player was mildly chastised by other team members.

The team also failed to develop any clearly stated investment strategy and did not define its relationship with other teams. As a result much of the toolkit session activity lacked focus and involved very little interaction with other teams.

Final Plan

The final plan largely ignored the FIA challenges described in the handbook. Challenges other than those presented were also discussed but not adopted as priority items. These included:

- Lack of credibility with constituents/stakeholders
- Complying with executive orders and regulations
- Bureaucracies impeding creativity (poor incentive structures in Federal agencies)
- Insufficient penalties

The players' own lack of knowledge of IE was reflected in the team's perception of challenges and its selection of objectives and strategies. The problem was seen largely as one of information and policy. Thus, the team pursued avenues that would expand networks of existing knowledge and expertise rather than seeking to create new knowledge and expertise. Lack of knowledge was reflected in several player comments: "There may be things we could do that don't cost money, we just don't know what they are." "IE is not part of my nomenclature." Lack of knowledge about IE may explain some of the reluctance to adopt aggressive positions early in the game.

Focus
40% Global; 40% National; 20% Regional

Implementation of Strategies

Were Moves in Concert with Strategies?
All of the team's imitated investments and agreements corresponded to a team strategy but not all of the planning session strategies were pursued and there was no effort to develop any kind of implementation plan. As the game progressed the team moved from a "Carpe Diem" mentality toward a "Crescit Eundo" strategy that linked agreements over time and across strategic currents. In the first open negotiation session, the team pursued networking and information-oriented strategies to build on and enhance the T1 tool. These were simple, easy to accomplish and non-threatening to the status quo. In the second round, the team developed more concrete agreements to develop procurement policy and promote implementation of IE. In the third round, the team was expanding its second-round strategies and looking at how its main themes of Eco-Industrial Park (EIP) development and Federal procurement policy could be linked together (suggesting an element of Partes Pro Toto in the team strategy).

Ability to Partner
Extra-team activity grew with each session. The team recognized that it needed to develop partnerships to accomplish goals. This was aided by requirements from control that some chits supporting agreements come from specific teams (e.g. EIP development required reg. chits from the State and Local Team).

Team Dynamics
Team decisions were generally made by consensus although the more forceful personalities in the team tended to dominate the agreement drafting process in the first round. Less assertive players had to be coaxed into action by the facilitator's encouragement to translate their ideas into draft agreements that the team could consider. The idea that led to the team's most ambitious agreements began as a minority position. One player voiced the idea of EIP development as an implementation strategy very early in the planning session and was discouraged by other players' comments that this should be taken up at a later stage. By the second open negotiation round the player drafted an agreement and got support from other team members who helped him sell the idea to other groups.

Team Successes, Failures & Highlights

In the players' view, they had two significant successes:

- They didn't behave like separate agencies; they built a team from diverse backgrounds and interests.
- They accomplished all their objectives, including the passage of toolkit options and follow-on agreements that fostered IE
- Information dissemination; leveraging procurement power to advance IE; and establishing a model Eco-Industrial Park.
- Expanding Eco-park development globally. (The Eco-Park model built communities and attracted inter-team support.)

Their greatest failure was a concern that they hadn't really impacted long-term IE. They were also concerned that some teams didn't seem to play their assigned roles.

Chits
The team may have had too many green chits--getting enough green chits never seemed to be problematic. Some players suggested that FIA should have had fewer (or zero) technology chits in order to encourage interaction with the DOE labs team.

Players tended to barter chits rather than enlist the investment and support of other groups primarily on the merits of the agreement. Despite continuous coaching, it was not until the last open negotiation session that some players realized this. With all of the team chits dedicated, one agreement was still lacking support. The agreement's primary advocate feared that the agreement would not go through because the team had no more chits to trade. The facilitator had to remind the player to seek someone who would support the project because it advanced their goals too. This may be an argument for greater chit scarcity in future games.

Panel Discussion Impacts
The expert panel discussion on Industrial Ecology did stimulate thinking about IE. It is difficult to tell whether or not this translated into specific actions in the play of the game.

The IE summit panel discussion had a more noticeable impact on team play. There was quite a lot of discussion within the team about what they heard. Their efforts in the final negotiation session became much more focused and effective.

Did players experience the value of IE?
Some players expressed a strong interest in IE and in promoting it in their organizations. One player saw IE as meeting a national and organizational need.

Others remained skeptical of industry's willingness to pursue IE in any meaningful way as reflected in one player's question: "Is the American industrial community willing to employ the discipline to sacrifice short-term gain for long-term survival?"

Follow-on Ideas
The team offered ideas but expressed concern that they did not have the authority or the influence to make them happen. Follow on ideas included:

- Finding a private company to drive the construction of a model Eco Park (John Marchetti and Antoinette Sebastian will meet to follow-up).
- Factor IE considerations into federal R&D.
- Continue efforts to develop and mature the concept of IE.
- Build public and government awareness and support for IE. Create stakeholder awareness through dispersed conferences and workshops involving all elements of society. These would grow to national and then international conferences.

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Mission
We represent private capital sources and multilateral institutions (world bank).
The mission is to protect and grow the capital our clients have entrusted to us.

Challenges
Limited Capital/How to get more capital
Getting intelligent laws and regulations; being aware of changing laws/regulations; influencing laws/regulations
Need to set reliable and concise information about total environment/community (economy, policy, legal)
Information about new/evolving technologies
Interaction between private capital and government support of new technology (valley of death) (incomplete commercialization)

Objectives
Alliances which leverage others' resources with ours
Have appropriate legislation enacted/ financially support other groups
Global Information System that tracks major trends on pollution, economics, political, (accounting system)
Global information and assessments of new technologies
Mechanism to bridge valley (Venture Capital to commercialization)

Strategies
Create global IE Fund
Change lender liability laws
IE accounting
Develop a mechanism which provides information (global and technical information)
Get public sector support for bridge
Achieve goals through alliances

Team Composition and Preparedness
This team came very prepared. They were interested in playing the game and apparently all had read the material thoroughly. Had some ideas already in mind.

Tony immediately started out with the idea that they should team up with Think Tank, Inc. to handle the people who come to them for money. Need to partner with them (or on a percentage basis) to handle the customers and separate the good from the bad (vet the technologies), leaving more time for Finance Group to handle other options. Mak Dehejia had the interest and suggestions for global environment in foreign countries. Tony Biddle had suggestions of real-life work situations that he is dealing with day to day. Paul Bailey would occasionally bring up a comment of how situations would work in the insurance world, but insurance was not a big factor in the discussions. Beau Roy contributed throughout, John Hevener was not actively participating at first, but was in full swing by the end of the game.

Description of planning session
Tuesday evening the team started to immediately discuss what they should do. They covered possible strategies, identifying that they represent capital shareholders. They need to maintain the value of their capital, conserve their

capital, but grow. Determine how much capital should be put in safe investments and how much in risk...want to prevent taking any more losses. Some of the discussions entailed questions or comments such as:

- Our first priority is to preserve capital
- Screen technologies for investments down the road
- Impact not just today, but later
- Do we want to do manufacturing or do service
- Use good strategy with our portfolio
- Cannot be reactive, need to be proactive
- Whose money do we represent
- Assistance from National Labs, Univ., Think Tank, Inc., to help evaluate certain types of technologies
- How do we invest -- the higher up we start, the better the investment -- lower, waste reduction -- higher, new technologies; the one we get more return on, we should go for -- that's real life.
- Purpose of Industrial Ecology -- leave the planet in as good a shape for our children as we have it.

In fact, everyone went home Tuesday night late, but with additional assignments -- e.g., do an initial draft mission statement and identify which teams are most likely to help or hurt us and consider how we should approach them. Wednesday morning Beau R. brought in a paper with some written suggestions for mission, options, objectives and strategies. He wrote them on the flip chart for everyone to read along with passing out a copy. Tony Biddle did something similar. After reading Beau's suggestions, everyone thought it was great, but they did a little word-smithing and after a few more discussions identified the Mission, Challenges, Objectives and Strategies.

Ground Rules:
Each player focused on their team's goals and objectives. They entrusted each other with going forth and making Tookit options and agreements with other teams. If something came up to question, they confided and made sure the other members were in agreement or if they were not, acknowledgment to proceed.

Role Assignments:
Bob Price quickly emerged as the leader of the group, with Tony Biddle as a strong second. [The group leadership apparently arose spontaneously as a result of personalities rather that from any deliberate group decisions.]

Final Plan

After reviewing the team's objectives and strategies in session 5 the players decided to go with a new plan in 2005. The changes can be summarized as follows:

- Bring evaluation process back in-house (away from Think Tank)
- Shift funding priorities/target levels, research-development-commercialization (internal, not government)
- Help integrate financial resources for entities we are funding
- Do everything to bridge the valley
- Use contracts and influence to link various teams/segments to improve IE - proactive as catalyst
- Proactively seek projects that fit
- Go to developing countries and do infrastructure with technologies for percentage of development gain (privatize infrastructure) (industrial revenue bonds)
- Develop a distributed IE voucher system - to be used only to invest in privatized industry (used in Latvia in real world - John Hevener.)
- Barriers: (How to get out of the box) Tied in by current relationships (banks for safety). Medium of exchange needs a broader set of social indicators.

Focus
Global 60%; National 40%; Regional 0% (The split between global and national was a close call, but there was virtually no regional focus.)

How strategies were implemented

Did individuals feel empowered?
They decided to individually meet with other teams representing the whole group, each given authority to make decisions, meeting back with the group to get approval.

Were moves in concert with strategies, or carpe diem?
They normally tried to work within the guidelines of the strategies and objectives, checking the flip chart to identify what was agreed upon, but sometimes in the closing minutes they went with whatever worked. (FIN-4 Global IE Voucher was a last minute idea by John Hevener, which worked.)

Long-term or short-term thinking?
More long-term -- as Tony Biddle (Chase Manhattan Bank) indicated: How do we invest? The higher up we start, the better the investment -- lower is investing in waste reduction -- higher is new technologies -- The one we get more return on we should go for -- that's real life.

Competition vs. collaboration; ability to partner?
Most dealings appeared to be in collaboration/partnering; however, I believe two agreements (i.e., with Think Tank or Mfg. II) turned into competition as to who initiated the agreement and what it involved.

Broad vs. narrow agreements/vision
One agreement , FIN-1, was similar to one of MII's. Their agreement was submitted first, but ours was a broader agreement .

Did agreements correspond to strategies?

Yes - The agreements we initiated and tool kit options we invested in covered the strategies put forth at the beginning of the game, except for bridging the valley which they worked on later.

Links between agreements?
A number of later agreements, many initiated by other teams or groups, were the outcome of and funded by the GIEF (Global Industrial Ecology Fund). Teaming to create the GIEF provided the basis for some of these future agreements.

Information that was not listed on the agreement forms?
There was a statement, Financial Industry Sole Screening Agent, between Think Tank, Inc. and Finance/Insurance whereby Think Tank, Inc. would be the exclusive representative and sole certification agent for any investment requests that Finance considers from any other groups participating in PG. This was signed by 2 members of each team and the facilitators of both teams. This was not put through as an official agreement.

Team Debriefing

Good points:
- GIEF and Consortium
- Summit - helped out of box thinking
- Challenges and strategies
- Preparation materials were good
- Staff

Ideas:
- Expand scope of game
- Key player for all panels
- Currency (Chits) - need more than money
- Central monitor for information

Needs improvement:
- Deal making confusing (tutorial not enough)
- Not easy to get out of the box and get an agreement on it - sell out of box - get detail
- Timing not obvious (1997-2007)
- Assumption that the environment is stable - no crises, disasters
- Build on own agreements, didn't know about all agreements
- Hard to get update - (wall updates not good)
- Mind mapping during first session was bad timing -- too involved in negotiating agreements
- Need better computers for information - maybe a large monitor centrally located with updates.

Follow on Activities:
- Have graduate game with same IE players (and from other games) possibly bringing in their own sample projects from real world to work on instead of simulated games.
- Modify prosperity game for third world
- Support for an IE Institute (non-profit, educational)
- Voucher scheme follow up

Foreign Governments and Public

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Global Community Team
(formally Foreign Team)

Vision

We are the global community. We create support and mobilize resources fostering policies and implementation mechanisms and projects for IE with specific emphasis on the developing world.

Challenges

- Socioeconomic or sustainable development for the whole world while respecting cultural identity.
- Reprioritize self-interest to align with the common good over personal, corporate, and national self-interest.
- Balance short-term and long-term impacts.

Objectives

- Identify and improve precision of information and communication related to IE.
- Develop a set of indices from local to global scale of cultural and environmental impacts.
- Foster broad-based education leading to global thinking in the decision process, including local mindset and awareness.
- Have every project initiated by MLDBs to include IE principles by the year 2000.
- Have US and multinational interests articulate long-term impacts on the global community.

Strategies

- Implement policy to require each project to incorporate language that recognizes long-term global impacts and identifies specific measurement, communication, and education tools to accomplish long-term benefits.
- Promote R&D to identify and develop new technologies to implement IE.
- Improve existing funding initiatives to better promote IE actions (including GEF).
- Foster and fund local empowerment for sustainable development decisions.
- Initiate program to promote global awareness through training and education.
- Establish global sustainable development IE academy.
- Promote harmonization of environmental regulations at "high" level (not at lowest common denominator) based on real data.
- Education for sustainable development must be short and long term -- implementation now to future

planning. Education is both formal and "continuing."

Team Composition and Preparedness

Familiarity with Handbook and Challenges:
Everybody on the team agreed that they had received the materials. However, they also admitted that they had not studied them in depth. Some also admitted that they had not read them at all. When the team was generating their challenges, they did not consider the challenges in the Handbook, possibly because few were aware of them. One team member asked why there was widespread discussion of the Rio Grande and expressed surprise when told about the Handbook section.

Appropriate Expertise for Roles:
Although we only had two "real" foreign national members on the team (Natalia/Viyek), most of the other members have traveled and conducted business worldwide. It was a good representation of global and regional perspectives. The team members had more education and training than project implementation experience.

Description of Planning Session

Development of Ground Rules and Role Assignments:
The team would not discuss ground rules and did not want specific role assignments for each team member. They agreed to just go out and discuss agreements with other teams and return for consensus from the rest of the team before signing forms.

Process -- Challenges (Environment and Problems):
The first thing the team did was change their name to Global Community. The team discussed how to balance short-term (economic) and long-term (environmental) impacts. They also discussed prioritizing the common good over local self interests while still preserving cultural identity. (Patricia, Natalia, and Viyek pushed educational, people, and cultural issues. The rest of the team primarily pushed economic development and policy implementation.)

Process -- Objectives (What) and Strategies (How & When):
The group was very adamant about raising the global interest in IE but did not want to turn into "information polluters." It was also important to the group to develop "statistically significant, accurate metrics on both local and global scales" to measure IE impacts.

Fidelity to Team Role:
There was a conflict between some team members wanting to be proactive (go out to find and make agreements) and other team members wanting to be reactive (wait and see who comes to us and what agreements they propose). This was hotly debated among the team. It was determined that whoever wanted to "go find something" would go and the others would stay and wait.

Final Plan

Focus
Global 98%
The focus of the group was very global. Even the smaller, local projects that were discussed were considered to be implementable worldwide.

National
Since we represented the Global Community, we had no national boundaries.

Regional 2%
Very minimal.

How Strategies Were Implemented

Did Individuals Feel Empowered:
The team really struggled in the beginning. There were many different conversations occurring at the same time. Viyek was very soft spoken, so he was constantly interrupted. Although the group looked to Natalia as the "foreign expert," the team did not easily adopt her opinions and ideas (too people oriented for the technology/economic mindset of most of the others).

Were Moves in Concert With Strategies or Carpe Diem:
The team did not appear to have a very solid strategy. They were encouraged to develop relationships with teams they could partner with on mutual interests, but they primarily waited until others approached them.

Long-Term or Short-Term Thinking:
The team discussed both long-term and short-term projects and impacts. They felt constrained that the game only covered 10 years. However, they did develop agreements that would extend beyond the ten years.

Competition versus Collaboration; Ability to Partner:
This team did not demonstrate proactivity. One team member (Arek) strongly encouraged the team to get out of the box and partner with other teams, but it was a hard process for most team members.

Broad versus Narrow Agreements/Vision:
The vision and agreements of the team were very broad. Some were also very vague.

Did Agreements Correspond to Strategies:
The team felt that all of their strategies corresponded to at least one agreement. However, not every agreement directly corresponded to a specific strategy.

Links Between Agreements:

The team did link agreements to their own previous agreements and a Toolkit option, but they did not look at linking agreements to other teams' agreements.

Information Not Listed on Agreement Forms:
Several of the agreements were initiated by the team using only their chits. In one case this appears to have been done to get the agreement (FOR-8) through without having to justify it to other teams.

Team Dynamics and Decision Making Process As Game Progressed

The women and Viyek were very people and culture oriented. They kept trying to get the rest of the team to see the "people" impact of IE. The rest of the team kept pushing growth and development, and helping others "see the light." The final agreement the team passed finally had all the human needs addressed, but it also stated that failure to follow the newly passed laws would be dealt with by a security force.

Team Successes, Failures, Other Highlights:
It was hard to get this team to work together toward a common goal. There were some very dominant personalities as well as some overly polite people. They would all say the same thing, but they had to say it their way. The team also divided into some small sub-teams (usually whoever would listen to them) and worked their own agreements (in line with strategies). One member who wanted to take over the team struggled with the role of the facilitator; partly because he wanted control of the team and partly because the game was not going as he would have liked. There may have been some deep-seated differences behind some of the disputes. In early discussion, at least one team member expressed anti-technology, anti-development sentiments. During the debrief, however, the team said they worked well together and felt they had a successful team and successful game.

Chits:
The chits were easily understood. It appeared that there was more money than necessary. Teams were dumping chits at the end of the sessions on whatever they could. It was discovered early in the playing of the game that whatever chit rating the team put on the form was accepted by the control team. We got agreements passed for low chits and without the buy-in from other teams although the agreements would impact them also.

During the debrief the team stated they felt that the agreements should have been more "costly" and that there should be a rule against using only your chits to pass any agreement. It is interesting that this comment directly conflicts with the team’s actions during the game.

What Impacts Did the Panel Discussion and Summit Meeting Have on Your Team and Their Play:
The team never discussed the panel discussions or summit meeting. They had no overt impact on the team.

Did Players Experience the Value of IE to Their Stakeholder Group:
They felt that they fully represented the Global Community and took IE to heart in all agreements made. However, there was no discussion of what it meant to implement IE .

Follow-on Ideas:
There were people who were interested in staying in touch with any outcome from the game, but they were reluctant to "sign up" for anything in particular.

Industry/Manufacturing I

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Vision
"To improve our value to stakeholders while aggressively decreasing impacts on the environment as a top business priority."

Mission
"Distinct manufacturing base with global industry leadership sourcing partially completed or assembled materials from tier 1/2 suppliers. Intense customer service is a growing need and value-added component of our offering. Global alliances are critical to our success."

Challenges
1. Continued improvements in environmental, energy, and financial performance may demand higher investments, more systemic approaches, and organizational changes.
2. European legislation requiring "extended producer responsibility," including return of products at the end of their life, presents significant organizational, financial, and logistical issues to manufacturers. Similar legislation has been introduced in the U.S.
3. Most corporate cost accounting systems bury environmental costs in overhead or other accounts, making it difficult to perceive the financial and organizational benefits of improved environmental performance.
4. Locally sponsored designed requirements may be difficult or impossible to achieve. For example, the Partnership for Next Generation Vehicles (PNGV) has set an efficiency goal for passenger cars of 80 miles per gallon.
5. Environmental costs raise the ultimate price of many products to the consumers (e.g., the Rochester Institute of Technology estimate of $400B to $500B per year; OMB estimates place paperwork burden alone at 5 billion hours per year).
6. Future consumer and environmental liability risks continue to mount.
7. Stricter U.S. environmental regulations make domestic products less competitive internationally.
8. Once-through manufacturing is inefficient and decreases potential profits.
9. The promises of eco-systems and eco-industrial parks have not been realized
10. Insufficient tools to guide design for the environment.
11. Insufficient incentives to design for the environment.
12. Insufficient education of the current and future workforce
13. Cheap labor outside the US

Objective(s)
1. Maintaining double-digit growth/profit throughout the next decade (return on sales and equity)
2. Develop and integrate I.E. concepts into our business processes.
3. Sustain healthy small business environment
4. Form alliances to create global leverage and drive standardization.

Strategies

- Foster the establishment of Int'l codes and standards for environmentally sound practices.
- Standardize the tariffs and duty structure
- Get agreement or one global business language
- Create incentives to reward businesses for incorporating I.E. concepts
- Expect and inspect that all factories including 1 and 2 tier suppliers are "waste free"
- Eliminate cross-border dumping of environmental impact
- Establish profit sharing strategies with suppliers that participate in recycling
- Establish metrics for measuring our progress toward and the value of IE
- Participate in consortia (Univ & Nat'l Labs) in developing IE tools and processes
- Establish "branding" strategies for identifying products and services that satisfy global IE standards
- Consider all products as services in the context of the total supply chain
- Drive our IE efforts with market forces vs. command and control

Team composition and preparedness

Familiarity with handbook and challenges?
The players seemed to have read the Prosperity Game Tutorial but had only briefly reviewed their Player's Handbooks and were very caught-up in understanding the game rules almost to the exclusion of understanding the IE game scenario. The team had many questions about the Game throughout the playing sessions. None of the team seemed to "fight the game." They seemed to learn quickly and were willing to become an active part of the game with only a little encouragement.

Appropriate expertise for roles?
The players all came from industry, but they had a wide range of knowledge and experience with Industrial Ecology. One team member was part of the IE expert panel (John Elter) while another was an environmental engineer and a third was the CEO of new startup company developing an environmentally friendly technology (Brad Lienhart). The remaining team members understood the basic Industrial Ecology philosophy with one exception, Phil Farley, who admitted that his knowledge at the start of the game was limited to the Player's Handbook. Phil was very enthusiastic about and during the game and attested to a great increase in his personal understanding of IE from playing the game.

Description of planning session

Development of ground rules, role assignments:
The team was very cooperative and willing to listen to all points of view. They decided that a majority vote of those at the table ruled concerning any decisions to be made for the team on toolkit investments, agreement support via chits, etc. (The de facto result however more closely resembled a consensus approach.) The team spent a great deal of time discussing and deciding on how the two manufacturing teams should coordinate and cooperate; the team tried to create a symbiotic relationship between Mfg. and MII. "Our waste becomes their raw material, and their waste becomes our raw material."

Mfg. and MII both tried to define their respective mission and strategy while avoiding conflict and minimizing overlap and duplication. Mfg. was very concerned about its role compared with MII. The Mfg. team saw MII as having a narrow agenda, short-term concerns, primarily representing small businesses, and more in the role of Processors who deliver final products. This contrasted with the role of Mfg. that was more involved in Services. The debate on Mfg. vs. MII was very lengthy and never truly resolved. In fact this discussion continued during breakfast on 5/21/97.

In addition to the Mfg. vs. MII debate, the team also considered the following issues and ideas:

- Who are we?
- Who do we represent?
- What is the agenda?
- Recycling
- Creation of Wealth
- Life cycle of Auto

From this analysis and review the Mfg. team considered that the Manufacturing arena was split as follows:

Team	
Mfg.	**MII**
FOCUS	
Product	Basic R&D
Services	Product
CUSTOMERS	
U.S. Congress (Fiscal Policy, inc. tax credits, small bus. initiatives	Universities
Fed. Ind. Agencies	Government Labs
Finance & Insurance, Int'l. programs	U.S. Congress (R&D Support)
Local/State Government	Fed. Advisory & Reg. Agencies
Public - U.S. & Global	Resource Providers
Control Team	Think Tank
Foreign Governments	

However, this was an interpretation of the Mfg. Team, and it was not formally accepted by MII. The MII team felt that there was more overlap in the respective roles of the two manufacturing teams.

Final Plan

Focus?
Global 5 %; National 75 %; Regional 20 %

How strategies were implemented

- ad hoc
- short term
- isolationist
- narrow
- only corresponded to strategies accidentally or inadvertently
- links between agreements were only random and inadvertent

Team dynamics and decision making

All opinions were considered and debated.

Chits: Too many, too few, or just right?
Probably not too many, but the team was not eager to invest chits solely to advance objectives, rather they preferred to either use the chits solely on their own initiatives or to barter with the other teams in a quid pro quo fashion of directly trading chits and/or chit support for deals.

What impacts did the panel discussion and summit meeting have on your team and their play?

The panel discussion and summit seemed to cause some entrenchment of the team as they remained skeptical about the state of the world as described in the Players' Handbook. This was especially true regarding what they considered alarmist, catastrophic projections regarding the depletion of the world's fossil fuels.

Did players experience the value of I.E. to their stakeholder group?

Probably not, as they were skeptical about the real relevance and applicability of IE in today's world where profit/loss and growth are the primary concerns. They also felt that it was an accurate representation of their constituents/stakeholders concerns that this IE exercise smacked of government imposition of more rules and regulations that constrain industry and negatively affect growth and profit. The teams objectives may shed the most light on their perspective and experience:

- Maintaining double-digit growth/profit throughout the next decade (return on sales and equity)
- Form alliances to create global leverage and drive standardization
- Develop and integrate I.E. concepts into our business processes

Follow-on Ideas:

- Keep group informed about any IE initiatives regarding tax credits, tax shifting, etc. (Group would be willing to be part of a team/take assignments for specific actions).

- Team would like to participate in June 24 meeting if it is related to this game
- Lots of networking occurred - team will keep up with this.

Industry/Manufacturing 2

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Vision

We represent manufacturers with R&D capability and associated services, including basic manufacturing and process industries.

Goal

Profitably provide customers continually improving products and services that take account of their full life cycle and environmental impacts.

Challenges

- The traditional "command and control" approach to regulatory enforcement does not promote voluntary improvements or innovations in environmental performance.
- Environmental costs raise the ultimate price of many products to the consumers (e.g., the Rochester Institute of Technology estimate of $400B to $500B per year; OMB estimates place paperwork burden alone at 5 billion hours per year).
- Continued improvements in environmental, energy, and financial performance may demand higher investments, more systemic approaches, and organizational changes.
- European legislation requiring "extended product responsibility, "including return of products at the end of their life, presents significant organizational, financial, and logistical issues to manufacturers. Similar legislation has been introduced in the U.S. .

Objectives

1. Develop better tools, data, and methodology to make better decisions.
2. Provide industry with greater regulatory flexibility to exploiting environmentally conscious processes and products.
3. Identify and promote incentives for industry to address long-range (life cycle) environmental needs using IE concepts.
4. Reduce waste from all sources to improve operational efficiency and lower costs.

Strategies

1. Develop tax and regulatory incentives that reward industry to employ IE processes (Obj. #2)
2. Strengthening and integrating existing data collection systems to support IE and flexible compliance

3. Support cooperative activities (industry, government, universities) to develop IE tools and common solutions (TKO 8, 11, 12, 14,).
4. Create an organization (e.g., UL, J.D. Powers) that manufacturers use to show their customers an IE seal of approval.

Team composition and preparedness

It was evident that the players had read their handbooks, but not as thoroughly as they should have. They did refer to their books occasionally, but seemed to be uninformed when it came to deciding on the tool-kit options.

Description of Planning Session

The facilitator led the group in organizing themselves for their role assignments, ground rules, and general organization. They agreed to use decision methodology; i.e., if an agreement corresponds with the objectives/strategies, and three players agree, then the home table player can sign any agreement. If the agreement is outside the objectives/strategies, and four players agree, then the home table player can sign. Jerry Swiggett was designated the Home Table representative, and several negotiating teams were defined to implement the MII strategies. Several of the players had specific areas of interest: Jack Silvey (Incentives), Tom Sciance (Long Range R&D, Tax Energy), and Greg Norris and Jerry Rogers (data collection).

Manufacturing I proposed the diagram below as a way to distinguish between the two manufacturing teams:

|R&D_____Products_____Services |

|_____Mfg 1_____
|_____Mfg 2 ?_____|

Mfg 2 includes R&D and process
Mfg 1 Examples: Xerox, Monsanto, Small Bus., Virtual Bus., EDS, GE, IBM, Ford/GM.

MII basically chose to restate their preferred role in their vision statement as representing companies having an internal R&D capability. MII felt the diagram from MI and the sample companies they listed as representing themselves were inconsistent. By this point each of the manufacturing teams were getting heavily involved in negotiations, and this "distinction" topic was never revisited.

Final Plan

Focus?
Global 20%; National 80%; Regional 0%

While the team was clearly aware of global issues, their actions and agreements were primarily focused on national issues. Since MII represented companies (though not explicitly stated, they clearly represented US-owned companies) with an R&D capability, they focused on IE issues relating to the US and R&D. There were several conversations about dealing with the foreign team and of different regulations in foreign countries, but no specific projects or interactions were undertaken. No regional issues were raised at all.

How Strategies Implemented

Did individuals feel empowered?

For the most part, all players acted as if they were empowered, although certainly with different social styles.

Were moves in concert with strategies, or carpe diem?

The players attempted to link their agreements reasonably well with their strategies. All of the players identified with manufacturing. Several of the players had specific agendas and interests that they pursued throughout the game. This team clearly approached their play from an industry perspective. From the beginning, the team had individuals assigned to the various elements of their strategies. In the end, they felt they had fundamentally built agreements in concert with their strategies and had made progress on all of them.

Long-term or short-term thinking?

Their vision and objectives contained long-term elements. Sometimes they would revert to short-term thinking to deal with a specific agreement, but their overall thinking was reasonably long term. They were all very pragmatic and understood there are no quick fixes to many of the IE issues.

Competition vs. Collaboration: ability to partner?

The team chose to collaborate rather than compete. They were, however, very selective in their choice of partners. Given more time they would have included more teams in their collaborations, but they chose to stay reasonably focused on the important few.

Broad vs. Narrow agreements/vision?

The agreements were broad in the sense that they were usually national in scope. Almost no company-specific or even regional issues were addressed.

Links between agreements?

The agreements would take into account which TKOs had passed and would also be modified because of other

agreements that had passed. John Powers set up a series of agreements that built upon themselves and had plans for further follow-on work when the game clock ran out.

Team dynamics and decision making process

The team interacted with each other well. You could clearly identify several different social styles, but everyone was generally given a chance to be heard. Several times there was difficulty in getting just one person to speak at a time. Under the pressure of spending their chits by the end of the session, they didn't always follow their own decision-making rules and considerable power automatically reverted to the Home Table player. No one, however, seemed to quarrel with the decisions that were made.

Team successes, failures, and other highlights:

This was a reasonably successful team. Their self-assessment was one of completing their strategies for the game. The winning proposal headed by John Powers in session 4 was their major success in that it helped fund their priorities in session 5. The only failures were Tom Sciance wasn't able to get the kind of tax legislation he wanted and Greg Norris couldn't get his data collection/flexible compliance issues passed in his form, but he felt several of the TKOs and other agreements essentially accomplished what he was after.

Chits: Too many, too few, or just right?

In the first negotiation session, the team felt constrained by the chit allocation. They soon figured out that they needed a "winning agreement" to increase their wealth as well as partnering with other teams. That led to their winning agreement in session 4 and provided them with more than adequate resources to implement their top priorities in session 5. The agreement costs were sometimes higher than they anticipated and that further encouraged their "winning agreement" strategy. For this team, the chit allocation seemed OK.

What impacts did the panel discussion and summit meeting have on your team and their play?

There were no obvious impacts from the panel discussion on this team. Several team members mentioned that the opening panel session seemed very academic and not necessarily based in the real world. However, the summit meeting was the catalysis of the whole game, and it gave the players the incentive to really get into their roles, and play the game (team plans and direction did not change). Prior to the summit meeting, there seemed to be a lack of excitement among the players (compared to other games).

Team Debriefing

1. What was our team's greatest success in the game?

- Executed/funded all strategies
- Had broad-based support and influence for agreements

2. What worked best in the game (i.e., for all teams)?

- Partnering with other teams
- Advance Material
- Good team type mix

3. What didn't work?

- Agreement pricing was arbitrary
- Having 2 manufacturing teams (complicated the play)
- Differentiate roles of 2 manufacturing teams prior to game
- Marshall was a gate to agreements
- Congress doesn't need to get appropriate consensus as in real life
- Roadmap OK, couldn't use during game
- Intro to IE not very balanced
- Panel of IE experts - too theoretical and no practice
- "Overhead Info" too big a part of game - game playing only about 1/3
- Didn't use some of tools available (e.g., IRN/Web)
- Didn't like mind mapping
- All money was spent in last 10 minutes of sessions/game

4. What Were the Key Learnings?

- Good networking
- Diversity in IE area
- Identified some barriers to IE
- Learned some different perspectives
- Reminds you that you don't know everything about IE
- Surprised to get broad consensus quickly

5. What Ideas and Initiatives Will You Try to Implement in Real Life?

- Work some of this info into NREL interaction (Tom Swiggett)
- Will try to work consortia concept (John P. and others)
- Should tie to existing consortia

- Will implement concepts with current Federal clients (e.g., DoD) (Jack Silvey)

6. What do you Suggest for Follow-Up Activities? Who Will Take the Lead (Names)?

- Interested in consortia concept (John Palmer)

7. Would You Participate in an Interest News Group/List Server Established After the Game (Names/email)

- All will participate if it turns out worthwhile

8. Other comments and suggestions?

- Would all play again if topic was of interest
- Need specific group chartered to follow up on this game

Resource Providers

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Vision

- "We are not saying GOOD BYE-we are saying SEE YA LATER !"
- "There are no foreigners!"
- "The largest polluter is the government, and that's who we go to for help?"

Our vision is to develop, communicate, promote, influence, and implement eco-industrial resource management systems globally. We will use the powerful leverage inherent in us as providers of society's primary input resources (energy, inert and biomass materials, etc.) to put in place by 2007 the societal mechanisms necessary to more effectively use all resources available.

Challenges/Objectives

1. Double society's end use of its industrial resources from 6% in 1997 to 12% by 2017.
2. DATA: Set up a world resources utilization center to track what is used by whom.
3. DEALS: Set up free market exchange for secondary resources like stock market.
4. LAWS: Lobby for laws that encourage closed-loop resource use.
5. MONEY: Create a world financing fund to help pay for closed-loop resource use.
6. PUBLIC EDUCATION: Use Public service advertising modeled on NIH programs.
7. Develop industry-specific technology needed for closed-loop resource use.
8. TRADE: Supporting the free market exchange of resources.
9. AVAILABILITY: Develop systems and procedures to ensure access to all needed resources.

Strategies -- We will use these common denominators in all agreements:

- Seek profitability for us and our partners
- Focus on re-use/1st, 2nd & 3rd level recycling
- Seek win/win, but will protect our fundamental interest
- Determine Environmental impact, saving
- Support Education of the public on IE ideas
- Go global "There are no foreigners!"

Description of planning session

- There was intense discussion regarding this because they wanted to know who they represented - the US or global representation of the World? Because 2 or 3 did business with international clients, they definitely

wanted to plan everything around the Global arena and not just nationally
- Those who provide input resources, such as raw materials, energy or transportation. Those who use the basic resources in manufacturing finished products or providing services. Those who provide financing.

Final Plan

Team Dynamics and Decision-Making Processes:

The team decided to make decisions by majority vote (4 out of 7). Our banker kept the overall view of our progression of strategies, communicating with our negotiators and keeping them up-to-date on the resource situation. They would work individually or in teams on an initiative, and would discuss the implications at team meetings.

Team Successes:
- Excellent intrateam communication and understanding: Our communication worked because of who we are -- mostly consultants doing global work. We take responsibility for our actions in real life, and we have had to learn how to adjust and adapt. We have multidisciplinary backgrounds and have experience working with multidisciplinary teams. This was our advantage over our competition.
- Excellent interteam communication: We brought in other stakeholders and related well to everyone. We determined our strategic advantages and weaknesses early, and found out we needed others. Our success hinged on creation of alliances and building trust. Publicity came from our winning agreements. We had good group and individual negotiating skills.
- We rarely "gave" one of our chits away. There was always some kind of trade.
- Resources play a key role in IE. We created an environment where our central role was noticed.
- We used shared leadership and acted egoless. We wanted the job done, and it was not important that We got it done.
- Our focus on re-use opened us up to the $$ and influence. We took responsibility for what the resources can do, Whether this was realistic, we incorporated solutions into the Resource Provider team.

What worked best in the game?
- Facilitator and analyst input kept us on track. Time constraints provided realistic confusion and quick decision-making.
- Game book and tutorials were useful, specific examples were valuable.
- Toolkit idea good, but limiting. You should just give us one example and we could develop our own. The toolkit content was good, use new name next time. "initiatives" "Ideas." Most men don't think of modifying, or changing tools. The name confuses the intent. (!!!!)
- Physical layout was excellent; food, lounge, restrooms, Dulles location, room, all very workable.
- Panel discussions: Peer ambassadors contributed more to the process than the experts.
- Rhythm good
- Mindmap: good, useful, needed copies to digest in the game. Gary's presentation was very professional. He did not insert himself personally, did not try to sell it. Good choice of people. COUNTERPOINT: The mindmap information was irrelevant, and the information was not used in the game. The mindmap did not really map our minds.
- Agreement map: a good social/closure process. Made us focus on winning. What did not work in the game? COUNTERPOINT: The agreement chart on the wall was not helpful at all. Peer voting was unfair, Control team only should vote, they have the perspective from 16 games.
- Stakeholder divisions. COUNTERPOINT: We had a tough time with U.S. vs. World resources disparity. How about two teams: U.S. Resource & Global Resource. Feds groups were out of proportion with reality. We had to quickly shift (in toolkits and in strategy) to accommodate them. Also need a Military Industrial Complex team. Needed UN instead of Congress (Congress created US geographical boundaries). Need an International NGO team and a Press/Media team. The public group was difficult to comprehend, how bout a Green group?
- Not a scarcity of chits (or was it just a scarcity of ideas?). Scarcity could have driven the game more.
- Need central accounting tool for chit spending.
- Should have players that have role-playing experience in the game.

What will we implement in real life now?
- I will rethink the role of the Labs in our company.
- I will encourage EPA to broaden the stakeholder group.
- I have more respect for the individual values in the international community to be used in my global business decision making.
- I will bring the Yale team into my business as a resource for system training.
- The Allenby quote "Ignorance is profound." I will share with my clients, the humility of experts and hope to prepare a paper with my clients on the difficulty of incorporating these concepts.
- I will explore the use of games within my company with Managers. Follow-on activities for game planners?
- Sponsors need to communicate to others the success of the event.
- Please communicate with players: who will get this information. Who is the real client of this process?
- All team members want to participate in an electronic communication system.
- All team members were willing to participate in follow-on activities and each said they would be willing to lead an effort. Ed was the only person with a specific

initiative in mind. He would like to work on consumer awareness. He suggests a Madonna tour called "Re-Use Material Girl."

Other comments:
The most important technology to bring to industry is collaboration. What they can do together does not impact their ability to compete.

Local/State Governments

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Session 1: Planning (Wednesday 9:30 - 11:30) 1/1/97

1. Who are we and who are our constituents? Constituents are those that live in entities that are under subfederal jurisdiction. We should represent an aggregation of local and state interests.
2. Desire a viable economy while simultaneously addressing the issues of energy and transportation. Want to work in a positive manner on the behalf of our public with local industry. Need to know about the concerns of people at the local level - meaningful employment, quality of life, access to information or knowledge.
3. Need an informed and educated populace. Need a life-long education provided at the local scale. Educational infrastructure that is accessible at the local level.
4. Competition to attract industry is having a destructive impact on local government. Attraction of industry often ignores the ecological impact. Trend is to maximize economic benefit at the expense of ecological impact. Our objectives from industries that locate in our community must be sensitive to quality of life, educational infrastructure, environmental issues. Must design a safety net for quality of life. Seek businesses where the waste of one industry is the input to another industry.
5. Intellectual capital is also a part of the model. Industrial ecology must also include intellectual capital.
6. Overall, want to be proactive in interacting with other teams.

Represent a group of subfederal constituents.

Looking for quality of life relative to those communities affected.

1. Develop ground rules for engagement and assign roles to team members.
2. Two Sentence Vision or Mission of Local and State Government Team - Who are we? (10 minutes). Attractive, healthy, vibrant communities with human systems designed to work in harmony with humans and nature. Engineered systems include both high-tech and low-tech classes.
3. Statement of challenges, threats, problems or issues that may negatively impact stakeholder group represented by team over the next 10 to 30 years. How to rationalize competition among communities to attract industry. How to assure that attracted industry does not destroy those community features that attracted them in the first place. How to assure an integrated systems perspective in local- and state-level negotiators just as decision making is becoming more decentralized. This includes attracting industries that have a broad sense of responsibility to the community. How can states and local governments lead in an era of reduced credibility of government? Global market forces are weakening industry sense of place and community responsibility. Perceived industrial need to grow at any cost. America's self perception that it suffers from a lack of resources rather than a lack of will.
4. Statement of set of solution paths, grand strategies, or objectives (outcomes) that are a response to challenges, threats, problems, or issues. Insure that local and state

governments and the communities and community values they represent are players in industrial choices. Establish coalitions of government, industry, and university partnerships to achieve the vision. Goal: sustainable local regulatory commission. Give local and state governments more self-rule and autonomy in dealing with industrial ecology issues, e.g., regional environmental actions. Establish a local process for determining local and state quality of life and environmental quality goals. Develop a way to reintegrate central cities into building American economic prosperity. Expand our concept of industrial ecology to include understanding what makes cities dysfunctional. Build a civic infrastructure (includes both physical and social capabilities) that includes ecologically based problem-solving skills. Goal: attractive, healthy community. Keep an eye on the distribution of wealth and the widening gap between the rich and the poor. Goal: social equity. Negotiate workforce training programs as part of the package of attracting industry. Need a more robust way of looking at how money affects communities. Goal: Address sustainability including consumer behavior in K-12 education and teach civic responsibility in K-12.

5. Decompose above into a prioritized set of strategies. Develop civic infrastructure including physical and social systems. K-12 education is one focus. Develop community-based environmental quality objectives. Grow business using a sustainable industrial ecology framework.

Team Composition And Preparedness

Familiarity with handbook and challenges
The team members appeared to have read the handbook and vaguely understood the challenges that they faced. However, none of the players came to the game with either a strong passion for the team's role, or a strong desire to accomplish a particular goal. Each team member had an impressive background in industrial ecology and spoke the IE language.

Appropriate expertise for roles
None of the team members had any experience in state and local government. Most had come to the game expecting to be members of other teams.

Planning Session:
The players developed the team plan with the prompting of the facilitator. There was little interest at this stage of the game in developing ground rules and assigning roles. Later the team assigned roles, but never had a need to develop ground rules. The team was sensitive to maintaining fidelity to state and local government issues. However, it's response to the strategic planning process was rather academic. The team did not identify itself as representing a specific local community or a specific state with clearly defined problems; instead, it stayed at a somewhat vague, intellectual, global level. The team shared leadership without any particular team member showing interest in emerging as the team leader; rather, all seemed content to work through the process suggested by the facilitator.

Final Plan

How Strategies Were Implemented

Each member of the team was empowered to make deals that supported their strategies. Members of the team cooperated throughout the game without any competition among members. Furthermore, members of the team did not feel that they were in competition with the other teams. The team asserted that local and state governments will continue to be where industrial ecology action is centered, even though knowledge of industrial ecology issues is distributed globally. Despite this assertion, the team discovered that the roles of state and local governments in industrial ecology are not yet well defined.

Team dynamics
They worked well together and, despite the lack of team members representing state and local government, it was effective in representing state and local government issues.

Team successes
The team met it's prioritized objectives and was effective in leveraging its influence with other teams.

Chits
The team found networking among people and making contacts throughout the game to be advantageous. They liked the chit exchange system and thought that it fostered creativity; and, they found the mind maps to be useful in helping think about options. However, the team felt that the tool kit inhibited creativity because they didn't have enough time to do thoughtful strategy and build on the toolkit options.

Summit
They felt that the summit was too long.

Follow-on Ideas
The team concluded that the IE community must take a systems perspective and connect its actions to sustainability. It concluded that the game had highlighted the need to build communication bridges between various groups that are key to the future of industrial ecology. In fact, most of the team members saw IE as primarily an education and communications issue. They were concerned that some of the teams represented in the game were looking for technology pieces of IE issues outside of their socio-political context.

The team recommended that IE considerations be integrated into existing social, economic, and educational systems including a joint NSF/Lucent project. Team members indicated that they would like to continue to work with

local/state groups and network with those interested in IE they met at the game. All of the team members indicated that they would participate in an Internet IE News Group and they suggested that this site be linked to other web sites that address IE issues. They emphasized the need for someone to nurture follow-on activities and avoid the IE knowledge vacuum. They concluded by emphasizing that technology is neither the driver nor the primary IE issue.

Think Tank, Inc.

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Vision and Mission

We represent an interdisciplinary team composed of ecologists, economists, engineering, management, and social scientists who have accepted the challenge to integrate and articulate a global vision to implement IE in a way that will coordinate the efforts of industry, the public, government and academia. We will accomplish this by being a reservoir and an active conduit for information and technology to accomplish the challenge through moving from simple ownership to stewardship of products and processes and their consequences.

Goals and Objectives

1. Expand the reservoir of knowledge
2. Change basis of regulatory policy from command and control to stewardship

Strategies

Related to (2) foster partnerships with universities, labs, resource providers, stimulate and participate. (1) Global influencer of public and private policy and investment.

Team Composition and Preparedness

Familiarity with Handbook and Challenges

Most of the team members said that they read the material. One said that they had "skimmed" it.

Appropriate Expertise for Roles

All five of the team members were well qualified to be involved in a Think Tank. All the players had the mental and technical skills necessary for game play. All held responsible positions within their respective domains of work. The most challenging aspect of the game for this team existed with the domain of entrepreneurial leadership and creativity.

Description of Planning Session: Development of Ground Rules, Role Assignments

The team spent a great amount of time discussing and identifying potential team construction. The following quotes from the Tuesday evening dinner session testify to the wide range of thought and position relative to the participants and to their initial attempts to position themselves within the game:

- "We need to go from our highest ideal, then to jobs and money."
- "We need to be pragmatic - technological creativity applied - we can be creative and stretch."
- "We need to make connections between individuals, government, the 3rd world and draw connections early and always - develop an understanding of the system."
- "What is the social dimension?"
- "The most important question is, where does our funding come from?"
- "Our purpose needs to be to eliminate energy scarcity as a cause for war - energy as it relates to biological resource; the ecology part of industrial ecology is the most important; our purpose is to align with those

initiatives that have as a purpose to have a sustainable planet. We provide a thought process, address future generations, not from the present, but from the future as we desire it to be."

Process: Challenges (what is the environment? what are the problems?)
The challenge of creating a Think Tank, Inc. identity occupied Tuesday evening and Wednesday morning. The Finance Team (G. Robert Price) provided some beginning structure for the Think Tank team by suggesting an alliance. Think Tank, Inc. was looking for a customer base. Finance wanted to bring TTI the deals brought to them and give TTI investment criteria, in order that the deals would be ecologically responsible and responsive. TTI would do the initial screening so that Finance would be relieved of that responsibility. In return, TTI would invest resources with Finance. Agreement TTI-02 was a redraft of TTI-01 and was the only TTI agreement made during Wednesday's game play.

Process: Objectives (What?), Strategies (How? When?)
Mid-morning Wednesday, Murray McCombs offered his view of a strategy for the team by identifying Resource Providers, Industry and Manufacturing, Foreign Governments (projects and infrastructure), along with the Public, as potential clients. TTI would then partner with Finance and would seek additional partnerships and agreements with Resource Developers, Universities and Labs, Congress, State and Local Governments, and Regulators. He suggested their domains be in the realms of Bio/Climactic and Energy/Environment, that they act as integrators of policy and products, and that they comprise an interdisciplinary team of ecologists, economists, environmentalists, management, and social scientists. This led to the creation of their vision and mission statement.

Final Plan

Focus:
Global 40%; National 60%; Regional 0 %

The team was concerned with global issues and chose to attempt to create and affect policies on a national level that would have global impacts.

How Strategies Were Implemented

Did Individuals Feel Empowered?
The team members felt far more empowered when they created their vision and mission. Their participation and involvement, as a team, increased dramatically on Thursday (the last day) and they felt, at the end of Thursday, that they had "created a very coherent team that had created important and powerful agreements."

Were Moves In Concert With Strategies, or Carpe Diem?
The team moves were primarily Carpe Diem in the beginning and became Crescit Eundo on Thursday.

Long-term or Short-term Thinking?
Prior to Thursday, their thinking, as a team, was primarily short term with occasional attempts at long term. Their thinking became more long term as they found their foundation and as they felt more comfortable within game process.

Competition vs. Collaboration; Ability to Partner?
The team's ability to collaboratively partner increased dramatically on Thursday.

Broad vs. Narrow Agreements/Vision?
The team began to expand their sense of themselves and their possibilities on Thursday. Their agreements made on Thursday testify to improvements in their collaborative interactions and ability to participate in meaningful and creative ways. Thursday's agreements TTI-03 (having to do with the creation of a full-cost pricing system generated in partnership with the Federal Regulatory Agency), TTI-05 (the creation of an IE education program) and TTI-06 (the creation of an IE labeling program) were closely linked, and were somewhat linked with agreement TTI-04 (providing Congress with independent assessment of IE objectives with developed metrics). All agreements were in keeping with the team's stated vision and mission. Wednesday's agreement TTI-02 (creation of a global IE certification body in partnership with the Finance team) was a redraft of Agreement TTI-01.

Did Agreements Correspond to Strategies?
The generated agreements corresponded to their stated vision and mission.

Links Between Agreements
Agreements TTI-03, 05 and 06 were closely linked, and somewhat linked with agreement TTI-04. Agreement TTI-02 was a redraft of Agreement TTI-01.

Team Successes, Failures, and Other Highlights

Successes:
Thursday's play was a huge improvement over Wednesday's as they felt greater definition as a team and as they moved into concerted purpose with respect to the creation of agreements. They succeeded in moving into collaborative partnership with one another and with other teams on Thursday. They also succeeded in coming to agreement (at the suggestion of Paul Chalmer) with respect to the tremendous importance of "stewardship" with respect to the environment. Agreements relating to the establishment of "full-cost pricing," an IE labeling program, an IE educational program, a Congressional IE assessment advisory, and a global IE certification system used in

concert with financing guidelines were steps this team took toward fulfilling their stated vision and mission.

Failures:
The Think Tank team did not understand the ToolKit session or its options and were unable to fully participate in that particular segment of the game. Also, they had difficulty in the establishment of purpose or ideals that would have made it far easier to create themselves as an entity. Culturally common, a lot of time and effort were spent attempting to determine potential sources of revenue before they had determined their own identity as an entity and the value they would add to the world.

Chits: Too Many, Too Few, or Just Right
The team seemed to have enough chits to interact, though they did have some confusion with respect to the use of chits overall.

What Impacts Did the Panel Discussion and Summit Meeting Have On Your Team and Their Play?
The panel discussion and summit meeting played an important role for this team and provided valuable input, ideas and potential structure.

Did Players Experience The Value of IE To Their Stakeholder Groups?
Yes

Follow-on Ideas
The players want to see a web site created which is informative with respect to the subject of IE, and which provides the ability to hold conversations and share learning and information (a web site that carries a bulletin board, perhaps). They were interested in harnessing "brain power" and having a follow-up meeting with respect to an R&D consortium. They also stated that there was a glaring absence of ecologists in the game and that they should definitely be included. Barbara Karn stated that she had tried to access the Sandia web site to no avail. Most of the players said that they made valuable contacts which they will pursue after the game and that they had seen and done some things they could take back into their professional lives. One player stated that she had experienced nothing to take back into their lives. They also stated that there were lots of talented people in the room and they want those people to expand their abilities to generate creative suggestions and solutions. Murray McCombs was very interested in the game process itself and plans to adapt certain aspects of the game for use in another participatory process he is designing on the subject of energy.

Universities

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Vision

We are the providers to adults of education, knowledge creation and research capacity building that resupplies educational, industrial and policy institutions with creative problem solvers. We will address and achieve a sustainable society and catalyze its attainment with the ideas tools of IE. The service we provide to society will reflect the advancing understanding of IE.

Challenges

1. Industrial ecology introduces complex new research themes which must compete with existing and familiar programs for an apparently shrinking pot of resources.
2. Typically, research institutions are highly compartmentalized, whereas industrial ecology demands a highly transdisciplinary approach.
3. Some industrial ecologists say that the major barriers to application are at organizational and policy levels, not technical. Yet the primary major research in IE so far has been on the technical side. Relatively few business organization researchers have participated.
4. The non-linearity of many systems of concern in IE presents unique challenges to researchers accustomed to working in a linear mode.
5. The diverse economic, environmental, and technical data bases required for IE analyses are often not available. Basic data on materials and energy flows and toxicity are incomplete and scattered across many data sources.
6. IE methods, such as industrial metabolism and design for environment, depend upon data on ecological and health impacts of substances and processes. The data are now available for only a fraction of chemicals.
7. Industrial Ecology work is fragmented and many efforts remain narrowly focused.
8. Environmental research is often politicized and motivated by reasons other than science.
9. Demonstrate competitive and institutional advantage to other stakeholders of IE - create understanding.
10. Stimulate reliable funding sources matching job market.
11. Profound influence of ignorance

Objectives

- Respond to challenges
- Analytical tools for IE
- Partnerships inside/outside universities
- Modify university reward system for cross-discipline studies
- Integrate IE into curriculum
- Practice what we preach

- Establish viable funding base
- Produce qualified/capable IE problem solvers
- Establish champions of IE

Strategies

- Influence the peer review process, change, improve peer review process in such a way that IE, cross-disciplinary research is effectively evaluated and rewarded accordingly.
- Stimulate a source of seed funds within universities to endow IE programs.
- Build University/community partnerships. Create living laboratories. Create models.
- Reprioritizing funding agencies towards IE.
- Build partnership with Congress
- Build partnerships w/Industry
- Team Composition and Preparedness:

Team Composition and Preparedness

At the first meeting on Tuesday evening it was not apparent that the team was very familiar with the handbook and challenges. However, their general expertise for the roles was very good. All had some knowledge of IE, but it varied from novice to true expert. They had a very lively discussion on what each of the players thought IE was and what role universities should play. This group was also composed mostly of educators rather than university researchers and that "colored" their view of the role they should play throughout the game; i.e., they felt strongly that it was their job to educate and train, not necessarily to be providers of technology. They felt like the game organizers "set up" the universities in the role as technology providers because that is how the labs view them, but that is not necessarily an accurate view.

Planning Session

During the planning session the team was anxious to get going, but realized that there needed to be ground rules and role assignments. John's first suggestion was that there be a CEO that had the ultimate decision-making power. After some discussion it was decided that group members would leave to bring back suggestions. They would have delegated power, but when crucial things came up, the would return to the table and come to a vote. At the initial planning meeting it was decided that Dick and Jean Lou would work with the Industry Team, Martin would work with Congress and John and Reid with regulatory agencies.

The group began to look at its challenges and with very little discussion decided to adopt all the University challenges in the handbook. Based on their roles at their own universities they also added three challenges (1-3). They didn't discuss any of them individually or choose any particular one to champion.

Final Plan

Focus:

The University group never discussed whether their focus would be global, national or regional. Their objectives and strategies lend themselves to a more national focus. When it was time to create agreements, the majority created by the University team were national in nature.

How Were Strategies Implemented?

Did individuals feel empowered?
Individuals in the group felt empowered. They went in different directions to negotiate agreements in small teams of two and a few by themselves.

Were moves in concert with strategies?
In looking at the strategies the team moves were in concert with their strategies:

Long-term or short-term thinking, etc.?
This university team focused more on long-term rather than short-term thinking. While their agreements were not complicated they were long range. There were several agreements that built upon other agreements.

Team dynamics and decision making process as game progressed:
The team changed as the game progressed. We lost three members by the second day. Two had other commitments and one left because he thought other teams were cheating on the voting process for agreements. We had two very vocal and opinionated members, yet they did not take over the team. One person who had been rather quiet at the start emerged as the peacemaker and leader of the group. The procedures they initially agreed upon were not followed. Voting was abandoned and agreements were supported if they were in line with the group's strategies. The team used its time well to accomplish what needed to be done. They didn't try to accomplish it all at the last minute. When it came to establishing agreements, teams of two worked on them.

Team successes, failures, and other highlights

The team felt very successful because they were able to fulfill their strategies and get their agreements in place. Literally, every agreement they put forward was adopted. They felt they were successful at teaming with other groups. However, by the second day they became less pro-active and less energetic. Team dynamics dropped significantly and they became more individualistic, each attempting to advance their personal agenda. However, true to the "academic freedom" model, none objected to what the others were doing and so each went out to champion their own favorite agreement, generally quite successfully.

Chits:
This team had no problem understanding the chits and the agreement process. However, they felt strongly that, in their case, chit distribution was not an accurate reflection of reality. They felt that there were too many chits which, therefore, allowed everyone to be reasonably accommodating rather than creating conflict like that which exists in the real world. The university team felt that they have significant influence in real life (to legitimize, press power) and this wasn't captured in the game structure; i.e., they wanted influence chits. Wildcards were mentioned at the beginning of the game and then never mentioned again. The team wondered who received the wildcards and thought it might have made a difference in negotiations of agreements if they had known who had the wildcards.

Impacts of the expert panel discussion and summit meeting:
The university team thought the expert panel discussion was interesting, but that the most important question was not asked. "What is IE all about"?. They felt that had this question been asked, it would have changed everyone's views on the game.

They felt that the summit was very good and had a positive influence on the agreements that occurred after the summit.

Did players experience the value of IE to their stakeholder group?
The university team felt that the game developers characterized them incorrectly. They felt they were given a limited role and that they were only construed as technology providers and not as educators. Each member of the university team really felt that their true purpose was education and teaching the teachers. As to technology.....if they need us, they will come and get us.

The university team wanted agreements to happen because they were good ideas, not because they were directly related to institutional interests.

Because the university team saw themselves more as educators than providers of technology, they thought the team should also include other educators - community colleges, K-12.

According to the members of the team, the university culture generally does what it wants to do and on our team each person was taking care of their own agreements on the last day. Each had an agreement that they championed or were teaming with other teams on and they went their own way.

Some in the group felt strongly that it was a serious oversight to not include a strong environmental advocacy group. They did not believe that the environmental advocacy position was well represented by the public (public didn't reflect strong enough views). Therefore, the outcomes of the game were critically shaped by the membership. Resource suppliers and manufacturers were pretty easy going (in real life there would be a lot more conflict)

Follow-on Ideas:
Team members advocated creating courses that will educate in IE.

U.S. Public

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Vision

Who are we?
Who might we be?

- NGO's
- Future Generations
- Consumers
- Religious/Spiritual
- Taxpayers
- Voters
- "Communities"--enfranchised and disenfranchised
- Enhance the quality of life for ourselves, our children, and for future generations

Challenges

- quality of air
- quality of water
- quality of life--health--education--independence--jobs
- environmental equity/justice
- maintenance of freedoms--whether intellectual or right to drive cars, for example
- management of resources
- established thought patterns
- making the plethora of data and information understandable and actionable
- finding visionary leadership (sustainable)

Objectives

- set specific environment quality goals
- foster a high priority and awareness of ecology
- issues--education--government
- purchases set to emphasize green
- Total systems life cycle cost--change accounting systems to reflect environmental costs
- design for the environment DFE--

Strategies

- Green Labels on consumer goods
- Government procurement to be required to use Total System Lifetime Cost
- Adopt ISO 14000 principles as law???--with respect to govt. purchases and through import regulations
- Education initiatives to increase awareness of environmental issues/solutions
- Incentives, based on science, for industry and for individuals to be environmentally correct--tax deductions--pollution credits--incentives for individuals
- Science-based standards to be developed--for example, RIO.
- Make data available, understandable, and relevant to public decision making.

Team composition and preparedness

Several of the team had read the books, and some had only scanned the materials. The expertise for the group was mixed, but was certainly more than ample if we were really trying to emulate the public.

Description of planning session

Bill McCulloch, the facilitator, got the group going rapidly by suggesting that it might be quite difficult to always come to consensual decisions, so some autonomy might be

needed for members, but Bill added that if the group at any time felt that a member was in "run-away" mode counter to the philosophy of the group, we would act rapidly to correct the situation. Everyone agreed.

Final Plan

Focus
The focus of the public group was varied, but everyone persisted, until close to the end, in proposing pet ideas with limited global impact. One person stayed focused on pushing for a regional project.

How Strategies Were Implemented

In general, it seemed that there was little in grand strategy, and therefore no complex links between agreements. Although there was no grand strategy, the group's resolve to entertain more strategic proposals from others on the second day certainly led to more thoughtful dialog.

Team dynamics as the game progressed
There was considerable difficulty in getting the team to stay focused on the issues at hand. There was a strong tendency to pontificate at high philosophical levels, but there was no initiative to discuss the truly global issues that had been discussed in the game book. The individuals in the group seemed to be used to thinking freely with little commitment to team and teamwork. Specifically, they did not listen to each other well, talking over one another, not letting others finish thoughts, etc. This diminished significantly as the game progressed but remained throughout.

At one point early in the game the players seemed to be hesitant to act. They seemed to be waiting for the forms/computer/staff to tell them what to do next. They soon caught on that they were free to do what they felt appropriate, as they saw fit.

Team successes and failures, and other highlights

Greatest success was their execution of their commitment to support nothing if there were no projects offering potential for significant long-term impact.

The team structure was what worked best in the game -- the right set of "stakeholders."

Things that didn't work so well:
- Completed deals went nowhere.
- Interaction with local government was missing.
- More defined role playing within the teams.
- The team was not able to act in keeping with their desire to be more forward thinking.

Key learnings:
- The value of IE needs marketing.

Chits:
In the first two negotiating sessions, the activity reduced to simply giving away chits for the last few minutes. During those times, deals were made without explicit regard to their contribution to our objectives and strategies.

Impacts on players of panel discussion and summit
These meetings were the most valued aspects of the conference/game. They conveyed knowledge and put people in a mindset to play IE.

As part of the summit meeting and as a result of our team's decision to "block," if necessary, all activities not holding some reasonable expectation of long-term positive impact, the Public Team effected an awareness of themselves and their position of power relative to the game. This proved to be a more appropriate role for the public and was an excellent maneuver toward their effectiveness in the game. They acted more in sync with their roles. It allowed them to raise their sights to longer range considerations. It enlivened the game. And, they did this without becoming barriers to activity; they still distributed all the chits to long-range ideas. In the process, in keeping with their public pronouncement, they made the conscious decision with respect to one proposal that they would rather fail to use a chit than to give it to a "substandard" idea.

Follow-on Ideas
Several of the team members indicated some interest in further participation with things dealing with IE. Possible real-life applications:
- Market advantage for real-life businesses.
- A way to "educate my customers."
- Things that can be used at home, with family.
- Use Prosperity Games as a teaching mechanism for the "Freshman" Congressmen?
- Conduct an IE game among various disciplines at MIT?

PART 3: Moves
(Tool Kits and Agreements)

New Toolkit Options (DRAFT) Index
(not all implemented -- see Successful TKOs list)

Con-01 Fuel taxes
FAR-01 Voluntary industry programs
For-01 Educational Initiatives
MII-01 Data collection systems
MII-02 Consortium to develop IE tools and common solutions
MII-03 Gasoline tax
Unv-01 Tradable ration certificates
Unv-02 (no record)
Unv-03 (no record)
Unv-04 (no record)
Unv-05 Reform the U.S. Tax Code

Draft Agreements Index
(items not finalized that are in various states of completion)

Con-01(A) IE Tax reform
Con-06 Nuclear Power Revitalization Act
Con-07 Fossil Fuel Reduction Act
DOE-02 A Coord. National Sys. of R&D Test Beds to Trial Alternative I.E. Methods
FAR-06 Comprehensive Transportation/Land Use Reinvention
FAR-07 Habitat Restoration Act
Fin-01 Global IE Fund
Loc-01 Voluntary industry programs II
Mfg-01 Free Market Incentives to Advance IE R&D
MII-A1 Data Collection Systems to Support IE and Flexible Compliance
MII-A2 Coalition to study complex toxicology
MII-A5 Exempt Allowance Revenues from Taxes
MII-A8 fuel tax revision
Pub-03 Provisions for displaced workers
Pub-04 tax credits for renewable fuel
RP-07 Application of nano-technology to IE problems
RP-08 Build two IE demonstration cities
RP-09 Ecoconsumer labeling
TTI-03 Full cost pricing system
Unv-02 Industry-University Leveraged Partnerships

Toolkit Investment Summary

TKO	50%	TO	R	Con	For	Loc	FIA	FAR	Int	Res	Mfg	MII	TTI	Unv	DO	Pub
Technology:																
Information Systems																
T1. IE databases	21	335	P	90	.	.	40	20	50	.	.	.	95	.	40	.
T2. ISO 14000 update	80	10	N	.	.	.	.	.	.	.	10	.	.	.	.	.
MII-01. Data collection	150	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
Energy and Transportation																
T5.5. fuel consortium	80	110	P	.	.	.	.	.	50	60	.	.	.	.	.	.
Materials																
T8. clearinghouse	10	110	P	.	.	.	.	.	.	30	20	.	.	40	20	.
Industry Initiatives																
T11. performance program	16	200	P	.	.	50	.	.	.	.	70	80	.	.	.	.
T12. reuse/reclamation	10	100	P	.	.	.	.	.	.	100	.	.	.	.	.	.
MII-02. IE tools consortium	45	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
Finance																
T16. investment guide	12	20	N	.	.	.	10	.	.	10	.	.	.	.	.	.
T17. internal accounting	14	405	P	.	.	.	50	15	15	90	10	.	.	30	.	60
Urban and Regional																
none																
Education																
T22. IE virtual university	80	60	P	.	.	.	50	.	.	.	10	.	.	.	.	.
T23. IE educational materials	70	75	F	.	.	75	.	.	.	.	.	.	.	.	.	.
For-01. Educational Initiatives	14	240	P	.	140	.	.	.	50	10	.	.	.	.	.	40
Policy:																
Reorganization, Reform and Administration																
P2. new reg. framework	13	30	N	.	.	.	.	.	.	.	.	.	.	30	.	.
FAR-01. Voluntary programs	10	235	P	.	.	75	.	100	.	.	.	60	.	.	.	.
Energy																
P7. greenhouse gas red.	29	30	N	.	.	.	.	.	.	.	.	.	.	.	30	.
Con-01. Fuel taxes	100	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
MII-03. Gasoline tax	30	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
Materials																
P10. reformed waste regs.	12	130	F	.	.	.	.	.	.	.	70	60	.	.	.	.
Unv-01. Tradable certificates	100	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
Unv-05. Reform Tax Code	120	0	N	.	.	.	.	.	.	.	.	.	.	.	.	.
Economic																
P12. GDP replaced	12	195	P	.	130	50	.	15	.	.	.	.	.	.	.	.
P13. R&D tax credit	16	210	P	160	.	.	.	.	.	.	.	.	.	.	.	50
Urban and Regional																
none																
Research																
P18. joint IE R&D	10	220	P	100	.	.	50	.	.	.	10	.	.	50	10	.
International																
P20. sustainability requirements	12	180	P	50	130	.	.	.	.	.	.	.	.	.	.	.
Education																
P23. public education	80	5	N	.	.	.	.	.	.	.	.	.	5	.	.	.

LEGEND

TKO Toolkit Option Number and short title
50% Investment required for 50% chance of success
TOT Total sum of actual investments
R Result from 'rolling the dice' (P = pass; F = fail; N = no roll (investment too small))
Con U.S. Congress Team investments
For Foreign Countries Team investments
Loc U.S. Local and State Governments Team investments
FIA U.S. Federal Industrial Agencies Team investments
FAR U.S. Federal Advisory and Regulatory Agencies Team investments
Int Finance, Insurance, and International Programs Team investments
Res Resource Providers Team investments
Mfg Manufacturers Team investments
MII Manufacturers Team II investments
TTI Think Tank, Inc. Team investments
Unv Universities Team investments
DOE U.S. DOE Laboratories Team investments
Pub U.S. Public Team investments

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DOE-1 Integrated Industrial Ecology Virtual System
FAR-2 Shift Industrial Policy to Reuse and Recycling of Primary Resources via Statute
FAR-3 Support for decentralized decision making
FAR-4 International Cooperation Initiative
FIA-1 IE World Conference
FIA-2 Global Industrial Ecology Network
Fin-XX Financial Industry Sole Screening Agent
FOR-2 IE Educational Certification
FOR-4 Agreement on the Preservation of Cultural Diversity
LOC-2 Integrated Infrastructure Renewal Strategy
PUB-1 incentives for alternative renewable fuel
RP-1 IE Implementation Fund
TTI-1 Global IE Certification Body
TTI-2 Global IE Certification Body amendment
Unv-1 University Community Consortia
Unv-3 Reform Peer Review/ Funding Procedures for Fed R&D Grants

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Con-02 Global Trade and Industrial Ecology Negotiating Authority
Con-03 Tax reform Agreement
Con-04 Endowed Chair in IE
Con-05 Research exchange Program
FAR-05 SEC Environmental Reporting
FIA-03 Bilateral Resources Ecology Park
FIA-04 Making Federal Procurement Support IE
Fin-02 Lender Liability Responsibility
Fin-03 Global Project Rating Agency
For-03 Global Ecological Living Institute
For-05 Global IE Education
For-06 Harmonization of International Industrial Ecology Standards
For-07 Expansion of GFE Scope to Include IE
Loc-03 Sustainable Communities Network
MII-A3 Industrial Ecology Consortium
Pub-02 Public-Industry Partnership for ... Integrated Next-generation Environment
RP-02 Global Consumer Awareness
RP-03 Recycling R&D Program
RP-04 Refining National Security
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FIA-06 IE Technology Demonstration Initiative
FIA-07 Require ... [all] federal suppliers to use best IE practices world-wide
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Mfg-02 Food & Water Conservation Through Innovative Agriculture
MII-A4 Institute for Industrial Ecology
MII-A6 Industrial Ecology Implementation
MII-A7 Technology Development and Deployment Risk Reduction Act
RP-DOE-TTI-P-1 Biotechnology for the IE Future
RP-05 Fisher Tropsch Industrial Park (PART I OF II)
RP-06 Home Utility Initiative (Energy & Water)
TTI-04 Congress IE Assessment Advisory
TTI-05 Industrial Ecology Education Program
TTI-06 Industrial Ecology Labeling Program
Unv-07 IE "Simtown" teaching software

PART 4: IE Summit

5/22/97 (Transcribed from video)

2004 IE Summit

Panel Members:

Team	**Ambassador**
Con	Dave Berry
DOE	Helena Chum
FAR	Marian Chertow
FIA	Antoinette Sebastian
Int	Tony Biddle
For	Natalia Tarassova
Mfg	Brad Lienhart
MII	John Powers
Pub	Cathy Imburgia
Res	Dave Odor
Loc	Joe Breen
TTI	Paul Chalmer
Unv	Bob Von der Ohe

Opening Remarks:

Marshall Berman [moderator]: President Madonna and leaders from all of the rest of the world have come together in this first-ever international summit on industrial ecology to discuss some of the issues that are going on at this time. (Which one is Madonna?) We did promise you a little fun. We would like to introduce you briefly as you begin to answer the questions, as there are a large number of delegates to this conference and a very large audience. We have put together four questions for you and will try to address them in approximate order. And we will be open to questions from the audience. ...

Questions:

1. What are the chief barriers to implementation of IE?
2. We know that IE tools and paradigms can be used to change technology. Can the same tools also be used in making the personal and social changes necessary to fully embrace IE concepts?
3. What are the appropriate metrics to determine if IE is making a difference?

I'm Tony Biddle with the Finance Group and I'll immediately show my bias by suggesting that a chief barrier, amongst many, would be a real lack of understanding, probably arising from the fact that there is very little experience in this so far. But a real lack of understanding for the pure economic benefits of implementing any one of a number of the IE principles and ways of doing business, which often require a given business or industry to change it's whole approach to things. Just like everybody else, nobody wants to be first. The future is very vague on these things; the only way that this gets solved is that various industrial units take fairly bold steps in very, very well-defined small controllable cases.

Cathy Imburgia representing the Public. I think one of the biggest challenges we have is that we are looking at short-term fixes instead of long-term solutions. Because of that the Public would like everyone with Influence Chits to hold back to all those who would like to propose a challenge that you come up with some long-term solutions; without that we are going to reject any type of solutions and agreements you bring to us. We would like anyone else to join us, and I think we have the Global Community who is going to join us. And I think between the two of us, we can hold out on the Influence Chits.

Brad Lienhart - Manufacturing 1. I think we should compliment large business and manufacturing units for all the great things they have done since getting involved in product stewardship in the early 70s and committing to a number of significant programs which can be called sustainable, or industrial ecology, in the last 10 to 15 years, remembering back to that conference that we all attended out by Dulles Airport back in 1997. We wondered how manufacturing would get recognition for all of the things it was doing, and certainly some of the measurements that were put in place at that time have allowed large manufacturers to be recognized for their contributions; much more is to be done of course. And global standardization of the approaches that we're taking is important, but what I'd like to say is, I think the missing link and the next challenge for IE is to get the many small businesses of the world committed to the same culture, the same process, and the same concepts and incentives and reward systems. Small business today is generating much more so-called waste than large business and we must get small business committed to the same concepts.

I'm Natalia Tarassova - Global Community. When I'm listening to my colleagues from business and manufacture, I wonder if we people exist for them, or do they work for us. This is not a problem of business or money, it's a problem of what we consume. To my mind the main barrier is a consumer society. That's my opinion and I'm with the Public of United States, and we will give our chits only to those who look for long-term consequences of any investment or any production method.

Marion Chertow - Federal Advisory and Regulatory Agencies. And now with the agency called "PHER." That's PHER (Public Health, Environment and Resources). We are very pleased that we solved so many problems, solved the 'big dirties." That was back in the 80s. We started to work with the small sources in the 90s, and the last 4 years we created these enormous trading programs so that Xerox can trade with dry cleaners and everything else in the whole region. Our problem is that this has only exacerbated the tendency of people to live farther from their jobs (I'm speaking of the United States, of course) because they think they can do it electronically. We're having land-use problems everywhere because we need more infrastructure. What was supposed to help us through telecommunications is proving out to be on the other side and we didn't have this data in 1997 when I met you, but we have the data now and it's discouraging because this is where we have the least impact, even PHER people like us, so were not sure what to do about this.

Joe Breen - State and Local Governments. The barrier at the state and local level continues to be in trying to work effectively with PHER. The major barrier that still remains is the government regulations associated with the transfer of waste. We are still dealing with reclamation problems - they talk a good line, but when you try to 'cook' a deal with them they just aren't very forthcoming. We're hopeful that Administrator Carra - is he here? - we are hoping there will be a very real effort to reduce or eliminate the barriers to dealing waste so we can have the industrial ecological concept of residues as opposed to waste.

Robert Von der Ohe - representing the Universities. Although I'm not sure I speak for the universities because we definitely are not of one voice. One of the issues that comes to me is from one of my lectures in my "Principles of Economics" class. We assume a given income distribution, and that's where all the action is. One of the things we are trying to deal with is, how do we deal with this question of income distribution and how do we break out of the box the administrators put us in and find solutions to using some of the things we are doing in R&D to solve population problems, to solve the consumption problems, problems of a consumption society. We go back and bring in some ideas from a liberal arts perspective, from Christianity, some of the things from Marx, from Utopian Socialists, to solve the problems on the demand side, as opposed to what the industries want to do to solve the problem on the supply side.

Antoinette Sebastian - I represent the declining Federal Industrial Agencies. The US government and Congress, in its infinite wisdom, has seen to it that we are reduced to bumping into each other in one building now–the Pentagon complex; and it seems that we really work desperately trying to do something in the bricks and mortar sense, and so we came up with an ecological park, bi-lateral, on the Tex-Mex border to see if we could handle some of the issues of maquiladoras, and the colonias. However, what we discovered is the Global Community is very stingy on Influence and were really reluctant to give us any, but we managed with the help of State and Local Governments, because they realized that when we're no longer there and our power is diminished, the burden is going to fall on them. Then it occurred to us, and there's so few of us we've actually had a chance to talk to one another, that the chief barrier - you don't mind if I go back to the original question do you? One of the chief barriers to the implementation of IE is to recognize what it's real limitations are. And yesterday, Marshall said something very interesting, he said that there's insufficient food, inadequate water, and energy. And, I thought, did Marshall write this book, because in our Handbook on one of the pages it says social issues are not a part of this game. That's one of the things that federal industrial agencies, who are not social agents, have come to realize that there is this incestual connection between social problems and what we do when a military base closes down. There are a few people around who may be adversely impacted. So we are

concerned about change in behavior, but our powers are so diminished, we are not in a position to do anything. What we would like to do, however, is have more dialogue with the manufacturing sector. They didn't want to talk to us at all. (Response from Mfg.–could not hear it.) That's only because you wanted to be the business located there and that's okay; we don't have a problem with that as long as you are willing to look at something other than the bottom line and cheap labor costs. It's the bottom line that's driving this and, as FIA, we see as one of our roles to still look out for the little people, contrary to sometimes what is perceived. We appreciate that chit.

Helena Chum - DOE Labs. We had a very interesting discussion yesterday, because the labs come from a highly technological point of view. We were talking yesterday about a consortia of labs, academia, industry, and finance, which is extremely exciting. Because 8 years from now we have stuff that is very interesting coming out. There are technologies that are in fact, dear public, sustainable, they will be permanent solutions to problems, not patching solutions to the next problem that we don't foresee. Can't you believe this? Can't you believe that renewable energy technologies will in fact get you solutions that will be permanent solutions to the energy problem for example. The problem is that in 8 years we have things that are being developed, we have technologies, that have very low pollution, very good life cycle, except we're not getting the financing that we need to get them moved into the market place. And so I have a negative and a positive, because in the same point we had ' let's do a virtual lab collaboration with universities and industries, and so forth; the following session came along with the finance guy saying, we need paradigm changes and in 8 years we report that, in fact, we have moved some technologies into at least from the demo phase into the first plant and hopefully into diffusion. So it's a problem that technology is a component of a problem; we have to get the solutions that actually are sustainable in the long run. We need all of us working together, otherwise we can't pull it. So, Finance and the Public will be helping us select and choose the options that will be sustainable for the long run.

Good morning, I'm Dave Odor from the Resource Providers side. I'm glad to hear that it looks like we've turned the corner here from some of the previous comments to a more positive side. I'm pleased to report that the Producers along with Finance, the two manufacturing groups, the Think Tank group, and to some extent maybe even some of the Local Governmental side, have expressed an interest to pursue this consortium that has been established with a way to fund and implement those types of activities that truly impact results to society. I think that what we have established is really the linchpin to start this thing forward and become positive. I think that the key, and I agree with some of the words that have come from Global and Government, but the key from the business side is twofold: True, the first thing as a business entity, we have to create wealth for our corporations; at the same time, we have to create wealth for society and in so doing, we both become winners. Thank you.

I'm Paul Chalmer from the Think Tank. From my point of view there are two major barriers to applying and implementing IE. The first is just the inertia built in to the system. It takes a long, long time to change over the world's capital stock to where we think it ought to be. The second is, we haven't the foggiest idea what IE is. In 1997 we had a matrix of 1000 empty slots. We have sort of filled in 5 of them, though there's some controversy in the last 8 years about those 5. So we really don't know where we're going. We had 40 years of oil left 8 years ago; we now have 32 years of oil left (actually 35) it's getting harder and harder to find. The way we've addressed this in Think Tank, we've taken a page from ecology where the (Delphi?) paradigm involves evolution and a selection process. The two key elements are massive parallelism and a selection factor where you have a thousand different possibilities or a million different possibilities contending - a few of them are successful. And then those things differentiate and contend. We don't see any way of improving on that. The way we've built that into the system is we have said that our chits or our certification will only go to programs where there is clearly identified in the program–built right in–a steward. A stewardship principle where somebody is responsible for all consequence chains that are unleashed whenever a particular program, a particular policy initiative, a particular investment, is made. We don't think that this is the solution, but we think that this will be the precondition for the solution. And, that's our approach, we are also quite cognizant of the fact that we have adopted a social systems approach to finding the solution rather than a technological approach. We do need some technological ideas and hopefully will be able to address that some more today.

John Powers from the Manufacturing community. I think that all I can add to what has been said is that there is still a barrier in this year and that existed 8 years ago and before that, that I still think has a lot to do with what would make a possible major impact. And that is a common base of selfish interest to support IE. The world, unfortunately, is made up mostly of countries and people who are have-nots and who don't have the resources or ability to do something about this because their sole priority in life is survival. And it's still true. And the rest of the world that has the resources is still highly motivated by bigger and better, and only incrementally has been able to make headway in this important area. Without a common base of selfish interest that affects every country and everyone's life, there is not going to be enough momentum to make radical change quickly. It will continue to be a slow, incremental process in the meantime.

Natalia Tarassova. I have to comment immediately. Selfish interests were mentioned. My country closed 70 percent of industry and we lost half of the population already to save the world. So we made our input to saving the global environment.

Robert Von der Ohe. I think we just picked up on question 4 on terms of what we heard from the Think Tank. To bring that back to the question of chief barrier to implementation, I don't know how we're going to get any funding. I understood the financial institutions early on, in terms of behaviors that they had, they were looking to overcome the risks of lending. They obviously think short term rather than long term, and if we have to take stewardship for the unknown consequences of anything we're going to do, in a world where we know nothing about what's going to happen, I wonder if we can ever get any financing for any of the projects that are radical to try to solve these long-term problems.

Dave Berry - Congress. I'd like to demonstrate one of the obstacles to the progress in IE, and that is Congress was very careful not to speak until everyone else has spoken because there's a risk of rushing off in a direction that no one's going. That's very embarrassing. Congress needs to lead by going in the direction that everyone's going in–and, I think everyone's going in circles these days. I think we visualize in our discussions in Congress, and I'd like to be very frank with you my fellow Americans, that we are not actually looking at the beginning of the obstacle, staring up at it like the mountain we have not yet begun to climb. We have spent several years being aware of some of these obstacles and working with them. For example, we have many diverse interests, that to varying degrees are somewhat self-serving and we've heard from all of these today. Yet, there's a sense that's gradually growing among all the individual interests that we stand together, or separately we fall, that the interests here are common interests. And I think if you look back to 1997 when we passed a landmark bill on shifting taxes, in cooperation with the Public and other sectors, the omnibus bill on IE that enabled us to even be here today, passed. There were many elements that weren't in the original package where industry came in and said tax waste, not corporate profits. And the Public had issues that they wanted, Finance liked some of it because it increased productivity, and we listened. I also wanted to say that in Congress for many years we have had a tradition of having to compromise. That often has made us somewhat wishy-washy, in fact maybe incapable of stepping out in front and leading or taking a long-term view, because there's been a need to make anything happen to go to the low common denominator. But, in facing some of these crises, with some degree of success, we have not shied from addressing these tough issues and working it out between left and right, between east and west, between prosperous states and states with high rates of unemployment, etc. I think we need to–Congress tends to be long winded, doesn't it? The way to address getting through the rest of the barrier is to increase the awareness of the common interest through greater education of the benefits. I don't think we should emphasize that this guy is following, I think we should emphasize the benefits of greater efficiency, the benefits of educating ourselves on changing procurement patterns, etc.–all the little decisions we make. Then, continue to work together to line up the incentives; to make sure we are not still rewarding unsustainable behavior. We welcome input from all our constituents, because we do want to get re-elected. I want the best ideas. Thank you.

Marshall Berman: Any questions from the audience?

(Could not hear question from floor - garbled on video.)

Let me read to you the questions we plan to address. The second one deals with social issues. We know that IE paradigms and tools can be used to change technology. Can the same tools also be used in making the personal and social changes necessary to fully embrace IE concepts?

Very pertinent to your comment is the third question: What are the appropriate metrics? Can you tell me if IE is making a difference?

And the fourth question, which we have begun to address significantly, is: How will IE be funded? We will treat your very important point as a full question.

Let me pause for a brief commercial (names game sponsors and introduces Adrian Gurule–chief electronic engineer, innovator expert, etc.).

Our next question deals with the social issues. The reason we inserted that statement into the Handbook is that we were concerned that some very intelligent person might propose some rather drastic social solutions, like forced sterilization or the selective use of nuclear weapons to reduce the population of the world. These are issues we really didn't want to grapple with in this context, and those were the severe population control statements that we wanted to avoid. But we recognize that social and personal issues are very important along with technology, and that leads to our second question, which I will read slowly.

Q 2: We know that IE tools and paradigms can be used to change technology. Can the same tools also be used in making the personal and social changes necessary to fully embrace IE concepts?

Paul Chalmer: This bears on one of the most interesting discussions we had at the Think Tank table. It's based on something unique. It's one of the big questions about humanity that seems to have an answer, and that is, I don't think anybody in the room is going to question the fact that a very good endpoint as far as material and energy flows and technology in the area of IE, is sustainability. I think we all worship at that altar and I find a very satisfying answer. Why we are doing what we are doing in IE? We are working toward a sustainable system. During the course of our preliminary discussions on Tuesday, somebody said, we have to look at the material and energy flows and the technology; we also have to look at social systems. Even though we have ruled out the population questions, we still have to talk about the social consequences of the choices we make. So the question came up, is there something in social systems analogous to sustainability? Sustainability doesn't seem like a very good endpoint for social systems. And, we realized that sustainability doesn't mean stasis. We know you can have a growing system if you're making things more efficient. You can do more with the same amount of material flows, but the very idea of sustainability, of a social order that doesn't change seems to flow against some basic principles of human nature. I don't want to be satisfied with life. There are several ways you can think of making a sustainable social system–none of them are very attractive; for instance, x is the lord and y is the vassal, because x's grandfather was the lord and y's grandfather was the vassal–that's one way of doing it. Another way that was brought up by our recorder/analyst is, if you give people Prozac and tell people they are happy with their life often enough, they will start believing it. Is there a concept or overarching endpoint in social systems that will fill the same satisfying role that sustainability fills for the technical side of things. I'll just leave that as an open question, because none of us can think of an answer.

Helena Chum: I would like to bring three or four concepts and let me hope to do this in the right way. Change technology. Let's think a little bit–and those of you from industry will agree with me. Change in technology and infrastructure technologies is a long-time process. Change in capital stock - some of the capital stock in some industries will turn around in the next 5 to 10 years. Some of it will go on for 20, 30 years, right? What do we want to do to change technology, how do we want to have the world business doing that change. I maintain this is actually starting, and starting right now. Some of the most powerful things that I'm seeing as I talk with people from the President's Council on Sustainable Development, talk with leaders in world business and talk with them about sustainable development. What I see is very powerful, and what I see is people using technology. The technology is social, not technological. We need scenario planning to help think about the world and about the future. Try to, based on those scenarios, based on what it could be find common solutions that would actually minimize the problems. So I'm looking at the moment at very interesting global scenarios, that if the global community of business does correctly take the cues what will they do? Highly likely very good ethical behavior in investments. Let's not forget the direct foreign investments. Those having the biggest chunk of money to invest are the companies themselves. Transnational companies will be making major investments in infrastructure in the world. This type of behavior needs to change and they, in fact, can help us do the most good for sustainable development. They can go into greenfield countries, into greenfield parts of countries, and start implementing direct investment in the right technologies that close the loops, make developments in those parts of those countries bypassing infrastructure, very costly for structure that needs to be set in for continuing to live the way we do. That first chart you saw on the industrial energy systems of the United States shows very high inefficiencies in your Tutorial. It doesn't need to be that way. So I am optimistic. I think I am one of the most optimistic, because I am seeing social issues bringing people together–technologists, business, and everybody else–to talk together on how can we bring solutions. I think they will translate–industries, businesses, personal level. And I'll end on a positive note. Thank you.

Cathy Imburgia: As Public, I guess we have a very simplistic view and it's basically, we become the consumers, and the type of consumers that we are, are because of the type of products that you produce. Change the type of products you produce and the way you market those products and we would be educated consumers to adopt and create social change. I think it's a real simplistic way that goes back into, yes, the technologies that are underway; but also I think as a Public, I have a concern that some of the technologies and collaborations going on don't really benefit the public, they stay within the laboratories. I think

that's something we also need to look at if we're going to bring about social change, that these technologies do get out to the public.

Dave Berry: I'm not that pessimistic either, because I think all of this might be an exercise as part of evolution in having a species that has the arrogance to call itself homosapiens sapiens to actually merit one of those stripes maybe, if we can figure this one out. Back in the 90s, in the late 90s, there was a group in the federal government called the Interagency Working Group on indicators of sustainable development or, what are the metrics? In its early days, we learned about it in '97 and '98 in Congress when they finally got around to briefing us. In the early days it was mainly populated by the people in the economic agencies and disciplines, resources and environment, and was highly underrepresented by anybody with any involvement in social concerns. But what happened as people started to grope with the big picture of shifting to IE, and to safe sustainability was that folks that had never thought about it before saw how important individual values and institutional values were in driving the behaviors; in filtering the information, however good the metrics, and seeing what they expected to see rather than getting the whole picture. So raising the awareness and shaping the values became an important part of the mission, and agencies on the social side were almost begged to come and play. The Rockefeller Foundation heard about the work and began hammering on the Feds to include some measures of culture as one of the things that would have something to do with sustainability, and there were some learning disabilities on the part of the Feds as to how that would relate, but after a while it became clear that that was also a part of the picture. One raises awareness, not just on technological possibilities and on how to finance and implement; but, I'll give you a personal example, I just bought a little 4-cylinder car with 4-speed shift that gets 40 mpg. And, I'm acutely aware that nobody is going to be impressed when I pull into their driveway. They would be positively favorably impressed if I pulled in with a 500 series Benz that used up the oil in 39.99 years instead of 40 years. We still have all our values based on giving each other credit for doing all the wrong things. One other little vignette. One of the grandfathers of metrics, all of the grandfathers of metrics, were very young in the late 90s–one of the partners in sustainable Seattle who was in '97 the executive director of redefining progress, the people that came up with the progress indicator that made the front page of Atlantic Monthly last year was contemplating bagging his career in metrics and becoming a full time folk singer because he thought getting there and influencing the culture and influencing the perception is a very important part of this.

Dave Odor: The question before us, of course, is whether or not the tools of technology can be applied to the social changes associated with IE. I think that's a positive move forward and technology can be a part of the tool. As a world and nation we also have to go back to the understanding of some of the things that came from the book of Solomon within the Bible; and if you remember in his proverbs, Solomon wrote in one of them that a good man builds his inheritance for his children's children. And if we can as a business and government work together and understand that culture and take that wisdom and apply it to how we live, I think we can build on technology and have these tools help us out.

Brad Lienhart: - Congress continues to be more amusing than Manufacturing. And these fundamental producers who have just spoken are wiser than we are. What manufacturing does is pretty simple. We make all the money and all the rest of you depend on us for that funding mechanism, and the money drives technology. And, it was a shame back in 1997 when we had that conference that most of you attended that that distinguished professor from MIT was running around at 5 o'clock on the second day of the conference with technology chits in his hand that nobody would take from him. And that's because there wasn't any money left to fund that technology. We've got to think about ways to allow manufacturing to retain its resources in the form of profits so we can invest them in technology and can drive the university and government laboratory research and development machinery so we can, in fact, make the fundamental changes that everyone is talking about.

Robert Von der Ohe: You have to recognize that we in the university are somewhat subversive. That part of our message did not get across. If you recognize some of the plans we put in force, a new model curriculum for industrial ecology, it appears the public wasn't totally listening. While neo-classical economics has some flaws, it does point to one key thing: the consumer is king, or queen, as the case may be. If the consumers demand that we change and we force these manufacturers to do the right thing, ultimately they will. But it appears we have not done a good enough job in transforming the ideas of the public even though we have these new curricula in our institutions. But to go back to the basic question here, can we use the same tools? Perhaps. But from a different approach. One of the things that we have–most of the thinking I've heard here–-particularly from government and the manufacturers, still is that rational, western linear thinking. We need to start talking about complex adaptive systems, we need to start talking about the application of chaos theory. Even things like fuzzy logic. Heaven forbid that we'd get those kind of ideas into the ways in which we do thinking. If we can get those things out into the public, then I think we can get the manufacturers to shape up. Congress, I think, is beyond hope in the short term.

John Powers: I think the basic question at hand is "how to influence individual behavior" in order to have some significant impact on the ecology. And, with that simplistic view of the question, I think the simplistic answer is to provide solutions, and I see that in two ways. Again in the underdeveloped world, I think the developed world has the opportunity to provide solutions that can mitigate the current problems and prevent some future problems, either through export or transfer in some way. In the developed world, I think people need to see attractive alternatives to the way they live today that are ecologically sound before the normal ways of life become prohibitive. The cost of individual transportation, the cost of solid-waste disposal, and so on. Solutions have to come from technology and industry with government support, but there has to be a transfer mechanism, both in the developed and the underdeveloped world.

Marion Chertow: I'd like to try to hit this question head on; it says, "can the 'same' tools be used?" in making the personal/social changes that have been used to change technology? And the answer is 'no.' We change technology with certain sets of people and training and certain groups, and we change other things in other ways. Industrial ecology, we abbreviate is the marriage of technology and ecology. That's great, but it does omit a few things. However, I want to pick up on the point about how good changes can lead also to good behavioral changes, not directly, but as a follow-on. I think there may be three cases here. For example, if that dry cleaner that's now been cleaned up by partnering with Xerox in our PHER program is cleaned up and doesn't pollute, no one minds, the consumer won't mind. It will be irrelevant, because we know she is there to purchase a service–pressed clothes–not cleaned clothes, right? –thanks Brad Allenby. I don't care which chemicals they use or don't use, I just want my clean clothes. It won't bother me, but fortunately the environment's been cleaned up. Now there are cases where a technological change could be intrusive, in which case the market won't bear it ultimately and we won't get those products, so they won't do that any more. And then there are cases where getting some technological things right enables good behavior, and here's where the change starts to come. I know this is a little bit trite, but I have to say it, to my 7-year old, putting a used vegetable can in the garbage is to her equivalent to putting it in the toilet. In her whole lifetime, we've never put steel cans in the garbage. She doesn't understand that steel cans go in the garbage. She only knows that they go in the recycling bin. So, if we can figure out recycling technologies, do this smoother, improve collection technologies–all the infrastructural change that's part of industrial ecology, then we can continue to go in that direction and save resources. So if we can get these structures right, –-no, they don't directly lead to the social and personal changes–I'm a believer that we'll have more influence on manufacturers than we will on individuals. Individuals are going to be recalcitrant. Individuals know that they should exercise and they don't; individuals know that they shouldn't be obese and we are. It's very hard to change individuals. The level of which we have to offer incentives to us is very high. Business, at least is responsive. So in this sense, maybe these manufacturers who have these motives will lead us in those directions.

Natalia Tarassova: I would like to argue the previous speaker. Can we use the same tools? I can give an example. You produce a waste and it is harmful. You include this waste into a system and it becomes your friend. You can use this waste as a new raw material. What happened yesterday? We came here and we were marked as 'foreigners.' Foreigners are enemies. If you have an enemy you can blame him or her for all the mistakes that were made in this country. It's easy. In an hour, my colleagues from the States decided to rename our team into Global Community and this is the same tool. You make someone your friend and make someone work in the same system to sustain the globe, and my idea is that love and respect for the cultural and ethnic diversity will save the world in the same manner as different materials may save the technology.

Tony Biddle: Speaking from the financial community, there have been a lot of lofty thoughts and concepts put out on this issue. Bankers, on the other hand, have never been known for their altruism, and so just a few, sort of nasty, venal, practical views on this issue of whether the IE tools can be used in fomenting personal and social change. Our view is personal and social change as unchangeable by anybody in here trying to make industry change. Society will change itself. I believe this was stated in a couple of different ways here. People will do what they do. Speaking from an economic point of view, they will act in such a way as to open their wallets to achieve quality of life and maybe at a better price. Some years ago when we were all here, somebody asked in the first plenary session a question, how do we work on the demand side? Everybody talked about the supply side. What about the demand side? Now 7 years later we have discovered the public have exercised their rights over the demand side. They are the demand side. And those IE principles which have been put into place, which resulted in greater productivity, higher efficiency, enhanced less cost, have won. For lower price. And they've won on the basis of higher quality of life and lower price.

Joe Breen: As the representative of the State and Local Governments, one of our main responsibilities is education. And I think in terms of this question the challenge is trying to figure out how we are going to take the comment made here about the kids really being one of the primary drivers for recycling. I think that the solution will be to get these concepts of balance, and what have you, into the schools and educational system. And, I'd like to share with you one of the vignettes from my own experience,

and that is going into the local elementary school where I live and being asked to come in and help them set up their computer lab and finding, much to my surprise, in a suite of CD programs, something called SIMTOWN, and it's a take-off on the SIMCITY program that's used in urban planning, but which tends to be, at least the way we adults play it, a very competitive thing. SIMTOWN is marvelous and I really encourage you to go back and find out about it, use it and get it to your kids and grandkids. It's the concept of building a town and keeping it in balance–balance between the population, business, and the environment. If the kids just produce playgrounds and parks and don't have any business, the town fails. If all they have in the business community is a bunch of ice cream parlors, and don't have pizza parlors, and a variety of other industries, the town fails. Then they have a series of what they call eco villains–the water grabber–people who use up all the water, the timber wolves–the people who come in and chop down all the trees. It's a really marvelous way for the kids to learn these ecological concepts within the context of the community.

Antoinette Sebastian: Well, I hate to tell you this, but in 1997 we tried real hard, but Federal Industrial Agencies agreed then and we agree now, we didn't have a clue. We still like our nuclear waste storage piles, we still produce weapons, we still have national security concerns, and, yes, the military has made some effort of being a little more ecologically conscious. We've bought the state of New Mexico so that we have someplace to put our nuclear waste. It is no longer a state, it is now a Federal Territory. And that, that we couldn't dispose of, we've been shipping to Africa and India and Southeast Asia like you couldn't believe. Now what we did realize, when Congress, in its infinite wisdom, decided to reduce us–we are now about 250,000 employees nationally–is that we do have a little more time to think and to talk to one another, which, communication across agencies has always been a problem. And we realized that not a whole lot has changed, and one of the reasons not a whole lot has changed is because basic tenets that drive the relationships have not been altered. When manufacturing companies decide to go abroad, they're looking for those things that make their profits bigger, and we appreciate that simply because as you know, federal agencies have never been in the business of profit. We like to spend money, we like to make rules, we like to make regulations, and we've relaxed them as far as you possibly can. In fact, the federal government has relaxed the regulations so much that states have now decided to sanction how their companies do business in other places in the world, because the federal government lacked the wherewithal to do that. So what we decided to do, and as soon as I get back to the team we'll explore this more, because this is the first time they've heard that. What we've decided to do is set up a new type of government system and ask that that the idea of profit and the cost of doing business be altered drastically. And that American companies that do business abroad are required to behave in the same ways and pay for the same consequences that they are required to do here. We don't think that's going to go down very easily, but we do think it's a major start.

Marshall Berman: What does industry think about that potential idea?

Brad Lienhart: Kalundborg is a concept that was introduced in 1969 and programs across our industry have spread to be global, and I will speak on behalf of the chemical industry which I came from. We had responsible care in force as a national program in 1992, and in 1997 we're enjoying some change in attitude from the public about the chemical industry as a result of our change in behavior. And we recognize we had a long way to go to rebuild respect with the public. Our image rating with the public in 1992 was just slightly above Congress's. And that wasn't very high, so we've done a good deal in the last 13 years to improve that respect, and we've done that through demonstrated results; and now there is no longer a frenzy about watching for the TRI list to show up on an annual basis in the newspapers to see which companies are doing bad things to the environment because the TRI list does not exist anymore. There is no more pollution occurring on that list, which was expanded by EPA back in 1996. So we can, I think, account for a lot of excellent results across American industry. But the important thing I want to tell you is that American industry, as leaders of world industry, in fact have carried the responsible care program in the chemical business to 33 other countries. And we won't be happy until it's uniformly applied across the world. The 33 other countries that it exists in today represent 85 percent of the world GNP. So, in fact, concepts like 'responsible care' embody in them a commitment to uniform behavior on a global basis, and the chemical industry has demonstrated that behavior through responsible care in 33 countries in the world and that list of countries is expanding.

Antoinette Sebastian: Federal Agencies would like to report that since the chemical industries have been so successful at this, that they will be our primary partner in helping us persuade other industries to do the same. Now, we realize that responsible care is an appropriate mechanism, but the other thing we are going to ask the chemical manufacturing industries to do is begin to look not just as the environmental impacts, but at the social impacts of types of activities that they pursue.

Marion Chertow: In 2001 Congress asked PHER, our agency, to spend less time on specific enforcement. We've moved to a third-party enforcement type of technique, and more time on technical assistance overseas in the hope that we could help the

environment. We would get 'greater bang for the buck' globally if we spent some of our time with our own employees overseas. We started some monitoring programs and started sending people over and found something that was very surprising to us–because we're from the federal government–and that was that the countries that were doing the best overseas were the ones where large, multinational companies had been putting up plants. And what we found was that in countries like China and in south Asia and in Thailand, where the auto industry had moved in, there was now a demand for people to have environmental training because these companies were coming in and saying 'we've got to enforce some standards here.' Companies were coming in and would say, "where should we put our hazardous wastes?" The host governments were saying "don't ask, don't tell." The companies were unwilling to put up with this kind of behavior for reasons like Bophal and other such things. We found in our studies it was actually the companies who were the motivating force for getting environmental infrastructure and putting capital into some of these countries and starting to train workers so that they could help with things like sewage treatment. And in areas where there was no water treatment whatsoever–even in the industrial park I think our colleagues built there was very little water treatment–it was only by the action of the companies to train the workers that they learned about sewage treatment and thus these environmental values started passing much more quickly because of this sort of globalization than they had up until now. So let me tell you, as a federal employee I got a real education. I don't think that's the whole story, but the companies got the ball rolling and I think they made people start to think about their air and their water and their land in a way they hadn't before and now some of the other … the World Bank, for example, has decided not to invest in the emerging markets anymore because they have emerged; but is solely concentrating on Africa and some of the other areas which have been less successful. So, we too, want to put our resources into those areas.

Brad Lienhart: Let me just say that the chemical industry which is committed to responsible care would like to take the challenge of the Dept. of Energy and Federal Agencies and actually help finance this program, this partnership, that you've spoken of on a global basis.

Marshall Berman: Any questions from the audience?

Question from Dale Dekker about conditions in NM–pollution, closing of Sandia Labs, unemployment, high prices, etc. (not clear on tape).

Our metric is, are we better in 2007 than we were in 1997? I think the answer is 'no.'

Marshall Berman: The message is "we're mad as hell and we're not going to take it any more"! And the people of Sandia have occupied the State of New Mexico; ATF and FBI are at the border; Texas has been called in to assist us, and your response is . . . .

Dave Berry: I'd like to say a word on metrics which is the next question since you mention metrics. We are not all reading the same newspapers in 2007. There are different scenarios of what's happening today. I believe we're in the 110th Congress. With regard to metrics, the 103rd Congress, which was a democratic Congress, gave a cease and desist order to the bureau of economic analysis in its work on satellite accounts to measure depletion of nonrenewable resources which were going to be accounted for but kept separate from the GDP accounts. That was finally reversed by I believe the 108th Congress, where we said we really need to measure these accounts. As you know, any business–we still are accepting contributions from any business–any business that kept its books without accounting for the depreciation of its capital equipment--first of all their accountants would be jailed for letting them keeping books that way. But they would be getting a very false impression of current prosperity because they weren't depleting the value of plant and equipment. And until recently the main metric for the economic prosperity, originally GNP, and recently GDP, made no accounting whatsoever for the depreciation of the capital stock, let alone depletion of nonrenewable and renewable resources; in the case of renewables, at rates faster than their ability to regenerate. As you know, for the past few years, the Wall Street Journal has been reporting Net Domestic Product as the main number, which at least gets in that metric of depletion of the capital stock. This is with the full support of industry, believe it or not. Because it's a sound practice. We also have satellite accounts. And the other appropriate metrics we pay attention to are the aggregation of net depletion of habitat which is also a proxy for diversity, and we have a net measure for the toxic waste accumulation in all media–water and air. So we are looking at the shrinking of the natural world, the toxification of the natural world, we have aggregate metrics for renewable resources, that is the rate at which we are using them as a ratio of ability to regenerate. And we have true net numbers on economic production We still think we have some areas to go . There is a raging debate on public health and person health and there are some metrics we haven't got in there, but we are making some progress.

Helena Chum: I'd like to come back to 2007–it's a big thing 2007, 2008. By the way, technology is coming to the rescue. During 1997, 1998, several groups of very interested people, like the corn growers association, a bunch of other farmers, and the like, decided that it was time to do the genome of corn and almost every single major plant in the planet that's responsible for our food and feed. By this time in 2007, we know what we need to do to increase the productivity, we are now at 80% of production so we've doubled and on the way to triple the yields of corn. Which is not quite yet the theoretical limit. So the milk consumption can increase again, the price is going to go down because the price of feed is going down. We have, not just in the U.S., but Brazil has cracked the sugar cane plant genome and we're on our way, wheat is done. In fact, we have the ability to produce much, much more food on much, much less land than we were before. We actually have developed refineries that use not just the food portion, we can take whatever is not used for that purpose, you plow back one-third and the other the two-thirds we can use for making chemicals, fuels, electricity, in a sustainable refinery way and we are on our way to begin the infrastructure that does that.

Dave Odor: I'm happy to report that Industry has listened to the Public with respect to the situation in New Mexico and, the time is here that I'm glad to tell you that through the help of the Sandia brain power, and the technology is developed, lo and behold, we have determined that nuclear waste can be used to enhance superconductivity. And besides that, as the industry from both the electricity utility industry we've determined that the byproducts and waste products of burning coal is indeed the answer that we've always been looking for on the phenomenon of cold fusion. And because of the brain power of Sandia and that technology, business is truly now moving what used to be waste products to byproducts, and the principles of IE have been the driving force in that arena.

Antoinette Sebastian: You are not getting New Mexico back. We have no place to put our nuclear waste. Our measurement for Federal Industrial Agencies is a little bit different. What we're doing is trying to keep track of conflicts, civil conflicts that are occurring, and where we are deploying our troops. We realize that you look to us for solutions, however, you looked in the wrong place. There is no one solution and there is no one individual who is responsible. However, to negotiate a treaty with your rebellious group, we would like to invite you to the FIA team along with the chemical manufacturing companies and see whether or not we can work something out. We did have an ecological park, and we thought it was a very small, seemingly insignificant effort; but what we figured was if we could write that up, come up with some sort of a 'how to' guide with business, local governments, residents of both the Mexican and Texas communities, we could find some small solutions that would work locally throughout the globe. I appreciate industry trying to hoodwink us into telling us that they found a way to resolve this nuclear waste problem, but as a FIA, I don't believe it. We had a much more simple request of industry, and that is HUD is one of the federal agencies that is part and parcel of this team and what we were looking for is affordable public housing, with dual systems for water. It's not real, real complex. It doesn't require managing nuclear waste. What we discovered is that the industrial sector said, we can build it, but we can't afford to sell it to poor people. So, we invite you to look for simple solutions that are transferable.

Robert Van der Ohe. I think we sort of shifted to Question 3, so I'd like to play off these last couple and when you start talking about what we measure and so on down the line. I'd like to go back to Brandeis and his court on pornography–"I don't know how to define it, but I recognize it when I see it." I think we'll recognize the changes as we see them. Now one of the other things is, be careful what you ask for, you might get it. We've heard our friends in the financial institutions talk about these wonderful increases in productivity, etc., etc. But we still haven't addressed the question of 'for whom?' The disparity in income in the U.S. has continued to increase for the last several years and the gap between the U.S. and the rest of the developed world has continued to increase as well. So our financial institutions really are looking out for their bottom, bottom line. I'm pleased, I said the public wasn't well educated in the sense they haven't caught on, but I think at least of the industrialists we've heard have caught on in the sense that they have actually gone out and incorporated this humanity training that went with their technical training to carry some of these ideas into some of the foreign countries. I don't think that's very universal but at least I think we've caught a few of them. At the same time, I really do believe some of our people in the resource industry must have been educated in 'lala' land. They really couldn't have gone to some of our universities to come up with these fantasy ideas in terms of how we have solved our problems of nuclear waste and the like. It stretches the bounds in anything we have heard in any educational institutions to believe that those solutions would, in fact, work. But again, to go back, we really are not dealing with the social questions. No one here wants to get in depth in dealing with the social questions that go along with income distribution. We do not want to develop the measures. I look at that measure. We put the fox in the henhouse in terms of measurement. We've got this depreciation in accounting and how this allows firms to increase their profitability. You want to go back and read the gap guidelines for the depletion of resource in terms of how those are deductible for taxes. It would scare you to death to see how much industry has taken out of the till in response to those changes.

Floor: Can we point out the tax system was changed. I think we voted on that.

Robert Van der Ohe: Analysis done at the universities indicates that the benefits to the industries are unbelievable in terms of their reduced taxation. And they are not passing it back except to the shareholders of the corporations.

John Powers: On the question of metrics, I would suggest on behalf of the manufacturing community that for the past hundred years, they have developed a very disciplined approach to managing costs. As part of managing costs, they have metrics that they continue to develop in trying to improve, with respect to their operational efficiencies. And, I believe with respect to an IE view of the manufacturing world, we now come to realize if we look at the total life-cycle of a product and apply some of those disciplined approaches, traditional manufacturing metrics, we find there are tremendous opportunities as well as challenges. For example, if you look at the energy and the waste involved at all stages of the manufacturing life cycle in terms of process losses, packaging, distribution, transportation from the point of extraction and processing of raw materials to the manufacture of components, to the manufacturing of subproducts, and ultimately products, then finally the disposal of those products and to whatever extent they are reused and reclaimed, I would contend that the typical total efficiency of that process is a fraction of a percent. That's the bad news. The good news is there is tremendous opportunity to make improvements and manufacturing is highly selfishly motivated to continue to improve that efficiency in order to maintain its competitiveness and its profitability. So if we give them the benefit of the doubt that they are typically one percent efficient in that total process and they take that view and make an improvement to get up to a whole ten percent, that's an order of magnitude of improvement. I think the good news is that the manufacturing industry is beginning to look at its business from a total product life cycle point of view and will find opportunities to significantly increase its efficiencies for selfish reasons that will benefit the total ecology.

Marshall Berman: A quick news note: I've heard that one of the last technological advances made at Sandia before it was shut down has just been reported in the Sierra Club newsletter. The plutonium-heated camping stoves are now being used throughout the U.S. national park system and have become very, very popular. Questions?

Question from the floor: How do we address the problem of how the real public behaves versus the idealized public. For example, improving the mileage of cars hasn't resulted in a decrease of gasoline consumption, it's resulted in an increase of miles driven. When we have made 'green' gasoline for a penny a gallon more, we found that the customers, even in highly active environmental areas, will drive past the station to save a penny a gallon rather than going with the environmental thing, so when we talk about what the public wants and what the public needs, then we run some of these experiments, we find out that the public actually isn't behaving that way, so is there any way to find a way to put realism into what we're doing and reconciling this? Apparently if we want to call it irrational behavior, at least it seems to be the actual behavior.

Cathy Imburgia: As the public, I just want to tell you, "stop giving me the temptations, don't give me all these choices and I won't be a sinner anymore."

Tony Biddle: Just a quick comment on my friends from the Universities. One of the problems we see now in regard to the social problems which was mentioned–the growing disparity between the classes in the U.S. It's partially due to the incredible rise in tuitions, which makes it impossible for anyone but the elite to go to college. Now, just a comment on metrics, to expand on what was said, we did manage to pass changes in the accounting system to compel banks and businesses and everyone to look at the total costs of what goes on and that's helped a lot.

Brad Lienhart: The metric that has helped Industry sustain itself and be able to distribute its profitability to all the stakeholders, not just its stockholders, is in fact the metric that says IE is good business. IE actually does make money and its most metrically measured in the fact that today in the year 2007 all durable goods are being recycled–60% of the aluminum is being recycled, 50% of the paper is being recycled, 40% of the glass is being recycled, and 50 % of the plastic is being recycled, that are manufactured today. Energy costs are stable and energy demands are actually plateauing, which will allow those barrels of oil and natural gas reserves to last a lot longer as we look for alternative ways to power our industrial base. Dry cleaners no longer use perchlorethylene, and the TRI system is no longer needed as nobody produces anything as waste that used to be accounted for on that system.

John Powers: I would just like to follow up on the back and forth on the Public and the views on how consumer demand drives trends. I look back to 1997 versus 1977 and I found I only use unleaded gas in all of my cars, I have catalytic converters on all of my cars, all of my appliances–all of my household things–including oil burners are a fraction of the size and they are much more efficient. I look at things like the computers and tools that are a fraction of the size, and orders of magnitude more efficient, and I can only be optimistic that there are solutions. Given the application of technology and the right financing, there will be a natural trend to continually improve.

Audience question: One of the questions I have concerns the design of the game which talks about social issues as a derivative of technological, programmatic initiatives. It seems to me as we move toward 2008, we ought to have shifted our thinking from figuring out how to have more sophisticated 'boxes of stuff' to begin to think outside the box about other alternatives, thinking more holistically, and less in reductionist terms. My questions to the panel is, having made that comment, my observation was that a majority of the panel was pretty pessimistic about how far you have made changes. And I want to reflect back on that to say, is it the fact that we didn't think ecologically mean that we came up with a set of shortfall solutions which look like action but are systemically insignificant, like the public was raising. It doesn't do the job overall. How do we begin to change that kind of thinking? Is it in fact possible to solve that problem, or will we be just another ten years closer to extinction because of the fact that what we've done is pedaled in place.

Helena Chum: Let me try to address that and make a closure on a point that I'm not so sure I made. Let's take something we all agree and make sure the basis correct. Does everyone agree that photovoltaic technology would, or wind technology, or some renewable technology, would be an example of a solution that you can deploy on a distributed system that would have much lower impact on the environment? Do we agree with that? Let me take the majority and go forward. In the 70's there were investments made in demonstrations, not investments made in R&D. Those investments did not succeed very well because the technology wasn't ready. The time that it takes to do technology development for major technological changes like that can be 20, 30 years. Before you get an implementation system, an industrial system operating, manufacturing, you're talking 30-40 years. Our whole oil system took an awful long time to develop; and the chemical system, we're talking 50-60 years. So, even though we started in the 70's in the oil crisis, at this point, now I'm really pleased to say it is beginning to take off, with announcements like this year's announcement from Shell Solar Energy Company and manufacturing PV and $100 million investments and joint ventures in Japan and Germany. We are moving in the right direction. We all need to understand technology development takes time; that's where I came back before and said we need to work together, because where it takes time is in the value of that.

Q from the floor: –- (could not understand audio). Re time factor: "If we are just now starting to solving the energy problem, that means my kids will be in big trouble …"

Helena Chum: What I'm saying–this is 2007 - we started in 1970. In 2007 we are much closer to having that. The problem is that we have sunk huge capital in the infrastructure and that's what you have to cope with, the change of infrastructure of capital and capital stock in energy is a 50-year, 60-year turnaround, so we have to be smart, and as that capital stock turns over we cannot do the same mistakes. And that's my point that placing capital stocks in developing and emerging economies; those capital stocks should be on the best technologies we can get.

John Powers : I'd like to follow up on this. Although I am really an advocate of technology - I grew up as a techie, I think this is a parallel complementary view in support of natural processes. In terms of significant impact on the environment, there is nothing more powerful than natural processes. There was an article in the NY Times about natural processes. It was really an economic study in trying to put a value on those. It really pointed out how powerful they are and they identified eight or ten fundamental natural processes like watersheds and what they can do far beyond anything technology or man can do. And one specific example was in upstate NY–the watershed area that feeds the fresh water to New York City. They decided that rather than spend $4B on another water purification plant, they would spend $600M on protecting the existing watershed. Do some land clean up, pesticide protection, etc. as a good business case for this very, very powerful eco-system.

Marshall Berman: Let's move on to the third question:

Q 3: What are the appropriate metrics to determine if IE is making a difference?

Panel: We've addressed that.

Marshall Berman: Are there any further comments on metrics?

Paul Chalmer: First a couple of cautionary notes, one, back in 2002 when the budget was actually balanced, the census department took quite a hit, so we're not getting as good data now as we were getting. Also we have advanced our understanding of systems a little bit and that's led to a problem. I'll paraphrase Richard Feynman here talking about physics–when Newton developed the gravitational theory. You could solve the two-body problem, you couldn't solve the three-body problem yet. Relativity came in and we couldn't solve the two-body problem, but you could still solve the one-body problem. Quantum mechanics came in and that became kind of difficult, and now with particle physics, you really don't know what the vacuum is doing. So if you don't have any particles, you still have too many to figure out what's going on. I think some of the same thing is happening with IE. As we understand the system better it's going to take more and more data to figure out what's going on. A complex system is a complex system. There's no getting around the butterfly fact that all those wonderful things that happen to make it very difficult to predict what a system is doing. I suggest we are a little bit better at that and I suggest we will have to start looking at different measures. Most of our accounting measures are based on linear theory, we need them, we can't throw them away; but as the one comment pointed out, if you're measuring miles per gallon on the car, you're going to miss the fact that more miles are driven. I suggest we start looking at some types of metric that has to do with loop systems–we are talking about closed loops. There are going to be some measures that involve what happens when you go around a loop. We need to take some concepts from thermodynamics, historesis(?), electromechanical systems, to come up with close bonding (sounded like 'clometies'?) which give us a handle on what's happening when we do interacting cyclic processes. I feel this was what John Ehrenfeld was addressing when he said we do need some new measures. I can't lay out what they are, but I think those are the areas in which you might find some fruitful analogies.

Comment from floor: I think you have missed the consumer in all of this. This is the first time I've ever heard of IE, or EI, or whatever it is. It will be 2010 and consumers still won't support IE because you've never answered the one question that's on the minds of all American consumers, that is, "paper or plastic?" As you can tell by my accent, I'm one of three representatives from the great state of Texas, and I'm a little disturbed by the New Mexico bias here. Anticipating the threat of nuclear terrorism from the great state of New Mexico, and as provided by law, subdivide it into 5 states and there are now 10 Texas senators. I don't have to continue.

Natalia Tarassova: Okay. As a global consumer, we have good news for you. Universal consumers are going to help us. Russian astronomers–there are still 5 or 6 of them alive–received a new signal from a space ship that is coming from the andromeda interstellar system, so this spaceship is of consumers. They are sending all the solutions, so wait two days, it will all be resolved.

Cathy Imburgia: As the U.S. Public, I did get agreement from the Global Community - we're still 'mad as hell' - that's the bottom line and what we're looking for now is a second challenge to offer you when we go back to the agreements. We are not going to give you any influence chits at all unless you do two things: come up with long-term standing solutions as well as a new metric system - not unlike what we heard from our friend at MIT. So please consider that before you try to get our influence.

Comment from floor: In all of these discussions, one thing that seems to have been substantially ignored is any incentive for commercialization of IE processes and technologies. Now there's all kinds of support going to the R&D community, to the university community, to all the folks that want to go through the mental exercise, but the practical application of these technologies in the U.S., in the world, getting them out, getting them operating, has basically been ignored. Now Congress, in its wisdom, did pass a doubling of carbon-based fuel tax and it did have a very positive effect on the federal budget, sharply reducing Medicare costs because no one in the northern tier could afford fuel oil anymore so the elderly have been dropping like flies. The largest windfarm in 2005 was closed down by the by fish and wildlife service for interrupting the migratory flow of snowgeese, also nailed a couple of ultralights in the process. But the fact remains that we really do need to focus on the economics of commercialization. And therefore, the manufacturing group is going to come around with what we think will be a relatively palatable approach to doing some of this–trying to recoup some of the damage that has been done by the

Congress.

Comment from the Floor: Please excuse the discontinuity with the last comments, which I thought were very thoughtful, but I wanted to come back to the question of demand by consumers and to say that I've been very dismayed by the black and white characterization of consumer behavior, that either consumers drive the economic system and we have consumer sovereignty and it follows the textbook economics and it's done, or consumers are the slaves to advertising and they are automatons. Why don't we have a more nuanced picture? Why don't we realize that sometimes we're shaped by mass culture, and clearly some of the commercial entities are trying to, with mixed success. And similarly, one of the examples cited, I'm now driving with unleaded gas. That was not done through consumer demand. That was done through public policy, which is not to say that consumer demand cannot drive certain things. But I think if we are going to incorporate the consumer into this question, we should bring the same kind of thoughtfulness and nuance to our description of it that we do to, say, technology development.

Dave Berry: The answer to paper or plastic is bring your own canvas bag and Giant will give you 3 cents for every one they fill. Pardon? Smith's will give you 5? That's in New Mexico. That's an example of out-of-the box thinking. I'd like to introduce something here about consumption decisions. It's a typical fault of government at all levels to say "we need to create policy so that 'You' will behave in a certain way." When government procurement itself is a huge piece of consumption–80% of all the materials used this year are being used in The business–that is The business of America, which is real estate development and construction of infrastructure. So, 80% of all the stuff we buy is going to build things–80% of the resources we deplete, 80% of the impact on the environment of using materials is coming from building things and we aren't even discussing that sector in this conversation. If we looked at The consumer, we could say The consumer is all of us, not really in our roles as householders, because even though I plead guilty to being in Congress, I'm also a father, I have household, buy color TV and things at home as do corporate executives. And Congressmen and corporate executives buy more TVs than the people working in the factories or driving the cabs. But consumption occurs primarily in the decisions of the federal government, the state governments, the school boards, and the 2000 largest commercial enterprises in the country–manufacturing, finance, etc. And if they, rather than only address policy of how do we influence the behavior of the great diverse multitudes, but start to create some guidelines of how do I as decision maker, not only in my household, but in my role in society start to make responsible consumption decisions, that will drive the process. The American Institute of Architects has a big thick book called The Environmental Resources Guide. They have given Congress several briefings on this to give continuously updated guidance on what are your alternates in materials and design to move towards–I guess we shouldn't say IE–construction ecology, infrastructure ecology. It's currently sitting in the offices (in 1997) of about 12% of the architectural firms. And we don't know how many of them ever cracked the book, but they spent a couple of hundred dollars to get it. As we've heard often, funding for that project, which we've heard was EPA money, has dried up and in 1997 architects were looking for other sources to fund this thing. Congress would urge the various interests to keep reminding us to think outside the box and remind us that we have an influence, not just on policy directing the behavior of others, but also on the behavior of government itself, which can drive through its purchases and drive by example, on a good day, appropriate behavior.

Marion Chertow: We've talked a lot in IE about tracing material and energy flows, and in the regulatory agencies - PHER - we've started information initiatives. Back in '97 when the agreement was made to establish data bases for a lot of things, we gathered a lot of data which is constantly changing and is characteristics of a complex system, but we weren't too worried about getting it out to the consumer. Now we have started some new initiatives. We have a new Web Zoom called, Environmental Consumer Reports. If you want to know anything about a product, or whether it's better to get paper or plastic, or whether it's better to shop from a mail catalog, how many trucks and how much energy is used to do that versus driving 50 miles to your regional mall. Or driving to your local–one store that's left in your town center–you can just click on our Web site. You don't have to click any more, you just have to talk to the Web site, and find out just which is the right move ecologically. We give you caveats, etc., but not everyone uses that function. Only people in New Mexico use that function. We found that by getting a lot of this information out in an accessible way, let's let that consumer–some of whom are slaves, some of whom are sovereign, but most of whom are somewhere in the middle–can start to act upon their own impulses from the various educational elements that they've gotten, not just from schools, and television, and other inputs and start to make their own decisions. And, if the consumer wants to use that information, it will have a counter effect on the market which has already provided that information.

Marshall Berman: Let's thank our incredible group of Ambassadors and yourselves for your excellent questions. Let's go out and change the world.

APPENDIX B: Pre-Game Materials

PART 1: Players' Handbook

Prologue

The Problem

The growth of human population and the industrial base required to support it are placing an ever-increasing burden on the life-support systems of the planet. These systems include global biogeochemical cycles (carbon, nitrogen, phosphorous, and sulfur), the integrity of local ecosystems, and biodiversity.

Although projections vary, it is likely that human population will reach 10 billion between the years 2020 to 2050[1]. Some impacts resulting from the current population alone include:

- **Energy Resources**[2]– While oil reserves are projected to be exhausted in 40 years at current rates of use, there are disagreements about coal reserves. Estimates have ranged from 60 years to possibly one or two centuries, if low-grade coal can be economically mined.
- **Energy Sources**[2] – Fossil fuels are the mainstay of the energy economy. Burning carbon-based, fossil fuels raises **air quality** concerns over human health (smog) and environmental damage (e.g., oil spills, strip mining for coal). The burning of carbon-based fuels is apparently leading to increased concentration of CO_2 and other greenhouse gases in the atmosphere, as well as to regional increases in acid content of rains. The Intergovernmental Panel on Climate Change projects an atmospheric warming from the CO_2 increase, which could affect agriculture, water supplies, and ecosystems. Other scientists disagree.
- **Water Resources**[3] – Depending upon diet, approximately 1300 to 8300 cubic meters of water per person per year are required to grow food. In 1990, 20 countries in Africa and the Middle East were home to 131 million people who had less than 1000 cubic meters per person per year available. In many other locations only marginal renewable water supplies exist, and shortfalls are increasingly overcome by pumping "fossil" water from underground aquifers at a rate faster than it is replenished. Surface- and ground-water pollution is also of major concern in much of the world.
- **Land Resources**[4] – Food demand is expected to increase by 64% over the next 25 years, yet harvested grain area per capita has been steadily decreasing for decades. In the past, loss of arable land has been offset by increased yields, but grain stocks have hit the lowest level on record. Land loss can be attributed to urban, infrastructure, and industrial expansion (especially important in Asia), damage from over production (e.g., salinization or loss of fertility), and erosion.
- **Biodiversity**[5] – Since 1600, 286 species or subspecies of mammals and birds are known to have become extinct. Since 1700, it has been estimated that over 5000 flora taxa have been lost to extinction.
- **Mineral Resources**[3] – Non-fuel mineral resources do not appear to be limiting in the foreseeable future except for the lead time and capital required to find, prove, and develop reserves. However, reserves are often concentrated under the control of a few nations. Also, many extraction technologies rely heavily on use of hazardous materials (e.g., use of arsenic in gold recovery) and produce large quantities of wastes (e.g., mine tailings).
- **Waste Production** – In the U.S., municipal solid wastes alone amount to 4 pounds per person per day[6]. The U.S. produces a total of ten billion tons of non-hazardous waste per year from municipal, industrial, and mining sources[6] that is regulated (or soon will be) under the provisions of Subtitle D. Most of this material

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[1] United Nations. Department of International Economic and Social Affairs (1992), Long-range World Population Projections: Two Centuries of Population Growth, 1950-2150, ST/ESA/SER.A/125, New York.
[2] Energy calculations based on data found in: *International Energy Annual 1993*, May 1995 ed., DOE/EIA-0219(93), Energy Information Administration Office of Energy Markets and End Use, U.S. Department of Energy Washington, DC 20585
[3] Cohen, J. E., 1995, How Many People Can The Earth Support? W. W. Norton & Company, New York.
[4] Brown, L.R., Flavin, C., and H. Kane, 1996, *Vital Signs 1996: the trends that are shaping our future*, Worldwatch Institute, W.W. Norton and Company, New York.
[5] Turner, B.L. II, et al., editors, *The Earth As Transformed By Human Action*, Cambridge University Press, 1990.
[6] O'Leary, P. and Walsh, P., Co-Directors, Solid and Hazardous Waste Education Center , University of Wisconsin-Madison Solid Waste Landfills course materials http://wissago.uwex.edu/uwex/course/landfill/

ends up in a landfill. Hazardous materials create additional burden. The current U.S. annual production of organic and inorganic chemicals exceeds 200 million tons (world production in excess of 500 million tons)[7]. As these chemicals are "consumed," some 2 billion tons of hazardous wastes are generated in the U.S. alone.[8] (Hazardous waste production exceeds hazardous chemical production by a factor of ten through contamination or dilution with other materials.)

- **Environmental Remediation** – Inadequate disposal practices in the past have caused both the federal and state governments to impose ever stricter regulations on facilities that manage or dispose of waste. Currently there are some 32,000 Superfund sites[8]. Bankers and insurance companies are also feeling the effects from environmental cleanup issues. More than 40 percent of commercial mortgage bankers have disapproved mortgage applications because of contamination fears[8]. Most insurance companies by now have changed their corporate insurance policies to exclude pollution claims, yet it is estimated that they will still pay out some $150 billion over the next 30 years for existing liabilities[8].

Good News and Bad News

The earth has recovered quite well from past extinctions. However, the quality of human life depends upon a balance in global and local life support systems. Increasing population and desire for higher quality of life is taxing the capacity of all natural resources: soil, minerals, water, oceans, and atmosphere. We are only beginning to understand the full range of changes now occurring.

We do understand enough about these changes to have mobilized innovative forces in all sectors of society. Corporations and government agencies around the world are defining the goals of sustainable development. Thousands of researchers are studying the ecological impacts of human activities and designing methods and tools for overcoming them. Some environmental organizations and grassroots activists are filling a dual role: opposing pollution and waste as well as creating positive programs and restoring ecosystems.

Technological optimists tell us we humans are an intensely clever species that has always created solutions for the problems we've faced before. However, some ecologists and earth scientists tell us we are creating problems at a global, not just a local level. As population continues to increase and economies continue to grow, we may reach thresholds of technological change and resource depletion that threaten our survival.

Fossil fuels are the foundation of our energy and transportation systems. However, burning oil and coal generates CO_2 and other greenhouse gases at a rate that some climate scientists believe is warming the Earth's atmosphere. The U.S. has joined over 167 countries in ratifying the Climate Change Convention, agreeing to reduce CO_2 emissions to meet the potential threat of greenhouse gas concentration.

U.S. companies ranging from AT&T to Odwalla Juice are applying industrial ecology to tune the design of their operations and products to ecological constraints (not just regulatory compliance).

In the U.S., the West and Midwest are hit by both massive floods and diminishing ground water resources.

The World Business Council for Sustainable Development is working through regional initiatives to increase the efficiency of all resource use and to lower pollution by its transnational corporate members and their suppliers. However, food experts project that global demand will increase by two thirds over the next 25 years, yet harvested grain areas have been steadily decreasing for decades. Erosion, desertification, and development are reducing agricultural land areas.

We are at a critical point in human evolution. There are some signs of doom and gloom. And there are many signs of new evolutionary stirrings expressing our inherent human creativity.

We have joined together to play this Prosperity Game on industrial ecology because we see both sets of signs. We are here to understand and develop this still new field of research and practice. Perhaps our efforts will increase the hopeful signs.

In an address to Congress on April 7, 1995, President Clinton issued a similar challenge[9]:

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[7] Chemical & Engineering News, June 24, 1996, American Chemical Society, http://pubs.acs.org/hotartcl/cenear/960624/prod.html
[8] *PPC Index of Sustainability Indicators* http://eande.lbl.gov/VirtualPresidio/vpjournal/beta96/beta4/suststats.html
[9] White House Press Release, April 7, 1995 http://library.whitehouse.gov/Retrieve.cgi?dbtype=text&id=4586&query=industrial+ecology

"In recent decades ... rapid technological advances and population growth have greatly enhanced our ability to have an impact on our surroundings -- and we do not always pause to contemplate the consequences of our actions.... Those who say that we cannot afford both a strong economy and a healthy environment are ignoring the fact that the two are inextricably linked. Our economy will not remain strong for long if we continue to consume renewable resources faster than they can be replenished, or nonrenewable resources faster than we can develop substitutes. We should strive to live in productive harmony with nature and seek to fulfill the social and economic needs of future generations. We share a common responsibility to see beyond the urgent pressures of today and think of the future. We share a common responsibility to speak for our children, so that they inherit a world filled with the same opportunity that we had."

Introduction

Industrial ecology (IE) is an emerging scientific field that views industrial activities and the environment as an interactive whole. The IE approach simultaneously optimizes activities with respect to cost, performance, and environmental impact.

Industrial Ecology provides a dynamic systems-based framework that enables management of human activity on a sustainable basis by: minimizing energy and materials usage; insuring acceptable quality of life for people; minimizing the ecological impact of human activity to levels that natural systems can sustain; and maintaining the economic viability of systems for industry, trade and commerce.

Industrial ecology applies systems science to industrial systems, defining the system boundary to incorporate the natural world. Its overall goal is to optimize industrial activities within the constraints imposed by ecological viability, globally and locally. In this context, “Industrial systems” applies not just to private sector manufacturing and services but also to government operations, including provision of infrastructure.

Industrial ecology integrates a broad range of disciplines, ranging from basic sciences to engineering, economics, and other social sciences. IE seeks to provide the scientific framework required for discovering the path to sustainability.

IE seeks a shift from linear resource flows in the economy toward closed-loop systems. Through its methods of analysis, it assesses the long-term impacts of sustained material and energy flows on the quality of human life and ecological systems. IE design methods seek to reduce the amount of energy and materials flowing through a process or embodied in a product, while providing the same or improved output.

Industrial ecology also seeks to minimize waste and pollution of process outputs. This often is achieved by tailoring former "waste" streams so that they become input streams for other processes. A related concern is replacing non-renewable resources with renewable ones.

Applying industrial ecology promises benefits to all sectors of society:

- Companies may gain increased efficiencies, reduced waste, and lower environmental costs and liabilities (thereby achieving higher profit margins).
- Investors and insurance companies may lessen exposure to environmental risk.
- Communities and individuals can reduce environmental damage and health risks while seizing new opportunities for local economic development and job creation.
- Government can benefit by replacing one-size-fits-all regulations with a focus on the results achieved.
- And finally, the world community can benefit from the renewed hope of a sustainable, economically viable future for all.

The Game

Note: See Section entitled "Game Concept and Description"

Handbook Appendix A: Team Descriptions and Challenges

General - All Teams

In order to successfully engage in and play the game, players should be familiar with the "state of the world." In that regard, this appendix undertakes to provide background information on the different teams and the constituencies they represent, including possible challenges. Some general challenges are also provided below that might be applicable to any team.

The material in this appendix is important for several reasons:

- Team planning should use the appropriate team description as a starting point in developing a mission and a set of challenges to pursue. The challenges given, however, do not necessarily reflect the correct path to follow. They are not presented as things that should be accomplished. Rather, they are provided to stimulate thinking. Your team must define its mission and challenges as it seems best to meet the needs of your constituents.

- In developing your team's challenges, you may also want to consider the challenges given below as well as the challenges given for other teams. Challenges relevant to multiple teams were not necessarily repeated. Team specific challenges may also have elements that overlap with concerns of other teams.

- When executing your team's strategies, partnering will be required. To be successful, this requires an understanding of the other team's needs and aspirations. The team briefings provide a good starting point for the environmental scans you will have to conduct if you are to develop this ability.

General Challenges:

1. Around the world the conversion, degradation, fragmentation, and simplification of ecosystems has been extensive. In many countries more than half of the natural habitat has been converted to other uses.
2. Human activity is impacting the global cycling of the basic building blocks of life –carbon, nitrogen, sulfur, and phosphorus. Given the fundamental nature of these biogeochemical cycles, continuing shifts in their balances may generate unpredictable non-linear impacts.
3. One hundred and sixty seven countries have ratified the Climate Change Convention, agreeing to reduce CO2 emissions to meet the potential threat of greenhouse gas concentration. China and other major developing countries are not party to this agreement.
4. Overall, fossil fuel sources are inexpensive and relatively plentiful, especially coal; dependence upon these sources could continue for many decades. However, their use generates heavy local and possibly global environmental and health impacts.
5. Developing countries are choosing automobile-based transportation systems, which use oil inefficiently, contribute to air pollution, and whose highway systems cover valuable agricultural land.
6. Materials themselves move relatively rapidly through the economy. In spite of industrial waste prevention and municipal recycling, most materials extracted still end up as waste in landfills or dispersed in the environment.
7. As population increases, the amount of agricultural land is decreasing, the quality of agricultural land is degrading, and world grain reserves are declining.

8. Useful water supply per capita is declining, and in some regions threatens to engender conflict.
9. Energy, materials, and transportation issues converge in the design of the urban system, where by the year 2000 close to half of the world's population will live.

Government Teams

U.S. Congress:

You represent members of the Senate, House of Representatives, and standing committees and subcommittees. You have been empowered by the people to " ... promote the general welfare … to ourselves and our posterity ... " You accomplish this task by enacting such legislation as deemed appropriate. These are difficult times for Congress. The public has a low perception of Congressional integrity and competence. The President and Congress often find themselves at loggerheads. The national debt is growing rapidly, despite recent reductions in the annual deficit. Some entitlement programs have been projected to go bankrupt in the near future. Public confidence is very low. Nevertheless, you wield enormous power for change for the better or for the worse.

In terms of the general welfare, you are concerned about a number of issues including pollution effects on health and the slow pace and high costs of remediation of polluted sites. You are especially concerned about the ability of the U.S. to compete globally. This, in turn, gives rise to concerns over costs for energy and wastes, and the maze of legislation that encumbers the economy.

That such issues exist indicate that the current policy and legal framework in the U.S. does not support a sustainable economy. As recognized in Technology for a Sustainable Future, recently issued by the Office of Science and Technology Policy (OSTP), technology, science and environmental considerations must be integrated into the economy. Although you are aware of this as an ideal, you are also sensitive to the fact that this goal cannot be reached with the current lack of a sufficiently sophisticated and coherent framework.

You also recognize that the United States has a leadership position in the world and its economy. You are interested in ways to direct the economic, scientific, and engineering resources of the United States in a way that will alleviate problems arising from undeveloped and developing nations.

You need to develop a list of requirements, assign priorities, and draft appropriate legislation. Creative solutions are encouraged. You should consider technology priorities, quality of life issues, time lines, and metrics to judge your progress. However, given the differing viewpoints among the voters, you must make a strong case for your proposals in order to be reelected.

Challenges:

1. Domestic and foreign nuclear material accumulations constitute potentially serious environmental and security issues.
2. The U.S. efforts to reduce CO_2 emissions will place our industries at a competitive disadvantage and raise consumer prices.
3. Decreasing domestic oil production and increasing reliance on foreign sources can lead to energy shortages; increasing costs; and global political instabilities.
4. The federal environmental regulatory system is inefficient, it inadequately protects the environment, and compliance is costly.
5. Fragmentation of congressional oversight committees makes efficient implementation of environmental policy and regulations difficult.
6. Congressional committee structures and agency-by-agency decision-making fragments R&D priority setting and funding decisions.
7. Superfund site cleanup estimates for the nation are approaching one-trillion dollars. Very little progress has been made on remediation.
8. Regulatory responses to environmental issues have failed to adequately consider systems solutions where both the environment and the economy can 'win.'
9. Increasing compliance-based environmental regulations are: causing industries to relocate overseas; suppressing new technologies; decreasing standards-of-living; and are providing less protection to the environment per dollar spent.
10. The role of government in IE is ill defined or absent.

Foreign Countries:

You represent the public and officials from all of the countries of the world other than the United States. The team may choose to subdivide, or develop other suitable procedures for ensuring the different types of economies and interests are adequately represented. Some discussions could possibly take the form of UN activities, in which case participation or representation should be sought from the U.S. Congress Team. You are interested in pursuing new relationships between your countries and the United States which would be mutually beneficial, particularly in the areas of development and sustainability. However, you are also concerned about some political movements that seem isolationist and threaten to increase tariffs and restrict trade.

Energy and environmental problems similar to those faced by the U.S. must also be confronted by the rest of the world's developed countries. Those countries that are moving up the development ladder may also end up dealing with these problems, but they do have some alternatives, for example, in how the energy sector of their economy is structured, or in how waste is treated. Thus it might be possible for developing countries to leapfrog the more wasteful and polluting aspects of the industrialized nations' development path through eco-efficiency design of products, industrial facilities, and infrastructure systems. By helping to achieve a greater measure of self sufficiency, it may also allow developing countries to avoid reliance on and political entanglement with resource providers (e.g., OPEC).

The poorest countries, however, have a different set of concerns. They are generally characterized by a paucity of resources (e.g., water, farm land, minerals, etc.) and a burgeoning population. Where resources do exist, they are usually exploited in an unsustainable fashion, often with collateral damage to other resources (e.g.: loss of arable land due to increased soil erosion or reduction in fertility; species destruction either directly or through loss of habitat; reduction in water resources through increased runoff or by quality degradation). Such actions only exacerbate attempts to overcome widespread poverty rather than help the country to begin sustainable development.

Challenges:

1. Developing countries have an opportunity to leapfrog inefficient and polluting infrastructure and other technical systems created earlier in the West. However, international development banks tend to replicate existing system designs in their technical criteria for lending programs.
2. In some countries soil erosion, desertification, and development is destroying farm land and decreasing domestic food supplies. A number of countries, including China, are becoming newly dependent upon food imports.
3. Countries dependent upon markets for commodity resources are likely to be harmed economically by a more eco-efficient global economy in which more is done with less.
4. The technologies for meeting increasing energy demand that developing countries believe are affordable involve burning fossil fuels.
5. Industrial developments often occupy farm land or endanger unique ecosystems.
6. Developing countries are reluctant to curtail greenhouse gas emissions without technical and financial support from industrialized powers. Providing this support will add to the costs involved in cutting back emissions for the developed countries.
7. In many countries growing and aging populations are undercutting the ability of state-run social security systems to continue underwriting pensions. Meeting this economic challenge could compete with funding for environmental programs.

Local and State Governments:

The U.S. Local and State Governments Team is, in many ways, a composite of all of the other government teams. Although you are subject to higher authority (e.g., federal environmental laws), you are responsible for drafting your own legislation, regulations, and policies. You are also interested in providing assistance to businesses, and are responsible for major industrial activities (public works). This team may represent any U.S. city, county, state, or regional authorities as needed during game play, subject only to the team members and their goals. The intended purpose of this team is to provide government representation that is more focused on issues related to the industrial sustainability of a specific locale, including both public and private concerns, rather than duplicating the policy level of the federal teams (although this team is in no way discouraged from drafting appropriate governmental policies of any type).

Local governments have an important role in implementing industrial ecology (IE) principles in that they are tied closely with their communities and associated industries. This places them in the unique position of being able to collect detailed information

on current local business practices, operations, and constraints, and to catalyze IE innovations in these areas. With an IE focus, local governments could serve to both assist in helping the local economy to be more competitive, and to assist businesses in reducing their impacts on - and even restoring - the natural environment. Implementation may be through education, local regulation, or other incentives.

Challenges:

1. Dominant patterns of city-and regional planning still favor sprawl, dependence upon auto transportation, and development of agricultural land.
2. City, county, and state governments are often fragmented in their approach to environment and economy issues, with ineffective collaboration between environmental protection, development, and public works agencies.
3. In the Midwest and Southwest demand for water is drawing down aquifers faster then they can be replenished.
4. Sustainable community planning processes tend to be initiated by environmentalists and environmental justice activists and often lack substantial involvement of industry.
5. Competition for major companies seeking facility sites often results in offering public incentives that reduce the economic benefits and increase the environmental burdens of winning.
6. Looser environmental regulation and enforcement in some states penalizes states with higher standards.
7. Federal solid waste regulations and the major investments of waste collection companies in landfills and equipment conflict with aggressive state and local targets for solid waste reduction and recycling.
8. U.S. cities and states on the Mexican border suffer from cross-border air and water pollution and mandated return of solid and hazardous wastes from Maquiladoras.

Federal Industrial Agencies (FIA):

You represent those federal agencies that support a large industrial base. This includes: the nuclear weapons production and stockpile complex and nuclear waste storage sites of the DOE; the Space Transportation System of NASA; and the extensive system of bases, equipment, logistics, and production systems of DOD. This means that your responsibilities include a strong manufacturing component.

The agencies represented by the FIA Team face problems that are similar to those of private manufacturing firms (e.g., waste management), although often more stringent goals and policies are issued by the Executive Office that exacerbate compliance problems (e.g., Executive Order 12856 requires the reduction of either EPCRA toxic chemicals or toxic pollutants by 50 percent between 1994-1999). Other problems come from many directions and include: facility closing and consolidation issues; dated specifications that “lock in” unnecessary use of hazardous substances; and shrinking budgets while environmental and energy costs continue to soar.

FIAs are actively trying to address these and related issues (sometimes by mandate) by using methods that either support or are related to industrial ecology concepts. For example, the U.S. Army has established the Industrial Ecology Center (IEC), located at Picatinny Arsenal, New Jersey; this organization is tasked to apply ecological principles to Department of the Army, Department of Defense and related commercial industrial processes. Specific DOD or joint DOD/DOE programs include: the Environmental Quality Basic Research & Development Program (EQBRD); the Strategic Environmental Research & Development Program (SERDP); the National Defense Center for Environmental Excellence (NDCEE); and the Environmental Security Technology Certification Program (ESTCP). Unfortunately, although the IEC has plans in keeping with the spirit of industrial ecology (“ECO-MGT” program), the bulk of all work to date focuses narrowly on compliance, restoration, conservation, and pollution prevention.

Challenges:

1.

2. Federal facilities generally fail to demonstrate systems thinking in executing agency missions.
3. Closure of bases and facilities requires remediation of often complex combinations of substances in the buildings, soil, and ground water.
4. FIAs generally do not use their procurement power to support changes toward use of environmentally preferred materials and technologies.
5. FIAs use hazardous substances and generate hazardous wastes at high levels relative to industry.
6. Military specifications often lock in use of toxic substances and preclude innovation by contractors in meeting the design goals. An example is continuing specification of chlorinated substances.
7. Estimated costs for Superfund cleanup at FIA facilities is approaching $400B. Very little remediation progress has been made.
8. There is still no agreement on what are secure and environmentally safe strategies and technologies for managing civilian and defense nuclear wastes.

Federal Advisory & Regulatory Agencies (FAR):

You represent those federal agencies that are primarily concerned with the implementation of policies and legislation that are passed by Congress. This may involve the interpretation and issuance of further policies and regulations, auditing and other compliance activities, and technical or educational support in implementation activities. Government agencies represented by this team would include the Environmental Protection Agency, Nuclear Regulatory Agency, Departments of Transportation and Agriculture, elements within the Department of Energy, etc.

The need for reform of many U.S. policies and regulations in support of sustainability and related issues has been noted by various FAR agencies and the Congress. Recent or active programs of note include: Technologies for a Sustainable Future (OSTP); Reengineering RCRA (EPA); Common Sense Initiative (EPA); and Industries of the Future (DOE).

Challenges:

1. Environmental laws are fragmented as a result of multiple oversight committees and responsible agencies. This results in less effective environmental protection and higher costs for compliance.
2. Many business advocates are demanding risk-based cost-benefit analysis of regulations while agency scientific advisors say that the tools and data to do this do not exist.
3. Funding cutbacks have hit programs for energy R&D and commercialization.
4. Current regulatory structures inhibit development of new environmental technologies by promoting the use of best available technologies.
5. The current regulatory structure encourages once-through industrial use of resources.

Industry Teams

Finance, Insurance, and International Programs:

You represent investment bankers, venture capitalists, international development banks (e.g., the World Bank), insurance firms, and other similar groups. Your team must adequately represent the interests of these different groups; you may not choose to form a single company. Although it may seem that you represent widely different aspects of the economy (e.g., foreign investments vs. domestic investments vs. insurance, etc.), you all share one thing in common. Your policies control a significant fraction of the world's capital expenditures, and thus you have the power to directly influence achievement of a sustainable economy and reduce environmental impacts.

Recently the insurers in your team have growing concerns about the major losses resulting from natural disasters. You are unsure of whether these losses are simply due to poor assumptions in generating actuarial tables, or due to some unforeseen factor like climate change.

For both insurers and investors you are concerned about liabilities resulting from pollution generated by your clients, which often ends up in the form of brownfield properties on your own books when the debts of these firms go into default.

Challenges:

1. Financial regulations, accounting practices, and company policies block factoring environmental costs into investment decision-making. This masks the true costs of less environmentally sound technologies and businesses, while the advantages of emerging preferred technologies are not financially visible.
2. The "external" costs of environmental impacts are not factored into infrastructure investment decisions, biasing them in favor of existing technologies and business models.
3. Insurance companies have incurred record losses due to hurricanes and other weather disasters (e.g.: $39.5 billion for U.S. companies between 1989 and 1992; in the U.S., 21 of the top 25 insurance claims paid out before 1996 had occurred between 1985 and 1995, and 16 of these involved weather related disasters).
4. Both banks and insurance companies experience financial losses from contaminated properties on their books, toxic cleanup costs, and potential continuing liability.
5. Financing of energy infrastructure projects emphasizes large, centralized systems, which lock in technologies and block technical evolution. Solid waste infrastructure investments tend to support continued wasting rather than resource recovery.
6. Pension funds and insurance companies have an intrinsic interest in investing in sustainable technologies and companies. However security regulations and their fiduciary responsibility severely limits their capability for doing this.
7. Economic globalization has created volatile markets biased in favor of short-term speculative returns and against long-term capital investments. This bias makes the financing of innovative environmental technologies and systems more difficult.
8. International development banks have often not generated the improvement in quality of life and general economic well-being they were chartered to achieve.
9. Some decisions made by developed countries in regards to potential environmental problems may result in human suffering in third-world countries (e.g., banning DDT and freon, carbon emissions restrictions).

Resource Providers:

You represent: extractive industries that provide raw materials (including required processing, refining, or reprocessing (of wastes)) such as metal and mineral mines, oil companies, water companies, logging companies, agriculture, and waste management firms (including recyclers); energy companies (power plants of all types); and transportation companies (trucking, railroad, airline, barge and ocean shipping, and any distribution networks such as power lines, pipe lines, and communications). Your team must adequately represent the interests of these different groups; you may not form a single company.

In the past, your primary concerns have dealt with issues related to competition such as: costs; resource depletion and the capital for finding and extracting new reserves; developing techniques for maximizing land productivity (from agriculture and forestry to infrastructure to waste disposal); and prompt delivery. Although these concerns remain high on your list, a new concern has spread across your activities – the environment.

Most of the extractive industries represented by your team have been poorly perceived on the part of the public. It is hard to overcome legacies such as ghost towns and abandoned mines, or new issues such as accusations related to the destruction of threatened or endangered species habitats.

The power industry faces similar bad press over popular issues such as nuclear power, acid rain, and global warming.

To date, the transportation (distribution) industry, as defined here, has not been in the public eye like mines or power plants. There are notable exceptions, such as the Exxon Valdez, leaking pipe lines in Russia, new pipe lines in Alaska, the occasional train or truck wreck involving hazardous materials, and even the proposed movement of radioactive materials. Activist environmental organizations focus on the errors rather than the overall performance of your industries, and are quick to raise the

alarm. While people currently tend to quickly overlook most such news, increasing population densities and increasing movements of hazardous materials will eventually bring such issues to the forefront.

Challenges:

1. Resource providers that continue exclusively as extractive firms could be harmed financially by a more eco-efficient global economy. Increased resource recovery, use of recycled feed stocks, and decreased materials per unit of product may cut demand for virgin materials.
2. If pressure continues to build that greenhouse gas emissions are destabilizing global climate, governments may demand deeper reductions than the rollback to 1990 levels.
3. Clean energy is a critical component to the improvement in quality of life of the developing world and maintaining quality of life of industrialized countries. Yet the long-term investments of the energy industry and Federal R&D and subsidies still emphasize continued dependence on fossil fuels.
4. Losses during extraction and delivery to market of material resources are as high as 50% of the estimated resource (e.g., coal[10] and crops[11]).
5. The waste industry has had difficulty making recycling work economically and many companies are cutting back to their core business of transporting and landfilling waste.
6. Transformation of mineral resources into usable materials for industry is highly energy intensive and generates significant amounts of pollution. In the U.S. over 80 % of energy consumption in the industrial sector is used by 5 resource industries: primary metals, glass and ceramics, chemicals, petroleum refining, and pulp and paper.
7. Environmental regulations often cause major losses in profits.
8. Based on projected consumption patterns and ultimately recoverable resource estimates, the world will run out of oil in forty years.

Manufacturers:

Your team represents those companies with fixed plants that transform resources into final products. Thus your team includes companies that manufacture items from cameras to pesticides to bats. Your team also represents the bulk of the service industry including food services (e.g., restaurants), housing (e.g., hotels), and medical (e.g., hospitals). (Only those services covered by the Resource Providers Team are excluded, such as those services related to the transportation of materials, people, or information.) Your team must represent the interests of these groups; you may not form a single company.

Much of the interest to date in IE stems from a desire on your part to maximize profit margins. Given competition, you have always sought to enhance profits by minimizing resource wastes (costs), and by maximizing productivity. What is new is the fact that there may be cheaper resources (other people's waste) and new product lines (own company wastes) that industrial ecology (IE) tools will help identify. You receive an added cost advantage when you reduce the amount of waste you ship to landfills.

Some of you have recognized a source of competitive advantage in staying ahead of the regulators. Your innovations in processes and materials have led your industries, defined new environmental policies, and often saved money through more efficient designs. IE can be used to keep you in this leadership position.

There is also a growing corporate commitment among your companies to establish a set of values and principles that include social and environmental issues, as well as the traditional economic drivers. This means that not all procurement or process decisions will necessarily be based on profit-margin decisions alone. This also implies that some information and decision-making tools are required, providing an additional context for IE's current use in the manufacturing industry.

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[10] *U.S. Coal Reserves: A Review and Update*, 1996, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Office of Integrated Analysis and Forecasting, U.S. Department of Energy, DOE/EIA-0529(95), Washington, DC, August.
[11] Cohen, J.E., 1995, *How Many People Can The Earth Support*? W. W. Norton & Company, New York.

Challenges:

1. Continued improvements in environmental, energy, and financial performance may demand higher investments, more systemic approaches, and organizational changes.
2. European legislation requiring "extended producer responsibility," including return of products at the end of their life, presents significant organizational, financial, and logistical issues to manufacturers. Similar legislation has been introduced in the U.S.
3. Most corporate cost accounting systems bury environmental costs in overhead or other accounts, making it difficult to perceive the financial and organizational benefits of improved environmental performance.
4. Federally sponsored design goals may be difficult or impossible to achieve. For example, the Partnership for Next Generation Vehicles (PNGV) has set an efficiency goal for passenger cars of 80 miles per gallon.
5. Environmental costs raise the ultimate price of many products to the consumers (e.g., the Rochester Institute of Technology estimate of $400B to $500B per year; OMB estimates place paperwork burden alone at 5 billion hours per year).
6. Future consumer and environmental liability risks continue to mount.
7. Stricter U.S. environmental regulations make domestic products less competitive internationally.
8. Once-through manufacturing is inefficient and decreases potential profits.
9. The promises of eco-systems and eco-industrial parks have not been realized

R&D Providers Teams:

The R&D needs for achieving sustainability are large and multidisciplinary. Examples include: environmental studies on the global heat balance, acid rain, and stratospheric ozone; renewable, clean, abundant, cheap energy; efficient transportation systems; high-yield, hearty crops; water purification technologies; and remediation and waste disposal technologies.

From an applied R&D standpoint, industrial ecology has several tools in its repertoire to support decision making, including: industrial metabolism; dynamic input-output modeling; and design for environment. IE has also evolved industrial ecosystem and eco-industrial park approaches. In addition, it is broad enough to integrate other methods, such as pollution prevention, environmental engineering, environmentally conscious design and manufacturing, and green engineering, into its solutions.

Although these tools are finding application, they are not equally mature and most require further development. Full integration of industrial ecology into the economy may also require that it mature by developing its own identity, including its own concepts, theories, models, and methodology.

Your teams have been selected to provide a tension within the R&D arena for the game, including generation of different perspectives and objectives. The first team, the Universities Team, has a broad charter with a focus on basic sciences, but is active in community-level applications of IE such as eco-industrial parks. The second team, the DOE Labs Team, has a narrower view based on past energy and environmental programs in both the basic sciences and applied technologies. The third team, 'Think Tank, Inc.,' although nominally placed in the R&D paradigm, is intended to operate outside of any box; it is hoped that this team will pursue sustainability issues without ties to any constituency.

Challenges:

1. Industrial ecology introduces complex new research themes which must compete with existing and familiar programs for an apparently shrinking pot of resources .
2. Typically research institutions are highly compartmentalized whereas industrial ecology demands a highly transdisciplinary approach.
3. Some industrial ecologists say that the major barriers to application are at organizational and policy levels, not technical. Yet the primary major research in IE so far has been on the technical side. Relatively few business organization researchers have participated.

4. The non-linearity of many systems of concern in IE presents unique challenges to researchers accustomed to working in a linear mode.
5. The diverse economic, environmental, and technical data bases required for IE analyses are often not available. Basic data on materials and energy flows and toxicity is incomplete and scattered across many data sources.
6. IE methods such as industrial metabolism and design for environment depend upon data on ecological and health impacts of substances and processes. The data are now available for only a fraction of chemicals.
7. Industrial Ecology work is fragmented and many efforts remain narrowly focused.
8. Environmental research is often politicized and motivated by reasons other than science.

Public Team:

Your team represents the general U.S. public including the “haves” and the “have nots” (who want to be “haves”), and the educated and uneducated. You represent the dreams of workers, consumers, taxpayers, savers, bankers, voters, the young and old and yet-to-be born, business people, and receivers of government entitlements. You must also represent environmental activist groups from the Humane Society to the extreme eco-system rights groups. You must decide how to ensure that a reasonable cross-section of these groups are represented. The problems of generating agreement among such a diverse group on the issues at hand, especially considering the very disparate views held by some, will be a major challenge.

From a simplistic view, “raising” the standard of living of an increasing population (which includes some form of reducing the gap between the poor and the rich) implies even faster economic growth. Thus the quandary. How much is enough, and is it within the natural limits of sustainability for the earth? Or do the people in developed countries already enjoy a standard of living that will have to be lowered in the near future? If no action is taken, the “doomsayers” tell us that current trends foreshadow the collapse of society as we know it in the not-too-distant future. Those with a strong belief in mankind think that we will get through it somehow, and expect technology to help save the day. Holders of either idea should be willing to take action. Taking action means there are lessons to be learned and taught. It means working with industries and governments in order to galvanize action in the desired direction. It also means helping the have-nots to become haves in a responsible fashion lest they do unnecessary and potentially unrecoverable damage to society and the earth.

Challenges:

1. Polarization of debate, media sensationalism, and plain lies often make it difficult for the public to follow complex environmental and economic issues.
2. Family and individual behavior contributes to environmental damage and resource depletion but public advocates tend to see the public only as victims of industry.
3. Annualized weekly wages, in constant pre-tax dollars, have been decreasing since 1972 and are now below 1956 levels. Continuing automation and/or movement of plants to low-wage countries has cut the quality and payscale of many jobs. As a result, economic concerns frequently outweigh concerns for the environment.
4. Forty urban areas continue to violate at least one of the present U.S. ambient air quality standards. The new Clear Air Act proposes even stricter standards.
5. Industry regulatory costs are passed on to consumers through increased prices, lowering family purchasing power. An average family of four pays out almost $7,000 each year to meet this burden (amounts to 20% of an average family's post-tax expenditures). This does not include those portions of federal, state, and local taxes related to environmental concerns.

Handbook Appendix B: The State-of-the-World

Prologue

There is a story as old as history – overpopulation. The Babylonians wrote about it ca. 1600 B.C.,[12] the Greeks ca. 650 B.C.[12], the Chinese ca. 500 B.C.[13], and the Romans around 200 A.D.[14] And such complaints have continued to the present. Somehow, advances in culture and technology have managed to keep pace with the population. Some times were better than others, and certainly disaster, starvation, disease, and war played parts in the drama. Today we again hear warnings of the impending arrival of the Four Horsemen of the Apocalypse.[15] Has it all finally caught up with us, or is it mere sophistry, however well intended? It is true that the current population explosion is occurring at a rate and level that far surpasses anything in history. This means that some non-renewable resources are being used at a pace where the "bottom of the barrel" may be in sight. Some also suggest that man is not only destroying precious natural resources, but damaging the very environment that makes life tolerable to us on earth. However, it is also true that today's science and technology far outstrip human abilities of even the very recent past. While it is popular to talk of population control and of lower standards-of-living to mitigate the problem, the ultimate challenge lies in a contest between technology and the population. The question is, can technology be managed within a set of limited resources in such a way that solutions are found with enough time to keep the horsemen at bay? And even better, can these solutions result in a higher standard of living for all?

Introduction

Data regarding the state-of-the-world are organized around country groupings. Two hundred and thirty-three countries and dependent territories were evaluated with respect to population, gross domestic product (GDP), economic structure, arable land resources, renewable water resources, and energy consumption. On the basis of these data, each country was assigned to one of six groups. These groups are summarized in Table B-1 below.

Population

Population estimates and projections were primarily adapted from the U.S. Bureau of the Census.[16] Data for the Falkland Islands, Holy See, Niue, Pitcairn, and Tokelau were adapted from CIA data.[17] Comparisons were also made with United Nations data.[18] The U.S. projections for the world population are bounded by the UN high and low projections. Selected years are plotted in Figure B-1. Although the data shown reflect projections by the UN out to the year 2050, it should be noted that such high-low projections are not of much use beyond 20 years (historically the high has been low).[19] This is likely reflected in the broadening uncertainty band after the year 2025 in the UN projections.

From a standpoint of the country groupings, all areas of the world will experience growth over the next 30 years, albeit at different rates. These different growth patterns will result in a major demographic shift, with the number of the very poor in

[12] Kilmer, A. D., 1972, "The Mesopotamian concept of overpopulation and its solution as reflected in mythology," in *Orientalia 41*, pp. 160-176.
[13] Hardin, G., ed., 1964, *Population, evolution, and birth control: A collage of controversial readings*, W. H. Freeman, San Francisco.
[14] Holland, B. K., 1993, "A review of population growth circa A.D. 200," in *Population and Development Review 19*, no.2, pp. 328-329.
[15] A popular allusion to four angels found in "Revelations," Chapter 9, *Holy Bible*.
[16] U.S. Bureau of the Census, 1996, *International Data Base*, International Programs Center, Population Division, Washington, DC, May.
[17] Central Intelligence Agency, 1990-1995, *The World Factbook*, Office of Public and Agency Information, Washington, DC.
[18] United Nations Department of International Economic and Social Affairs, 1992, *Long-range world population projectins: Two centuries of population growth*, 1950-2150, UN,ST/ESA/SER.A/125, New York.
[19] Frejka, T., 1981, *World Population Projections: A Concise History*, Working Paper 66 (March), Center for Policy Studies, New York.

Table B-1. Country Groupings with Selected 1993 Statistics.

Group	Description	Countries	Percent of world's population	Percent of world's GDP	Average GDP per capita (U.S. $)
I	Most developed. People in these countries enjoy a higher standard of living, as a whole, than any other group.	67: North America, West Europe, selected US and European dependencies, Australia, NZ, Israel, developed East Asia	18%	60%	$17,000
II	Transition economies. More developed economies that collapsed with the dismantling of the USSR.	28: former USSR and Eastern Europe countries	8%	6%	$4,100
III	Oil producers. Countries whose economy is based on oil exports.	13: Most OPEC countries represented here	4%	3%	$3,700
IV	Developing countries. Countries with some minimum but growing industrialization.	40: Represents most people – struggling to get ahead. Countries are from around the world.	53%	26%	$2,400
V	Troubled economies. Countries which had been developing, but whose economy is now being overtaken by population.	19: Countries are scattered around the world.	5%	3%	$2,700
VI	Least developed. Countries with minimal production capacity.	66: Includes countries so categorized by UN plus additional poor countries.	12%	3%	$1,000

Group VI doubling. These trends are summarized in Table B-2. Only 31 countries totaling 820 million people (15% of world) currently exhibit a stable population.[20]

Economics

Gross Domestic Product (GDP) is used in this briefing as a measure of the economic well being of a country. Often this will take the form of GDP per capita, although it is recognized that wealth is distributed unequally within countries as well as among countries. The majority of the economic data were taken from the World Factbook[17] series of publications because of their completeness, although the data compare very well with the Penn World Tables[21]. Out year projections assume that GDP growth rate (in constant dollars) can be related to the GDP per capita as:

$$\text{GDP growth rate} = 2\,(\text{GDP per capita})^{-0.5}$$

Exceptions to this were as follows: (1) Group III countries had a constant GDP; i.e., oil production in these countries and the price per barrel remained constant (which has been the trend for the last 10 years)[22]; (2) Group II countries remained with depressed economies until they fully recovered in the year 2001; and (3), Group VI countries had growth fixed at 3% per year.

[20] Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Italy, Japan, Latvia, Lithuania, Montenegro, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom. Source: Population Reference Bureau, *1995 World Population Data Sheet*, Washington, DC.

[21] Summers, R., and A. Heston, 1991, "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988" in *Quarterly Journal of Economics*, May, pp.327--368. Data set online at http://datacentre.epas.utoronto.ca:5680/pwt/pwt.html.

[22] Brown, L.R., Flavin, C., and H. Kane, 1996, *Vital Signs 1996: the trends that are shaping our future*, Worldwatch Institute, W.W. Norton and Company, New York.

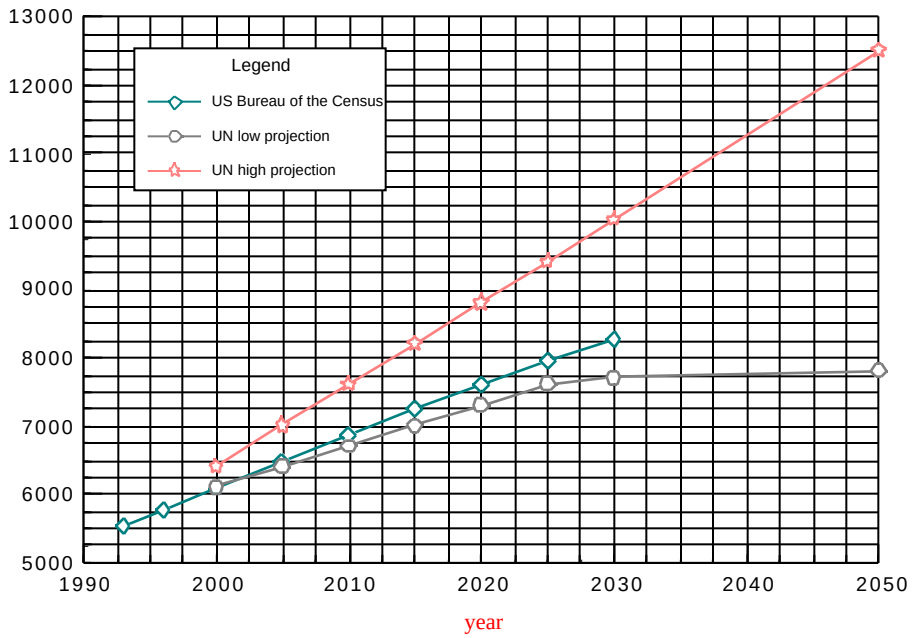

Figure B-1. World Population Projections.

When these assumptions are combined with current economic data and the population projections discussed previously, a world GDP growth rate of 2.8% is predicted (consistent with the Brundtland Report[23]). Model output and world GDP data[24] since 1950 are plotted in Figure B-2.

When the country data are broken down by group, it is possible to consider shifts in the average GDPs. The current GDP distributions are illustrated in Figure B-4. Initial group averages were presented in Table B-1. Once the economic model is applied to these data, out-year averages can be calculated. Selected results are provided in Table B-3.

From the data in Table B-3 it can be seen that the high population growth rates in groups III, V, and VI made a noticeable impact. Economies with a constant GDP (III), constant GDP growth rate (VI), and floating GDP growth rate (V) all suffer under high birth rate scenarios. The data of Table B-2 and Table B-3 also predict a shift in the general economic health of the world population. This is illustrated in **Error! Reference source not found.**, where it can be seen that a larger fraction of the people are involved in producing the wealth. Of course, this is just a very smoky crystal ball that only serves to illustrate that it may be possible to improve the economic health of people as a whole. However, it also shows that the rich tend to get richer while the poor stay that way.

- A major world issue is to find a way to equitably bring resources to the least-developed countries so that they too can contribute in a responsible fashion.

Table B-2. Selected Population Growth Statistics by Country Grouping.

Group	% of world population in 1996	% of world population in 2030	% growth from 1996-2030
I	17	14	15
II	7.2	5.4	8.9
III	4.4	7.1	130
IV	53	51	36
V	5.1	5.9	67
VI	13	17	95

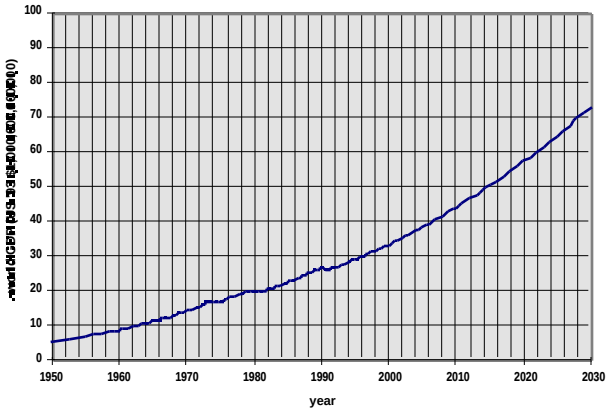

Figure B-2. World Gross Domestic Product Projection.

[23] Brundtland Report, 1987, *Our Common Future*, World Commission on Environment and Development.
[24] adapted from World Bank and International Monetary Fund data as presented in reference 25.

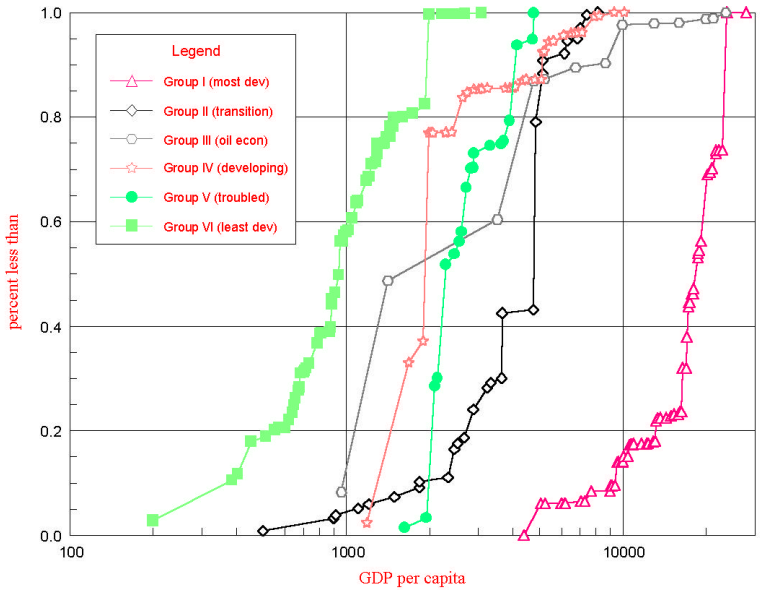

Figure B- 3. Distribution of GDP Among the World Population.

Table B-3. GDP Projections by Group Average.

	GDP/capita for selected years		
Group	**1996**	**2006**	**2030**
I	17,000	19,000	24,000
II	3,600	4,500	7,800
III	3,500	2,600	1,500
IV	2,600	3,300	5,700
V	2,900	3,400	5,100
VI	1,000	1,100	1,500

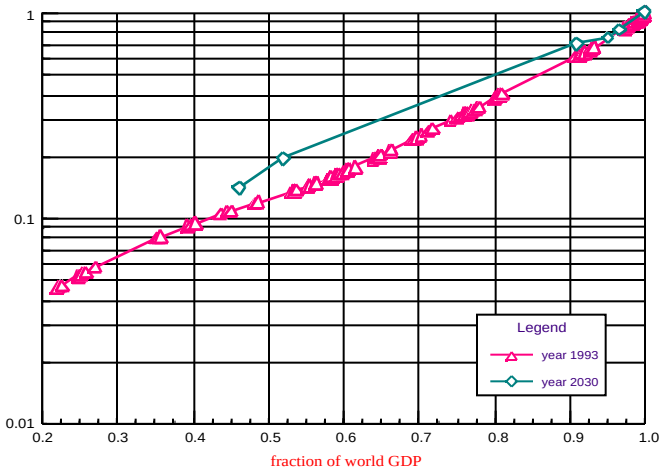

Figure B-4. Country GDP Distributions by Group.

Energy

Energy consumption data for the world's countries were primarily drawn from DOE documentation,[25] as supplemented by CIA[17] and other miscellaneous sources. These data do not include the use of noncommercial fuel (e.g., firewood, animal dung), which has been estimated to provide 90% of the energy needs in poorer countries[26]. Desertification and deforestation have often resulted from a lack of sufficient firewood (over 60% of global deforestation is a result of the use of wood as a fuel[27]). Shortages of fuel wood are often met by using crop wastes or animal dung. Annual consumption of cattle dung for heating and cooking was estimated to be 400-million tons in 1985 for Africa, Asia, and the Near East.[26] This, in turn, impacted soil fertility and food production (dung not available for fertilizer); it may also have a bearing on health issues. However, recognizing that noncommercial energy sources are not reflected in the analysis that follows, a comparison of commercial ısumption and the economy is still useful. That the two are closely linked is graphically illustrated in Figure B-5. What was unanticipated about these data was that there appears to be two basically different economic structures or paths that can be followed. The U.S., countries of the former Soviet Union, and China are on a high-energy consumption trajectory, while other major industrialized countries are on a low-energy trajectory. The question is, why the factor of three difference? Certainly in a comparison between the U.S. and other developed countries there is not a big difference in power production, household, or industrial efficiencies.

A quick answer might attribute these differences to much larger transportation expenditures driven by population densities. However, the data do not support this. As can be seen from Figure B-7, while there are differences in transportation energy consumption between the U.S. and other developed countries (a few percent), they do not explain the differences in total energy consumption.

The total energy consumption shown for the U.S. also clearly indicates the economic disruptions of the early '70s and early '80s caused by jumps in oil prices. This highlights the need for plentiful, inexpensive energy. It also indicates that it is possible to make structural changes in the economy vis-à-vis energy consumption, and move along a different trajectory.

[25] U.S. Department of Energy, 1995, International Energy Annual 1993, DOE/EIA-0219(93), U.S. Department of Energy, Washington, DC, May.
[26] Cohen, J. E., 1995, How Many People Can The Earth Support? W. W. Norton & Company, New York.
[27] Maduro, R.A., and R. Schauerhammer, 1992, *The Holes in the Ozone Scare*, 21st Century Science Associates, Washington, DC.

Questions that arise from considering these consumption data might include:

- How can poor countries make the necessary capital investment to achieve energy independence from wood (alleviate habitat destruction) and needed fertilizer sources, while at the same time enabling future productivity growth?
- Can IE tools be used to characterize differences in energy consumption patterns, and thus enable in-country changes to lower energy paths without disrupting economic productivity?
- Can an understanding of energy consumption patterns in different economies be used to develop infrastructure designs that will move developing countries up a low-energy trajectory?

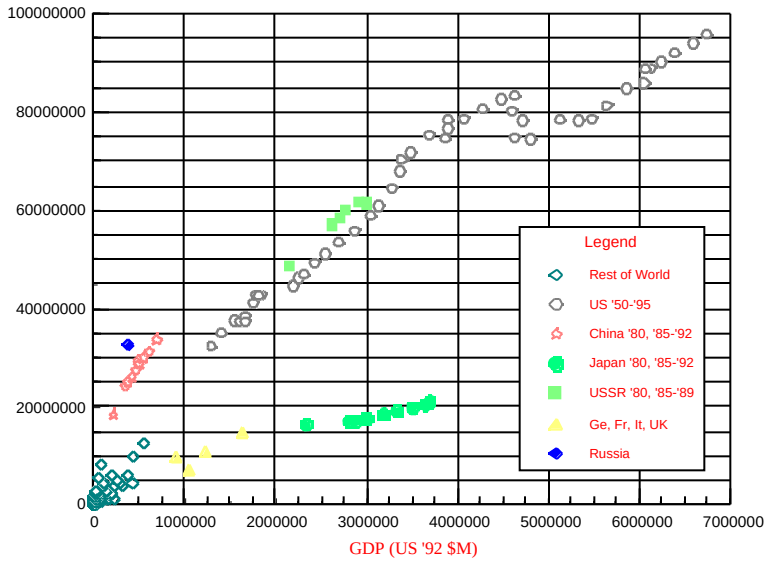

Figure B-5. 1992 Energy Consumption Data, with Selected Time Series.

The world economic and energy consumption trends were combined to predict future energy consumption rates, as shown in Figure B-6. The pre-1994 data were adapted from reference 25. The temporary slowdown in energy consumption growth noted in the early '90s (can also be seen in the economic data of Figure B-2) was a result of the collapsing economies of the former Soviet Union and Eastern Europe. These simple predictions for 2015 compare very well with recent DOE projections.[28] The discontinuity at the year 2030 in Figure B-6 occurs because world oil consumption has depleted the global oil resource base (ultimately recoverable resource (URR) data from Masters, et al.[29]). If coal and gas are used to fill in the oil shortfall, their URR will be consumed by the year 2055 (assumes increasing consumption trends are continued, and neglects the potentially large sources of methane in gas hydrate reserves). That this projection will not hold true in these out years is certain; population and economic data are simply not that predictable. The "cliff" could come sooner or later.

- How soon should action be taken to find suitable replacement energy sources in order to avoid the economic disruption that will result from loss of current resources?

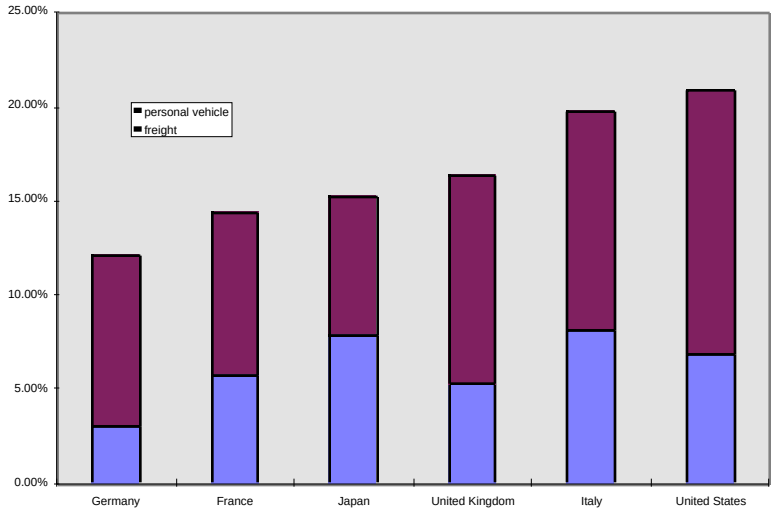

Figure B-6. World Energy Consumption Projection.

[28] U.S. Department of Energy, 1996, International Energy Outlook 1996, with projections to 2015, Washington, DC, http://www.eia.doe.gov/oiaf/ieo96/

[29] Masters, C. M., et al., 1994, *World Petroleum Assessment and Analysis*, USGS, Reston, VA.

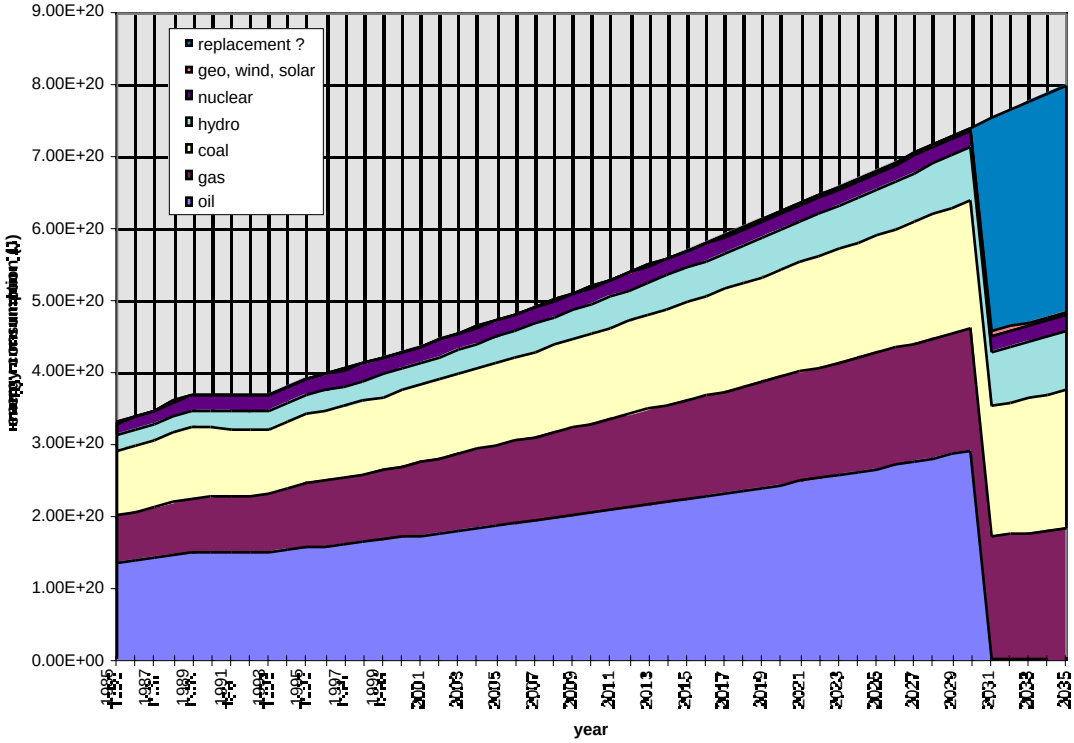

Figure B-7. Surface Transportation Energy as a Percent of Country Total[30].

Climate Change

It can be readily established that human activity alters the local climate; it is simply a matter of scale. The use of housing or wind breaks are a few obvious answers to small-scale changes. On a larger scale, changes due to urbanization are also well documented. Even on a regional scale, it may be possible for humans to influence the climate through deforestation, desertification, and irrigation, although changes at this scale have not been proven.[31] Finally, on a global scale, it is possible that changes in the atmospheric composition due to anthropogenic emissions may be affecting the climate.

That the global climate is changing is a certainty. Reconstructed temperature records for the past 20,000 years[31] clearly show that the climate has never been steady. Global mean annual surface temperatures, regional warming in places from Antarctica to India to Siberia, a 3-mm rise per year for several years in sea level, expansion of forests into tundra areas, and northward expansion of warm water genera along the California coast are a few of many indicators that the earth is currently in a warming trend[32]. Climate models used in trying to understand this trend warn, however, that minor changes of a few degrees in average global temperature may be accompanied by large shifts in global circulation patterns. These shifts, in turn, may cause significant changes in regional temperature and precipitation patterns. Recent, unprecedented weather-related disasters are pointed to by some as being driven by climate change[32], although it may be more related to burgeoning development.

- How can humanity configure itself to accommodate ongoing changes in climate that may be disruptive to food production and other important aspects of society?

Over the past two hundred years, carbon dioxide levels in the atmosphere have increased from 280 ppm to 360 ppm[32]. This increase is attributed to human activity, primarily as a result of burning fossil fuels[31]. Carbon dioxide, along with other gases such as chlorofluorocarbons (CFCs) and their substitutes (HCFCs and HFCs), nitrous oxide, and methane, act to lower radiative heat losses from the earth to space, and are thus called “greenhouse gases.” Increases in greenhouse gas concentration have been

[30] Davis, S. C., and D. N. McFarlin, 1996, *Transportation Energy Data Book*: *Edition 16*, ORNL-6898, Center for Transportation Analysis Energy Division, Oak Ridge National Laboratory, Oak Ridge, TN, August.
[31] Turner, B.L. II, et al., ed., 1990, *The Earth as Transformed by Human Action*, Cambridge University Press.
[32] Brown, L.R., et al., 1996, *State of the World 1996*, W. W. Norton and Company, New York.

correlated with recent global warming trends. This type of evidence was sufficient to lead the IPCC to issue a report[33] wherein it was stated that the recent changes in global climate are "unlikely to be entirely due to natural causes."

Once the link was forged between human activity and climate change, calls for changes in policies were made that would curtail greenhouse gas emissions. To a first-order approximation (e.g., neglecting different uses and mixes of nuclear and renewable power sources), greenhouse gas emissions are proportional to energy production. From this it can be readily seen in Figure B-5 that the United States is by far the biggest "polluter," emitting 1,371 million tons (Mt) of carbon in 1994[32]. Following behind are China (835 Mt), Russia (455 Mt), Japan (299 Mt), and Germany (234 Mt). On an economic basis (GDP), for a given energy consumption level, a higher output is better (U.S. drops to tenth place in a list of the top 20 polluters).

- How soon and what size cuts in greenhouse gas emissions are required to minimize climate disruptions?
- How soon and what types of energy sources will be used to offset cuts in carbon fuel use, and how will economic disruption be avoided?

Of course it should be recognized that the relationship between atmospheric carbon increases and global warming has not been proven to be causal, and it may only be circumstantial. The effects of carbon dioxide only account for about 1% of the atmospheric radiation budget, which can not even be calculated to that degree of certainty[34]. Are the arguments mere sophistry, as many now believe about the ozone hole,[27] or issues like Alar, asbestos, PCBs, and dioxins[35], or even acid rain[36]? Or is there sufficient cause to take the drastic action that many call for?

- How can good decisions be made when risks may be high but only inadequate data are available?

Agriculture

Ultimately, human survival depends upon food, which in turn places requirements on land and water. To feed a person at a level equivalent to a U.S.-type diet takes roughly 2000 square meters of "standard land[37]." In reality, diets and land fertility vary around the world, and land requirements range from 6250 m^2 per person in Southwest Asia down to 720 m^2 per person in Southeast Asia.[38] These values can be reduced with higher levels of technical input (e.g., more irrigation, fertilizer, mechanization, controls) or increased yields through hybridization. However, to present some indication of the scarcity of arable land, country averages and population projections were combined to illustrate the global problem. This data (principally from reference 20) has been plotted in Figure B-8. No corrections were made in anticipation of land loss to urban, infrastructure, and industrial expansion, damage from over production (e.g., salinization or loss of fertility), or erosion. Depending upon what value is selected as an average land requirement, the data show both the current inability of many people to grow sufficient food for themselves, and how the problem will worsen because many of these same countries are experiencing rapid population growth.

- How can poor countries with marginal lands acquire needed technical resources to make their lands more productive?
- How can resource poor countries with sub-marginal lands (that will never be capable of supporting their growing population) acquire sufficient food resources?

In a similar vein, water resources can be considered. The water data[17] available for this briefing covers 149 countries and 97% of the worlds population (rather than the 233 countries found in the rest of this briefing). Approaching the problem from a sustainability standpoint, only annually renewable water supplies were considered. Surface and ground water is also subject to pollution in most of the world, but such limitations were not included.

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[33] United Nations, 1995, *Second Assessment Report*, Intergovernmental Panel on Climate Change (IPCC), December.

[34] Ellingson, B., University of Maryland, as quoted in Garcia, N., 1996, "Unmanned weather research aircraft sets a new record," *Sandia Lab News*, Vol. 48, No 24, November 22.

[35] Ray, D.L., 1990, *Trashing the Planet*, Harper Collins, NY.

[36] Singer, S. F., 1989, *Global Climate Change*, ICUS, NY.

[37] Clark, C., 1977, *Population growth and land use*, 2nd Ed., Macmillan, London.

[38] Higgins, G.M., et al., 1983, *Potential population supporting capacities of lands in the developing world*, Technical report of project INT/75/P13, Food and Agriculture Organization of the United Nations.

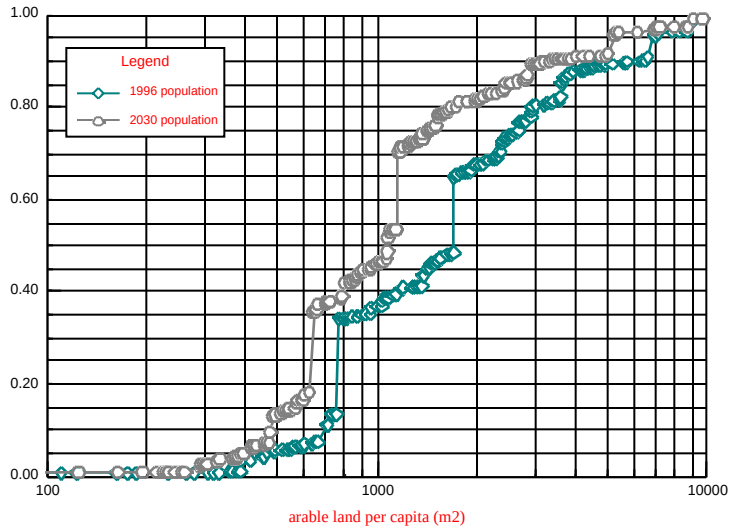

Figure B-8. Arable Land Distribution Across the World Population.

The world's available, renewable fresh water is on the order of 10,000 cubic kilometers. However, it is not evenly distributed in terms of time or space. For example, the average person in Djibouti has "available" only 23 cubic meters of renewable fresh water per year, while the average Icelander has potential access to roughly 670,000 cubic meters.

Annual drinking water requirements for a person are approximately three-quarters of a cubic meter; yet one-half of the people in the world suffer from diseases related to contaminated or insufficient water supplies. Domestic water consumption ranges from roughly 70 cubic meters per person per year in the U.S., while in developing countries it is closer to 10 cubic meters.

More importantly, far larger amounts of water are required to grow food; approximately 1300 to 8300 cubic meters per person per year are required. Water is also required to support industries other than agriculture. It is generally considered that populations with less than 1000 cubic meters of water available per person are experiencing water scarcity[39].

Populations with more than 1000 but less than 1,670 cubic meters per person are considered water stressed. In 1990, 20 countries in Africa and the Middle East that could be classified as "water scarce" were home to 131 million people. These countries will be home to about 1,000 million people in thirty years. At the same time, 3,000 million people will live in "water stressed" countries.

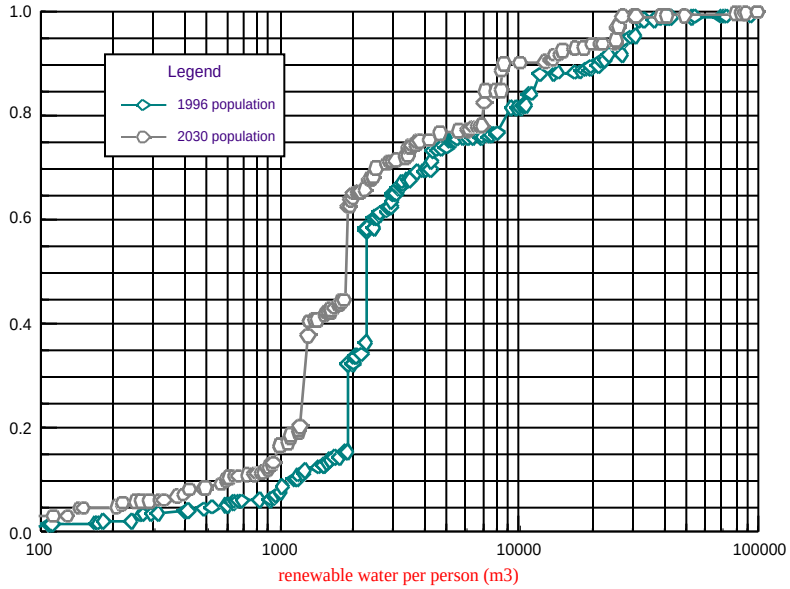

Figure B-9. Renewable Water Distribution Across the World Population.

To further illustrate the problem on a global scale, the available water data have been plotted in Figure B-9. When the "scarcity" and "stressed" thresholds are compared with the data shown in this figure, it can be readily seen that having sufficient water is an issue for a significant and increasing fraction of the world population. When water is not available on a renewable basis to meet demand, it has principally been pumped from "fossil" groundwater sources. Major aquifers across the world are being depleted in the countries of Southeast Asia, the Arabian Peninsula and North Africa, in the United States and Mexico, and in China and India[32]. It should be noted that many of these areas, on the basis of a country-wide average, have more than enough renewable water. However, like many minerals, water

[39] Falkenmark, M., 1991, "Rapid population growth and water scarcity: The predicament of tomorrow's Africa," in *Resources, environment, and population: Present knowledge, future options*, Davis, K., and M. Bernstam, ed., Oxford University, New York.

resources are not always located where the demands are.

- How can renewable water resources be efficiently and equitably distributed to meet needs?

Handbook Appendix C: The State-of-the-Nation

This briefing presents data and issues pertinent to the United States as a whole. In 1997, the population of the U.S. is approximately 268 million. This number is expected to grow 30% by the year 2030 according to the middle series projection of the U.S. Census Bureau,[16] as shown in Figure C-1. This growth rate is slightly less than the 40% they predict for the world as a whole (see State-of-the-World, Figure B-1). The U.S. is also predicted to gain in terms of standard of living. Historical and projected GDP values for the U.S. are shown in Figure C-1 in a constant dollar basis. The historical and projected values through the year 2002 were taken from the President's 1997 budget document,[40] which assumed a real growth rate of 2.8% from 1997 to 2002. We assumed a 2.2% real growth rate for later years.

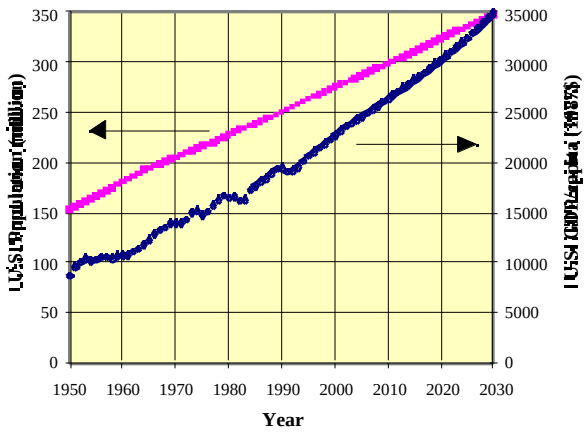

Figure C-1. U.S. Population and GDP Projections.

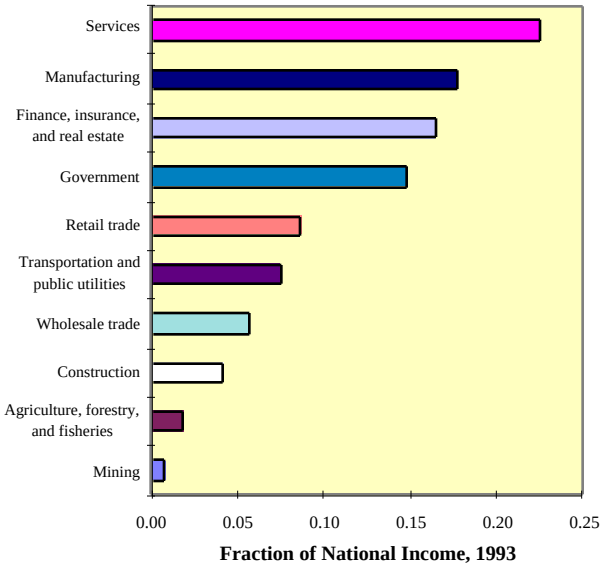

Figure C-2. Fraction of National Income by Industry Sector.

Industry

The U.S. has by far the largest GDP in the world. As a result, the American industrial base is very complex. Nevertheless, industry can be grouped by sectors to show their relative importance to the economy, as shown in Figure C-2. Services account for the largest fraction of the national income (a measure related to, but smaller than GDP), followed closely by manufacturing, financial areas, and government. Income from these four sectors makes up nearly 72% of the national income.

While industrial concerns operate primarily on profit motive, they must deal with ongoing issues such as: hazardous, medical, nuclear, mixed, and municipal-type waste management; air pollution control; contaminated site remediation; recycling; water pollution control; water and energy usage; underground storage tanks; etc. This is particularly true for the manufacturing, government, transportation, and construction sectors.

- How can industry maintain or improve profits while simultaneously addressing these and other environmental issues that impact quality of life?

Although they represent only about 3% of the national income, the extractive industries (agriculture, mining, etc.) are perceived as having a large effect on the environment. Public perception is that these industries extract what they can and then leave. A trail of environmental damage in the form of pollution and species destruction is often in evidence, which has given rise to extensive environmental legislation.

[40] The Budget of the United States Government, Budget Supplement and Historical Tables, FY1997, http://www.doc.gov/BudgetFY97/index.html.

Energy

The U.S. has less than 5% of the world's population, but accounts for nearly 25% of the world's energy usage (along with 25% of the world's GDP). U.S. energy comes from a variety of sources, both foreign and domestic, and is used in many different ways, as shown in Figure C-3.

Energy problems are now being largely ignored by the media and public figures, despite their continuing importance. The American Physical Society recently issued a white paper[42] that documented some of their concerns that included the following facts. DOE's current energy R&D budget has dropped by about 74% (in constant dollars) from its 1978 budget. In 1995 the total

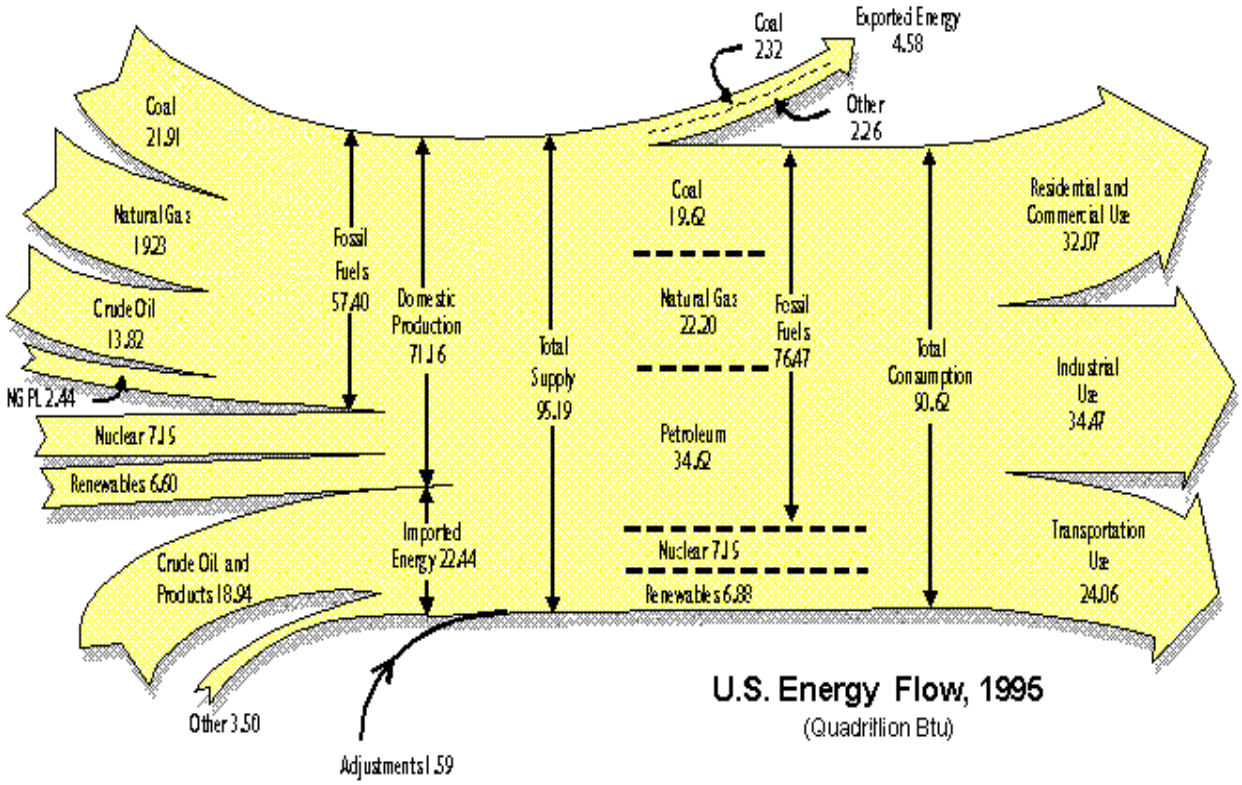

Figure C-3. U.S. Energy Sources and Usage Breakout.[41]

federal investment in energy R&D was only about 0.5% of the total U.S. energy expenditure. Meanwhile, U.S. proven reserves of crude oil have declined from 32 billion barrels (Bb) to 22.5 Bb between 1977 and 1994. And in spite of the new Alaskan oil fields, U.S. production dropped from 9.6 million barrels per day (Mb/d) in 1970 to 6.5 Mb/d in 1995. Shortfalls are met with rising imports (from a low of 6.0 Mb/d in 1973 at the time of the "oil crisis" to 7.9 Mb/d in 1995), a trend that is expected to continue. Reliance on oil imports creates problems for the U.S. ranging from trade deficits (about 30% of the total trade deficit in 1995) to wars (e.g., the 1991 Persian Gulf War) and potentially destabilizing foreign affairs (e.g., arms shipments to the Middle East). Looming oil shortages (if not for us, at least for our posterity) are not the only problem. U.S. proven natural gas reserves dropped from 200 trillion cubic feet (TCF) to 164 TCF from 1983 to 1994 and are presently being consumed at the rate of 21 TCF/y. There are very large resources of coal that are referred to by some (see Figure C-4), but this generally ignores the fact that half of it would require strip mining and that the use of coal entails major environmental problems. The attitude prevalent today apparently stems from shortsightedness, and the current bounty of supplies and relatively low prices.

[41] Energy Information Administration Fuel Overview Page, http://www.eia.doe.gov/fueloverview.html.

[42] The Current Energy Situation: Summary Points. A policy statement from the American Physical Society, July 8, 1996, http://eande.lbl.gov/VirtualPresidio/vpjournal/beta96/beta5aug/beta5index.html.

The power industry faces similar bad press. Our understanding of environmental impacts and how to manage them has, unfortunately, always lagged behind the technologies incorporated into actual plant design and construction. The large amount of capital required to build these plants and their long lifetime then leaves a continuing concern by some of environmental impacts. On occasion, plant retrofits of pollution controls (e.g., stack scrubbers) served to reduce concerns, but have not eliminated the criticism. Other solutions, like nuclear waste disposal, seem to be mired in bureaucracy. And hopes of "pollution free" or renewable energy designs that can accommodate the *majority* of the demand continue to dwindle.
Relevant questions concerning energy sources and usage include:

- Is it wise to rely on foreign energy supplies, and, if not, how does the U.S. achieve energy independence?
- Can IE tools help the U.S. reduce it's energy consumption?
- Should replacements for fossil energy sources be developed, and if so, when? (See the State-of-the-World briefing for related information.)

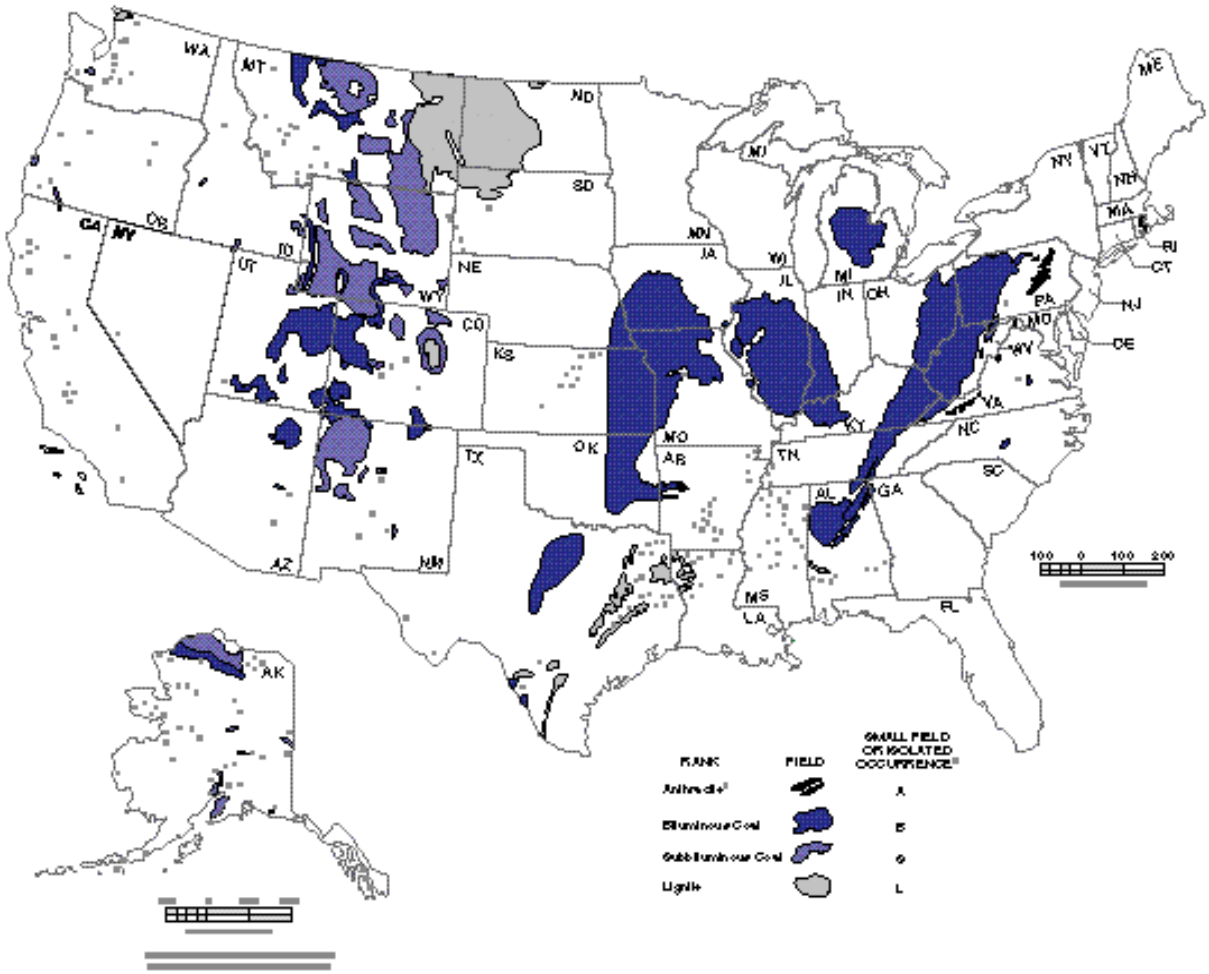

Figure C-4. Location of U.S. Coal Reserves.[10]

Water Resources

Fresh water makes up only about 3% of the earth's water supply, with two-thirds of that locked up as ice. These fresh water resources are made up of surface and ground waters. "The economic support offered by plentiful and high-quality surface waters includes agricultural irrigation, process and cooling waters for power plants, and chemical, steel, lumber, mining, and other industrial operations. The eastern U.S. has a bountiful supply of this natural resource, while in the western states, the relative scarcity of surface water serves to increase its value. In all parts of the country, however, we need to use our water efficiently. Using less water reduces the amount of wastes discharged into our lakes, streams, rivers, and oceans, as well as the energy needed to treat wastewater." [43]

"A major challenge remains to reduce and control pollutants that enter all surface waters. Water that runs off city streets and parking lots during rainstorms may contain metals, oil, grease, and other automotive fluids. Runoff from agricultural fields contains animal waste, fertilizers, and pesticides. These contaminants and others are called non-point source pollution and cannot be reduced by traditional end-of-pipe controls. Discharges from industries, midnight dumping of toxic wastes, urban runoff, acid rain, and agricultural chemicals have polluted and degraded wetlands as well. Recent stormwater regulations are beginning to reduce non-point source pollution from industries and cities. Farming practices that emphasize soil conservation and appropriate use of pesticides are effective in reducing pollutants in runoff." [43]

"The nation's groundwater resources are extremely valuable. Half of all Americans and more than 95% of our rural population get their household water supplies from underground sources. Groundwater also is used for about half of all agricultural irrigation and a third of industrial water needs. In many places, this vital resource is already contaminated or threatened. Groundwater may become contaminated when rainfall and surface runoff pass through contaminated soil. Water dissolves many substances and can carry particles and microorganisms with it into the ground water. Landfills, mining, improperly applied pesticides, improperly stored chemicals and de-icing salts, leaking underground storage tanks, improperly installed or failing septic tanks, and other surface activities can significantly alter ground water quality. Contamination often goes undetected for many years." [43] Groundwater depletion is also a long-term concern. Even across much of the Midwest and West of the 'water-abundant' U.S., over-pumping of aquifers is occurring. For example, net depletion of the High Plains Aquifer system totals over 325 billion cubic meters; groundwater overdraft in California averages 1.6 billion cubic meters per year; and water tables have dropped more than 120 meters in the high desert country east of Phoenix, AZ.[32]

- Can IE processes and tools be used to reverse the trends of fresh water resources becoming more contaminated and less available?

Air Quality

Air quality is affected by many human and natural activities. Manufacturing companies, power plants, small businesses, automobiles, forest fires, and volcanoes are all sources of air pollution.

Although the U.S. has made strides in improving air quality, combustion of fossil fuels continues as a major contributor to poor air quality in many cities, with 40 urban areas continuing to violate at least one of the U.S. ambient air quality standards.[42] This can result in an adverse affect on human health. From a broader perspective, energy production and use can adversely affect the environment in many ways. These impacts can arise from both routine and accidental releases of pollutants, the preemption of land (and rivers), and the accumulation of waste products. If current trends in fossil fuel use continue, carbon dioxide concentrations will double in the next century, and may also impact the environment in uncertain but possibly harmful ways ("greenhouse effect").

- How can air quality issues be adequately addressed in an economically viable fashion while still allowing and promoting necessary growth in the U.S. economy?

Waste Production

In the U.S., municipal solid wastes alone amount to 4 pounds per person per day. The U.S. produces a total of ten billion tons of non-hazardous waste per year that is regulated (or soon will be) under the provisions of Subtitle D, from municipal, industrial, and mining sources.[44] Most of this material ends up in a landfill at a cost of roughly $20 per ton; landfill space is at a premium in

[43] Guide to Environmental Issues, U.S. EPA, 520/B-94-001, September 1996, http://www.epa.gov/epadocs/guide.

[44] O'Leary, P. and Walsh, P., Co-Directors, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison Solid Waste Landfills course materials, http://wissago.uwex.edu/uwex/course/landfill/.

the U.S. today. Hazardous materials add an additional burden. The current U.S. annual production of organic and inorganic chemicals exceeds 200 million tons (world production in excess of 500 million tons).[45] As these chemicals are "consumed," some 2 billion tons of hazardous wastes are generated in the U.S. alone[46] (hazardous waste production exceeds hazardous chemical production by a factor of ten through contamination or dilution with other materials). Dealing with such vast quantities of waste has become a major challenge for business and government. Inadequate disposal practices in the past have also caused both the federal and state governments to impose ever stricter regulations on facilities that manage or dispose of waste. Past, inadequate disposal practices have caused environmental degradation and the need for costly remedial actions.

- How can products be reformulated, packaged and distributed to reduce or eliminate associated solid wastes? Should these actions be taken now, or should we wait until lack of landfill space forces action?
- How can IE tools be used to develop alternate methods of disposal?

Remediation

Concerns exist over the slow pace and costs of remediation of environmentally polluted sites on federal lands, including costs for processing the wastes that are generated annually by federal agencies. The Department of Defense has over 10,000 contaminated sites requiring restoration that the CBO estimates will eventually cost in excess of $40 billion.[47] The Department of Energy, as part of the research, production and testing of nuclear weapons, has a legacy of 132 sites requiring cleanup,[48] remediation is projected to eventually cost $200 - $350 billion and require some 50-75 years to complete.[49] These cleanup costs represent a tremendous strain on the federal budget and the taxpayers. However, the taxpayers are also faced ultimately with the bill for non-federal remediation work. Currently there are some 32,000 Superfund sites, and it is expected that this count will grow by an order of magnitude; the final cleanup bill for non-federal sites may reach $500 billion.[46]

Bankers and insurance companies are also feeling the effects from environmental cleanup issues. More than 40 percent of commercial mortgage bankers have turned down mortgages because of contamination fears. Most insurance companies by now have changed their corporate insurance policies to exclude pollution claims, yet it is estimated that they will still pay out some $150 billion over the next 30 years for existing liabilities.[46]

As regards brownfield remediation, technical barriers (current state-of-the-art) and regulatory factors (sometimes arbitrary and unattainable standards, and permitting, reporting, and approval processes) make remediation a slow and costly process. These difficulties create large uncertainties concerning environmental liabilities, and tend to discourage involvement of purchasers and lenders with properties which are encumbered with contamination problems, despite any potential profitability.

Cleanup of non-federal sites is proceeding at a very slow pace due to barriers that fall into three general categories: technical know-how, regulatory factors, and liability issues. Technical barriers include the specific limitations of current cleanup technologies. Regulatory factors inhibit cleanup at some sites by making the permitting, reporting and approval process slow and costly, by limiting the availability of cleanup technologies, or by setting cleanup standards which in some cases are both arbitrary and unattainable. Liability issues represent the legal and financial outcomes of environmental contamination; due to the difficulties of completing the cleanup process, environmental liabilities are notoriously uncertain, and tend to discourage investments of purchasers and lenders in properties which are encumbered with contamination problems. It is possible that these costs and the cleanup times involved could be reduced by development of new remediation technologies and policies. Although funding for research and development of new technologies for cleanup increased dramatically between 1991 and 1994, it has since fallen by about 50 percent.[48] Failure to adequately fund needed R&D could result in further inflation of these projected and already excessive remediation costs.

Regulation

The current regulatory environment contributes to the slow pace of correcting environmental problems. Environmental laws (including those related to biodiversity and ecosystems) are fragmented across multiple Congressional committees, agencies, and agency branches. This fragmentation prevents a systems view from developing. Regulations rigorously define wastes and their

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[45] Chemical and Engineering News, June 24, 1996, http://pubs.acs.org/hotartcl/cenear/960624/prod.html.
[46] *PPC Index of Sustainability Indicators*, http://eande.lbl.gov /VirtualPresidio/vpjournal/beta96/beta4/suststats.html.
[47] Williams, C., Congressional Budget Office, March 21, 1996 testimony before the House National Security Subcommittee, http://www.cedar.ca.gov/military/psc1.html.
[48] U.S. Department of Energy Offic of Environmental Restoration, http://www.em.doe.gov/er/index.html.
[49] *DOE, An Emerging Market for Remediation*, http://www.ohm.com/doe.html.

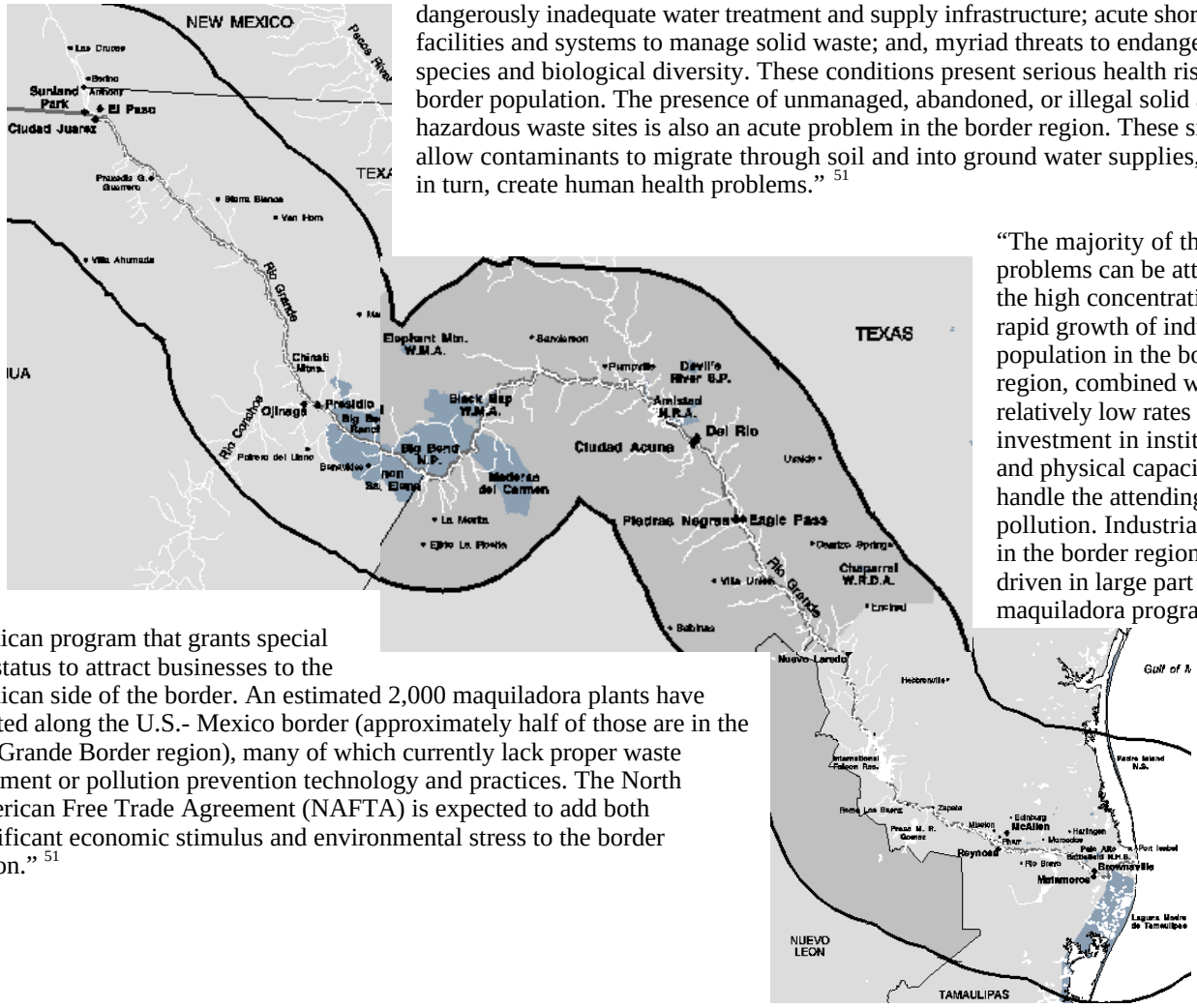
sources in ways that at times limit their reclamation, reuse or recycling, and also severely restrict disposal options. Technological or management innovation is thus inhibited, disposal problems and costs continue to mount, and potentially useful resources are dispersed beyond recovery. Regulations, pricing, and economic support policies exist that encourage nonsustainable use of various resources including land, water, crops, energy, and transportation.

- Can IE play a role in designing and proving regulations that are effective in terms of both environmental effects and cost? How?

Handbook Appendix D: The Rio Grande Border Region

The Rio Grande Border Region is defined to be the land within 100 km. on each side of the boundary between Mexico and the U.S. extending roughly from Las Cruces, NM to the Gulf of Mexico. This region encompasses parts of four Mexican states and two U.S. states, and includes a population of 4.6 million people (2.1 in the U.S., 2.5 in Mexico) which is expected to double in the next 20 years. The majority of this population resides near El Paso/Ciudad Juarez or within 100 miles of the Gulf of Mexico. Poverty rates on the U.S. side of the border in South Texas are among the highest in the nation.[50] "As an environmental region, the U.S.- Mexico border must also be described in terms of the larger ecosystem of which it is a part. The U.S.- Mexico border region is a component of a highly interdependent, transnational system where natural resources are intensively shared by both Americans and Mexicans. The region's water is supplied by transnational river basins and aquifers, the Rio Grande Basin being the most notable example. Many pairs of U.S.- Mexico twin cities share common airsheds, with airborne pollutants freely moving across political boundaries. There are numerous national and state parks, recreation areas, and wildlife sanctuaries populated with migratory species, many of which are endangered. The Gulf of Mexico is a common ecosystem in which aquatic life and pollutants move in and out of national waters. In the border region, environmental events on one side of the border affect the other side almost equally." [51]

"The border region has some of the most serious environmental problems in the western hemisphere (in part, because they are transnational in nature): extensive industrial pollution of water, land and air; dangerously inadequate water treatment and supply infrastructure; acute shortages of facilities and systems to manage solid waste; and, myriad threats to endangered species and biological diversity. These conditions present serious health risks to the border population. The presence of unmanaged, abandoned, or illegal solid and hazardous waste sites is also an acute problem in the border region. These sites often allow contaminants to migrate through soil and into ground water supplies, which, in turn, create human health problems." [51]



"The majority of these problems can be attributed to the high concentration and rapid growth of industry and population in the border region, combined with relatively low rates of investment in institutional and physical capacity to handle the attending levels of pollution. Industrial growth in the border region has been driven in large part by the maquiladora program, a Mexican program that grants special tax status to attract businesses to the Mexican side of the border. An estimated 2,000 maquiladora plants have located along the U.S.- Mexico border (approximately half of those are in the Rio Grande Border region), many of which currently lack proper waste treatment or pollution prevention technology and practices. The North American Free Trade Agreement (NAFTA) is expected to add both significant economic stimulus and environmental stress to the border region." [51]

[50] Rio Grande Valley, Texas Empowerment Zone, http://www.ezec.gov/ezec/TX/riogrande.html.
[51] Texas Natural Resources Conservation Commission - Border Affairs, http://www.tnrcc.state.tx.us/exec/ba.

Industry

Rapid growth in exports to Mexico has made the soundness of the Mexican economy a major determinant of the health of Texas manufacturers and the growth of the overall Texas economy. A major portion of the Lower Rio Grande region's economic support comes from trade, manufacturing and agriculture. Manufacturing jobs account for only 12.5% of the non-farm jobs. By contrast, over 20% of the jobs in the El Paso region are in manufacturing[52]. Free trade zones currently operate in the McAllen - Reynosa and other areas.[53]

The large Mexican border cities have established programs to attract industry to their areas. For example, Reynosa has five industrial parks which are the home to over 100 manufacturing plants. Global leaders in electronics, apparel, medical supplies, publishing, auto assembly, and many other fields have established large operations in Reynosa. These cities also profess to have abundant supplies of electricity and natural gas, sufficient for economic growth.[53]

The maquiladora program has provided for many manufacturing jobs on the Mexican side of the border; over 300 plants in Cd. Juarez, over 110 plants in Matamoros, and over 100 plants in Reynosa supply roughly 160,000, 50,000, and 45,000 manufacturing jobs, respectively.[53,54,55] However, these are primarily unskilled assembly jobs with low pay. Maquiladora plants report high turnover rates, and have not provided the sought-after boost in standard-of-living that many residents expected.

Energy

Texas has about 7% of the U.S. population, but in 1989, the state accounted for 12% of the nation's total energy usage. Texas consumes more electricity, natural gas, coal and petroleum than any other state, and leads the nation in the production of CO2 and other gases that some link to global warming. The global warming issue and the 1990 Clean Air Act could force Texas to change its energy consumption patterns.[56]

Oil production in the state is falling. Natural gas consumption is increasing but reserves are shrinking. Coal use has risen sharply. For the first time, Texas faces the prospect of becoming a net energy importer. Some estimates show that conservation alone could reduce demand for electricity in the state by one-third.[56]

Texas has large proven reserves of lignite, a soft, low-energy coal. However, very few of the reserves are in the border region. The largest border region reserves lie in and near Big Bend National Park. Studies have shown that up to twice the state's current total electricity generating capacity could be generated if all the state's wind resources could be captured. Some areas along the Texas - Mexico border from El Paso to Big Bend are particularly promising for wind power generation. The new class of wind turbines can generate power for as little as five cents per kilowatt-hour, slightly more than the cost of coal-fired plants. But when external costs, like air pollution, are figured in, wind may be a cheaper power source. Texas also has extremely high solar energy potential, with the highest potentials in southwest Texas, near El Paso.[56]

Water Resources

"Water pollution is one of the principal environmental and public health problems facing the border area. Deficiencies in the treatment of wastewater, the disposal of untreated effluent, and inadequate operation and maintenance of treatment plants result in health risks. Additionally, the lack of adequate distribution systems for drinking water increases potential risk for gastrointestinal infections. In the Mexican border region, the greatest need is for water and wastewater infrastructure in urban areas where sewer systems have exceeded their useful life and require rehabilitation; similar needs also exist in small communities. In the U.S. border area, there is a great need for water and wastewater infrastructure in unincorporated communities (colonias) as well as in small communities." [57]

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[52] Gaining Ground - A Regional Outlook, http://www.window.texas.gov/ecodata/rmdata/rm.rrhome.html.
[53] McAllen Economic Development Corporation, http://www.medc.org/.
[54] Brownsville Economic Development Council, http://brownsville.clever.net/bedc.html.
[55] Chihuahua Now, http://suenlace.com.mx/ChihNow/indice.htm.
[56] Texas Environmental Almanac, Texas Center for Policy Studies, 1995, http://www.tec.org/almanac.
[57] Border XXI Framework, http://134.67.55.16:777/R9/MexUSA.nsf/.

Southern New Mexico and Far West Texas have a very limited water supply. The major aquifers in the area - the Hueco and Mesilla Basins - are shared by New Mexico, Texas, and Mexico, and provide nearly all municipal and industrial needs. These aquifers in are being mined to the point that water from adjacent saline bearing sands is encroaching upon higher-quality groundwater. High salinity in the Rio Grande is due to frequent low flows and municipal and agricultural return flows[56]. Domestic water supply in the colonias is a serious community concern. The lack of adequate wastewater treatment and improper hazardous and solid water management are considered major contributors to the insufficient environmental conditions and the high risk to human health. The public has identified drinking water quality and groundwater contamination as major concerns in this geographic area. Other residents believe a large number of colonias have contaminated water supplies.[57]

The Lower Rio Grande Valley region will face potentially serious water supply and resource challenges over the next 50 years. Groundwater is naturally high in salinity and most cannot be used for drinking water purposes in the Lower RG valley. Bays and estuaries in South Texas and other environmental needs must compete with the growing population of the area. Brownsville and Harlingen in Cameron County will exceed their permitted rights to surface water by 2010 and will need to purchase additional rights, probably as agricultural land is converted to suburban use. The preponderance of improperly built septic tanks and drainage fields is affecting the quality of water in the LRG region as a whole. Residents also cite the illegal dumping of waste in water bodies that flow into the Rio Grande as a concern.[56]

Over the next 50 years, the Texas Water Development Board estimates Texas will need $41B in funds for wastewater and water systems, etc. An additional $700M will be needed to provide basic water services to Texas residents living in colonias.[56]

Potential solution areas to water-related challenges include:[57]

- developing and rehabilitating infrastructure for drinking water, wastewater collection and treatment,
- developing innovative ways to deal with waste brines in desalination processes (currently very costly)
- establishing binational guidelines for developing and implementing pretreatment programs,
- developing long-term binational priorities and programs for watershed planning and management,
- continuing and expanding water quality monitoring programs to determine water quality status of surface and ground waters,
- supporting personnel training and programs related to water management issues,
- developing infrastructure upgrades, educational programs, and incentives to enable much more efficient and rational use and re-use of water, and
- encouraging public participation in water infrastructure decision-making processes.

Natural Resources

“The border region of both countries includes a vast wealth of resources and diverse ecosystems, including freshwater, marine and wetland ecosystems, deserts, rangelands, and several forest types. Identified environmental problems include: degradation of air, soil, and water; introduction of exotic species; habitat loss; poaching; illegal trade in protected species; increased wildfires; illegal exploitation of forest and marine resources; over-cultivation of plants and animals; overgrazing; trespassing of livestock; and, road construction.” [57]

Increased human population along the border has increased the demand for wood and wood products, while land availability for growing trees is decreasing. Forestry and soil conservation concerns include soil erosion control, loss of forest lands, threatened and endangered species protection, and habitat management.[57]

Potential solution areas to resource-related challenges include:[57]

- promoting sustainable management of natural resources in the entire border zone through productive projects to improve the quality of life for local communities,
- improving binational law enforcement capabilities through cooperation and strengthening mechanisms for verifying regulatory compliance,
- expanding links between research and natural resource management, and
- training and education programs.

Waste Production

"Rapid industrialization and population growth have created a need for improved hazardous and solid waste management infrastructure. Important waste issues include the illegal transboundary shipment of hazardous waste, health and environmental risks posed by inactive and abandoned disposal sites, the need for proper development of new sites, and the proper operation and closure of existing sites." Landfill issues require special attention due to the potential for runoff into the Rio Grande.[57]

Under both Mexican law and a U.S.- Mexico agreement, the waste from maquiladoras production must be returned to the country from which the raw materials were imported. Despite this, Texas commercial facilities only treated 1800 tons of hazardous waste from Mexico in 1991. Evidence suggests that the volume of waste is many times higher than that returned. The World Bank estimated that 80% of the hazardous waste is not repatriated, but remains stored on-site or is otherwise illegally disposed of in Mexico.[56]

Mexico currently has a ban on the import of hazardous waste for disposal, However, it does allow the import of waste if it is used to recover or recycle valuable materials (e.g. cement kiln facilities can burn hazardous waste to power production processes).[56] Texas residents are concerned about the possible impact of the burning of municipal waste in Mexican solid waste facilities on the binational airshed.[57]

Potential solution areas to waste-related challenges include:[57]

- developing a vulnerability atlas to target geographic priorities for solid and hazardous waste management projects,
- improve monitoring of the transboundary movement of hazardous wastes and substances in the border area,
- continuing enforcement activities related to illegal hazardous waste practices,
- improving waste management practices and promoting waste minimization and recycling,
- defining aggressive waste reduction goals and promoting economic development strategies to encourage new reprocessing, recycling, brokering, and reuse companies, and
- implementing industrial ecosystem and eco-industrial park strategies.

Air Quality

"Many border area residents are exposed to health-threatening levels of air pollutants, including ozone, particulate matter, CO and sulfur dioxide. The need to evaluate levels of targeted air pollutants is particularly urgent in heavily populated areas where air quality problems are compounded by emissions from increasing numbers of vehicles - many of which are older and poorly maintained; extensive industrial activity; and numerous air sources (e.g. unpaved roads, waste disposal fires)." [57]

El Paso and other cities along the Texas/Mexico border face unique pollution problems because environmental standards differ on the two sides of the border. In fact, air pollution originating in Ciudad Juarez may contribute as much or more to overall air pollution in El Paso than pollution originating on the U.S. side of the border. These two cities, along with Sunland Park, NM, share a common airshed in a valley characterized by the RG and surrounding mountain peaks. The principle sources of CO, particulates and ozone in the area include motor vehicles, industries located in the airshed and open burning of domestic and agricultural waste. Temperature inversions in the area contribute to air pollution problems. If the Texas Natural Resource Conservation Commission (TNRCC) can prove that pollution from Mexico prevents El Paso's compliance with standards, the city will not bump up to a severe non-attainment area. However, El Paso will still have to adopt stringent pollution control rules.[56]

Potential solution areas to air-related challenges include:[57]

- developing air quality assessment and improvement programs (monitoring, emissions inventories, modeling),
- continuing to build institutional infrastructure and technical expertise in the border area,
- encouraging on-going involvement of local communities,
- promoting air pollution abatement strategies (e.g. at border crossings, brick kilns),
- research focused on potential pollution prevention breakthroughs specific to the region's largest sources of emissions, and
- studying potential for innovative programs for reducing air pollution, such as incentives or cross-border pollution control investments.

Some Current Efforts (not comprehensive)

- Brownsville, TX has been designated by the President's Council on Sustainable Development to develop an eco-industrial park where energy and water cascading and process control will produce a profitable industrial park whose highest priority is environmental protection and energy efficiency.[58]
- The Transboundary Resource Inventory Project (TRIP) is working to link data along and across the U.S./Mexico border. Graphical Information System (GIS) maps play a role in this, yet still need a great deal of data.[59]
- The Commission for Environmental Cooperation (CEC) is funding projects to explore environmental effects of NAFTA.[60]
- Several joint U.S.-Mexico border programs are underway, including: Border XXI, the Rio Grande Toxics Substance Study, and the Rio Grande Alliance. [2] Border XXI participants include: EPA, DOI, USDA, HHS; and Mexico's Secretariats for Environment, Nat. Resources and Fisheries, Social Development, and Health; and the International Boundary and Water Commission.[57]

[58] Border Information and Solutions Network, http://www.triplesoft.com/bisn/Ongo.html.
[59] Http://www.txinfinet.com/mader/ecotravel/border/0695gistory.html.
[60] Commission for Environmental Cooperation, http://www.cec.org/english/about/apb96.

Handbook Appendix E: Industrial Ecology Tutorial

(Contributed by Ernest Lowe, Indigo Development)

Defining Industrial Ecology

A diversity of definitions

Industrial Ecology (IE) is still in a formative stage, with a diversity of definitions and understandings of scope of application. Although consensus is emerging around certain key themes, there are critical areas of divergence among industrial ecologists. The following discussion is based upon a content analysis of over 25 definitions, similar to an analysis by University of Michigan researchers[61].

Common themes – an emerging consensus?

The majority of discussions of industrial ecology tend to agree on the following elements:

- IE is *a systems approach* drawing upon methods from systems engineering.
- This systems approach focuses upon the *interaction of human industry and ecological systems*.
- Through system redesign, IE seeks to reduce the ecological impact of human activity to levels natural systems can sustain.
- IE is *interdisciplinary*, linking the research and planning of many fields, including ecology, engineering, economics, business management, and public administration and law.
- IE studies the *flows of materials and energy* through the economy, ranging from those of an industrial or public facility to the planet. It seeks strategies to *increase the efficiency and reduce the impact* of these flows. (This study is often termed "industrial metabolism.")
- IE encourages *transformation from a linear, often wasteful economy toward a closed-loop system* of production and consumption. In such a system, industrial, governmental, and consumer discards would be reused, recycled, and remanufactured at the highest values possible.
- IE enables creation of *short-term* innovations with awareness of their *long-term* impacts. Similarly, it enables *local decision-making* with awareness of broader *regional and global impacts*.
- IE seeks to achieve a *balance between environmental protection and economic viability*. This balance must be dynamic, adapting to new knowledge about industry's impacts and nature's responses.
- IE is a major component in "*the science of sustainability*," with the role of designing the *transition path for industrial activities*, broadly defined. It offers an objective though complex foundation for *coordinating design of public policy* in environmental, technical, and environmental realms.

Industrial Ecology will interact with other fields such as ecological economics and environmental accounting, in creating the foundation for sustainable development.

Areas of divergence

While there is a fair degree of consensus on the elements of IE just listed, there is also much divergence as to its scope and emphasis. In part this is due to specialization within the field, but differences can go to the heart of how researchers define and use IE.

- *Time scale:* Some industrial ecologists emphasize incremental change in existing systems. Others speak of far reaching transformations.
- *The ecosystem model:* With some, it is popular to model industrial systems on the principles of ecosystems. However, some ecologists and many engineers question this approach.

[61] Garner, A. and G. Keoleian, 1994, *Industrial Ecology: An Introduction*, National Pollution Prevention Center for Higher Education, University of Michigan. Ann Arbor.

- *Materials flows:* Some industrial ecologists focus on increasing the efficiency of materials flows, often emphasizing using one company's waste as another's raw material. In some writings the whole field appears to be little more than this.
- *Scope of application:* Much discussion focuses on changes in manufacturing. Other practitioners emphasize that IE is relevant to agricultural, service and financial industries, public policy, infrastructure, facility operations, and even consumer behavior.
- *Key ecological concerns,* such as biodiversity, carrying capacity, and restoration, are emphasized by university researchers but are seldom mentioned by more application-oriented industrial ecologists.
- Some see *institutional change* as a fundamental component of IE. Others discount this, emphasizing the centrality of technical innovation to IE.
- *Materials choices:* The shift from non-renewable, synthetic materials to renewable bio-materials is a central concern for some industrial ecologists. Others focus on improving the environ-mental performance of synthetics.

Industrial Ecology is both a field of scientific research and a framework for design and decision-making in public and private sectors. These two aspects should be seen as complementary rather than divergent. They need to be closely inter-related, to insure a sound basis for developing applications and continuing research on the results of IE-based projects.

Industrial Ecology Methods and Approaches

IE methods seek to answer basic questions such as:

How can we act with creativity and rigor to design effective environmental solutions at each level of the system?

How can we best evaluate alternative solutions?

How do we know the right level of design or management for approaching a particular issue?

How do we resolve conflicts across levels?

How do we maintain a coherent view of the whole system in order to make design and management decisions well at any level?

The following pages provide a glimpse of some of the more prevalent IE methods and approaches found today. The methods covered here are: Industrial Metabolism, Dynamic Input-Output Modeling, Design for Environment, Product Life Extension, and Industrial Ecosystems This selection is not meant to be complete or exclusive. The material presented was adapted from the work of Lowe and Warren[62].

Some Illustrative Cases of Industrial Metabolism Analysis (see Table E-1):

A National Study of U.S. Water Use.

An IM analysis of water usage in the U.S. shows a high level of inefficiency and waste. Very little wastewater is directly recycled in the system, with most reuse being for irrigation. In addition, a significant amount of water remains unaccounted for or is lost in transit (through leaks in pipes, irrigation systems, etc.). The use of water in the energy sector almost equals that in agriculture. Overall, a metabolic view of the water and wastewater system shows high levels of throughput, significant waste, and little reuse of resource and waste streams.

River Basin Studies of Heavy Metals and Toxic Materials

The International Institute for Applied Systems Analysis (IIASA) has completed the first phase of an industrial metabolism study of the Rhine Basin, the largest application of IM so far. This basin is probably the most heavily industrialized region in the world.

[62] Lowe, E., and J. Warren, 1996, *The Source of Value: an executive briefing and sourcebook on industrial ecology*, PNNL-10943, Pacific Northwest National Laboratory, Richland, WA, February.

The study examined sources of pollution and pathways by which pollutants end up in the river for the whole basin. Materials studied include cadmium, lead, zinc, lindane, PCBs, nitrogen and phosphorous.
The results suggest that in the Rhine basin industry has made major progress on reducing emissions. However, there are increasing flows of pollution from "non-point" or diffuse sources, including farms, consumers, runoff from roads and highways, and disposal sites. These findings are of great value in design of policy, industrial practice, and public education.

Chaparral Steel

Chaparral Steel is a Midlothian Texas company seeking to define every output as a product, saying, “Waste is a sacrificed financial opportunity!” CEO Gordon Forward's strategic goal is to generate zero waste. Chaparral's Project STAR (Systems and Technology for Advanced Recycling) sets targets for reduced resource consumption; enhancing value of by-products; and reducing waste volumes. The company estimates this program has gained over $6M in new revenues and $2.9M savings per year. Specific improvements include:

- Baghouse dust -- process changes reduced disposal costs and increased recovery of metals . Cost saving $2.9M
- Slag value: -- process changes increased value of the by-product to $6M (as cement component)
- Solvents -- replacement with non-toxic products and reduction in volumes saved $400K
- Using other wastes -- water and energy

Three German Companies Develop Ecological Controls

In Lower Saxony, Germany, three medium-sized companies have become demonstration sites for development of ecological controls, parallel to their financial control systems. (They are manufacturers of foil packaging, wallpaper, and paint industry supplies.)They have conducted an ecological balance study, identifying all material and energy flows. This study goes beyond plant boundaries to cover the entire product life-cycle. The results have enabled them to discover ways to conserve raw materials, energy, and water and realize cost savings.

Some Illustrative Cases of Dynamic Input-Output Modeling (see Table E-2):

An IO model of the Brundtland Report

This application of IO modeling by Drs. Faye Duchin and Glenn-Marie Lange evaluated the Brundtland report's recommendations. Their findings indicate that this landmark in sustainable development seriously underestimated the need for change.

"Our results show that if moderate economic development objectives are achieved in the developing countries over the next several decades, the geographic locus of emissions will continue its historic shift from the rich to the poor economies while total emissions of the principal global pollutants will increase significantly. This is true even under optimistic assumptions about pollution reduction and controls…”
This IO analysis proposes that industrial ecology methods will be needed to achieve dramatic reductions in use of fossil fuels and near-zero emissions of persistent toxic chemicals. Duchin says IE will have to be applied in agriculture, forestry, fisheries, and other sectors beyond manufacturing to achieve a sustainable world.

A National Input-Output Model

From 1991-93 the Indonesian government worked with Duchin and her staff in modeling development alternatives for the country. They built three basic technological scenarios and analyzed them with IO modeling predicting moderate and high growth rates for each. One scenario assumed continuation of present moderate trends in increased energy and materials efficiencies; a second assumed more aggressive government measures for resource efficiency and environmental protection; and a third added measures for cleaner and more efficient energy production.

The team analyzed potential economic and environmental impacts of these scenarios in terms of changes in 15 major industrial sectors, including agriculture and forestry, food processing, pulp and paper, chemicals, iron and steel. Environmental impacts

included land use and land degradation, local and global air pollution from fossil fuel energy production, water withdrawals and pollution.
The project was designed to train local staff in the process of dynamic IO modeling and to install a national model for continuing use. This will enable Indonesians to integrate environmental priorities into an effective development planning process.

Plastics

A two phase IO study by Duchin in 1994-5 focused on the use, disposal, and recycling of plastics in the U.S. This work is of particular importance to policy makers, given the volume of plastics in municipal solid waste flows (24%), the limits on future fill capacity, and the relatively low rate of recycling (4%). Duchin analyzed potential industrial consumption of the various forms of recycled plastics, finding that an optimistic forecast would still see 89% of the materials going to landfills by 2005. Source reductions of plastic use in products and packaging are likely to play a smaller role in reducing the overall waste stream than recycling. The study also analyzes policies creating obstacles to recycling and those facilitating the practice. The first phase of research was one of the few industrial ecology studies of *household consumption and disposal patterns*.

Design for Environment (see Table E-3):

Design for Environment is probably the most developed aspect of industrial ecology, with many applications in industry. It is difficult to draw clear boundaries between DFE and other approaches seeking to improve environmental aspects of product and process design.

The other terms include: Environmentally Conscious Design (and Manufacturing), Green Manufacturing, Green Design, and Sustainable Product Development. Life Cycle Assessment methods seek to provide an overall process for the many facets of design decision-making involved.

The Design-for-Environment web-site at Stanford (http://dfe.stanford.edu/) provides *links to a variety of design initiatives*, including: The Technology, Business and the Environment program, Massachusetts Institute of Technology; Systems Realization Laboratory, Georgia Institute of Technology; ECDM Group, Michigan Technological University; and Environmental Programs at Microelectronics and Computer Technology Corporation; Design For Environment, and Sandia National Laboratories as well as programs in Europe.
These programs are evolving methods and tools for use at engineering and management levels and field testing them in client or partner companies. For instance:

The University of California Consortium of Green Design and Manufacturing works with companies like Ford and Hughes Aircraft in "Development of environmentally-conscious manufacturing process models that reflect waste streams, energy utilization, scrap production and process rate in machining and cutting fluid planning, .

The Environmentally Conscious Manufacturing Program at Rochester Institute of Technology (http://www.isc.rit.edu/~633www/research/ecm/ecmp.html) includes a focus on design for remanufacturing, a field central to extending the life of the energy and materials invested in equipment.

This RIT program works in concert with major remanufacturing trade associations in fields such as the electrical apparatus service, automotive engine rebuilders, automatic transmission rebuilders, Imaging products remanufacturing, and production engine remanufacturers.

Research subjects include design for remanufacturing, disassembly, recycling, remanufacturing processes, material recovery opportunities, automatic tools for dfd analysis, and the economics of remanufacture.
The Green Design Initiative at Carnegie Mellon (http://www.ce.cmu.edu/GreenDesign/) "promotes environmentally conscious engineering, product and process design, manufacturing, and architecture. The initiative forms partnerships with industrial corporations, foundations, and government agencies to develop joint research and education programs.
Typical projects have included Environmental Implications of Battery Powered Cars; Identification and Specification of Recycled Materials for Use in New Products: A Case Study in Post-Consumer Carpets; and Design for Environment: The Building of Environmental Design Capabilities (focused on organizational capabilities required).

AT&T

AT&T has been a major promoter of the concept of design for environment, contributing to the development of methods and information system tools for use in design of equipment the company designs and manufacturers. AT&T's Sr. VP for EH&S, Braden Allenby, has played a key role in forming the DFE task force of the Electronics Association. This work group includes representatives of major electronics manufacturers working together to evolve DFE tools and apply them in their companies.

Product Life Extension (see Table E-4):

A European example

The Swiss photocopier company, Agfa-Gevaert , demonstrated a systems shift in mission that reduces demand on material and energy resources. AGt leases copiers in Switzerland with a long-term flexible agreement which covers all consumables in a price per copy. The company assumes responsibility for product quality and utility. Therefore designers have a strong incentive to use long-life components, standardize components and systems, lower costs of supplies, and aim for ease of repair and reconditioning.

A U.S. example

The Asset Recovery Management initiative at Xerox Corporation is working toward achieving 100% recyclability of all manufactured parts and assemblies. Remanufacturing to high quality standards and resale to new users will extend the life of equipment several fold and reduce demand on virgin resources. The initiative is also designed to streamline the process by which returned machines are reconditioned. The company estimates it has added hundreds of millions of dollars to its bottom line since ARM was formally started in 1991.

Some Illustrative Cases of Industrial Ecosystems (see Table E-5):

Kalundborg –

The industrial symbiosis at Kalundborg, Denmark has been one of the “superstar” cases in industrial ecology. Here a closely linked network of materials, energy, and water exchanges among industrial facilities, farmers, and the town's district heating developed over a twenty year period.
The pattern brought new revenues and cost savings. (Managers estimate they have gained a total return of US$120M on a $60M investment in energy and materials transfer infrastructure.) Environmental benefits include significant reductions in emissions and waste to landfill.
Critics of Kalundborg as an example of sustainability emphasize that the anchors for the series of exchanges are a petroleum refinery and a power plant with coal as its primary fuel. While emissions are within regulatory limits, these two facilities still generate typical levels of greenhouse gases.

A Recycling Network in Styria

A much larger, more diverse "industrial recycling network" exists in the Austrian province of Styria. Here a complex network of exchanges exist among over 50 facilities. Industries participating include agriculture, food processing, plastics, fabrics, paper, energy, metal processing, wood working, building materials, and a variety of waste processors and dealers.

Materials traded in the Styrian network include the familiar recyclables like paper, power plant gypsum, iron scrap, used oil, and tires, as well as a wide range of other by-products.

The plant managers in Styria are not aware of the larger pattern of exchange that has evolved. They are motivated purely by the revenues from by-products they can sell and the savings in landfill disposal costs for either sold or free outputs. In some cases the by-products are less expensive or higher quality than primary materials would be.

The Styrian recycling network suggests that Kalundborg may be unique only in the level of awareness developed there. There may be many other spontaneously occurring industrial ecosystems with significant flows of materials and energy among different companies. However, they can become more effective by calling attention to the patterns of trade and making information on resources and needs available to plant managers.

Eco-Industrial Parks (see Table E-6):

President's Council on Sustainable Development demonstration projects

The President's Council on Sustainable Development adopted the eco-industrial park concept as a basis for demonstration projects and named four communities as sites for these demonstrations

Brownsville, Texas

The project team from Research Triangle Institute and Indigo Development surveyed selected local companies to identify potential players in an eco-industrial park in this cross-border region. The project's purpose was to build an economic and environmental model to simulate the benefits and costs of an EIP. The process uncovered the possibility of creating a park at the Brownsville Port, with links to other companies in the area. (Martin et al 1996)

The City of Brownsville has received an Economic Development Administration technical assistance grant to do feasibility studies for a cross-border network of by-product exchange as a first stage of moving toward an actual EIP. This work is deepening the initial survey of industrial waste streams, modeling the flows for the city and region, and researching the specific regulatory changes needed to enable exchanges.

The Baltimore Empowerment Zone Eco-Industrial Park

The Baltimore Development Corporation has led this local EIP initiative by including the concept in the city's successful Empowerment Zone proposal to the Department of Housing and Urban Development. With support from a Cornell University Team, BDC moved the project forward through processes for building vision and broad community support. They have completed an extensive survey of materials flows in the 1300 acre industrial region as well as characterization of a potential site for a ca 50 acre industrial park within the region .

The Port of Cape Charles Sustainable Technologies Industrial Park

The Port of Cape Charles Sustainable Technologies Park is located on the Chesapeake Bay at the southern tip of Virginia’s Eastern Shore. The site includes 300 acres of developable land and 300 acres dedicated to ecological reserve. Ecologically based design standards have been established through community involvement processes. These cover infrastructure, building design, and broad recruitment targets. Planners aim to recruit food processing companies to add value to the area's seafood and farm products and environmental businesses. The first tenant is a firm making photovoltaic based solar roof tiles and building facades.

Chattanooga, Tennessee

Chattanooga has created a sustainable community initiative with broad citizen involvement. It features ecosystem cleanup, an environmental business economic development plan, and identification of four potential sites for eco-industrial parks. These sites include a set of now contaminated properties downtown; a former Army munitions manufacturing facility; a greenfield parcel to be developed for light industry, commercial, and residential; and a decommissioned glass factory in a low-income neighborhood. Funds for planning two of the parks have already been raised.

Other North American Communities with Eco-Industrial Park Projects (EIPs) include

Burlington, Vermont; Burnside Park, Nova Scotia; Eugene, Oregon; Londonderry, New Hampshire; Matamoros, Tamaulipas; Minneapolis, Minnesota; Alameda and Contra Costa Counties, California; Plattsburg New York; Raymond, WA; Skagit and King Counties, Washington; Trenton, New Jersey; Tucson, Arizona; and Wake Forest, North Carolina.
These projects range from 5 to 1000 acres in size. Many reflect a comprehensive eco-industrial park design strategy. Some aim to develop little more than by-product exchange networks (industrial ecosystems).

Table E-1. Industrial Ecology Methods: Industrial Metabolism.				
Method	Purpose	Application	Benefits	Challenges
Industrial Metabolism *Analysis of materials, water, and energy flows through any relevant economic or environmental entity.* Industrial metabolism (IM) is an early and central foundation for industrial ecology developed by R.U. Ayres[63]. Major regional and global studies are under way at the International Institute for Applied Systems Analysis in Austria.	Model and analyze materials, water, and energy flows from initial extraction of resources through industrial and consumer systems to the final disposal of wastes. Industrial metabolism analysis offers several useful metrics for assessing the sustainability of a plant, company, community, region, or other entity: 1. *The ratio of virgin to recycled materials* 2. *Ratio of actual to potentially recycled materials* 3. *Ratio of renewable to fossil fuel sources* 4. *Materials productivity* (economic output per unit of material input). 5. *Energy productivity*	IM can be usefully applied at many different levels: globally, nationally, regionally, by industry, by company, and by site. Some companies have also conducted environmental audits based on this method. Regional application gives valuable insight into the sustainability of industry and public services in natural units such as watersheds or atmospheric basins. Mapping sources, processes of transformation, and sinks in a region offer a systemic basis for public and corporate action.	IM's integrated analysis helps managers and regulators avoid narrowly conceived 'quick fix' policies, which may actually have negative impacts. Supports managers in identifying and evaluating potential opportunities for cost and environmental performance improvements. Provides a logical, semi-quantitative and disciplined means of assessing sustainability within a specific unit of the economy. Enables users to better determine the full costs of materials, factoring in the value of non-renewable resources and environmental pollution. Provides a foundation for regional economic development planning, in both developed and developing countries.	Data needed for full analysis may not be available. (IM often requires extrapolation from existing data.) Processes for applying IM need more development for use in corporate settings. Many waste materials are unusable *in the quantities generated*, including nitric acid, sulfur oxides, lignin wastes, fly-ash from coal, etc. Accelerated R&D is required to develop uses, processes to make them usable, or substitutes. Present uses of many materials are inherently dissipative (the materials are degraded, dispersed and lost in the course of normal usage.) IM is useful to highlight this fact, but solutions will be found only through redesign of products or services.

[63] Ayres, R. U. and U. E. Simonis, eds., 1994, *Industrial Metabolism – Restructuring for Sustainable Development*, UN University Press, Tokyo.

Table E-2. Industrial Ecology Methods: Dynamic Input-Output Modeling.				
Method	Purpose	Application	Benefits	Challenges
Dynamic Input-Output Modeling *Tools for modeling the integrated economic and environmental impacts of complex webs of technical change.* Dr. Faye Duchin[64] has been the principal researcher developing this method on the foundation of Wassily Leontief's Nobel Prize winning work on economic input-output models. *"Dynamic input-output models are used to develop a set of possible solutions rather than a single optimal one . . . (making it) possible to experiment with changes in input structures that might reduce water usage in production, for instance, or recover products of economic value . . . A more complex set of results, involving economic and environmental trade-offs, can be evaluated."*	This dynamic *what-if method* enables business and policy decision-makers to perceive the broad business, economic, and environmental implications of technical change. The IO models add environmental resource accounts to economic information about the 100+ industrial sectors found in static national input-output tables. By incorporating a time dimension they provide *a means of analyzing the total impacts of alternative scenarios of industrial change -- How would the changes affect the environment, businesses in the target industry, and their major suppliers and customers?*	Researchers have applied dynamic IO modeling to analysis of global sustainability, national and regional economic development strategies, consumer behavior, and recycling. Corporations could also use this method. An automobile manufacturer could study the impact on the environment and its own future of possible socio / technological changes such as: innovations in engine design resulting from much higher standards for emissions and fuel efficiency; an increase in U.S. fuel prices to the global average; or a dramatic increase in short to mid-distance rail transport. Agencies planning transportation policy might explore the implications of an integrated, multi-modal transportation system compared against motor vehicles and their infrastructure.	Enables users to consider the interactions among natural, systemic technical change, internal and external accounting, market forces, regulations, and international treaties. Serves as the basis for the development of incentive schemes, legislation, and international agreements. Helps to identify bottlenecks in research and development that will not be resolved in a timely fashion by private markets. Evaluates the costs and potential contribution to reducing pollution of alternative design for environment strategies. *A powerful global IO model and ones for the U.S. and other countries are already available, needing additional input relating only to particular technical innovations to be explored.*	Models must factor in a significant time lag because data required is not available on a current basis. Model-building is a lengthy process requiring assembly of diverse data-bases -- economic, environmental, and technical. Data may be incomplete, requiring estimates. Participants in a modeling exercise need to understand that the process is designed to guide their search for solutions, not to automatically provide the answers.

[64] Duchin, F. and G. Lange, 1994, *The Future of the Environment: Ecological Economics and Technological Change*, Oxford University Press.

Table E-3. Industrial Ecology Methods: Design for Environment (DFE).				
Method	Purpose	Application	Benefits	Challenges
Design for Environment (DFE) *"DFE practices require consideration of all potential environmental implications of the product or process being designed, not just those that are mandated by law. DFE practices are meant to develop environmentally compatible products and processes while maintaining product price/performance and quality standards[65]."* (Allenby & Fullerton 1991-2) The phrase, "Design for Environment" is also used more generally by a broad range of designers not identified with industrial ecology. Environmentally Conscious Design and Manufacturing and Green Design are other parallel initiatives.	DFE supports decision-making in design of products and processes, enabling designers and managers to balance environmental, financial, and technical criteria. DFE focuses on the Life Cycle Assessment stage, enabling design teams to weigh options for improvement of environmental performance while attending to the traditional design issues relating to technology, costs, and user satisfaction. Some industrial ecologists recommend a largely qualitative rather than quantitative approach in DFE. They believe the design task is often too complex to lend itself to quantitative analysis.	DFE has been applied primarily to design of products and processes. The basic tools are potentially useful in broader design tasks, i.e., design of facilities. DFE considers all potential environmental implications of a product or process: energy and materials used; manufacture; packaging; transportation; consumer use, reuse or recycling; and disposal. DFE also enables designers to consider traditional design issues of cost, quality, manufacturing process, and efficiency as part of the same decision system. ———————————— **Generic DFE** includes the development of competencies, organizations, meth-odologies, rules, and tools across the firm. Examples: "green accounting", "green business planning", and "green specifications and standards."	Provides a common framework for evaluating a project. Allows assessment of environmental concerns with manufacturability, costs, performance, and other design issues. Limited experience indicates DFE provides cost advantages with reduced regulatory risk. DFE integrates well with concurrent engineering practices already in place in many companies. ———————————— **Specific DFE** includes rules, tools, and data sets intended to directly improve the environmental preferability of product and process design and operation. Examples: development of product and process checklists, DFE figure-of-merit software (in CAD/CAM systems); and inclusion of lifecycle considerations in the analytical process.	Incremental improvement in a product may mask a broader need to simply not continue making that product. Industrial materials data bases do not yet provide reliable and accessible information on environmental impacts of many materials, chemicals and processes. Full application of DFE demands involvement of the public sector in defining values for the design trade-off process involved. Currently there is simply too much divergence and controversy concerning environmental objectives and risk assessment. DFE is largely qualitative rather than quantitative analysis (by intention). Some organizations do not support the cross-functional approach required by DFE.

[65] Allenby, B. R. and A. Fullerton, 1991-92, "Design for Environment -- A New Strategy for Environmental Management," *Pollution Prevention Review*, Winter.

Table E-4. Industrial Ecology Approaches: Product Life Extension.				
Approach	Purpose	Application	Benefits	Challenges
Product Life Extension & the Service Economy *Walter Stahel[66] is the principal developer of this approach.* *Achieve a shift from selling products themselves to selling the customer service they yield, thereby greatly increasing efficiency of materials use.*	Enable manufacturers to move to a service identity. Success may depend upon improvements in product life by strategies such as: making products durable; modular; and multi-functional; products are standardized, self-repairing or easy to repair and upgrade; components can be reused in new systems; units or systems can be easily reconditioned and remanufactured; a distributed network provides maintenance and upgrades.	Has been applied primarily to office and capital equipment. Potentially very useful for home appliances and some smaller consumer goods. This approach requires strong integration of advanced Design for Environment with all management functions including definition of mission, strategic planning, accounting, supply chain management, human resources, etc.	Could increase the productivity per unit of resource used as much as ten fold. Improved resource productivity = increased profitability and competitiveness. Offers a decentralized means of developing skilled jobs in repair and remanufacturing. Could give entrepreneurial ventures competitive advantage in entering markets when major corporations remain focused on selling products.	Requires long-range vision and major organizational and technological redesign on the part of corporations Companies risk making major investments in technologies for service delivery that may become outdated.

[66] Stahel, W., 1994, "The Utilization-Focused Service Economy: Resource Efficiency and Product-Life Extension," in Allenby and Richards, *Greening of Industrial Ecosystems*, National Academy of Engineering, Washington, DC.

Table E-5. Industrial Ecology Approaches: Industrial Ecosystems.

Approach	Purpose	Application	Benefits	Challenges
Industrial Ecosystems *". . . the traditional model of industrial activity – in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of – should be transformed…[where] the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process … serve as the raw material for another process*[67]*."* Variants of this concept include 'industrial clusters' (UN University Zero Emissions Research Initiative (ZERI)), Environmentally Balanced Industrial Complex (Nemerow), and Eco-Industrial Parks[68] (EIP).	An *industrial ecosystem* is a network of companies and other organizations in a region who seek increased efficiency and lowered costs through exchanges of by-product materials, water, or energy. Researchers have identified several such networks that evolved spontaneously and are studying the conditions needed to support their development. EIPs tend to promote additional collaboration over material and energy exchanges including: resource efficiency in design of park infrastructure and plants; ecologically guided landscaping; effective management systems to provide shared services; and inter-company partnering.	Attempts to develop industrial ecosystems are a regional, inter-company endeavor that utilizes IE methods in design efforts. EIP initiatives in North America, Europe, and Asia generally involve the area's companies, industrial associations, economic development and environmental protection agencies, and the community. ZERI activity focuses on bio-mass intensive industries such as logging, paper, beer brewing, and fish farming. Within limits, EIP strategies can also support rehabilitation and renewal of existing industrial parks and regions.	Reduction in the use of virgin materials as resource inputs; Increased energy efficiency leading to reduced energy use; Reduction in pollution and the volume of waste requiring disposal; Reduction in pollution and disposal related costs; Increase in the amount and types of process outputs that have market value. Reduced costs through shared support services (esp. under the EIP concept). Economic development opportunities for new local businesses and jobs, as well as enhanced attraction in external recruiting.	Risk of losing a critical supply or market if a plant closes down or changes its product mix. Proprietary information could become available to competitors. Uneven quality of by-product materials could cause damage to equipment or poor products. Exchange of by-products could lock in continued reliance on toxic materials. Possible innovations to enable industrial ecosystem development may not be allowed by regulatory agencies. The ZERI goal of zero emissions may be a useful tactic, but different stakeholders interpret "zero" in very different ways. Many companies are not used to working 'in community,' and may fear the interdependence.

[67] Frosch, R. A., and N. E. Gallopoulos, 1989, "Strategies for Manufacturing," in *Scientific American*, September, pp. 144-152.
[68] C.f., Lowe, E., S. Moran, and D. Holmes, *Fieldbook for the Development of Eco-Industrial Parks, Volume 2, Final Report*, Research Triangle Institute, Center for Economic Research, Project Number 6050.

Table E-6. Industrial Ecology Approaches: Eco-Industrial Parks (EIP).				
Method	Purpose	Application	Benefits	Challenges
Eco-Industrial Parks (EIP) *An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials.* *By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only.* (Based upon Lowe, Moran, and Holmes 1995)	The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impact. Components of this approach include resource efficiency in design of park infrastructure and plants; by-product exchange; pollution prevention; energy efficiency; ecologically guided landscaping; an effective management system providing shared services; inter-company partnering. Through collaboration this community of companies becomes a *fully developed* industrial ecosystem.	EIP design strategies are guiding development of new industrial parks in North America, Europe, and Asia. Within limits, they can also support the rehabilitation and renewal of existing industrial parks and industrial regions. A strong public-private partnership is required to apply these concepts. Successful EIP development involves real estate developers and investors, tenant companies, design professionals, community representatives, and economic development, environmental protection, and planning agencies.	Decreased production costs through higher materials and energy efficiency, waste recycling, and reduction of practices that incur regulatory penalties Reduced costs through shared support services, including waste management, training, purchasing, emergency management teams, environmental information systems, and others. Reduction in many sources of pollution and waste, therefore a decreased demand for natural resources Reduction in solid and liquid waste streams will reduce demands on municipal infrastructure and budgets. Economic development opportunities for new local businesses and jobs as well as enhanced attraction in external recruiting.	EIP development is a complex undertaking, demanding integration across many fields of design and decision-making. The financial community may be reluctant to support development of an ‘unproven’ approach to industrial parks. Valuing an EIP's costs and savings may require a longer payback period than used for typical industrial financing. *EIPs may* cost more to develop than traditional parks, depending upon the design choices in a project. The additional costs may or may not be offset by savings in operating the park as an EIP. Possible innovations in regulation to enable EIP development may not be allowed by regulators. Many companies are not used to working ‘in community’ and may fear the interdependence this creates.

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Handbook Appendix F: Toolkit Options

Game play utilizes two types of “moves” which players use as a means to pursue their strategies and objectives, and alter the future accordingly. One move is referred to as an “agreement,” which replicates real-life activities including negotiations, consensus building, resource allocation, and contracting (see Appendix H-G). The second type of move involves making investments in “Toolkit” options, which can only be executed during Toolkit sessions.

Toolkit options are simply a list of some of the many types of technologies, methodologies and policies that might be selected and pursued in the interest of promoting the use of industrial ecology and in achieving sustainability. The primary purpose of the list is to serve as a “jump start” to the creative abilities of the players, due to the limited game time available.

The players may select and invest in some of the Toolkit options that are important to their strategies. Players may also create new Toolkit options (see procedure below). Solicitation of support for selected options from other teams may be important to their success. Toolkit investments must be completed prior to the end of the designated session. The Toolkit results will also be used as a metric to evaluate team interests and priorities. The Toolkit budget for each team, which can only be used during the Toolkit session, is proportional to a qualitative estimate of the discretionary funds available within the organizations represented by the team in real life.

Some Toolkit options may usurp a specific team’s authority. For example, option P2 mandates a reduction in greenhouse gas emissions. If passed, this option remains in effect until or unless the Congress team revokes the option in a subsequent session.

Each Toolkit item listed in the Handbook has been assigned a "price" (nominally a 50% success value), which is the designated amount that will provide a specified probability of being activated. No option has a 100% chance of success (activation). A variable is introduced into the process of Toolkit option enactment by the use of a computer probability program (electronic "dice;" further details below). This is used to introduce an element of speculation and chance into the game, and to be representative of real life uncertainties. A cumulative, minimum investment of one-half of the listed price is required (total of all teams). Teams can enhance the probability of activation of any selected Toolkit item by increasing the amount of money allocated to it.

The Toolkit options will also be posted on a wall board. Players are encouraged to enter their investments on the board, and observe the investment patterns of other teams. Since the board is unofficial, no team can hold another team liable for mistakes or for investing differently from the board entries. However, formal agreements can be made between teams on investments (with Control’s signature); violations of those written agreements can be litigated.

Teams are allowed to create their own Toolkit options by following these steps:

1. Clearly write up the new option on an “agreement form” (see Appendix H-G).
2. Discuss the new option with a designated member of the Control Team; if accepted, "experts" on the Control team will assign a median probability cost and a Toolkit option number.
3. Provide potential investors with copies of the finalized version of the new option. (Marketing of new options to other teams is the responsibility of the initiating team.)
4. Bring investments in the new option along with all other Toolkit investments to the Control Team prior to the close of the Toolkit session.

All investments must be completed and turned into Control by the end of the Toolkit session. Toolkit investments are the responsibility of each team. Each team must turn in its own Toolkit spreadsheet (which constitutes the “investment” action). Toolkit resources are not available for any other uses later in the game. Investments made in unsuccessful options are permanently lost. The results will be published at the start of the next session. All successful technologies and policies will be implemented and become part of the environment of the game.

The outcomes of the Toolkit investments are determined probabilistically as shown in the example of Figure F-1 (where the mean cost is represented by a fraction of 1.0). First, the baseline probability will increase with increasing investment following a normal distribution with mean x and standard deviation s = x. For an option with a mean cost of 100, an investment of twice the mean, 200, would yield a success probability of 0.84. To take into account factors other than total investment, a uniform distribution is superimposed on the normal distribution to reflect uncertainties and risks in the real world for accomplishing major technology or policy breakthroughs. This uniform distribution can increase or decrease the baseline probability by as much as 16%. The minimum total investment for any option is one-half the mean.

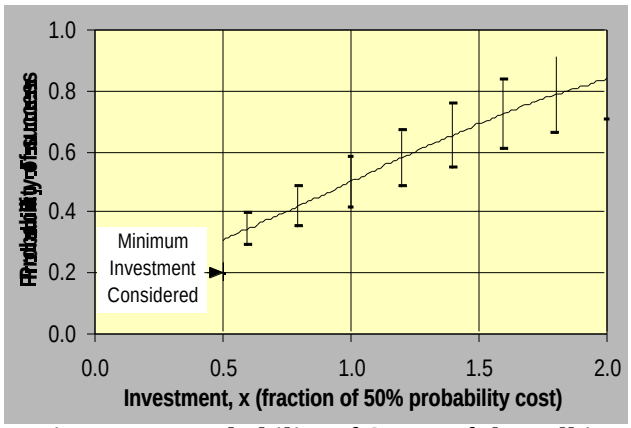

Figure F-1. Probability of Successful Toolkit Option for Cumulative Investments.

The total investments from all teams are fed into the computer and success or failure is determined by this process. A list of technology and policy options is given in Table F-1.

The teams can invest up to the maximum allocations shown in Table F-1. Those resources represent relative influences of the different stakeholders.

Negative investments are permitted for policy options. If your team strongly opposes a particular policy, your negative investments can make the realization of that policy less likely. Negative investments are deducted from the team's credits as if they were positive.

Some Toolkit investments involve joint ventures or partnerships among several stakeholders. To be considered, all involved parties must invest some funds in the option. The investments need not be equal. E.g., a joint industry-labs-university program must have some funds invested by all three teams to be accepted.

Many more Toolkit investments have been provided than can be successful with the funds available. Hence, you should carefully consider which options are most important for accomplishing your objectives. Teams should invest in areas important to their goals or strategies. These selections allow the assignments of the players' priorities to the many possible investments.

Table F-1. Toolkit Investments - Descriptions of Technology and Policy Options.

Indicate the number of credits your team wants to spend for each option. Credits can be used to support or oppose any option. The investments by all teams will be added for each option to get a total investment. The probability of an option being implemented increases with the total investment for that option, so influencing other teams to partner with you will improve your chances for success. Negative investments are subtracted from the total for each option. Negotiations are strongly encouraged.

Team	Credits	Team	Credits
U.S. Congress	400	Resource Providers	300
Foreign Countries	400	Manufacturers	300
Local and State	250	Think Tank	100
Federal Industrial Agencies	200	Universities	150
Federal Advisory & Regulatory Agencies	150	Department of Energy Laboratories	100
Financial	300	Public	150

Technology and Policy Options	Credits for 50% chance	Your offer

Example: A total investment of 150 credits in T1 will yield a nominal success probability of 50%, while an investment of 300 credits will give a nominal success probability of 84%).

Technology:

Information Systems

T1. An integrated, accessible set of databases is established for information necessary to conduct IE related studies at the U.S. and international levels. Data include: industrial economic profiles; land uses; environmental contamination problems; sensitive habitats; resource flows including materials, energy, wastes; natural resources; and documentation of transportation and other infrastructures.. 210_____

T2. The ISO 14000 standards are modified to include IE-based methods for setting performance objectives within the ISO Environmental Management Systems structure. They are also modified to include reuse, re-manufacturing, and product life extension criteria in the life cycle assessment standards. 80_____

T3. An insurance and banking consortium funds lab and university researchers to develop an IE-based decision support system for industry leaders in selected sectors. It enables executives and managers to track: research and debate on global and regional environmental issues; the contribution of their industries to these problems; and their implications for corporate strategy. 170_____

Energy and Transportation

T4. DOE partners with energy companies and its Labs to develop business and technical strategies for restructuring the U.S. energy system to meet source type, efficiency, and pollution goals. The research consortium evaluates the full range of alternatives and gives special consideration to integration of discrete technologies into cost-effective systems.. 120_____

T5. The oil, gas, coal, petrochemical, power, and automobile industries form an R&D consortium focused on hydrogen-based energy systems. Its goals include: to develop technologies supporting conversion of carbon based materials to hydrogen for use as transportation fuel; to design infrastructures for these technologies; and to understand the strategic implications for their businesses. 80_____

T6. A UN funded R&D program develops systems designs for electrical power systems and integrated transportation systems that can be adapted by developing countries to enable a low-energy consumption economic structure. This enables higher efficiencies and lower emissions of greenhouse gases than is typical for developed countries.. 120_____

T7. DOT partners with state transportation agencies to fund design of a prototype regional transportation system that achieves the objective of drastically reducing the environmental and energy burden of transportation while optimizing the interests of citizens and businesses in moving people and goods. The outcome of this design initiative will determine if the project should move to implementation. 300_____

Materials

T8. An industry-university-lab joint venture creates a national clearinghouse of materials science. It coordinates research and implementation of: economically feasible uses of major industrial and consumer resource streams now wasted; development of advanced materials, bio-materials and other renewable materials to replace major toxic and non-renewable material streams; creation of processes and products enabling reduction in use of inherently dissipative materials; and wide dissemination of its members' research results. 100_____

T9. Toxicology studies are initiated to assess synergistic and antagonistic interactions among chemicals, beginning with major substances used in agriculture, auto and airplane production and servicing, electronics, and household settings.. 200_____

Industry Initiatives

T10. An industrial consortia develops IE policies which can be adopted by corporations and their suppliers/customers. A certification process is established.. 100_____

T11. An industrial consortia undertakes a program to identify opportunities for improving the competitiveness and environmental performance of U.S. manufacturing companies and their supplier/customer chains through industrial ecology methods and tools. (The focus is on increasing the business usefulness and variety of IE tools, including DFE, industrial metabolism, and dynamic input-output modeling.). 160_____

T12. Resource extractive industries(primary metals, chemicals, other non-fuel minerals) form a coalition to develop services (new businesses) and strategic partnerships with existing companies to reduce the throughput of raw materials in the economy by optimizing reuse/ reclamation cycles. A major goal is development of strategies to cope with the potential reduced demand for major commodity materials.100_____

T13. The Chemical Manufacturers Association and chemistry professional organizations form an industry task force to study the business implications of emerging toxicological and ecological research, including: endocrine disrupters, synergistic interactions among chemicals; and synergistic interactions across types of impact (toxic chemicals, radiation, disease organisms, immune system response, etc.). The goal is to develop proactive response strategies. 100_____

T14. A durable product and service economy research initiative is started to investigate key success factors for companies making the shift from maximizing product sales to optimizing customer service and providing highly durable, leased products. The initiative is expected to strengthen DFE tools in support of highly durable product designs, including guidance in design for repair and self-repair, re-manufacturing, upgrading, modularity, etc.. 100_____

T15. USDA, EPA, and corporate sources support an agribusiness industry-university research consortium to develop a strategic and technical road map for farm service and suppliers companies. The consortium uses industrial ecology concepts and methods (including dynamic input-output modeling) to explore the business and technical transition to farms that are more productive, more efficient in resource use, more ecologically sensitive, less petroleum dependent, and less polluting. 80_____

Finance

T16. Investment and insurance groups develop an impact-assessment tool to guide investment decisions, based on a systems (IE) approach. The metrics included are: use of non-renewable resources; greenhouse gas emissions; other pollution of air, water, and land; generation of solid wastes; patterns of energy and resource use; and direct ecological, social, and economic impacts. These metrics are tied to assessment of the financial viability of the business being evaluated. 120_____

T17. Leading U.S. manufacturers adopt internal cost accounting systems that break out real environmental costs from overhead or other accounts. This allows internalization of environmental costs, and provides management systems and incentives to better control these costs and to account for the benefits of innovations. 140_____

Urban and Regional

T18. An interagency grant funds universities and city agencies to develop models of the industrial metabolism of ten major urban/industrial regions. These models trace resource flows in transportation, physical infrastructure, food, energy, solid waste, and other systems. They facilitate identification of major sources of environmental impacts, patterns of activities which generate them, and environmentally preferable technological or mitigation options. They become the foundation for sustainable community planning, including identification of business and job development opportunities. 170_____

T19. Research on the 18 U.S. eco-industrial park projects currently underway or planned assesses their development and recruitment methods, regulations, management systems, and business strategies. The research aims to enhance opportunities for existing projects and to

guide possible future projects.. 170_____

T20. HUD funds the design and development of a prototype affordable housing complex with systems integration of heating, cooling, cooking, and lighting equipment, use of energy cascading and co-generation, and cost-effective use of renewable resources.. 170_____

T21. The Border Environmental Cooperation Commission funds development of a dynamic input-output model of industry and environment in the Rio Grande Basin to test alternative scenarios for sustainable development. The model can be applied to water use planning; transportation systems; and to improving efficiency and reducing pollution in border industrial parks and facilities. 270_____

Education

T22. Universities taking a lead in IE R&D form an IE virtual university for corporate and governmental managers and staff. They provide a combination of teleconference and interactive online computer classes, week-long campus sessions, on-site training, and an IE Prosperity Game. The multi-disciplinary curriculum includes introductory and advanced courses; modules specific to high priority industries; and a virtual campus intranet. IE U also connects to campus colleges to bring IE into their curricula. 80_____

T23. A coalition of environmental organizations, universities, and Think Tank, Inc. creates and distributes educational materials for use in high schools on the principles, methods, application, case histories, and benefits of applied industrial ecology. 70_____

Policy:

Reorganization, Reform, and Administration

P1. Congress reorganizes the Environmental Protection Agency and combines it with selected offices from other governmental agencies (those with any environmental protection oversight, including biodiversity and ecosystems). The intent of this reorganization is to reduce problems associated with a legal framework that is fragmented across multiple Congressional committees, agencies, and agency branches.. 210_____

P2. The Environmental Protection Agency directs the Reinventing Regulation Office to take a central role in ending the agency's fragmentation by medium of pollution, stage of life cycle, and organizational design. Congress appropriates funding to develop more voluntary programs which serve as experiments in achieving better than compliance performance in industry. These programs emphasize industrial ecology tools for analyzing energy and materials flows, for risk assessment, and for improving product and process design. Their successes and failures guide broader reform of policies and regulations. 130_____

P3. Federal agencies implement procurement policies designed to: build upon present recycled content specifications; encourage use of DFE and LFA by providers; and create stable long-term markets for renewable energy equipment deployed in public facilities.. 170_____

P4. EPA forms a public/private partnership to develop decision methods to make trade-off choices between economic, environmental, and health risks involved in selecting materials and processes in design for environment. 80_____

Energy

P5. The President announces the Energy Competitiveness Challenge, setting a national goal to increase energy efficiency 30% in 10 years. Presidential directives are issued to all federal agencies to incorporate this goal into all planning, including R&D funding, industry and consumer initiatives, and the energy performance of the agencies themselves. 120_____

P6. Congress modifies tax laws to encourage owners of utilities to retire inefficient power plants and replace them with more efficient generating units. 210_____

P7. Congress funds a national program for reducing emissions of greenhouse gases. Provisions include: support for combustion and emissions control R&D; voluntary programs that promote carbon-reducing actions by private-sector actors; regulations that impose efficiency standards, renewable resource use quotas, customer help programs, and greenhouse emission limits. 290_____

P8. Congress imposes a $0.05/gallon energy tax. Revenue from this tax goes exclusively to fund

advanced energy R&D and incentives and technical support for replacement of inefficient technologies in industry, commerce, local government, and homes. 210_____

Materials

P9. Congress passes durable product and packaging take-back requirements, phased in over a five year period, depending on the industry. 250_____

P10. Waste management policies and regulations are reformed to enable safe exchange of "waste" by-products among companies. 120_____

P11. Blanket permitting for clusters of companies in industrial parks is authorized to enable on-site by-product exchange and effective collaboration in meeting regulatory requirements.. 80_____

Economic

P12. A new measure of economic well-being is developed that overcomes the limitations of commonly used indicators such as the gross domestic product (GDP). The new index reflects key quality of life indicators (e.g., costs of health and environmental impacts, pollution cleanup). Methods for assessing interactions between different environmental, demographic, and social sectors are included.. 120_____

P13. Congress authorizes a tax credit for research and development of technologies, processes, and tools that reduce the energy and material consumption and pollution in major end-use sectors (i.e., transportation, heating/cooling, refrigeration, lighting, food production, etc.) 160_____

P14. Federal agencies serving U.S. firms in foreign markets create tax and funding incentives supporting the export of preferred environmental technologies and processes. The evaluation processes use IE methods and tools. (The agencies include Export-Import Bank, Technology Development Agency, Overseas Private Investment Corporation, Department of International Trade, etc.) 120_____

Urban and Regional

P15. DOC and HUD set policies and strategies designed to optimize investments in urban infrastructure development and redevelopment through IE methods. The agencies fund five demonstration projects to serve as action research development sites. The resulting design of water, liquid and solid waste, and transportation systems integrates business, social, technical, and environmental solutions for much more efficient use and re-use of resources and reduction of pollution. 250_____

P16. DOI, DOA, and EPA convene an inter-regional Water Task-Force. Its agenda includes: the rapid decrease in underground water aquifer levels; the degradation of regional potable water; and flood management, resource access, and ecological issues for each major river basin. The Task Force is charged to form systemic strategies integrating agricultural, industrial, residential, and ecological water use, flood risk management, pollution control, and restoration of riparian ecosystems. 190_____

P17. Building upon present EPA and state brownfield initiatives, Congress passes the National Reclamation Act with the goal of reducing the costs and time involved in restoring Superfund and other contaminated lands, including Federal facilities. Provisions include: support for remediation actions informed by risk/benefit analysis (qualified by emerging understanding of health and ecological risks); streamlined liability laws and limits; expeditious regulatory mechanisms; local field offices to provide technical as well as regulatory support; support for research and implementation of cleanup technologies; and support to ecological sound redevelopment. 210_____

Research

P18. NSF and DOE design and fund a joint industry-labs-university research program to coordinate industrial ecology research. This program links U.S. research with IE initiatives in the UN and other countries. (The agenda includes but is not limited to: modeling of material and energy flows, development of tools for optimization of flows to minimize environmental impacts, design for environment tools and infrastructure, systems integration of technologies, use of advanced and bio- materials, and effects of human behavior on ecosystem viability. Technical research is closely integrated with business systems and policy research.). 100_____

P19. Congress establishes a National Economic Security Center that is responsible for promoting a sustainable economy in the U.S. The Center establishes a government-wide industrial ecology project portfolio; generates funding for industrial ecology R&D projects; and recommends to Congress legal, regulatory and economic incentive structures to support integration of environmental considerations into all economic activity. A key responsibility is seeking a science-based, dynamic balance between environmental, economic, and social values. 120_____

International

P20. International development banks require that all major funded projects be evaluated with respect to sustainability principles by independent review committees that include public and private sector members. The sustainability principles include basic industrial ecology principles for resource efficiency, prevention of pollution, and protection of ecosystems as well as social and economic principles. 120_____

P21. The Border Environmental Cooperation Commission forms an inter-country regional partnership to develop a U.S./Mexican border policy strategy based upon industrial ecology which can be implemented in both countries. It seeks a unified approach to the economic and environmental issues confronting the businesses and residents of the region.130_____

P22. Congress reinstates the policy of encouraging spent fuel reprocessing, nuclear waste repositories, and encouraging growth of fission nuclear power generation systems that are inherently safe and which can be sited as stand-alone systems. 210_____

Education

P23. DOE and EPA develop and implement a public education plan to teach principles of IE and sustainability formally as part of K-12 curricula and as adult education and community programs. 80_____

Handbook Appendix G: Open Negotiation Sessions

All open negotiation sessions will begin with the distribution of resources to each team to be used in meeting their challenges and implementing their strategies. These resources are in the form of Chits and represent the types and relative amounts of influence exercised by each team. Four types of chits will be used in this game: money (green), regulations and laws (red), political influence (white), and technology (blue). Table G-1 contains the qualitative distribution of chits and shows that, while no team has all types of chits, and some teams have only one type of chit, there are sufficient chits available in the game to bring about any desired action. Chits are meant to be 'spent' on agreements. In general, an agreement will require one or more of each type of chit to be valid; thus, the table can be used to suggest the teams you may wish to partner with to gain the chits you need to complete your agreements.

Table G-1. Distribution of Chits by Team and Type.

Team	Money	Regs & Laws	Influence	Technology
Congress	Medium	Medium		
Foreign Governments	Medium	Medium	Medium	
Local Governments	Low	Low	Low	
Industrial Agencies	Medium			Low
Advisory & Regulatory Agencies		High		
Finance	High			
Resource Providers	Medium		Medium	Medium
Manufacturers	Medium		Medium	Medium
Universities				High
DOE Labs				High
Think Tank, Inc.	Low		Low	Medium
Public			High	

The primary move in the open negotiation sessions is an 'agreement' (or completed contract) between multiple teams. These agreements may be oriented toward technology, investment, policy, or any other area that you feel will bring about your desired objectives. Agreements may pursue actions on a global, national, or regional scale, in concert with the briefings given in Appendixes A-D. As champions of particular technologies and policies, you should pursue the agreements necessary to bring your ideas to fruition. Agreements are most robust when they build upon previous successful moves.

Agreements must be submitted on the **Agreement Form** to be valid (see Figure G-1). The Agreement Form requires certain information: the **terms and conditions** of the agreement; **justification** for why the action is being taken, why it is expected to be of benefit, and why each team is participating; and the **expected results**. In addition, the originating team is expected to state the relationship between the current agreement and any previously existing agreements.

The participating teams should rate the **importance to the agreement** (high, medium, low, or none) of each of the four types of influence (chits) by circling the appropriate numbers in the lower left corner of the agreement form. Once this has been done, the agreement should be **submitted to the Control Team** for their concurrence on the rating. The Control Team has the option to modify the rating based on their understanding of the agreement. This rating specifies the number of chits of each type that are required for the agreement to be accepted. Once the rating has been accepted and initialed by the Control Team, chits may be gathered from the teams participating in the agreement. The teams and the number and color of chits they contribute to the agreement must be entered on the form, and must accompany the form to the Control Team for final acceptance and validation of the agreement.

Please note that the Control Team will also judge agreements based on their reasonableness and consistency, and has the right to require changes to an agreement before it is accepted. For instance, if public acceptance of an action would be required in the real world, public influence chits will be required for that same action in the game. Influence chits from another team could not be substituted for public influence. The teams that would need to be involved in real world actions will need to be represented by chits in the game agreements that parallel the real-world situations.

It is intended that the open negotiation sessions produce agreements that are based on quality, valid negotiations with the right people, and partnering or strategic alliances. Note that partnerships are key in this game. Since the colors and quantities of chits

are not distributed equally, but rather in a semi-quantitative manner that reflects real life, partnering will be required to execute most agreements. Teams unwilling to pursue strategic alliances or partnering to create agreements will find themselves isolated and generally ineffective in making any progress toward strategic objectives.

A final word: While pursuing your objectives through negotiations and the creation of great agreements, build relationships with your teammates and those from other teams that will last beyond the game. Other people can help you implement your strategies in real life as well as they can in the game.

INDUSTRIAL ECOLOGY PROSPERITY GAME™ AGREEMENT FORM

Agreement Number
RP-10

TITLE **Intelligent Infrastructure ("SMART")**

Expected Results: **Develop and prototype (in one city) a public/private transportation syste includes components in vehicles ($1500) and at traffic control points ($10K/mil location, and routing information will be exchanged between vehicles and routing Traffic flow and speed information will be exchanged between roadside locations and the routing computers (and even construction and accident databases). Algori dynamically control traffic flow to increase efficiency. Emergency vehicles can be assigned p ratings that can override normal system efficiency considerations. The program will be funde level such that it will be completed in three or four years.**

Justification: **Although this idea is not new, technology limitations in a num prevented the idea from maturing. Recent advances in positioning systems (GPS) performance and cost, digital cellular networks, and massively parallel computing concept practical. The necessary transportation control logic model also has the by virtue of the successful 'Transportation Model' (DOE-4) completed in the last information flow can also be managed thanks to the 'National Computing and Networking Ini (FIA-3) that developed the necessary protocols and hardware to support secure, high-bandwi computing networks that will be fundamental to this system.**

Circle **rating** for each row	Relative Importance High	Med	Low	None
Dollars: **G**reen	(3)	2	1	0
Regs & Laws: **R**ed	3	2	(1)	0
Influence: **W**hite	3	(2)	1	0
Technology: **B**lue	3	(2)	1	0
Facilitator review:	**JBQ**			
Control team signoff:	**M. Berman**			

Team Chits:	G	R	W	B
Resource Providers	1			
Manufacturers			1	
Universities				1
DOE Labs				1
Local Government	1	1		
Public			1	
Fed Adv & Reg Agcy	1			
Totals (must = **rating**)	3	1	2	2
Control team acceptance:	**K. Boyack**			

Relates to previous agreement #(s): **DOE-4 and FIA-3**

Terms and Conditions: **The Resource Provide Team has developed this agreement as a strategy to reduce the pending impact of Manufacturing Team support was receivec large potential markets of this "eco-frien The Universities and DOE Labs Teams will work together to solve the remaining technical innovat needs. Federal support was in line with existing agency missions. The Local Governments sponsored this agreement as a means to quality regulations. The Public Team supp agreement from a quality-of-life perspect included both the improved air quality pr well as the idea of spending less time in t**

Figure G-1. Example of a Completed Agreement.

Handbook Appendix H: Glossary

Alar	a pesticide used to treat apples (banned by EPA in 1992)
arable land	land that is fit for cultivation
Bb	billion barrels
billion	10^9 (a British milliard)
brownfield	contaminated, former industrial site requiring remediation before redevelopment is possible
BTU	British Thermal Unit
CAD/CAM	computer-aided design/computer-aided manufacturing
CBO	Congressional Budget Office
CEO	chief executive officer
CFC	chlorofluorocarbon
chaos theory	the study of complex, nonlinear (recursive or high-order functions), dynamic (nonconstant and nonperiodic) systems
chit	a voucher indicating a credit against future expenditures
CIA	Central Intelligence Agency
CO	carbon monoxide
co-opetition	A revolutionary mindset that combines competition and cooperation. Coined by Ray Noorda in *Electronic Business Buyer*, December 1993.
colonias	unincorporated communities along the Mexican-U.S. border
complexity theory	the study of non-reducible problems (e.g., systems which do not behave as the sum of their parts) that generally exhibit some form of self-organized behavior
cybernetics	the science, craft, and art of communication, computation, and control in a machine, a living being, or an organization
DFE	Design for the environment
dioxin	generally used to refer to a group of 75 compounds; a molecule of dioxin consists of 2 carbon rings connected by 2 oxygen atoms with 2 chlorine atoms at each end of the chain.
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EIP	eco-industrial parks
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-know Act
FAR	Federal Advisory & Regulatory Agencies Team
FIA	Federal Industrial Agencies Team
fly ash	ash produced by the combustion of coal; approximately 300 tons/MW/year in the U.S.
fossil fuel	fuel ultimately derived from once living things (e.g., coal, oil, natural gas)
fossil water	deep aquifers originally charged in the geologic past, often in areas where there is currently little or no recharge
GDP	Gross domestic product: The value of all goods and services produced within a nation in a given year.
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HHS	Health & Human Services
high-plains aquifer	underlies 20 percent of all U.S. irrigated lands; located in central U.S.
IE	industrial ecology
IM	industrial metabolism
industry	systematic labor for the creation of value
IO model	dynamic input-output model
IPCC	Intergovernmental Panel on Climate Change
lindane	an insecticide
LRG	lower Rio Grande
maquiladora program	a Mexican program that grants special tax status to attract businesses to the Mexican side of the border
Mb	million barrels
Mt	million tons

NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Protection Act
NG PL	natural gas plant liquids
NRC	Nuclear Regulatory Agency
NZ	New Zealand
OPEC	Organization of Petroleum Exporting Countries
OSTP	Office of Science and Technology Policy
PCB	polychlorinated biphenyl – used principally as a transformer coolant
ppm	parts per million
quadrillion	10^{15}
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, development, test, and evaluation
salinization	Irrigation water dissolves naturally occurring salts from the soil as it runs over and through the topsoil. When the water evaporates or is transpired, it leaves the salt in the soil.
Subtitle D	federal landfill regulations as embodied in Subtitle D of the Resource Conservation and Recovery Act
Superfund site	a contaminated site where responsibility for cleanup falls under the purview of the EPA under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)
sustainability	a concept wherein resources are managed so that they are not depleted or permanently damaged
systems dynamics	the study of systems that are not in equilibrium
TCF	trillion cubic feet
TJ	terajoules (10^{12} joules; 1 BTU = 1055.056 J)
Toolkit	a list of investment options involving many types of technologies, methodologies, and policies that might be pursued in a game
TQM	Total Quality Management
trillion	10^{12}; a British billion
USC	United States Code
USDA	United States Department of Agriculture
ZERI	Zero Emissions Research Initiative of the UN University

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PART 3: Game Schedule

	Tuesday, May 20, 1997
4:00 PM	Participant registration and badging; collect materials. Players gather in Concorde Ballroom. Explore the posters, handouts and computer materials available; go to assigned tables; get acquainted with team members.
4:55 PM	Go to Aviator Suites for Plenary Session
5:00 PM	Welcome. Kathleen Schulz, Joan Woodard, Joe Laia
5:30 PM	Prosperity Game briefing/overview with questions and answers; polling Marshall Berman -- Game Director
6:50 PM	Return to Concorde Ballroom. Cash bar.
7:30 PM	Dinner with your team members and staff. Questions and answers. Discuss key IE questions to raise with the expert panel tomorrow morning.
9:00 PM	Meeting adjourned.
	Wednesday, May 21, 1997
7:30 AM	Breakfast Buffet
8:00 AM	Plenary Session (Aviator Suites): Panel of IE experts. Kathleen Schulz, moderator Questions and answers.
	SESSION 1 – Planning – May, 1997:
9:30 AM	Return to Concorde Ballroom. Facilitators lead teams in initial assignments: **All teams**: Set ground rules for deliberation, decision-making, etc. Decide on your team's vision (10 minutes). Review the team challenges defined in this Handbook. Modify and complete the challenges for your team. Define the different roles appropriate to your team and which players will represent each role. Develop game and team objectives and strategies to meet your challenges. Prepare deliverable to Control Team: Vision, Challenges, Objectives, Strategies. Begin to discuss the Toolkit Investments; prioritize them.
11:30 AM	Lunch
	SESSION 2 – Toolkit Investments – January 1, 1999:
12:30 PM	Prepare Toolkit Investments. Make appointments with other teams to discuss investment priorities, partnering possibilities, new Toolkit ideas.
1:45 PM	End of Session 2. ***Complete all Toolkit investments and submit only your own team's options to Control team. No further Toolkit investments are allowed after 1:30 PM.***
	SESSION 3 – Open Negotiations – January 1, 2001:
1:50 PM	Chits distributed. Continue deliberations and negotiations. Develop high-quality agreements.
2:15 PM	Successful Toolkit investments are announced and implemented into the game.
3:00 PM	End of session. Turn in all successful agreements from Session 3.

3:10 PM	Go to the World IE Roadmap board. Vote for the "best" agreement (only one).
3:25 PM	Break

SESSION 4 – Open Negotiations – January 1, 2003:

3:40 PM	Staff updates the world. Successful technologies and policies that have been negotiated among the teams are announced and implemented into the game. New chits are distributed, including awards. Check progress on World and Team IE roadmaps. Continue deliberations and negotiations.
5:00 PM	End of session. Turn in all successful agreements from Session 3. Teams select Ambassadors to National Industrial Ecology Summit Meeting (one per team). Submit names to Control Team. Provide one key question for the Summit Meeting.
5:30 PM	Go to the World IE Roadmap board. Vote for the "best" agreement (only one).
5:45 PM	End of day's activities.

Thursday, May 22, 1997

7:30 AM	Breakfast Buffet
8:00 AM	Plenary Session. Announcements. Introduction to Summit Meeting.
8:30 AM	**National Industrial Ecology Summit Meeting**
10:00 AM	Break. Return to Concorde Room.

SESSION 5 – Open Negotiations – January 1, 2005:

10:15 PM	Staff updates the world. Successful technologies and policies that have been negotiated among the teams are announced and implemented into the game. New chits are distributed, including awards. Check progress on World and Team IE roadmaps. Review objectives and strategies developed in Session 1. Make changes as appropriate. ***Turn in planning changes to Control Team.*** Continue deliberations and negotiations.
11:50 AM	End of session. Turn in all successful agreements from Session 5.
12:00 PM	Go to the World IE Roadmap board. Vote for the "best" agreement (only one)
12:15 PM	Lunch

SESSION 6 – Debriefing – January 1, 2007:

1:00 PM	Internal team debriefings. Teams digest game results, document best ideas, plan for follow-on activities; get volunteers to champion follow-ons. Select spokesperson to provide brief overview at town meeting. ***Document and provide results to Control.***
2:00 PM	Move to Plenary Session. Wrap up; final polling; fill out evaluation forms. Announce and present awards.
2:30 PM	Town Hall meeting.
3:30 PM	Game adjourned.

PART 4: Industrial Ecology Tutorial

Annotated Table of Contents

The following links open PDF files containing a mix of graphics and text that illustrate some of the basic industrial ecology concepts and methods. A brief description of each topic, along with appropriate credits accompanies each link.

U.S. Energy Flows

Quantified flow charts of U. S. energy flows, subsidies, and R & D budgets. Information of this type is useful, for example, to industrial ecologists who are trying to improve material cycle energy efficiencies. (These charts were developed by Dave Bassett and others at the Pollution Prevention Office of EPA as part of a 1991 Pollution Prevention Strategy for Energy and Transportation. A sister EPA organization, the 3-person Futures Group, assisted in the development of the financial data. Other sources of data for the charts include: National Air Pollution Emission Estimates, 1940-1987, 1989, EPA; Environmental Trends, 1989, CEQ; 1990 Annual Energy Outlook, DOE; 1991 National Energy Strategy, DOE; Peter Blair, OTA, 1991; Paul MacCready, AeroVironment, 1991; "Road Vehicles," TRW/US-ERDA, 1977. Reprinted with permission.)

Industrial Metabolism (IM)

IM is a method to model and analyze material and energy flows in a given system. In doing so, it helps to identify opportunities for reducing wastes and pollution and increasing efficiency of materials and energy use. (Figures reprinted with permission from Robert Ayres, "Industrial Metabolism," in B.R. Allenby and D.J. Richards, The Greening of Industrial Ecosystems. Copyright 1994 by the National Academy of Sciences. Courtesy of the National Academy Press, Washington, D.C.)

Design for Environment (DFE)

DFE is a method to assess product and process life cycles whereby design teams can weigh options for improvement of environmental performance while attending to more traditional design issues. (Figures reprinted with permission from T. E. Graedel and B. R. Allenby, Corporate Environmental Practices . Copyright 1994 by the National Academy of Sciences. Courtesy of the National Academy Press, Washington, D.C.)

Product Life Extension (PLE)

PLE is a business approach that is focused on optimizing service to end-users rather than maximizing product sales. PLE is a logical extension of DFE methods. ("Quality =" figure reproduced with permission from Walter R. Stahel, 1991, Langlebigkeit und Materialrecycling-Strategien zur Vermeidung von Abfallen im Bereich de Produke. Essen: Vulkan Verlag. "Xerox's Asset Recycle Management." Reprinted with permission.)

Ecofactory Japanese researchers have independently developed industrial ecology concepts that parallel many of the concepts found in DFE and PLE, which they call "ecofactory." (Charts from Ecofactory _ Concept and R&D Themes, Japan External Trade Organization, 2-2-5 Toranomon, Minato-Ku Tokyo 105, Japan, tel 81-3-3291-3761, fax 81-3-3256-3160, 1992. Reprinted with permission.)

Industrial Ecosystems

Kalundborg is often held up as an example of how industrial symbiosis can reduce material and energy wastes through by-product exchange. (Flow chart developed by Doug Holmes; reprinted by permission. Photographs by Ernie Lowe, Indigo Development; reprinted with permission.)

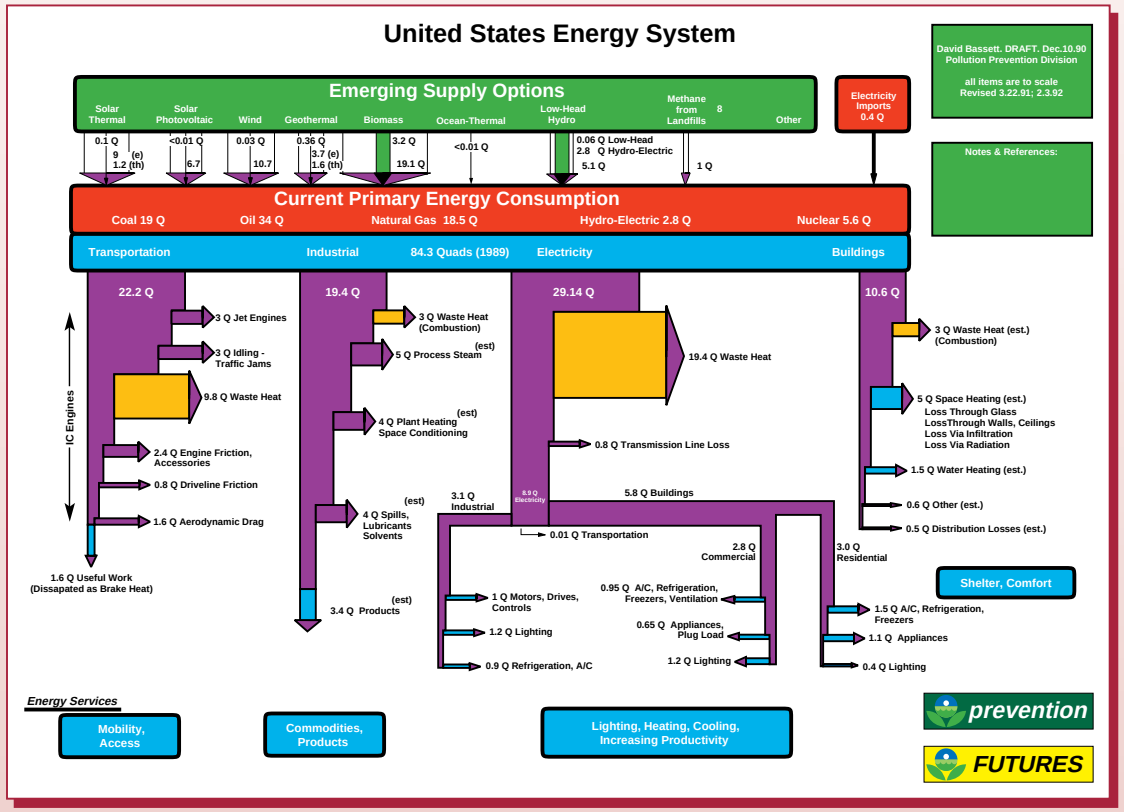
The President's Council on Sustainable Development named Cape Charles, Virginia, as one of four demonstration eco-industrial parks in the U.S. The park will be focusing on integration of agricultural and industrial growth with an emphasis on adding value to seafood and agricultural by-products. (Chart reprinted with permission.)

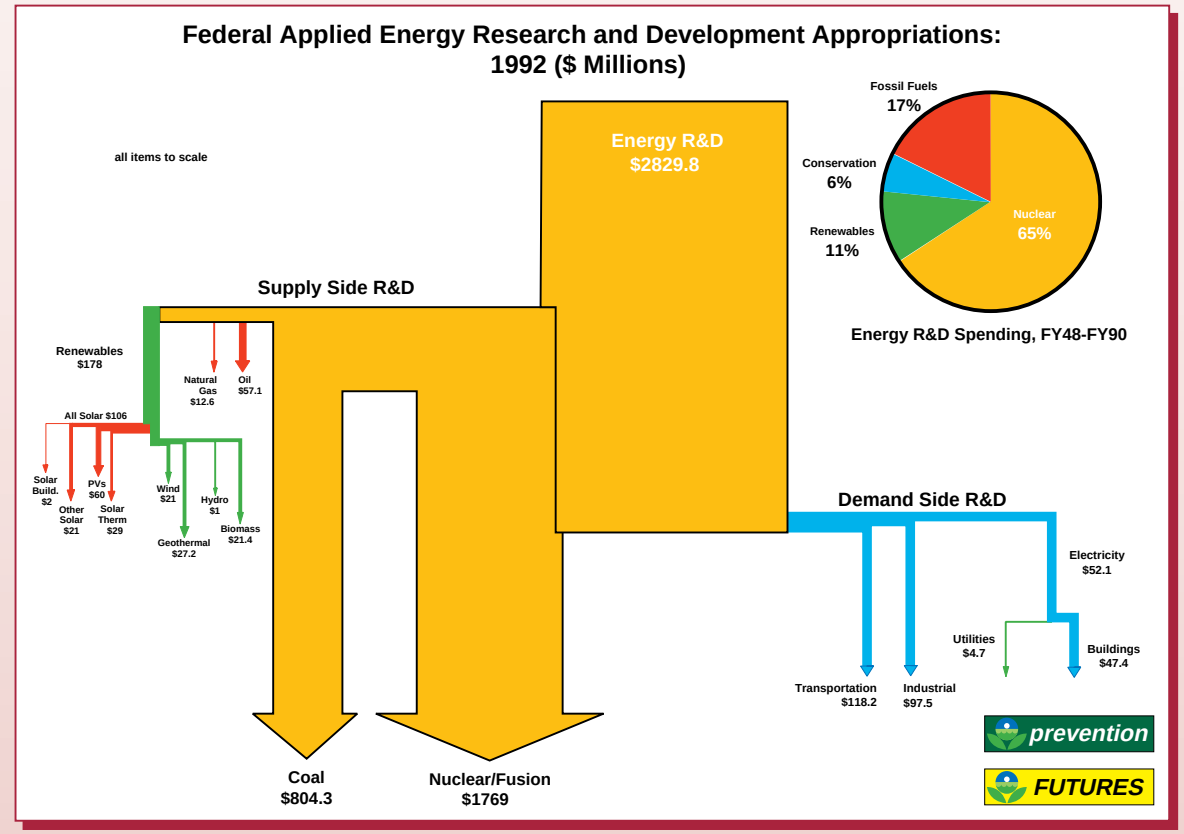
Berkeley's Serial Materials Recovery Facility (MRF) provides an example of how resource use at the community level can be improved through an integrated reuse, recycle, compost, resale program. (Chart reprinted with permission from Reuse, recycling, refuse and the local economy: a case study of the Berkeley Serial MRF, Urban Ore and the Center for Neighborhood Technology, Publication Series No. 2, September 1994. Reprints available from Urban Ore, 1333 6th Street, Berkeley, CA 94710-1403, phone 510-559-4460.)

IE Perspectives

This chart summarizes some ideas of what IE is and what it's not as a result of observations made during the Industrial Ecology Prototype Prosperity Game. This compilation was drafted by Ernie Lowe of Indigo Development.

U.S. Energy Flows



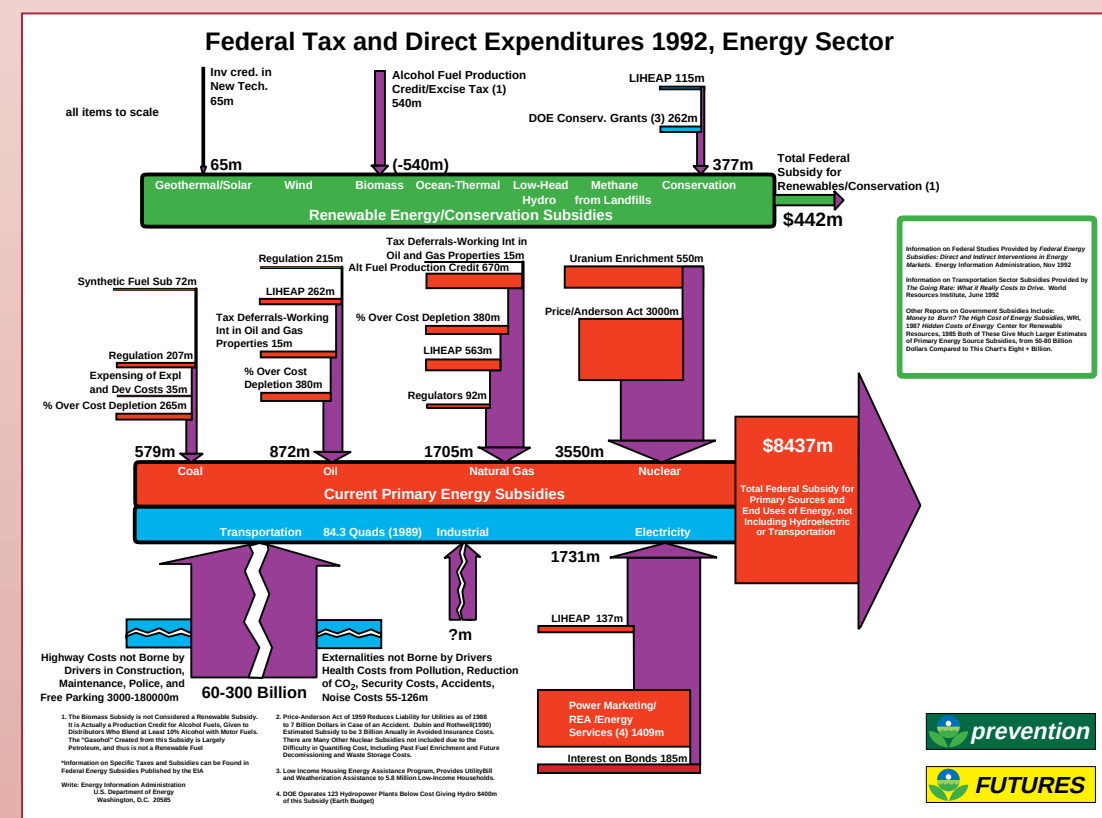


U.S. Energy R & D Budgets

U.S. Energy 1992

This mapping of U.S. energy flows is a dramatic picture of design opportunities in policy, technology, and business. The orange horizontal arrow from each of the four main vertical streams of usage shows wasted heat (and dollars). For comparison, Japan's total energy budget is ca 20 quadrillion BTUs each year. The waste heat in the U.S. electricity industry equals Japan's total budget. The total waste heat in the four sectors is 35.2 quads, almost double Japan's energy budget. Many of the other horizontal arrows represent other forms of waste, such as engine and driveline friction.

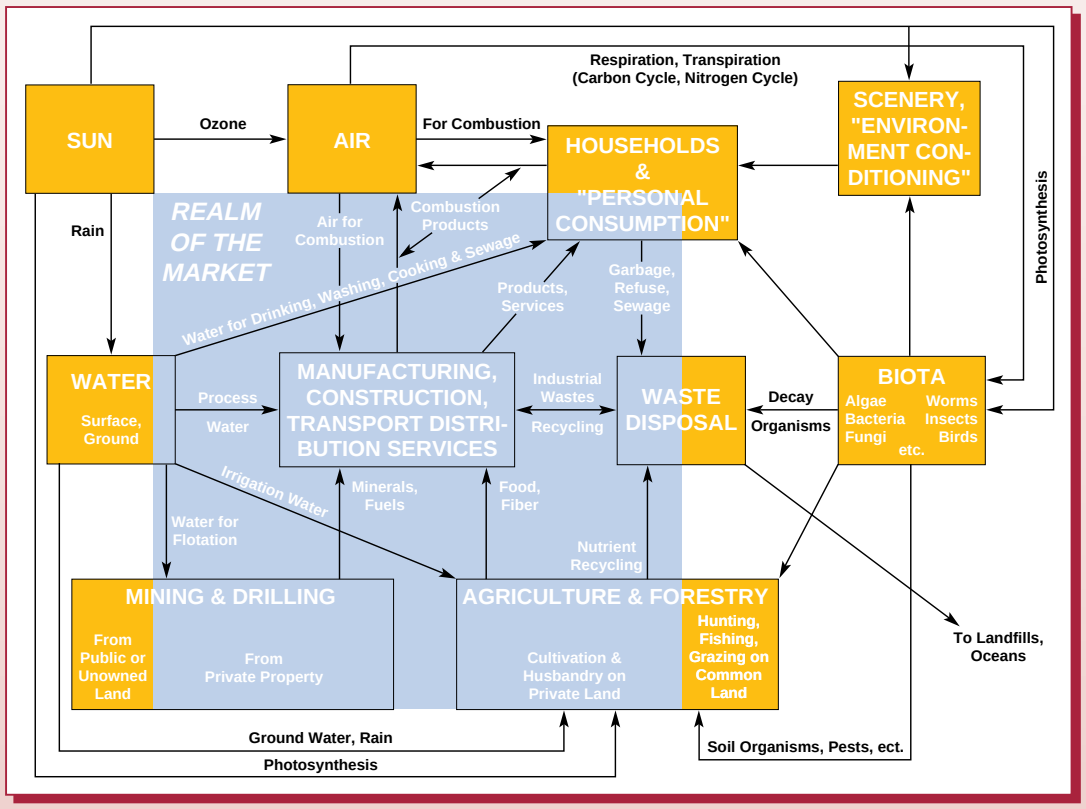
Industrial ecologists see major opportunities throughout this chart for improving efficiency by retrofitting facilities and equipment and improving the design of new products and the systems in which they fit. Power station managers are realizing bottomline benefits by selling steam and hot water to neighboring facilities (an option not possible with some power plant designs.)



U.S. Energy Subsidies 1992

These quantified flow charts of U.S. energy flows, subsidies, and R & D budgets demonstrate the power of graphic depiction of environmental information. They were produced by Dave Bassett when he worked at the Environmental Protection Agency, Pollution Prevention. He is now at DOE, continuing to develop such graphics.

Industrial Metabolism



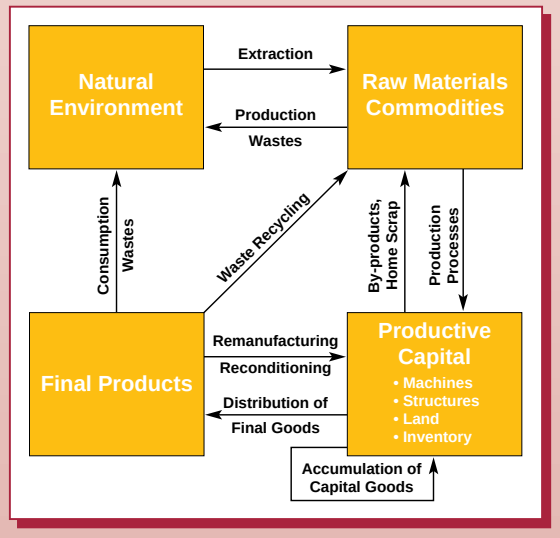
Realm of the Market

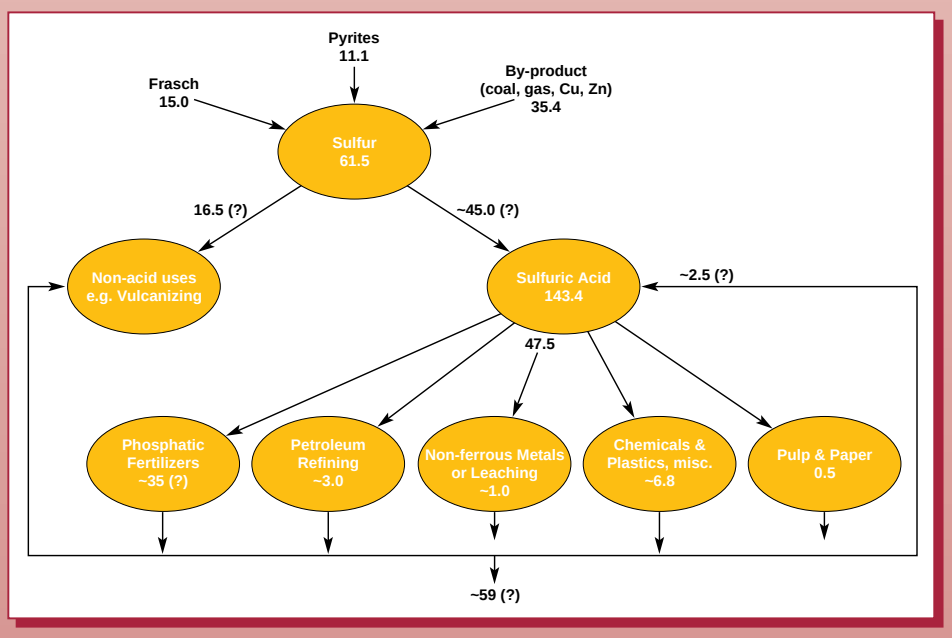
This chart shows the industrial system as the "Realm of the Market" (shaded area) with the major flows between this realm and the natural systems of which it is a part. Industrial metabolism's focus is on assessing these flows for a given system (e.g. a factory or a river basin) and identifying the priority opportunities of reducing waste and pollution.

Industrial Metabolism (IM)

Industrial metabolism models and analyzes materials, water, and energy flows from initial extraction of resources through industrial and consumer systems to the final disposal of wastes. IM analysis has been done at many different levels: globally, nationally, regionally, by industry, by company and by site. Some companies have conducted environmental audits based on this method. The basic engineering technique of analyzing a system's inputs and outputs through a materials balance study is a key aspect of IM work.

Industrial metabolism methods can support policy makers and industrial managers in setting priorities for reducing pollution and increasing efficiency of materials and energy use.





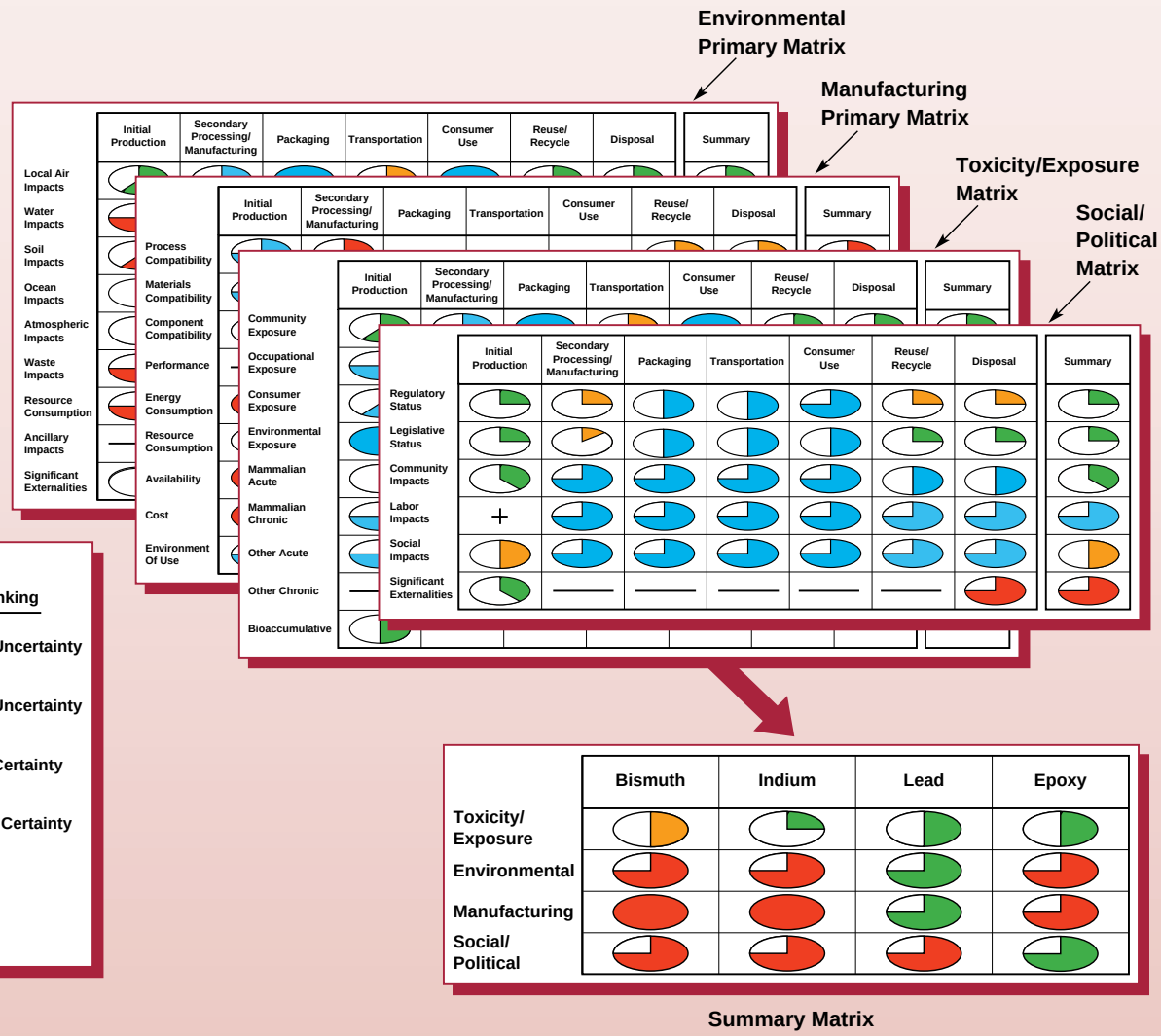
Dissipative Uses of Sulfur

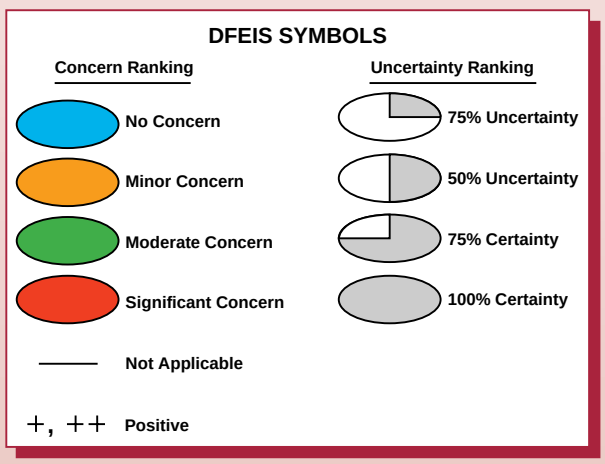
"Dissipative use" is where materials are degraded, dispersed or lost in the course of a single normal usage and are thus unavailable for recycling. This IM chart of global sulfur use indicates that of 61.5 million metric tons generated, 59 tons are dissipated each year.

These charts are from Robert Ayres' work pioneering work in industrial metabolism, as summarized in Ayres, Robert. 1994. "Industrial Metabolism," Greening of Industrial Ecosystems. National Academy Press, Washington DC.

Design for Environment (DFE)

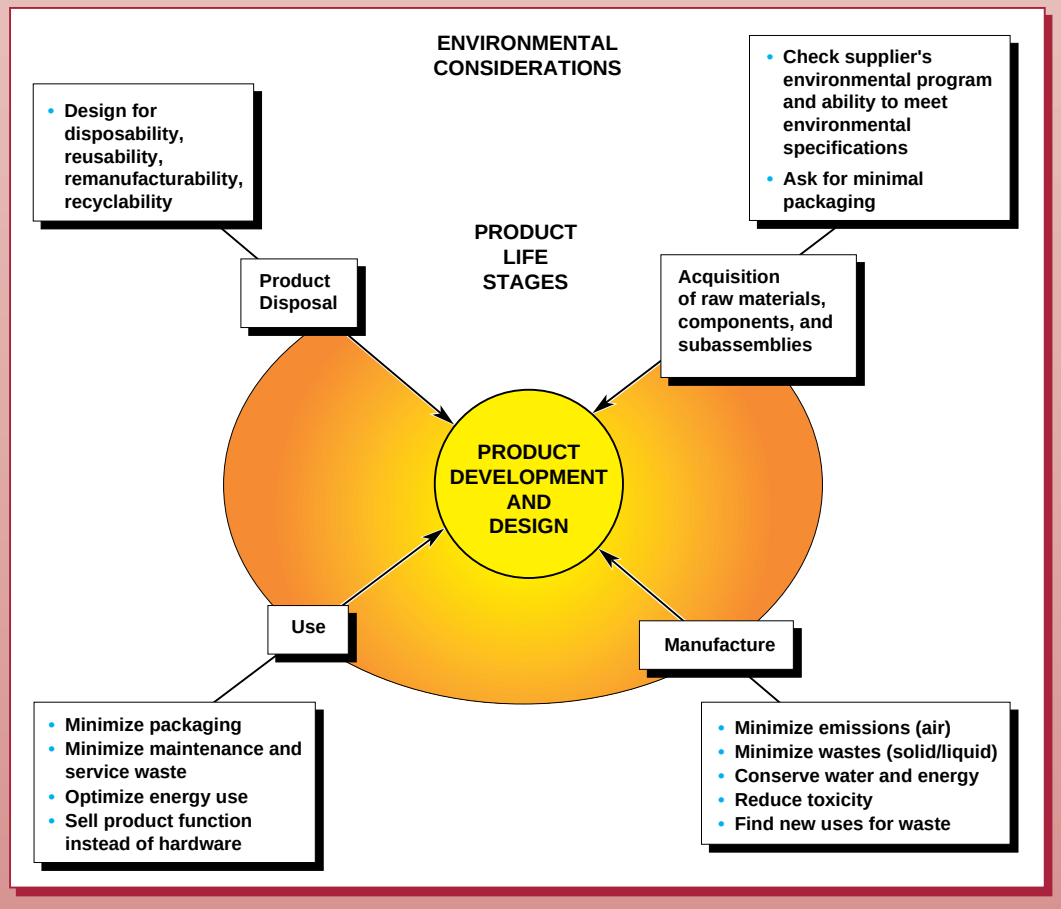
Design For Environment (DFE) supports decision-making in design of products and processes. DFE focuses on the life cycle assessment stage of *improvement assessment*, enabling design teams to weigh options for improvement of environmental performance while attending to the traditional design issues relating to technology, costs, and user satisfaction.





Qualitive Matrix Analysis of Substitutes for Lead

These charts show the basic types of matrices used in DFE to analyze options for a particular material, lead solder. A designer will use questions sets for each cell in the detailed matrix to form qualitative judgments (within the limits of current knowledge). The detailed matrices are compiled into a summary matrix to guide the design process. (This form of matrix analysis was developed initially in the electronics industry, under leadership of AT&T's Braden Allenby and Thomas Graedel.)

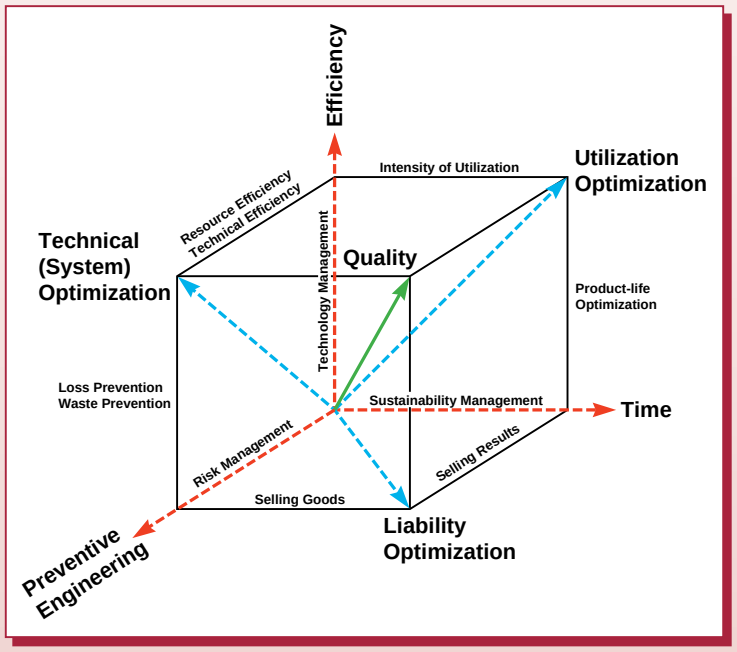


DFE incorporates environmental considerations into product development and design through consideration of options for improvement across a product's life cycle.

Product Life Extension

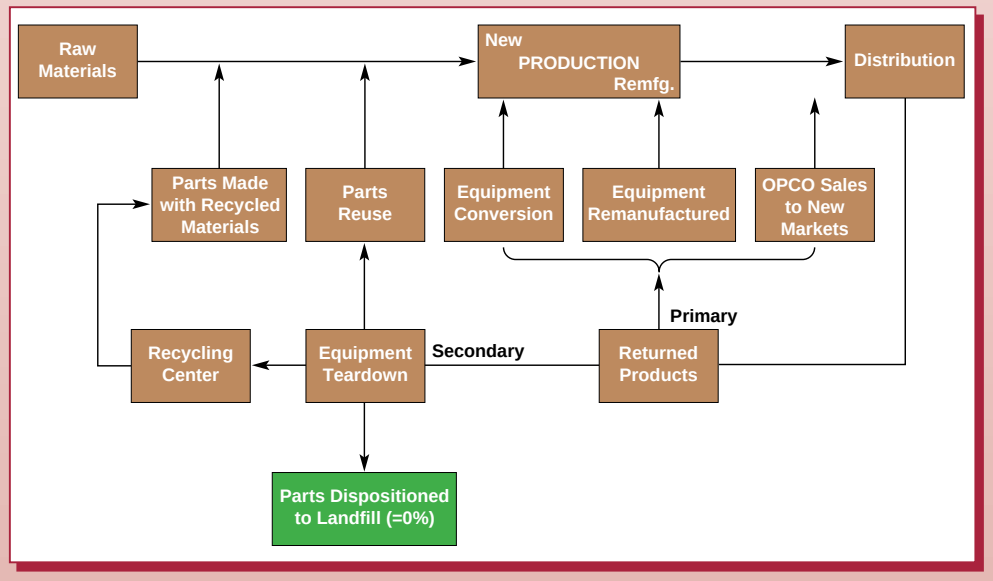
Product Life Extension and the Service Economy

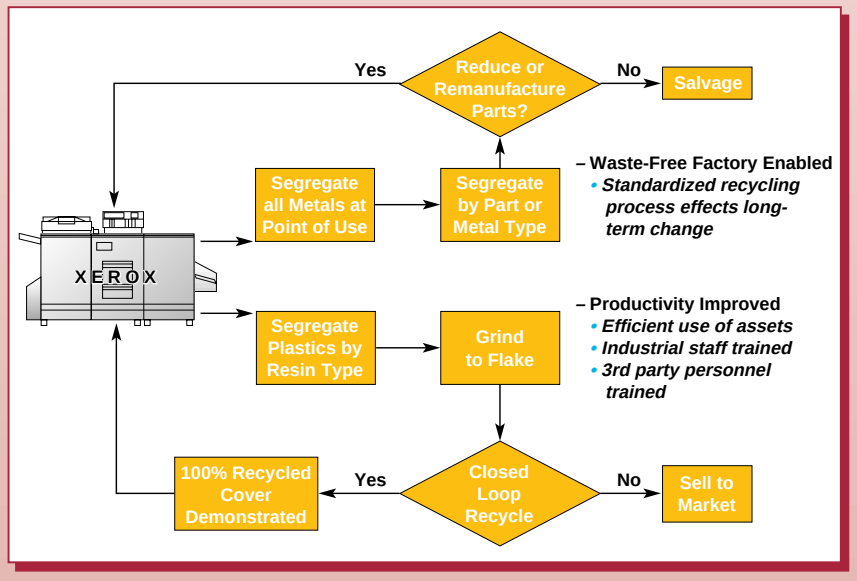
A logical extension of design for environment is creating products that are intensely durable and easily repaired and upgraded. This extension of product life requires a business model based upon optimizing service to end-users rather than maximizing products sold. This approach has been applied primarily by office and capital equipment firms, such as Agfa Gevaert, Schindler (elevators), and Xerox. It is potentially very useful for home appliances and some smaller consumer goods. Walter Stahel developed these basic concepts and methods at the Swiss Product-Life Institute, which he directs. (Graphics from Stahel, Walter. 1994. "The Utilization Focused Service Economy: Resource Efficiency and Product-Life Extension," in Allenby, Braden R., and Deanna J. Richards. The Greening of Industrial Ecosystems. Washington: National Academy Press, 1994.)



Quality = optimization of system function over time

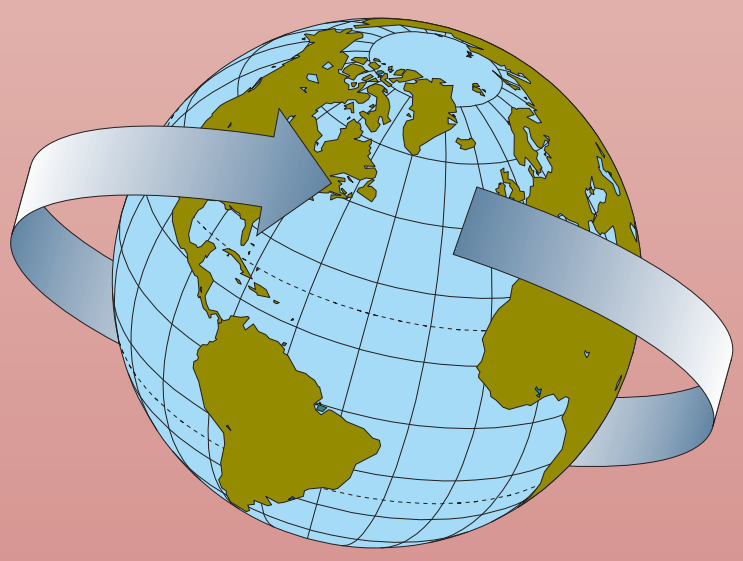
Stahel defines quality as optimization of system functioning over long periods of time. This three dimensional chart expresses his view of how such optimization can enable sustainable businesses to balance optimization of technology, utilization, and liability exposure in this concept of quality.



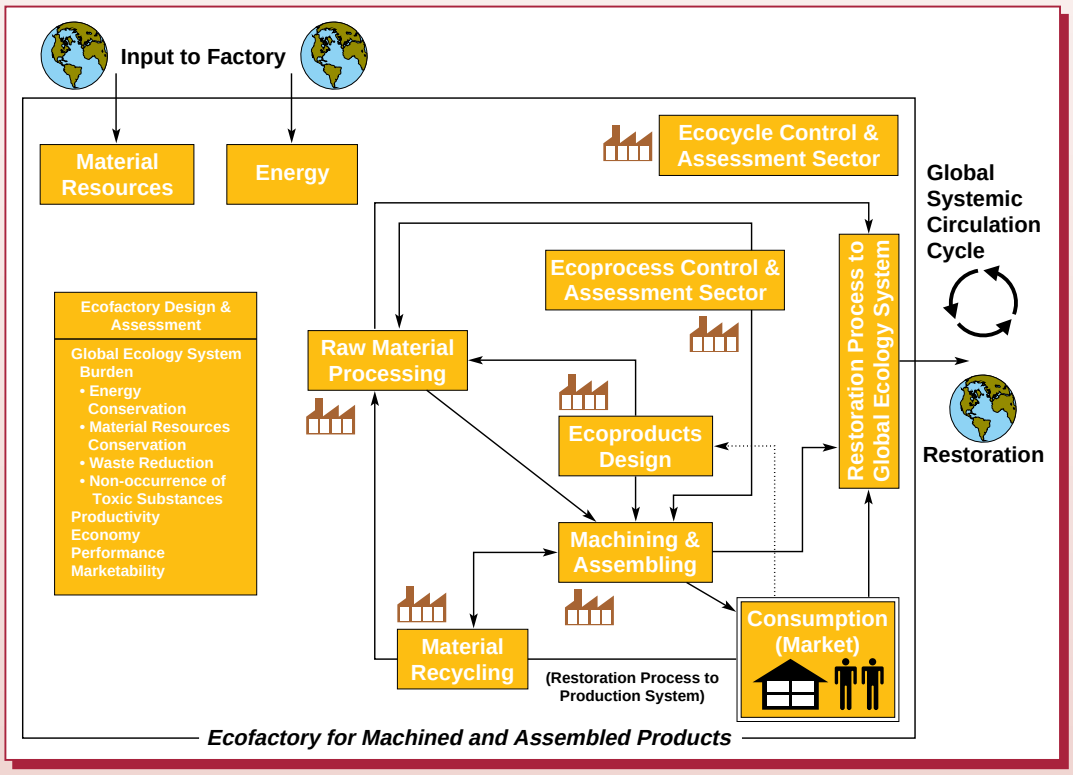


Xerox's Asset Recycle

Xerox's Asset Recycle Management organization guides a company-wide effort to demonstrate that, ". . . all recycled equipment (and parts) shall retain the same quality as new build while complying with all environmental requirements." This reflects the design strategies for product life extension. Copier bodies, for instance, are designed to last 100 years.



Ecofactory for Machined and Assembled Products



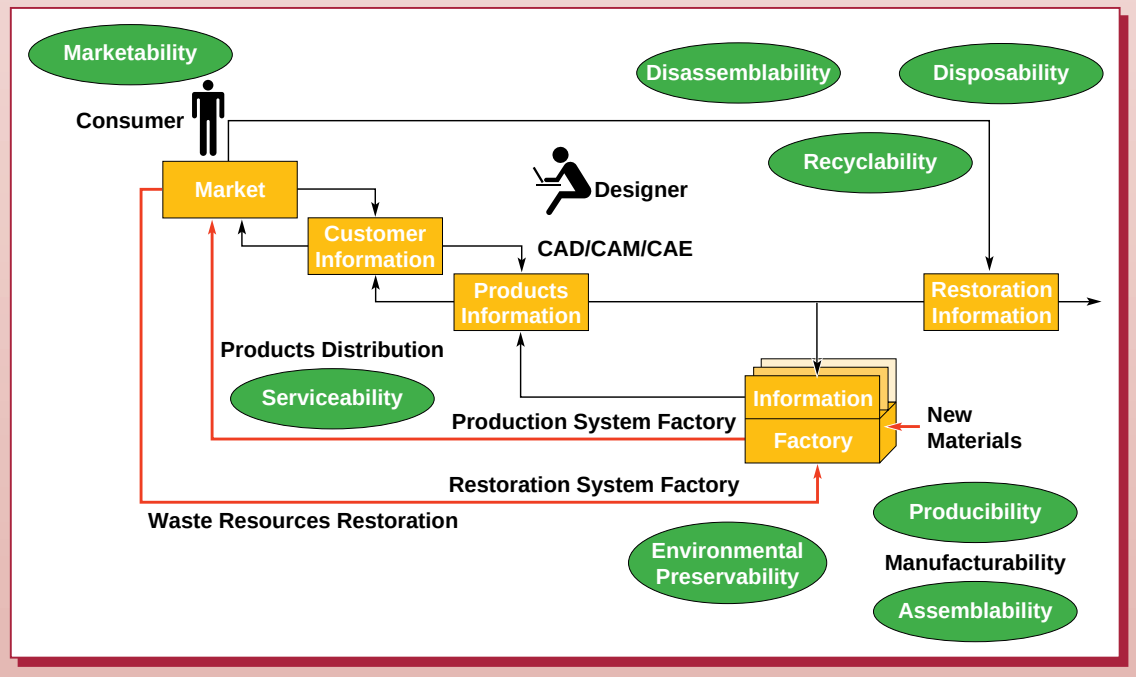
Ecofactory

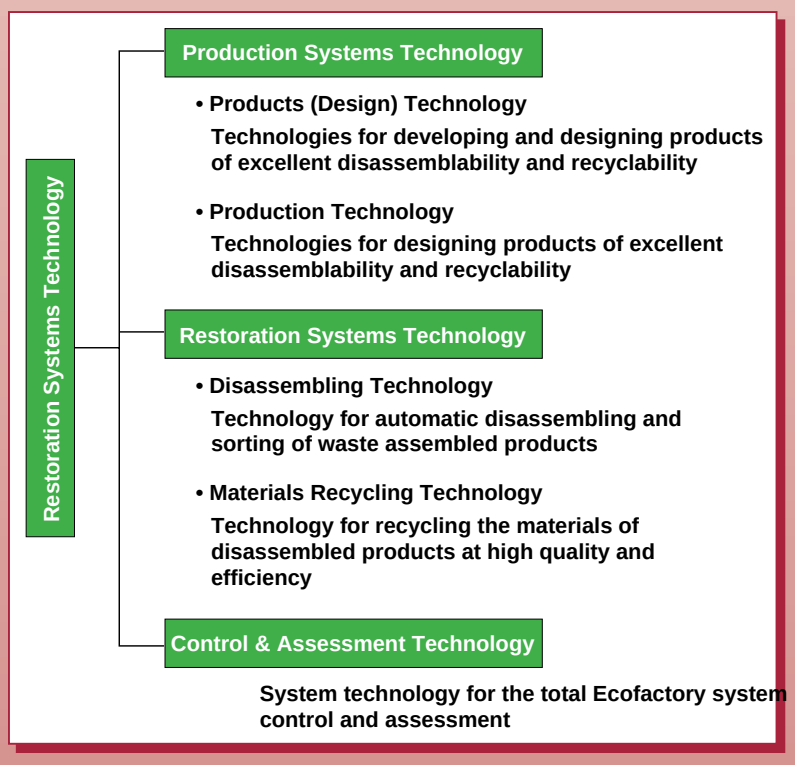
Japanese researchers have modeled the technologies needed to achieve the closed-loop system ideal. Their report on The Ecofactory is an independent development of an industrial ecology model. The model integrates design of production systems technology -- including design for environment at product and process levels -- with disassembling, reuse and materials recycling technologies. These two large components are then linked to control and assessment technology.

The Ecofactory paper offers the most detailed *technical* R&D agenda for industrial ecology to appear. The agenda includes items in energy, design, production, robotics, materials, systems, and information technologies. This model was developed at the Agency of Industrial Science and Technology in Japan.

Global Concurrent Design System Environment

The Ecofactory model traces information flows in the concurrent design system needed to achieve closed loop manufacturing. This is parallel to the design for environment infrastructure proposed by Allenby and Graedel.

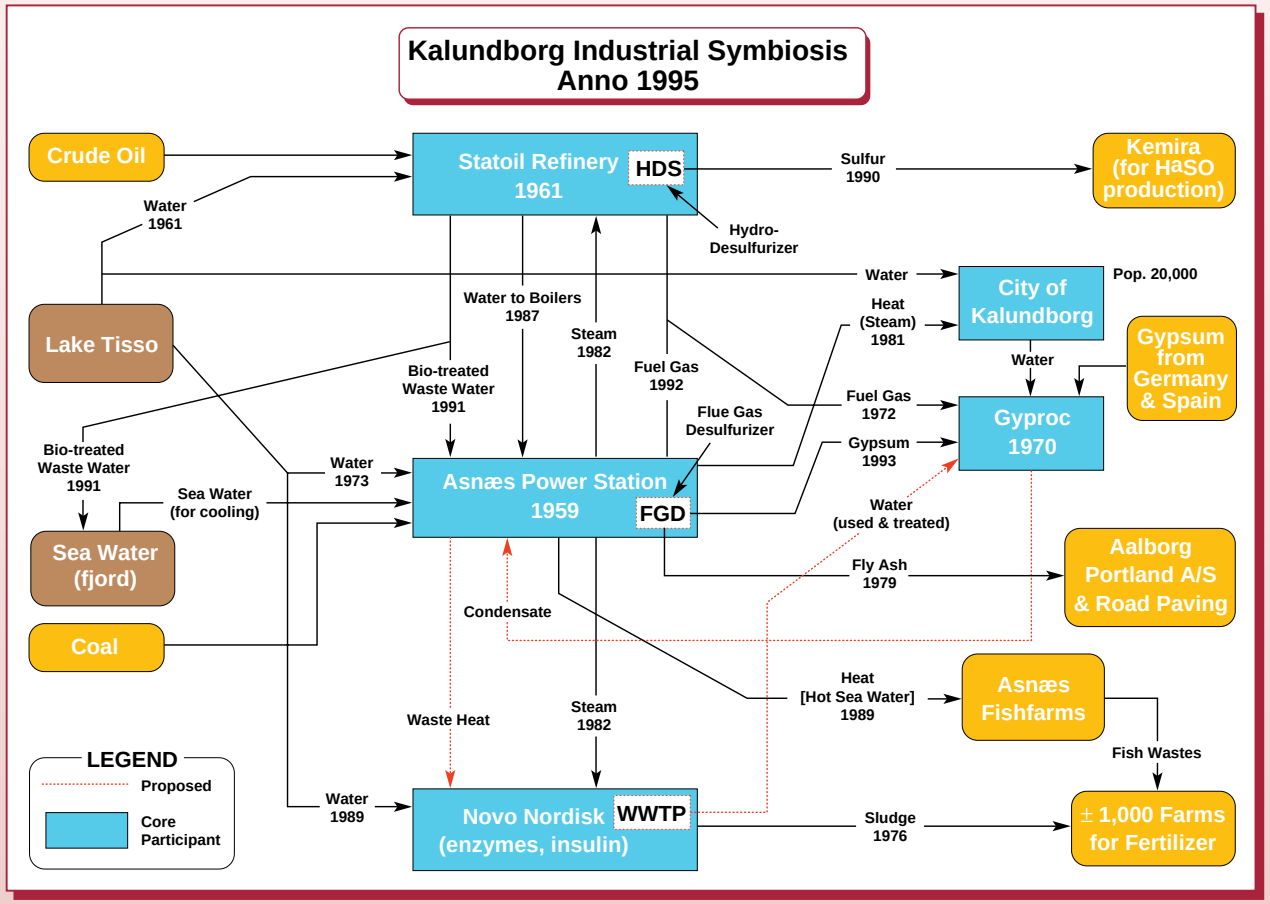




Major research themes necessary for implementation of The Ecofactory Model.

from: JETRO, "Ecofactory - Concept and R&D Themes," special issue, *New Technology*, FY 1992, Japan External Trade Organization, Tokyo. Report based on work of the Ecofactory Research Group of the Mechanical Engineering Laboratory, Agency of Industrial Science and Technology.

Kalundborg Industrial Ecosystems



The Industrial Symbiosis at Kalundborg, Denmark . . .

. . . has been celebrated as a powerful example of the industrial ecosystem aspect of industrial ecology. Over a twenty year period, plants there developed a network of energy and materials trades, as indicated on our flow chart and table of exchanges. Up to 1994 a total investment in infrastructure of US$60M has netted returns of $120M through sales of by-products and savings in disposal fees. The evolution of the Symbiosis was a self-organizing process motivated both by financial returns and more stringent regulation of emissions.

Critics of the example remind us that although Kalundborg demonstrates improvements in eco-efficiency, its core is still basically a petro-chemical complex generating greenhouse gases and other emissions within-compliance. Plant managers there are committed to continue improving their environmental and financial performance and have formed a Symbiosis Institute to assist them in further innovations.

Chart of Kalundborg energy and materials flows developed by Douglas B. Holmes, Massachusetts chemical engineer and co-author of Eco-Industrial Parks, a guide for local development teams (Indigo Development 1997). Photos by Ernest Lowe, Indigo Development.

The near view shows part of the Asnaes power station complex, with the Statoil refinery in the distance.

Some of the large pipes that move steam from Asnaes to Gyproc's wallboard plant and Kalundborg's district

The round fish tanks in this photo are at a corner of the Asnaes power station, which supplies them with heated sea water. This fish farm produces over 250 tons of fish each year, as well as sludge used by farmers in the region as fertilizer. The yellowish substance on the left is a small mound of gypsum from Asnaes scrubber, which goes to Gyproc for wallboard.

The Industrial Symbiosis at Kalundborg, Denmark: terms of exchange

Material	From	To	Sold/free	Began	Quantity[T/yr]
Fuel gas	Statoil	Gyproc	sold	1972	8,000
Sludge	Novo Nordisk	1,000 farmers	*free*	1976	1,100,000
Fly-ash & clinker	Asnæs	Aalborg Portland	sold	1979	200,000
Steam	Asnæs	Kalundborg	sold	1981	225,000
Steam	Asnæs	Novo Nordisk	sold	1982	215,000
Steam	Asnæs	Statoil	sold	1982	140,000
Water (x-cooling)	Statoil	Asnæs	sold	1987	700,000
Hot sea water	Asnæs	Fish Farm	*free*	1989	?
Sulfur (liquid)	Statoil	Kemira	sold	1990	2,800
Water, biotreated	Statoil	Asnæs	*free*	1991	200,000
Fuel gas (x-flue gas)	Statoil	Asnæs	sold	1992	60,000
Gypsum	Asnæs	Gyproc	sold	1993	85,000
			Total annual quantity T/yr		2.9 million

Cape Charles

Cape Charles

These principles, created on the basis of a community design charrette with broad citizen involvement will guide development of the Sustainable Technologies Park.

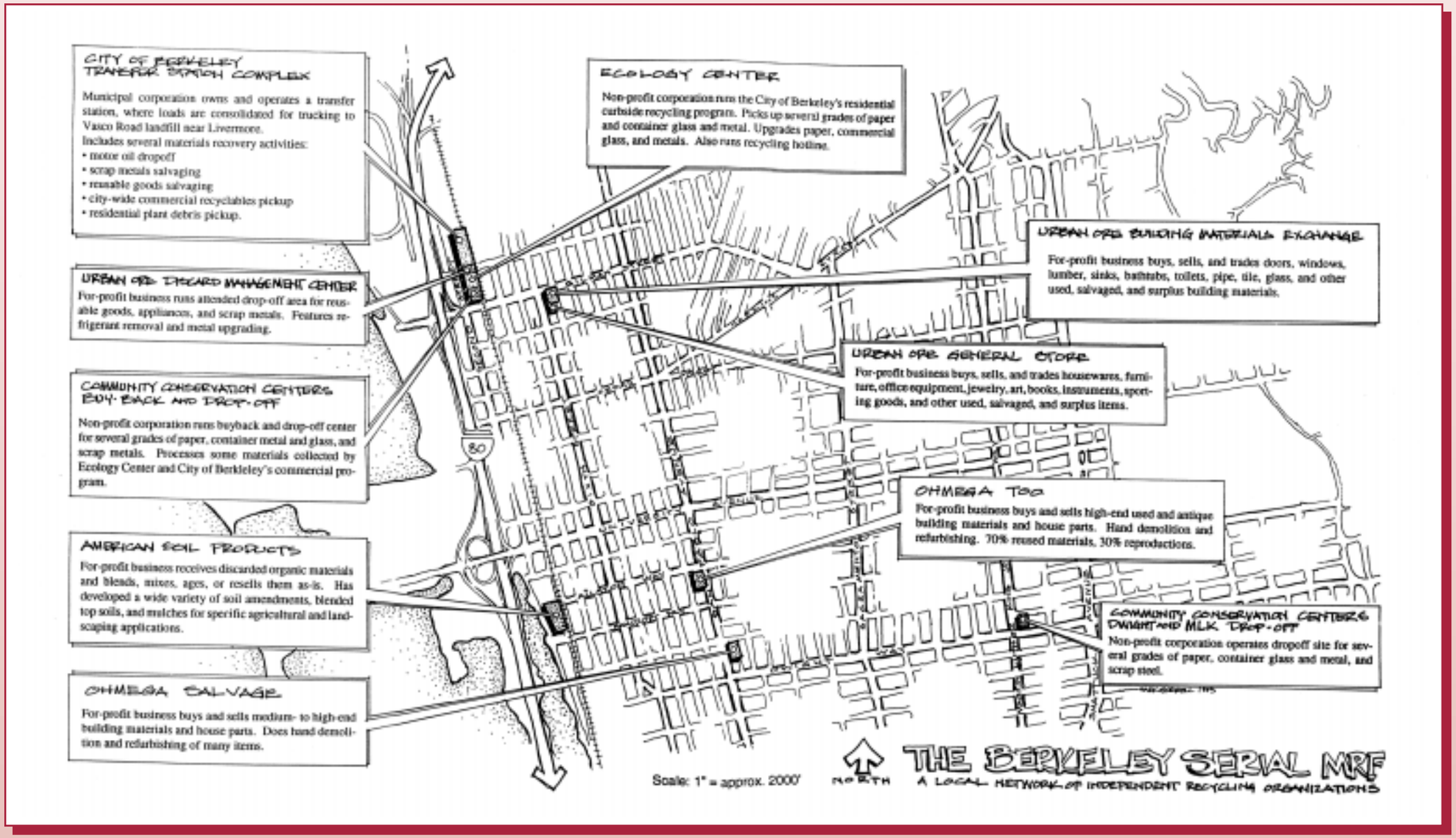
1. The Sustainable Technologies Park will seek to provide support for industrial, job creating opportunities to:
   - ¥ Support existing local enterprises
   - ¥ Attract new ecologically compatible enterprises
   - ¥ Create new ecologically compatible industries
   - ¥ Offer a national model for environmentally sound coastal development
2. The design of the park will encourage the revitalization of the Cape Charles' historic residential, commercial, and industrial landscape. The sense of place embodied by historic Cape Charles, with its culturally and historically rich landscape, architecture, and society provides the keystone for the responsible future development of the town. Working with the historic landscape aims to discourage ruinous sprawl on surrounding open and rural land.
3. The town and the park will serve as a model for preserving and advancing the Eastern Shore's traditional settlement pattern of compact villages and towns surrounded by productive land and water. Consistent with this development pattern, the town of Cape Charles will be reestablished as an integrated employment and residential center for the region.
4. The park will seek to create "family wage" local employment, training, and opportunities for advancement. The design, capitalization, construction, and occupation of the park should seek to achieve local training and employment during every phase. Local companies which assist citizens in saving energy and water should be created immediately, to begin the entrepreneurial activity in the community, consistent with the goals of the park.
5. All designs should attempt to be ameliorative or restorative of the coastal watershed's natural systems, to consider and support the fundamental hydrological and biological characteristics of the site's natural state.
6. The park should evidence world leadership in coastal resource management, particularly water quality management. It will consider all scales from the entire watershed to individual water conservation as a model of conservation and remediation. It should discharge only water unavailable for reuse and in a clean and safe condition.
7. As part of a comprehensive resource management program, the park will implement "Industrial Ecosystems" and "Zero Emissions" protocols, and establish recycling and composting facilities for the region.
8. Through the information and technologies fostered by the park, the community will seek to become more reliant on natural energy flows. The citizens of Cape Charles have adopted the concept of becoming a "Solar City".
9. The park will serve as a model of integrated agricultural and industrial growth and will foster technologies/enterprises that add value to seafood and agricultural by-products.

Prepared by William McDonough + Partners, April 6, 1995, on the basis of a community design charrette for The Port Of Cape Charles Sustainable Technologies Industrial Park

The President's Council on Sustainable Development named Cape Charles Virginia as one of four demonstration eco-industrial parks in 1995. The project concept emerged from a lengthy county-wide sustainable development planning process that emphasized preservation of coastal lands and waters of this Eastern Shore region of the state. The first tenant, a company manufacturing photovoltaic roof tiles and building facades, is already active at the site. The county and city are developing park infrastructure and actively recruiting further tenants.

***At least eighteen other communities in North America are planning eco-industrial park projects*, ranging from 6 to 1000**

Berkeley's Serial Materials Recovery Facility



Map of Serial MRF from report prepared by Urban Ore, a Berkeley-based resource recovery company.

Berkeley's Serial Materials Recovery

Berkeley's Serial MRF illustrates a system for efficiency of resource use at the community level. Three major for-profit firms, two non-profit corporations, and the city work together to divert regional discards from landfills back into the economy. Materials and products are reused, recycled, composted, and retailed, usually at a relatively higher value than if they were collected through typical "waste" management technologies. These major players are complemented by dozens of smaller firms forming business clusters, such as building materials reuse companies.

Industrial ecologists ask, how can community agencies support development and optimization of such self-organizing systems? How can a broader resource recovery system fully integrate industrial as well as residential discard streams?

IE Perspectives

IE offers an integrated view of energy systems

For instance, IE enables evaluation of fuel cell technologies through comparison with life cycle assessment of other present and emerging energy sources. Its methods support design of the infrastructure for a potential hydrogen economy and weighing this option against other major scenarios for sustainable energy. At another level, IE analysis can also assist development of energy sector strategies for navigating the economic transition from fossil to renewable fuels.

IE complements specific manufacturing methods such as pollution prevention

Industrial ecology is concerned with assessing options for product and process change as a whole system and weighing trade-offs among them in environmental, technical, and financial terms. Its view extends outside the plant to include possible innovations to improve performance in supplier companies and to open possible markets for by-products. IE isn't focused on developing specific processes to prevent pollution within a plant. That's already well covered by P2.

IE methods can help end the fragmentation in environmental regulations

Policy makers recognize the need to integrate design of policy, regulations, and voluntary programs across media of pollution and product life cycle. IE methods that can support design and evaluation of innovation include industrial metabolism analysis of materials and energy flows, life cycle assessment, and design for environment. IE also emphasizes partnership in setting objectives and self-organization within industry to design the best means for achieving them. IE offers a complementary alternative to existing fragmented command and control approach and strong support to the reinvention of regulation.

IE seeks systems design of transportation

Industrial ecology supports designing vehicles and their production and use systems with attention to environmental impacts at every stage of product life. It enables managers to weigh the environmental and economic consequences of their design choices.

—and at another level—

IE is a context for designing integrated systems that achieve highly effective transportation with minimal environmental impacts and within economic constraints. It supports making decisions on policy and R & D concerning all types of vehicles, their fuels, and their infrastructure.

IE offers means for evaluating scenarios for increasing world food supply

For instance, industrial ecology is concerned with developing and evaluating technologies and strategies for ecological management of the fishing industry. Goals include design of effective aquaculture systems, restoration of ocean and lake fisheries, optimization of production, and reduction of environmental impacts. IE isn't a way to develop specific technical answers, such as cloning fish to increase world food supply, though this may be one of the options to evaluate.

IE can play a vital role in urban and regional planning

Sustainable communities require a systems approach, one integrating ecological (re)design of infrastructure for energy, transportation, water, material resources, and communications. This is the foundation for design of commercial and residential areas and for the mobilization of educational and civic institutions.

Industrial ecologists can support this process through their perception of the inherent links between all human systems and their host ecosystems. For instance, industrial metabolism methods enable planners and citizens to view their communities as flows of resources. With a systems view they can better improve efficiency, lower pollution, and restore ecosystems, thus improving economic competitiveness.

These perspectives emerged from the Prototype IE Prosperity Game and were compiled by Ernest Lowe.

APPENDIX C: IE Prototype Prosperity Game™

March 5-6, 1997
Albuquerque, NM

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PART 2: IE Prototype Game Schedule

Wednesday, March 5, 1997

3:00 PM Participant registration and badging; collect materials. Players gather in Conference Center; go to assigned tables; get acquainted with team members.

3:30 PM Welcome. Prosperity Game briefing/overview with questions and answers; polling (Marshall Berman -- Game Director)

SESSION 1 – Planning – March, 1997:

4:30 PM Process Managers lead teams in initial assignments:
All teams: Set ground rules for deliberation, decision-making, etc. Review the team challenges defined in this Handbook. Modify and complete the challenges for your team. Define the different roles appropriate to your team and which players will represent each role. Develop game, team and personal objectives and strategies to meet your challenges. Begin to implement those strategies. Prepare Toolkit Investments. Make appointments with other teams to begin preliminary negotiations.

6:30 PM Cash Bar
7:00 PM Dinner

8:30 PM Meeting adjourned

Thursday, March 6, 1997

7:30 AM Continental Breakfast

SESSION 2 – Toolkit Investments – January 1, 1998:

8:00 AM Plan Toolkit investments; negotiations and agreements.

9:15 AM End of Session 2. ***Complete all Toolkit investments and submit only your own team's options to Control team. No further Toolkit investments are allowed after 9:15 AM.***

9:15 AM Break

SESSION 3 – Open Negotiations – January 1, 2001:

9:30 AM Successful Toolkit investments are announced and implemented.

9:35 AM Chits distributed. Continue deliberations and negotiations.

11:45 PM Lunch

SESSION 4 – Planning:

12:30 PM ***Staff updates the world.*** Successful technologies and policies that have been negotiated among the teams are announced and implemented into the game. Update team challenges, objectives, and strategies.

1:25 PM Continue deliberations and negotiations.

SESSION 5 – Toolkit Investments:

1:30 PM Plan Toolkit investments; negotiations and agreements.

2:15 PM	End of Session 5. ***Complete all Toolkit investments and submit only your own team's options to Control team. No further Toolkit investments are allowed after 2:15 PM.***
2:15 PM	Break

SESSION 6 – Open Negotiations:

2:30 PM	Successful Toolkit investments are announced and implemented.
2:35 PM	New chits distributed. Continue deliberations and negotiations.
4:00 PM	Active play ceases. No further agreements will be accepted by Control.

SESSION 7 – Debriefing:

4:00 PM	Team debriefings conducted by Process Managers. Results provided to Control.
4:30 PM	Wrap up; final polling; fill out evaluation forms.
5:00 PM	Town Hall meeting.
5:30 PM	Adjourn

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