Working Paper Series

INFORMATION TECHNOLOGY AND SUSTAINABILITY: ENABLING THE FUTURE

By
Sahra Girshick, Rajesh Shah and Sissel Waage
The Natural Step, San Francisco, California

With Sections
By
Olga Meydbray, Michael Stanley-Jones, and Ted Smith
Silicon Valley Toxics Coalition, San Jose, California

June 2002

"…Two of the most powerful drivers of change within modern economies are the explosion of digital technologies and the shift toward sustainable development.

Both require us to rethink the nature of goods and services; both have the capacity to transform the relationship between governments, companies, citizens and consumers."

James Wilsdon and Paul Miller,
Digital Futures[1]

"Over the next decade or so sustainable development will constitute one of the biggest opportunities in the history of commerce."

Stuart Hart, Professor of Corporate Strategy,
University of Michigan Business School[2]

Table of Contents

List of Figures

Acknowledgements

Within The Natural Step, this report would not have been possible without the vision of George Basile. Of equal importance have been the tireless efforts of Catherine Gray and Taylor Fogelquist in articulating a new approach to technology and IT sector leaders. In addition, Jill Rosenblum assisted in design and layout of the final document.

The Silicon Valley Toxics Coalition played a key role in providing data and maps, as well as in writing sections of this report. We would like to offer our deepest thanks to Ted Smith, Michael Stanley-Jones, and Olga Meydbray.

Our sincere thanks also go to Frances Stanley-Jones—of TeleAtlas North America and a volunteer for the International Campaign for Responsible Technology GIS Research Group and Interactive Health Ecology Access Links—who offered her time in developing and refining the maps used in this report.

Michael Meuser—of Clary-Meuser Research Associates, in Santa Cruz, California—also deserves thanks for the groundwater contamination, point source pollution, and hazardous air pollutants cancer risk maps.

Richard McMurtry, of the San Francisco Regional Water Quality Control Board, and Tim Hayes—another volunteer for International Campaign for Responsible Technology GIS Research Group and Interactive Health Ecology Access Links—provided important assistance in gathering data for the maps in this report.

Frank Marquardt greatly assisted with clarity of writing in the section on business in this new century.

Finally, thank you to everyone else who devoted their time, expertise and insight in the development of this report.

Any errors that remain are those of The Natural Step authors alone.

Sahra Girshick, Rajesh Shah, and Sissel Waage
San Francisco, California
June 2002

Executive Summary

The Information Technology industry (hardware, software and services) has provided many tools to help generate and process data, communicate globally, and improve productivity. However, all the rapid advances in this sector has not made our society more sustainable. Integrated economic, ecological, and social sustainability issues have been largely overlooked by the IT sector and Silicon Valley leaders, despite the significant opportunities that these issues present to 21st century businesses.

Analysts are assessing a broader range of factors and "intangibles" to forecast business performance.[3] This report discusses the increasing relevance of integrating sustainability factors into business, including ecological and social impacts of operations.

Over the course of the past decade, The Natural Step (TNS) has advised companies around the world on integrating sustainability issues—including, ecological, social, and financial factors—into core strategy and operations. TNS, and other organizations in the sustainability field, have noted a growing need for integration of sustainability factors into information flowing within businesses. Since the IT industry has provided many tools to track, measure, and broadcast the financial performance of companies, it is in a strong position to provide tools to understand, track, and address the social and ecological performance of business. We urge the IT industry to take seize these business opportunities and to develop solutions for organizations moving towards sustainability.

The core argument of this report is that there is potential for IT to transform modern business into a more efficient, cyclical, networked, and sustainability-oriented system that pays returns to a "triple bottom line," through economic, ecological, and social prosperity.

The report also addresses some of the unsustainable practices of the IT industry. A case study of Silicon Valley draws out IT industry-related impacts that threaten the quality of life and the sustainability of the local economy. These issues include human health risks and costs related to industrial practices; intensive use of natural resources; production and use of toxic; persistent and bio-accumulative substances; water contamination, and disposal of e-waste. In addition, there are a number of social issues that has made the region less livable, such as significant income disparities, civic service delivery challenges, and citing of hazardous waste facilities. Throughout the document, opportunities are highlighted for the IT industry to be a leader in making both business and society sustainable.

The report is divided into four sections. Section one addresses the importance of sustainability to 21st century businesses and the role of IT in facilitating this shift. Section two begins to explore sustainability-related business opportunities for the IT sector. Section three outlines a few of the issues that the IT sector itself faces and offers an overarching framework for understanding sustainability concepts. The report concludes by describing a new vision for the role of IT in the future.

The report makes the following key points:

- Ecological and social issues have been largely ignored by the IT sector. In the rare instances when included in decision-making process, these issue areas are perceived of as costs and not as opportunities for profits.
- Addressing sustainability issues will require new data generation and information flows, which offers new business opportunities for IT.
- Addressing sustainability issues will almost certainly translate into increased efficiency and considerable cost-savings in operations.
- There already exist are some leaders and role-models within the IT sector.
- Applying sustainability principles to the IT sector itself will have significant impact on Silicon Valley.

In light of these challenges and opportunities, this report offers a new vision for the IT sector, as the source of innovation to produce tools for, and examples of, advancing society towards sustainability.

Introduction

> "Foresight is the key to survival. Managers able to perceive trends and weak signals where others see only noise or chaos can capitalize on the changing nature of the market to reposition their firms before new entrants become a serious threat…. Today's corporations can seize the opportunity for sustainable development."
>
> *- Stuart Hart and Mark Milstein. MIT Sloan Management Review (1999)*[4]

When the excitement of the internet's "information superhighway" abated and the downturn began, companies with vision began to focus on perceiving and investing in new trends.

One of these new trends is sustainability-oriented business, which considers, addresses, and devises solutions to prevailing ecological, social, and economic problems, while also seeking to ensure the "triple bottom line" of their own firm, through realization of economic, environmental, and social returns. The information technology (IT) sector is uniquely positioned to realize new opportunities from this shift. The need is growing for sustainability-oriented IT systems that can capture, manage, and integrate a complex range of economic, ecological, and social information for use in core business strategy and operations decision-making.

Technology Sector:
High Tech and IT Definitions
High and Information Technology (IT) is generally defined as the technology for using, creating, storing, and exchanging information in a digital format**.** The industry is typically broken into three sectors: hardware, software and services. There are also a growing list of various sub-sectors.

What is the value of the market?
In 1999, the Information and Communication Technology (ICT) market was valued at over $2 trillion worldwide, and growing rapidly. (Source: World Information Technology and Services Alliance. 2000. "Digital Planet 2000."

Leading companies such as Hewlett Packard, Ford Motor Company, and DuPont are all exploring how to apply sustainability factors to supply chain logistics and product design. These firms are part of the first stages of a larger transition from environmental management to sustainability-oriented strategy and operations. An increasing number of analysts assert that this shift is becoming integral to corporate success in the changing context of the 21st century.[5]

As both multi-national companies and governments further explore realizing "triple bottom line" returns—measured by financial, environmental and social parameters—there will be a growing need for managing complex data sets. The challenge will be tracking and integrating different types of information related to dynamics within ecological, social, and economic systems that affect businesses.

Whereas many of today's companies track linear flows, of inputs and outputs, tomorrow's sustainability-oriented businesses will incorporate cyclical flows in the development, delivery and "reverse logistics" related to returning and re-using products at the end of their use by consumers. IT will become essential to this shift by providing the information architecture to enable the cyclical flow of data through businesses. As companies move toward more complex information flow systems—and a better understanding of how to lessen environmental,

community and social impacts—more IT tools will be needed for incorporating sustainability issues in business operations.

Similar to the period of integrating internet technology into business operations, the expansion of IT and sustainability tools will have early adopters and latecomers. The early adopters will embrace the possibilities and innovate new trends. The latecomers will be either those without resources or wedded to old ways.

This report describes some of the sustainability issues that offer both opportunities and risks for companies in the IT sector. It is intended to begin a discussion about a new vision for the role of information technology in 21st century business.

The report is divided into four sections. Section one addresses the importance of sustainability to 21st century businesses and the role of IT in facilitating this shift. Section two begins to explore a few of the business opportunities ahead for the high technology and IT sector. Section three offers a framework for understanding sustainability issues and their relevance to the sector. Finally, the report concludes by describing a new vision for the role of IT in the future.

SECTION 1: 21st Century Business, Sustainability and the Pivotal Role of IT

> "…[W]e have become increasingly aware of an inescapable and disturbing fact: We will not be able to sustain our businesses over the long haul because they are based on two assumptions that no longer hold. One is that cheap, unlimited supplies of hydrocarbons and other non-renewable resources will always be available. The other is that the earth's ecosystems will indefinitely absorb the waste and emissions of our production and consumption"
>
> - *Chad Holliday, CEO, DuPont*. Harvard Business Review (2001)[7]

1.1 Business in the 21st Century: The Triple Bottom Line and Sustainability

A growing number of companies are looking to sustainability as a way to increase overall value and gain competitive advantage.[8] Bank of America, British Petroleum, DuPont, Ford, IKEA, McDonalds, Nike, Royal Dutch Shell, and Starbucks are a few of the companies exploring applications of sustainability to their businesses. Why? Sustainability practices increasingly make business sense.

Sustainability-oriented companies focus not only on economic performance, but also social and environmental performance. Investments in all three areas—as an integrated approach to business decision-making—are paying off in the form of:

- *Innovation*
  Sustainability-oriented companies continually position themselves to perceive of, and adapt to, competitive pressures and changing contexts.[9]

- *Operational efficiency*
  Sustainability-oriented re-design and re-engineering of products can significantly cut operational costs, including material and energy use.[10]

- *Brand equity*
  The enhanced brand equity and reputation that comes with more sustainable business practice attracts customers and talented employees while increasing shareholder value.[11]

- *Lower risk*
  The stakeholder engagement and environmental process focus of sustainability-oriented companies decreases risks of public relations disasters, fines, boycotts, and clean-up costs.[12]

- *Talent*
  Sustainability-focused firms find it easier to attract and to retain talent.[13]

- *Shareholder value*
  Research shows that companies pursuing sustainability-oriented business strategy have greater shareholder value than their peers.[14]

It is not surprising that sustainability-focused business practice increasingly makes economic sense. All businesses and economic systems operate within—and are fundamentally reliant upon—social and ecological systems. Corporate value creation has always been affected by three dimensions—of environmental, social, economic—rather than one. Social unrest and environmental problems have effects on business. The challenges faced by builders and contractors in contaminated neighborhoods reveals the direct links between the environment and the economy. The workers' rights issues that Nike and Gap have faced clearly show that social performance matters in how firms are perceived. In sum, environmental and social issues affect the bottom line, whether or not they are captured on balance sheets.

Forward-looking CEOs are recognizing these additional dimensions as essential to business. As DuPont CEO Chad Holliday has written, cheap, unlimited supplies of hydrocarbons and other non-renewable resources will not always be available and the earth cannot indefinitely absorb the waste and emissions of our production and consumption. Holliday states that to meet the needs of the population in the near future, we will need *three* planet earth's.[15] Or we will need to change the way that business is done.

And in the Silicon Valley there are some leaders who are trying to make IT sustainable. Rolltronics has committed itself to the triple bottom-line. It is pioneering a cradle-to-cradle semi-conductor manufacturing system, ready to license and share the technology and committed to making its employees partners in the company.

1.2 The Role of IT in Enabling the Shift to Sustainability

Information technology is positioned to play a key role in facilitating the shift toward sustainability-oriented business. As the use of IT in business grows—and both public and private demand for environmental and social responsibility increases—the need for effective sustainability-oriented IT systems will similarly expand. Figure 1 outlines a few of the present and future uses for IT in enabling sustainability.

Figure 1. A View of Future Information Technology's Sustainability Tools	
IT applications that are…	**Tools that will help to…**
Presently available	• Track and enable achievement of compliance with regulations • Reduce risks • Increase eco-efficiency (by assessing and decreasing life-cycle costs)
Currently in development and/or early models in existence	• Track full life cycle of product and service inputs, flows, and impacts • Enable sustainability-oriented product design by engineers and product designers • Create "green chemistry" and sustainable materials quality databases and services • Increase innovation and creativity, through other easily accessible sustainability information sources, improved searching functions of internet, and more on-demand software capabilities • Develop waste e-trading marketplace in which companies sell their "waste" products as raw material ("food") for other companies manufacturing process • Establish, and widely use, more sustainable circuits/chip manufacturing processes
Future arrivals	• Engage stakeholders on sustainability issues and concerns • Facilitate sustainability-oriented supply chain system decision-making • Create waste trading industrial clusters of closed loop manufacturing

Through R&D innovation and entrepreneurship, the IT industry has the opportunity to provide leadership and create solutions that will revolutionize the industrial system and address core 21st century environmental and social issues. IT can enable the shift from a "take-make-waste" economy to a closed loop system, by providing the necessary information flows that will enable cyclic industrial systems, which use waste from some processes as inputs for other processes. With such systems, and re-considered design and business propositions, waste can become non-existent. Simply stated, IT could link sustainable processes to sustainability-oriented products, the local to the global, and the present to the future.

SECTION 2: Business Opportunities for the IT Sector Related to Sustainability

2.1 Strategies for Moving Forward

Think of "e-sustainability" as using information technology tools—from sensors to databases and websites—to integrate sustainability factors into business operations. Just as using the internet dramatically altered business strategy and operations, using IT tools for "e-sustainability" will require rethinking traditional business models. In place of the current market role, a more integrated, systems-based economy will develop over time. To achieve this transformation, the capabilities of the IT sector will be expanded significantly.

For example, researchers at the Massachusetts Institute for Technology (MIT) are creating new identification tags to track products throughout their lifecycle. These tags could assess interactions with the environment and send data to various systems. Information technology can also enable a switch from products to services, such as through computer leasing programs. Already, many applications are available, but the real integration of sustainability concepts in IT and business is still to come.

This report highlights the following four strategies to create economic, social, and environmental value through the use of information technology:

- **Strategy 1: Build a *Real* e-Company: Dematerialize and Digitize**
  Technologies available today are ripe for applying throughout any company or office, including a focus on dematerializing products, digitizing documents, and teleconferencing or netcasting meetings.

- **Strategy 2: Maximize Efficiency**
  Efficiency—through sensors and computerized control of energy and material use—can provide a range of environmental benefits. Motor systems account for fully 50% of total energy use in the U.S.[16] A new generation of computerized controls with sensors and information flow could enable variable speed motors and continual adjustments to minimize energy use.[17]

- **Strategy 3: Create Tools for Sustainability**
  Combining software, networks, and sustainability-oriented thinking has the potential to create powerful tools for more sustainable businesses. Designers and engineers could use sustainability-focused databases and software to improve product design and/or dematerialize products into services. Companies could manage the supply chain in terms of minimizing ecological and social impacts.

- **Strategy 4: Network with Nature and Re-Design Products into Services**
  IT systems can capture information about how the ecological systems work, which can then be used to build better businesses. Natural systems can show, and inspire, smarter, more connected systems. In addition, nature offers examples of smarter materials and production methods, which businesses can apply through biomimicry techniques.[18]

These four strategies represent enormous opportunities for visionary leaders to reap market advantage by integrating sustainability into IT business models, products and services.

Fortunately, a small number of early adopters exist. The following sections illustrate how companies are beginning to apply elements of each strategy and finding real economic bottom line benefits.

2.2 Build a *Real* e-Company: Dematerialize and Digitize

What may seem like very standard applications of IT—telecommuting, electronic documentation, file storage, and intranet sites—are only recently being used by companies for their full potential benefits.

For example, electronic documentation is resulting in savings in paper. By storing files on laser disks or other electronic media, sending out manuals in electronic format, and offering customers online records, businesses can save large quantities of paper, staff time, and money. In addition, through a shift to electronic record storage, companies have the potential to also save money in reduced warehouse space. Figure 2 highlights a few other efforts in which firms are using IT tools to save money and move in a more sustainable direction.

Figure 2. Profits for People, Planet and Company: IT innovators

- XEROX **remanufactures or recycles** 95% of their **electronics equipment**. This effort saves several hundred million dollars annually and keeps millions of tons of waste from the landfill.[21]
- Weirton Steel Corporation installed **computerized controls and sensors**, which saves $12 million annually on fuel and is polluting less.[22]
- Estee Lauder used **a reverse logistics software application** and saved over $30 million in one year from reduced volume of destroyed products, while also preventing the materials from going into a landfill.[23]
- AT&T initiated a **telework program,** saving the company $125 million per year in reduced real estate costs and increased productivity. Plus, there is the added environmental benefit from keeping cars off the road.[24]

These measures represent sound first steps. However, to truly build a company that takes advantage of information technology for sustainability purposes, businesses should consider turning products into services.

2.3 Maximize Efficiency

A Fall 2001 *Business Week* special issue described the current period as the "era of efficiency." According to the journal, the most successful companies are the ones that, "either achieved the efficiency long promised by the technology revolution or that sell products and services that help others improve their bottom line."[33]

The number one company on that issue's "Top 100 Info Tech" list was Celestica, which uses IT to stay extremely lean, fast, and efficient. As *Business Week* points out, "Having all the plants wired proved critical. Celestica keeps one huge database of parts it buys…" Celestica is using IT to do more work, but IT systems can also be an effective tool in becoming more energy efficient or reducing waste.

Another example of growing use of IT for efficiency is evident in use of computers in automobiles. Systems like those that control the energy flows of Rocky Mountain Institute's HyperCar provide a crucial element in the new generation of hybrid vehicles.[34] The Toyota Prius, a hybrid vehicle, uses an onboard computer that factors in inputs from the battery, accelerator pedal, engine, and other parts and then selects the correct energy source and other outputs in order to maximize energy efficiency. Toyota's website claims the Prius' computer system is, "like having an efficiency expert onboard at all time."[35]

The market in new "clean" transportation is predicted to grow from $2 billion today to $10 billion in 2005 and $48 billion by 2010.[36] IT systems will play an important role in guiding both the development and deployment of clean transportation technologies.

Since motors account for over 50% of total U.S energy use, one of the most powerful uses for computerized efficiency-oriented controls is clear. Motors traditionally have just two settings, off and on. However, sensors and computer-based controls can create variable speed motors that can cut the energy use—and accompanying emissions—of industrial motors in half.[37] Pairing new variable speed motors with a networked system of sensors and computer controls allows for much higher energy efficiency. Sensors throughout the supply chain and manufacturing process can provide real time information flow.

All of these factors are increasingly critical, as Vinod Khosla asserts:

> "Corporations will not be competitive five years from now unless they have near-real-time information systems."[38]

One company that has implemented exactly such a system is Weirton Steel Corporation, the 8th largest U.S. steel producer. Within two years of replacing antiquated control equipment with computerized controls, the plant has been able to achieve a 30% reduction in blast furnace gas and waste steam releases and a 50% reduction in the amount of fuel it purchases. In fuel savings alone, Weirton has reached $12 million in annual savings. The system also allows Weirton to go one step farther and create a networked system that will allow real-time communication between 22 different operating units. In so doing, Weirton will be able to continuously evaluate and optimize flows, thus continuing to save on energy, emissions, and fuel costs.[39]

As transparency is increasingly demanded by corporations in a post-Enron era, and as the parallel trend of Corporate Social Responsibility reporting also grows, information flow in the coming years will include additional aspects of operations. That is, another layer of information flow within businesses will relate to complete understanding of, and accounting for, a firm's environmental and social impacts. Sustainability-oriented IT systems are an essential way to enable this task, particularly within large multinational firms.

2.4 Create Tools for Sustainability

After the foundations of hardware and operating systems were firmly established in the late 20th century, software applications emerged to enable customer relationship management, supply chain management, e-commerce, and many other business functions. Every new category brings a host of competing designs.

There are a growing number examples of concepts and practices that represent early forays into the field of software for sustainability-oriented business, including:

- **Logistics Tracking**

  One study by AT Kearney, estimates that inefficiencies in supply chain can waste up to 25% of a company's operating costs. Therefore, even a 5% reduction in waste throughout the supply chain can double a typical company's profit margins.[40]

  Examples of sound investments in logistics systems abound. Estée Lauder spent $1.3 million on a reverse-logistics IT system of scanners, business-intelligence tools, and a data warehouse. In the project's first year, it recovered more than it invested in the effort through reduced staffing and decreased costs. In additional, destroyed products—that end up in landfills—plummeted from approximately $60 to $30 million a year.[41]

  Home Depot also found a creative application for IT in the supply chain. By having sales associates walk through the aisles and electronically record what needs to be restocked, the company has virtually eliminated their need for warehouse space. 85% of their merchandise moves directly from manufacturer to retail store, saving energy-using storage space and transportation costs.[42]

  Increasing efficiencies in these ways is the first step to integrating sustainability factors into the business. IT is enabling this shift.

- **Data and Knowledge Management**

  The companies that create systems to capture sustainability information flow will become invaluable in the future. The field is already growing.

  For example, Ecos Technologies (http://www.ecostech.com), created a "Knowledge Management System" to track environmental information flows. Their software system is helping large businesses, such as Timberland and Unisys, in supply chain management,

decision making, and product design. Natural Logic (http://www.natlogic.com) is creating a software system for assessing flows, as are other entrants into this expanding field.

- **Product (Re)Design**

A product design tool that could integrate environmental and social considerations into engineering plans could offer an invaluable resource to companies. However, one of the current obstacles to creating sustainability-oriented products is the time and expense required to gather information and conduct analyses, such as life cycle assessments. This issue offers a number of business opportunities for software and computing power for assessing products.

For example, researchers at Carnegie Mellon's Green Design Initiative[43] have developed a software program to measure the environmental impact per dollar of product. In addition, the Alliance for Environmental Innovation has created an IT-enabled tool to guide designers in selecting the least environmentally damaging material, process, and products to use.[44]

In the future, sustainability software programs will include additional components, such as assessing working conditions in the country where materials and products originate and considering various measures of sustainability on an array of materials and products.

2.5 Network with Nature and Re-Design Products into Services

One of the most exciting new strategies in business today—used in companies from Interface carpets to engineering firm CH2M Hill—is to learn from nature how to build better products and improved business models. Janine Benyus details the concept of designing with nature in mind in her 1997 book *Biomimicry*.[45] Mimicking nature's approaches to solving problems can be readily applied to IT systems to create new business opportunities.

For example, a business can start by asking completely new questions, such as: What can a computer chip learn from a leaf? What can computer networks learn from an ant? These questions are not as far out as they may seem, and scientists and business leaders are already considering possible answers.

Ants have emerged as a possible source of inspiration for innovating faster networks. Ant communication models are based on chemical signals, which are used to determine the most efficient pathways to gather food and supplies. The power of ants' approach to conveying information is in "swarm intelligence," in which large numbers of local interactions can lead to global problem solving.

This observation has led to the idea that "virtual ants" can be set loose as well, gathering and sorting information from databases. With such a model, web search engines could become more useful and more organized. According to Steven Johnson, author of the 2001 book *Emergence*, ants build "a system where macro-intelligence and adaptability derive from local knowledge."[46]

Learning from Nature:
Potential Biomimicry Applications

- **Cell Membranes**: A design for a super filter desalination device
- **Mussel Adhesive**: An underwater adhesive that works without catalysts or primers
- **Teeth and Bones**: Layering technique for 3-D structures
- **Mother of Pearl**: Super strong coatings for airplane wings and cars

(Source: http://www.biomimicry.org/case_studies_materials.html)

Several information technology companies are currently assessing how to merge ant models into business ideas. The BiosGroup, a Santa Fe-based company that develops science-based software, has studied ant behavior to develop optimization software for supply networks. Their clients include Ford Motor Company and Southwest Airlines, among other Fortune 1000 companies.[47] Other companies are considering ant behavior as a model for organizing the web, peer-to-peer computing , and even, urban planning.[48]

Nature can also play a role in computer hardware design through applications of biomimicry. (For more information, see adjacent box and http://www.biomimicry.org.)

In addition, scientists are exploring ways in which manufacturing can be more intelligent and have less impact. For instance, Xerox PARC researchers are creating "smart matter" and devices that allow microscale optical and mechanical systems to take the place of traditional manufacturing systems.[50] DuPont has already created a complete chemical plant on just three silicon wafers and capable of synthesizing 18,000 kg/yr of chemicals.[51] From an environmental standpoint, this process has several benefits, including the reduction of storage, transportation, and excess use of chemicals. In addition, a microscale plant might be able to use ingredients available almost anywhere (sunlight, water, air) and transform them into substitutes for the myriad of petroleum-derived chemicals currently in the industrial system. The potential for transitioning the chemical industry towards a more biologically-based industry—using sustainable natural resource management practices—is an area for a great deal of further research.

These measures represent sound first steps. However, to truly build a company that takes advantage of information technology for sustainability purposes, businesses will consider turning products into services.

Traditionally, the purchase of new products—such as, computers, desks, and office carpeting—has involved a one-time cost resulting in ownership of an item and the responsibility for disposal at the end of its use. This model has created an economy where a mere 1% of the materials used in America remains in use six months after they are sold.[52] What will transform this "take-make-waste" economic system is a more dematerialized, service-oriented, cyclical economy?

A growing number of products are becoming dematerialized and even "servicized" as companies consider fundamentally transforming their business models from product-makers to service-providers. This approach offers a key benefit of establishing long-term relationships with clients, as products are longer-lived and companies offer on-going support for the items. The real engine

underlying this business model is information technology. Ensuring ongoing information flows will be crucial to the provision of quality service.

One early example of a shift to a service-oriented business is the replacement of car ownership with "car sharing." In cities around the world—including Paris, Tokyo, and San Francisco—car share programs have been established to offer inexpensive access to cars for short periods without paying for insurance or other associated expenses of ownership. At City CarShare in San Francisco, cars are reserved through an internet reservation system that can immediately locate which parking lots have cars available for use. Drivers are given an electronic key with a computer chip inside.[53] This type of information system—that captures data and transmits it throughout a networked system—offers an example of how IT can enable the transition from a product to a service-based business model.

However, even the most cyclical service-based company may not be sustainable without attention to addressing human needs and social issues. Indeed, meeting basic human needs may become a core business strategy of a sustainability-oriented company.

Information technology can, and already is, providing a necessary tool for the integration of social aspects of sustainability into business. For example, World Resource Institute's Digital Dividend website maintains a clearinghouse of projects focused on bridging the digital divide, the gap between those with access to digital information and those without, through technology and business.[54] Hewlett Packard has begun to consider how to meet the information needs of the 4 billion humans on the planet without access to computers as a business strategy.[55] The company's "e-Inclusion Solutions" project is aimed at creating profitable solutions for bridging the gap between technology-rich and technology-poor countries. Current approaches include establishing an internet center in Ghana and using handheld computers with coffee farmers in Costa Rica to help them achieve organic certification.

2.6 Innovating for Sustainability

An increasing number of companies have begun to address various aspects of sustainability, and at least one is developing integrated efforts. Rolltronics is taking the lead in sustainable manufacture of semi-conductor devices and is committed to the triple bottom-line:

- Rolltronics technology is "cradle to cradle"
- No lead is used in their products
- Less energy used (using temperatures under 250 degrees compared to industry standard of 700 degrees)
- Use PET plastic film that is completely recyclable: Silicon circuit is only 2% of material content
- Smaller footprint: manufactured in one small plant compared to industry standard of many large dispersed plants to make final product
- Employees are owner/partners.

The Rolltronics model does show that Silicon Valley has visionaries who are trying to go "all the way" in sustainability. Figure 3 offers a list of illustrative approaches to applying sustainability within IT companies.

Figure 3. Illustrative Approaches to Applying Sustainability Concepts to IT Businesses

CREATING IT SYSTEMS TO MONITOR ENVIRONMENTAL DYNAMICS

Conservation International has partnered with Intel to create maps of biodiversity "hotspots" for use in planning conservation efforts.[56]

Opportunities exist for IT-enabled precision agriculture and forestry techniques.[57]

DEVELOPING SOFTWARE TO INTEGRATE SUSTAINABILITY INTO DECISION-MAKING

- Integrating environmental management functionality into Enterprise Resource Planning (ERP) systems, SAP has already launched their Product Lifecycle Management tool (http://www.sap.com).[58]
- According to the nonprofit organization Cool Companies (http://www.cool-companies.org), "Analysts at Ernst & Young estimate that collaborative planning systems between manufacturers and suppliers could reduce inventories by $250 to $350 billion across the economy, roughly 25 to 35 percent of finished goods stock. IBM says its e-commerce solutions are delivering inventory savings as high as 50 percent for some of their customers."[59]
- Companies such as Ecos Technologies (http://www.ecostech.com), Natural Logic (http://www.natlogic.com), Greenware (http://www.greenware.com), and Ecostream (http://www.ecostream.net) are all creating new tools to manage environmental information while saving time and increasing value.
- The MERGE tool (http://www.environmentaldefense.org/alliance/merge/merge.htm), created by the nonprofit Alliance for Environmental Innovation, enables product designers to gauge environmental impacts while developing the product, allowing for cost savings and environmental benefits.

ENABLING INFORMATION TRANSFER THROUGH ON-LINE SYSTEMS

- U.S. Department of Energy Best Practices Database (http://www.oit.doe.gov/bestpractices/) offers tools and case studies for improving energy efficiency in business.
- ThinkCycle (http://www.thinkcycle.org), an online "collaborative design space," is using an open-source model website to tackle clean water, health care, and other sustainable development challenges.

ADDING VALUE TO TECHNOLOGY EQUIPMENT THROUGH ENVIRONMENTAL FEATURES

- The 2000 Roadmap of the National Electronics Manufacturing Initiative says of the four leading trends in the high tech industry: "Environmental profile of products is becoming more important."[60]
- A manager at Panasonic said, "We've increased our sales dramatically, and were able to get contracts away from several entrenched competitors solely because we had EnergyStar qualified TVs."[61]
- Intel, Transmeta and Advanced Micro Devices all introducing energy-saving chip lines by 2003.[62]

The field of IT and sustainability also offers numerous opportunities not only in corporations, but in governments and communities as well. For example:

- **LINCOS** (**L**ittle **In**telligent **Co**mmunitie**s**) (http://www.lincos.net/html/eng/menu.html) is a new effort by *Fundaciòn Costa Rica Para el Deserrollo Sostenible* that uses shipping containers that convert to a wireless communications office. The networked, portable offices are used for telemedicine, soil and water analysis, and educational resources in Costa Rica and the Dominican Republic. Hewlett Packard and MIT Media Labs have helped implement the project.

- **Greenstar** (http://www.greenstar.org/) creates solar energy powered community centers with connections to the internet for a growing list of rural areas, including parts of India, Jamaica, and Ghana.

- **TaraHaat** (http://www.tarahaat.com) is designed to help rural Indians, with visuals and audio for illiterate users, as well information on farming, education, and jobs.

Many additional examples are developing and documented at the Centre for Sustainable Communications website, a UK-based nonprofit (http://www.sustainit.org/). The website also discusses the opportunities for decreasing the environmental impacts of computer hardware. Figure 4 presents a few examples of best practices from SustainIT and examples of how IT has the potential to catalyze sustainability-oriented enterprises, products, and design.

Figure 4. Examples of Best Practices from SustainIT (http://www.sustainit.org/)	
Application Area	***Example***
Business	IBM Japan has implemented an **integrated mobile office system**, including 10 satellite offices and working from home. They now have over 4,000 employees—approximately 20% of workforce—taking part in telework options. (A case studying outlining the financial and environmental savings of the project, is at: http://www.sustainit.org/Files/CaseStudies/PDFcases/ibm.pdf)
Health	**Video-conferencing at hospitals** in the UK is enhancing training for nurses, and saving money by reducing the cost of training sessions. The program is even sharing information and training with health care facilities in South Africa. (For more information: http://www.sustainit.org/Files/CeStudies/PDFcases/oswalds.pdf)
Education	**Virtual schools**. In rural Colombia there are 28 schools using networked computers for online learning, teacher training and community collaboration. Virtual universities are also flourishing around the world, including the African Virtual University (http://www.avu.org/).
Communities	**"Telecottages"** have been set up in rural England, providing new jobs, community centers, access to information sources, and skill training. (http://www.tca.org.uk/).
Communities	**Scorecard** (http://www.scorecard.org), a project of Environmental Defense, provides information on local and national health and environmental impacts to the general public.
Government	**Centrelink** (http://www.centrelink.gov.au/) in Australia is the federal government's effort to provide a "linked up" electronic source for government services. With web and telephone services available at over 400 access sites, Centrelink now reaches remote and rural areas that previously were almost inaccessible. The centralized computer system and networked access sites save the government time and money.

The strategies laid out above offer immediate pathways forward. However, they may be just the tip of the iceberg when it comes to opportunities for IT in enabling sustainability.

SECTION 3: The Relevance of Sustainability to IT Companies

Just as sustainability has become a pressing issue for many multinational corporations, understanding the environmental and social impacts of the IT sector will become increasingly essential in the 21st century. Sustainability analyses begin with several very simple questions:

- What is sustainability?
- How does it apply to my organization?
- What is the future vision of my organization, in light of sustainability issues?
- Where is the organization today, in terms of economic, environmental and social issues?
- How do we move from where we are today to reach our sustainability-oriented enterprise vision?

In order to begin this discussion, the following section provides an overview of a sustainability assessment of the high technology sector, based on The Natural Step Framework. It offers another vantage point on understanding impacts, opportunities and potential ways forward as businesses. (Appendix A explains The Natural Step Framework in detail.)

3.1 The IT Sector and Silicon Valley

Silicon Valley offers a case study of the impacts of the high technology sector on a region. Although sustainability issues will be different in other locales, this assessment provides an overall approach and highlights issues that may be relevant to other regions in which the IT sector is present.

Key Facts About Silicon Valley

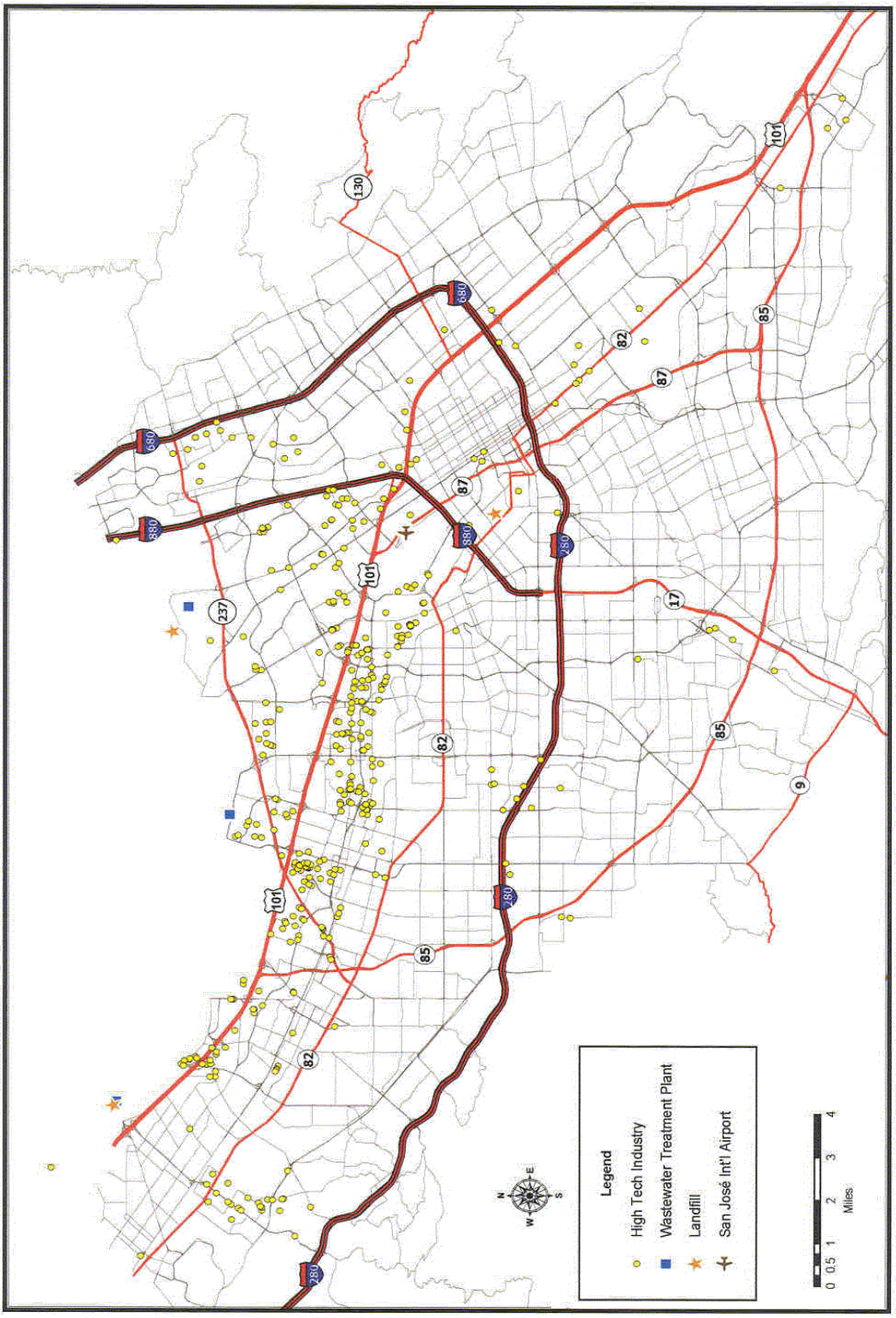
- Located South of San Francisco, California
- Comprised of Santa Clara County, plus adjacent areas within San Mateo, Alameda and Santa Cruz counties
- Population over 2.5 million
- 35% of residents were born in a foreign country
- 88% of adults have at least high school degree
- In 2000, average wage per worker was $66,400
- A representative household in the bottom 20% of the income distribution earns $40,000
- A representative household in the top 20% earns $149,000

(Source: Joint Venture: Silicon Valley Network. *2001. Index of Silicon Valley.* http://www.jointventure.org)

Silicon Valley developed within a region of world-class universities and with the potential to create economic value from innovation. Hardware manufacturing was established in the Valley in the middle of the 20th century, furthering the area's reputation as a center for new ideas. By the 1980s and 1990s, the area had become the internationally recognized capital of information technology and the internet.

This shift was manifest in land use changes. Orchards were replaced by industrial parks and sub-divisions. The technology sector spread throughout the area south of the San Francisco Bay, as is clear from Figure 5, which lays out the geography of high technology manufacturing.

Figure 5. Geography of High Technology Manufacturing in Silicon Valley, California



3.2 Community and Social Impacts of the IT Sector in Silicon Valley

The most notable community and social impacts of the IT industry, in the Silicon Valley, include:

affecting human health, through materials and manufacturing;
increasing the disparity between rich and poor, as well as the gap between people with access to high technology-based information systems and those without access;
contributing to dynamics that result in housing shortages and roadway congestion,
offering appropriate salaries for civic services—such as, education, police, and fire departments—in light of rising costs of living, and
exporting sustainability impacts through outsourcing.

Each of these issue areas is discussed below.

- **Human Health Impacts**

The high technology sector has impacts on human health that have been documented within both the workers and communities surrounding hardware manufacturing companies.[63] In the only comprehensive, long-term study of the electronics industry and its health impacts, researchers found that although industry workers have a fewer injuries than heavy manufacturing, they have a higher rate of occupational illness.[64]

Figure 6. Computers and Human Health[65]

In general, electronic equipment is a complicated assembly of more than 1,000 materials, many of which are toxic to humans. For example, several of the most commonly used items include:

lead and cadmium in circuit boards,
lead oxide and barium in computer monitors' cathode ray tubes,
mercury in switches and flat screens, and
brominated flame retardants on printed circuit boards, cables and plastic casings.

Comprehensive health impacts of combinations of these and other chemicals in the products are not known. However, it is widely known that the production of computer components—such as, semiconductors, printed circuit boards, disk drives and monitors—use significant amounts of toxic gases, acids and industrial solvents.

While there is a perception that high tech is a "clean industry," the majority of high tech assembly workers–often immigrant, women of color–work in a context with hazardous chemicals and some of the lowest paying jobs in the industry. These workers experience disproportionate impacts on their health compared to employees in other sectors. For example, many workers in chip manufacturing are reporting cancer clusters and birth defects.

(Contributed by: Silicon Valley Toxics Coalition 2002 (For further information see http://www.svtc.org))

Another concern emerges from the long list of chemicals used by semiconductor plants that are frequently changed due to innovations in the industry.[66] The issue is that the speed of new

developments seldom offers sufficient time for complete testing the health safety or the interaction with other chemicals. To date, the Semiconductor Industry Association (SIA), the industry group of all the major chip manufacturers, has opposed conducting health studies.[67] Even when their own Scientific Advisory Committee recommended that the SIA, "commission an epidemiological cohort study of wafer fabrication workers,"[68] the industry association responded with a cautionary press release that indicated they would conduct a preliminary review before undergoing the recommended health study.[69]

The human health effects of the technology sector commonly include reproductive problems among female workers. A recent study found miscarriage rates among wafer fabrication plant workers to be 40% higher than that of other women in the high tech industry.[70] Additionally, a 1992 IBM assessment confirmed previous findings that women workers were subject to increased rates of miscarriages from handling specific chemicals.[71] Although more restrictive handling protocols have been adopted by IBM following the study, there remain unanswered questions about the causes of the reproductive risks and how to ensure that protection measures are indeed reducing these risks among workers.[72]

Figure 7. Human Health and Computer Chemicals: Brominated Flame Retardants

Of all the chemicals found in computers, brominated flame retardants (BFR) may have the most dramatic effects on Bay Area residents. BFRs are found and used in the plastic casing of computers and several other products, and are part of the chemical family PBDEs (Polybrominated Diphynylethers). PBDEs are considered potential endocrine disrupters, which are substances suspected to cause developmental and reproductive health problems.

A recent study found the *highest human concentrations ever reported (in the world) of PBDEs in the breast tissue of San Francisco Bay Area women.*[73] Nationally, the concentration of PBDEs in human breast milk is rising exponentially, doubling every five years.[74] Though data gathering and analyses are ongoing, studies to date highlight one of many examples of public health implications from the high tech industry.

(Source: Silicon Valley Toxics Coalition (For more information, please see: http://www.svtc.org))

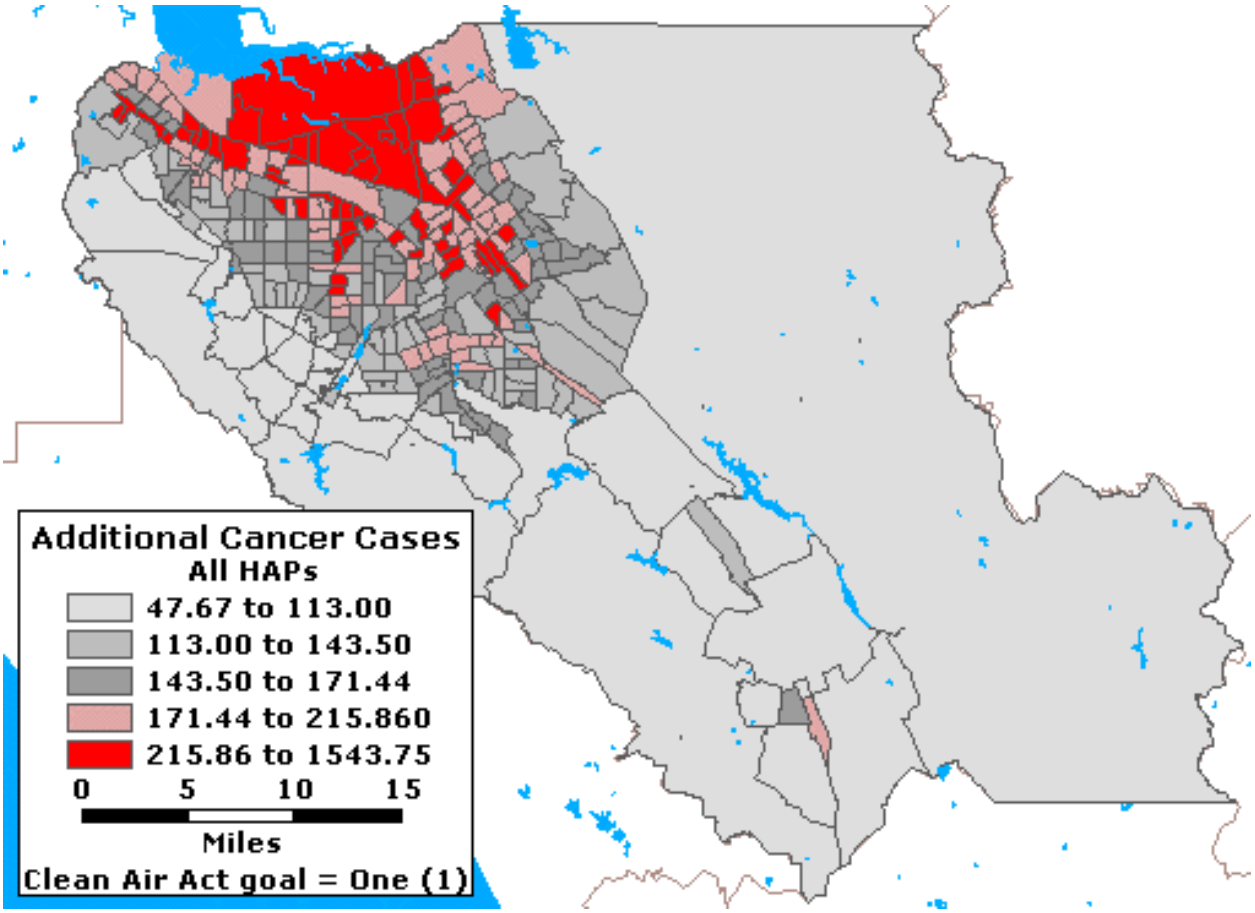
Other human health impacts have arisen from computers following the end-of-life of a machine and its disposal. The chemicals in components can leach into the environment when discarded, with the potential to affect health well after the manufacturing process is over.[75] These effects greatly broaden the geographic area of human health impacts, from the local production area to other areas around the world where technology equipment is used or discarded. The growing piles of "e-waste" globally represent potential non-point-source health impacts related to the high technology industry.

To illustrate some of the human health risks of living in the Silicon Valley, the Silicon Valley Toxics Coalition (SVTC) created the Cumulative Exposure Project Eco-Maps. Using data from the U.S. Environmental Protection Agency's Cumulative Exposure Project (U.S.E.P.A./CEP), these maps visually represent the areas at risk from 118 different Hazardous Air Pollutants (HAPs). These HAPs include pollutants from high tech manufacturing, transportation, refineries, as well as other sources. The SVTC website

(http://www.svtc.org) shows the entire series of geographic and demographic maps using the U.S. E.P.A. data.

Figure 8 presents a map of the cancer risks in the Santa Clara county area. The map reveals that an individual living in Santa Clara County has a cancer risk ranging from 47.67 to 1543.75 in one million, which is above the one in a million goal established in the Clean Air Act of 1990.

Figure 8. Map of Additional Cancer Cases from Hazardous Air Pollutants



HAPs = Hazardous Air Pollutants

NOTE: *Legend represents additional cases of cancer, exceeding the one per million people U.S.E.P.A. goal. For example, the darkest red areas have 215.86 to 1543.75 more cases of cancer per million people due to the cumulative exposure of 118 Hazardous Air Pollutants (HAPs).*

All of this data clearly shows that the information technology sector has had, and has the potential to continue having, impacts on the health of Silicon Valley residents. Figure 9 discusses some of the specific legal implications computer firms have had to face in response to worker and community health concerns.

Figure 9. Legal Implications of Links Between the High Technology and Human Health[76]

In 1982, the perception of high technology as a "clean" industry was shattered. A birth defect and cancer cluster was discovered in South San Jose, due to drinking water contamination by the Fairchild Semiconductor Plant. Although the plant was subsequently closed, many lives were disrupted and the effects of the technology sector were vividly illustrated. Personal injury lawsuits were filed against Fairchild for health problems caused by exposure to toxics. In July 1986, the lawsuits were resolved for 530 residents in a multi-million dollar settlement.

Fairchild Semiconductor Contamination Case Details

- 17 children were born with major cardiac birth defects
- 60 families suffered miscarriages
- 530 people filed suits for illnesses related to drinking contaminated water
- 5 residents died from cancer before the suits were settled

In response to concerns raised by health professionals and workers in the industry, three epidemiological studies were conducted in the 1980s and 1990s examining the rate of miscarriages among women working with industrial solvents in tech "clean rooms." Each of the three studies—conducted by Digital Equipment Corporation, IBM and an industry-wide analysis undertaken on behalf of the Semiconductor Industry Association—identified statistically higher rates of miscarriages than were expected in other worker populations.

More recently, IBM and National Semiconductor have also been involved in lawsuits filed by several hundred of their employees related to illnesses—primarily cancer and birth defects—that claimants assert are due to working with chemicals in the semiconductor industry. Brain cancer, lymphomas, breast cancer, miscarriages, sub-fertility, and complex birth defects are among the most startling health issues among workers at IBM "clean room" manufacturing facilities in New York, Vermont and San Jose. Similar health problems have been reported at National Semiconductor's, semiconductor manufacturing facilities in Santa Clara and Scotland.

Currently, over 200 IBM workers and their offspring are engaged in lawsuits for health impacts due to chemical exposures on the job. The first case set for trial was settled last February for a child with devastating birth defects whose parents both worked in the IBM "clean rooms." Trials for other "clean room" workers' children—and for workers with lymphoma, multiple myeloma and testicular cancer—are set for September 2002 in New York.

(Contributed by: Silicon Valley Toxics Coalition (for further information please see: http://www.svtc.org))

Income gaps

The IT sector, in Silicon Valley as well as other areas, is stratified and includes a significant range of salary levels. Engineers, designers and business people represent the upper echelon, with many highly-educated, well-paid, males. At the other end of the spectrum are the line workers, comprised of predominantly immigrant females. A 2001 Working Partnerships report noted that:

> "The rise of high-tech and information technology has fostered the growth of a local economy shaped similar to an hourglass. At one end is a growing number of well-compensated positions in management and highly skilled technical fields. However, at the other pole we see a far greater expansion of low paying and even lesser skilled technical positions."[77]

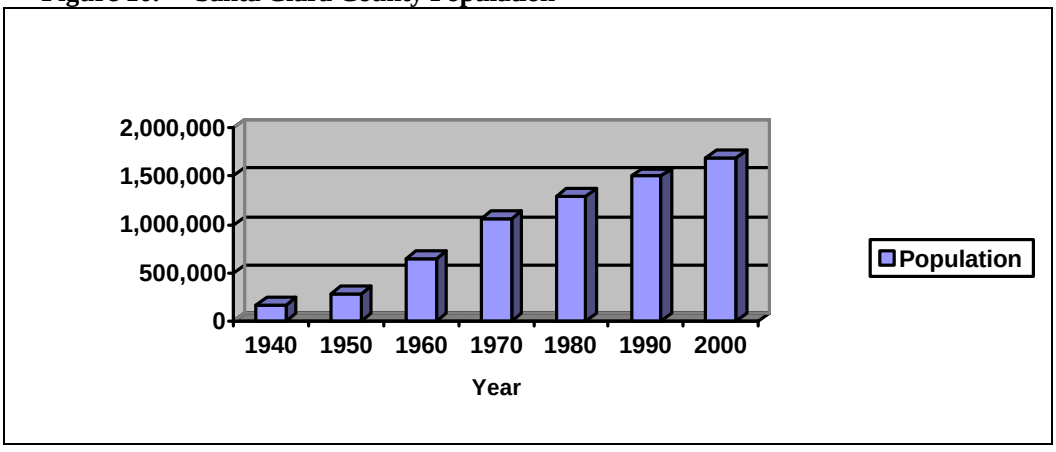
The high tech industry commonly uses temporary and contract workers, even for long periods of time, without the benefits the regular workers receive. Additionally, there are few, if any, active unions at Silicon Valley electronics firms. The lowest paid group of workers have seen little rise in the standard of living compared with many others in Silicon Valley.

Increased Population and Housing Shortage

During the second half of the 20th century, both jobs and population increased in the Silicon Valley area, as revealed in Figure 10. Housing, however, did not keep pace.

In 2000, jobs in Silicon Valley grew at four times the rate of housing production, continuing to cause the long-term trend of housing shortages. [79] However, in 2001, the rate of housing growth surpassed job growth for the first time in ten years[80]. Still, the costs of housing continue to be among the highest in the nation. Only 15% of houses are affordable to median-income households.[81]

Figure 10. Santa Clara County Population [82]



Education and Civic Services

Attracting high quality teachers has emerged as an ongoing problem in an area where a beginning public school teacher would have to pay around 75% of his or her salary to afford the average one-bedroom apartment.[83] Not surprisingly, the rate of Silicon Valley teachers who are not fully certified climbed from 9% to 13% from 1997 to 2000, an indicator that more teachers are coming in with only the bare-minimum, "emergency," requirements.[84]

The need for quality education is clear. Perhaps most vividly illustrating this need is the fact that in the Silicon Valley, African American, Hispanic, and Pacific Islander students often fall below state averages in percent of students completing college entrance requirements.[85]

Digital Divide

At a global and local level, there is a gap—or "digital divide"—between those who have access to information resources and those who do not. There are more telephones in Tokyo than the entire continent of Africa. In Bangladesh, a computer costs an average of eight years pay.[86] At a global level, lack of access and equipment is the major focus of the digital divide.

However, at the local level—and within Silicon Valley—the digital divide strongly manifests along lines of education, income, and race. For example, in 1999, an American child in a low-income Caucasian family was three times as likely to have internet access as a child in a low-income African-American family.[87]

Fortunately, due to increasing attention to these issues in the late 20th and early 21st centuries, there are efforts to address and narrow these gaps. Silicon Valley technology companies have contributed volunteer time and technology equipment donations. Targeted programs—such as, San Francisco's OpNet, Santa Clara's MentorGirls, and East Palo Alto's Plugged In—are all helping to increase access and skills, as well as the potential for high-tech employment.[88]

These efforts illustrate that when the sector's power of innovation is applied to a problem, significant gains can be made. If this same level of dedication is applied to other problems, the future of the region has the potential to hold continued promise from multiple perspectives, including the potential for integrated ecological, social, and financial sustainability.

Outsourcing

In Silicon Valley there has been a growing trend toward outsourcing production of high tech equipment. Many widely recognized brands currently focus on design, engineering, and marketing within their Silicon Valley offices, and manufacture in other parts of the world.

The growth of outsourcing is expected to skyrocket in the next few years. Robertson Stevens estimates that the current 18% to 22% of outsourced activity will expand to 60% to 70% in the long term.[89] The result of this increase in outsourcing, particularly without changed practices, has to potential to translate into more areas polluted and transformed by high tech manufacturing, especially in Asian countries, where environmental and labor laws are often more lenient than in the U.S.

Globalization of Silicon Valley: Sustainability Impacts

Fifteen to twenty years ago much of the chip manufacturing of chips was concentrated in Silicon Valley and a few other places within in the United States. Today, most semiconductor manufacturing takes place in internationally, including Ireland, Scotland, Taiwan, Malaysia and China. Other components such as disk drives, circuit boards and monitors are manufactured in Thailand, Singapore and the Philippines. Electronics assembly has been growing in many additional countries including Mexico, Costa Rica and Eastern Europe. While there have been some improvements made, many of the environmental and health problems that have been documented in Silicon Valley are beginning to emerge in these other areas.

(Contributed by: Silicon Valley Toxics Coalition (http://www.svtc.org))

3.3 Environmental Impacts of the IT Sector in Silicon Valley

Not surprisingly, some of the most significant environmental impacts of the technology sector arise from the manufacturing and disposal of computer hardware. The ecological impacts of the sector in the Silicon Valley, include:

- intensive use of natural resources;
- production and use of toxic, persistent, bioaccumulative substances;
- contributions to contaminants in water;
- creation of materials and products that ultimately become hazardous waste and electronic waste, and
- participation in dynamics leading to urban sprawl.

Each of these environmental impact areas is discussed below.

- **Intensive use of natural resources—especially water and energy—in manufacturing and plant development.**
  As in many other contemporary industrial processes, the high technology sector uses considerable inputs. As an illustration, Figure 11 provides an overview of the uses and amounts of key natural resource-based inputs needed for chip manufacturing. Perhaps most surprising is that a substantial amount of the resources used in chip manufacturing quickly become waste. One estimate is that over 99% of materials do not end up in the final product.[90]

Figure 11. Overview of Resource Use In Semiconductor Manufacturing

Resource	*Illustrative Uses*	*Quantities*
Energy	• Air conditioning • Air filtration • Water filtration	240,000+ kilowatt hours, per day, per plant
Water	• Wafer fabrication and cleaning • Air conditioning	2-5 million gallons, per day, per plant
Land and Building Materials	• Fabrication plant • Concrete columns • Clean rooms	*Average new plant with 1 million sq. ft space:* • 150 miles electrical wire • 80 miles pipe • Concrete for 15 miles of road • 3,000 miles of reinforcing steel

(Source: Mazurek (1999): 29, 48, and 49.)

- **Production and use of toxic substances**

Producing computer chips requires hundreds of different chemicals and gases. Many of these chemicals are known carcinogens. Although the high tech industry has a relative low use of chemicals compared with the other industries, the human health impacts noted above remain a cause of concern.[91] Figure 12 reviews a few specific toxic substances used in manufacturing and the quantities released into the environment, which reveals emissions reductions in recent years.

Figure 13 and Figure 14 are drawn from an interactive map (http://www.svtc.org) that shows the location of hundreds of point sources where toxics are found in the Silicon Valley, many of which correspond with the areas in which manufacturing facilities are located. The interactive capabilities of the map allows users to find detailed information about each specific location, types and levels of pollutants, and contact information. Figure 14 provides a sample close-up map, illustrating the level of detail the interactive website provides.

Figure 12. Santa Clara County Manufacturing[92]

As of 1999, the latest Toxics Release Inventory (TRI) data showed that in Santa Clara County, 48 companies, out of the hundreds of facilities in the area, emitted roughly 100,000 pounds of toxics listed on the TRI into the county air basin. Given that this study examined only a very small subset of companies—which are in the Electrical and Electronic Equipment sector, employ more than ten employees, and use over 10,000 pounds of any chemical on the TRI list of 667 chemicals—it is likely that there are far greater quantities of toxic chemicals emitted into the air each year from the high-tech electronics industry alone.

Within recent years, however, the air emissions from high-tech manufacturing facilities have been reduced drastically as compared to previous years. For example, in 1989, 1.6 million pounds of emissions were released into air, as compared to 100,000 pounds in 1999. It is important to note, however, this progress must be evaluated within the context that during the same period of time, many manufacturing facilities have moved out of state and out of country.

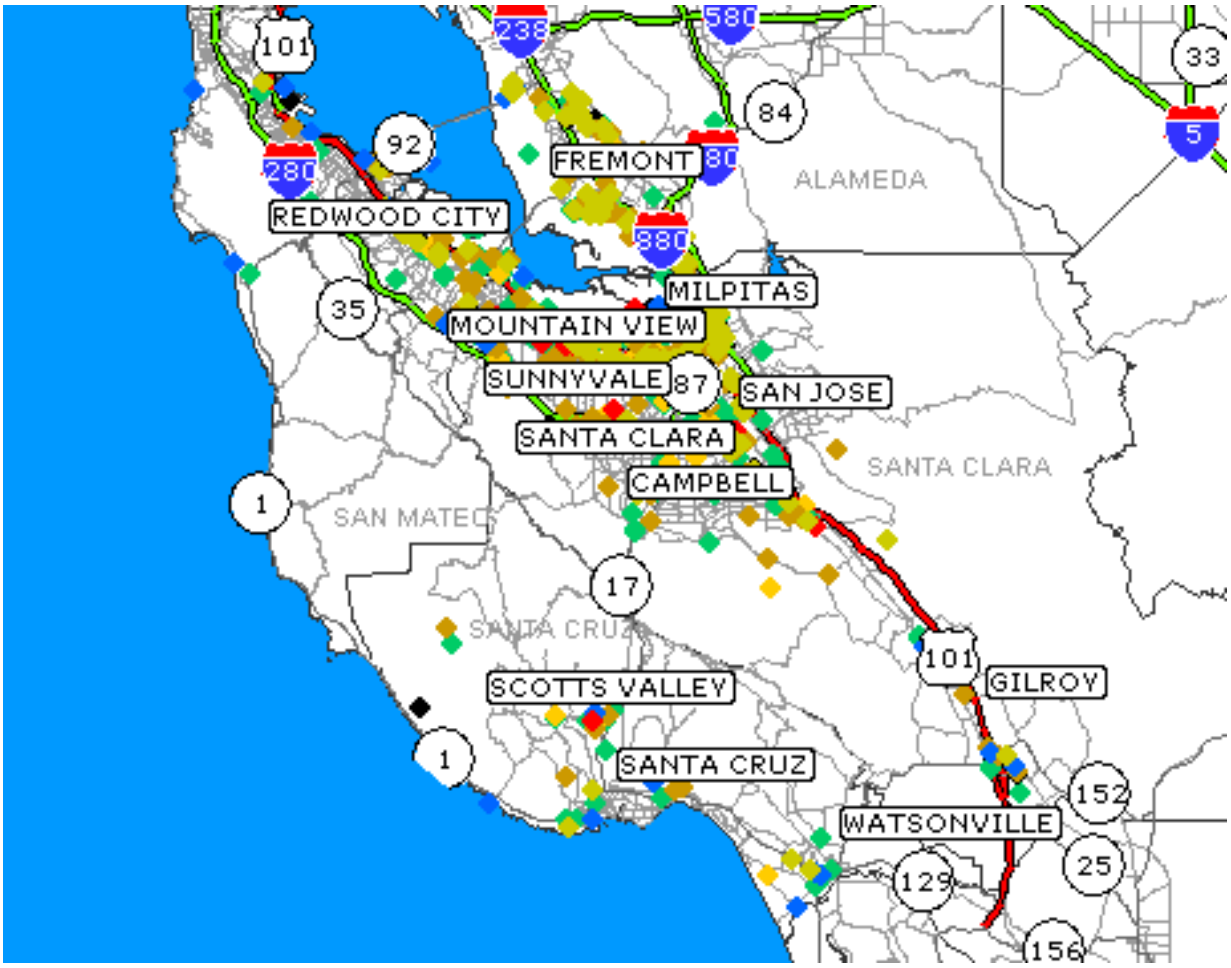
Listing of the largest quantities of chemicals that are either:

- released in Santa Clara County by semiconductor manufacturers, or
- remained inside computer products until eventual disposal.

Chemical Name	**Amount** (in pounds)
N-Methyl-2-Pyrrolidone	52,000
Nickel Compounds	30,000
Methanol	12,000
Hydrochloric acid	10,000
Sodium Dimethyldithiocarbamate	10,000

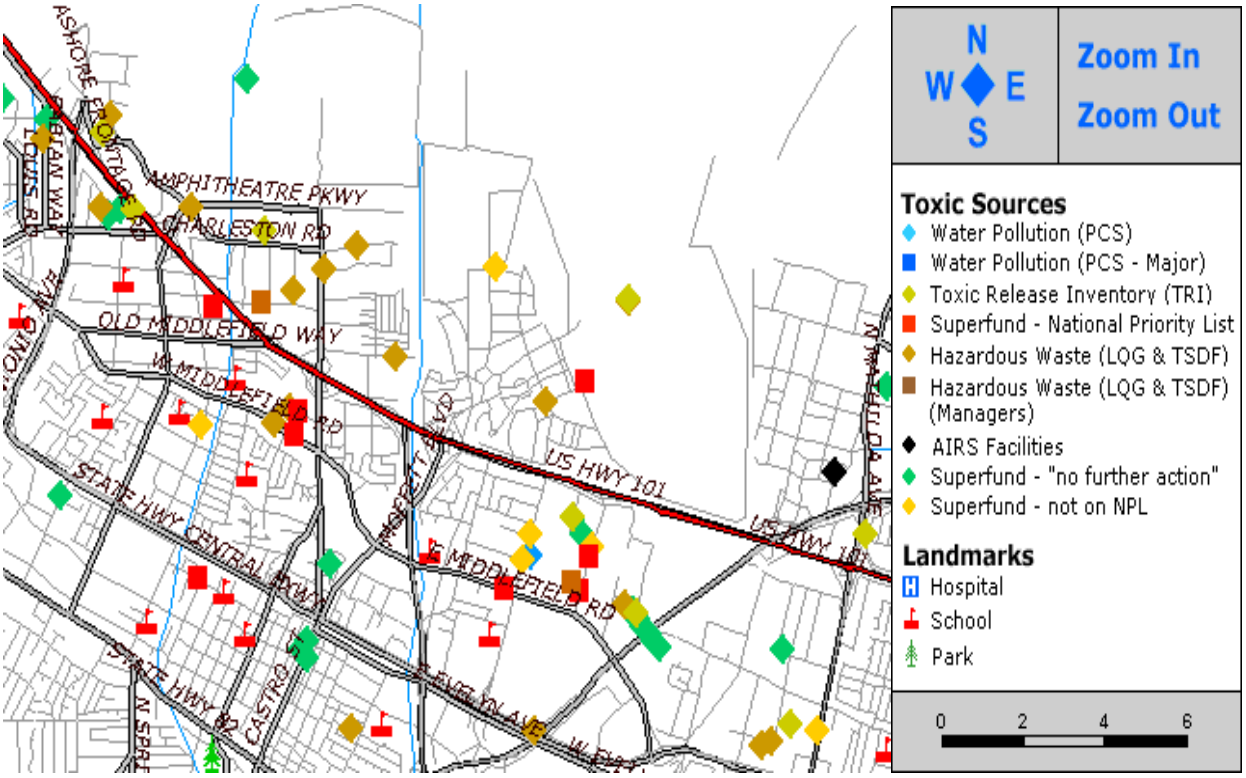
(Contributed by: Silicon Valley Toxics Coalition (For more information please see: http://www.svtc.org))

Figure 13. Toxics Point Sources Map for the Silicon Valley Region, California



(Source: Silicon Valley Toxics Coalition http://www.svtc.org/resource/maps/index.html,
Data from the Right to Know Network at: http://www.rtknet.org)

Figure 14. Close-Up on the Toxics Point Sources Map for the Silicon Valley Region



(Source: Silicon Valley Toxics Coalition http://www.svtc.org/resource/maps/index.html, Data from the Right to Know Network at: http://www.rtknet.org)

- **Contributions to Water Contamination**

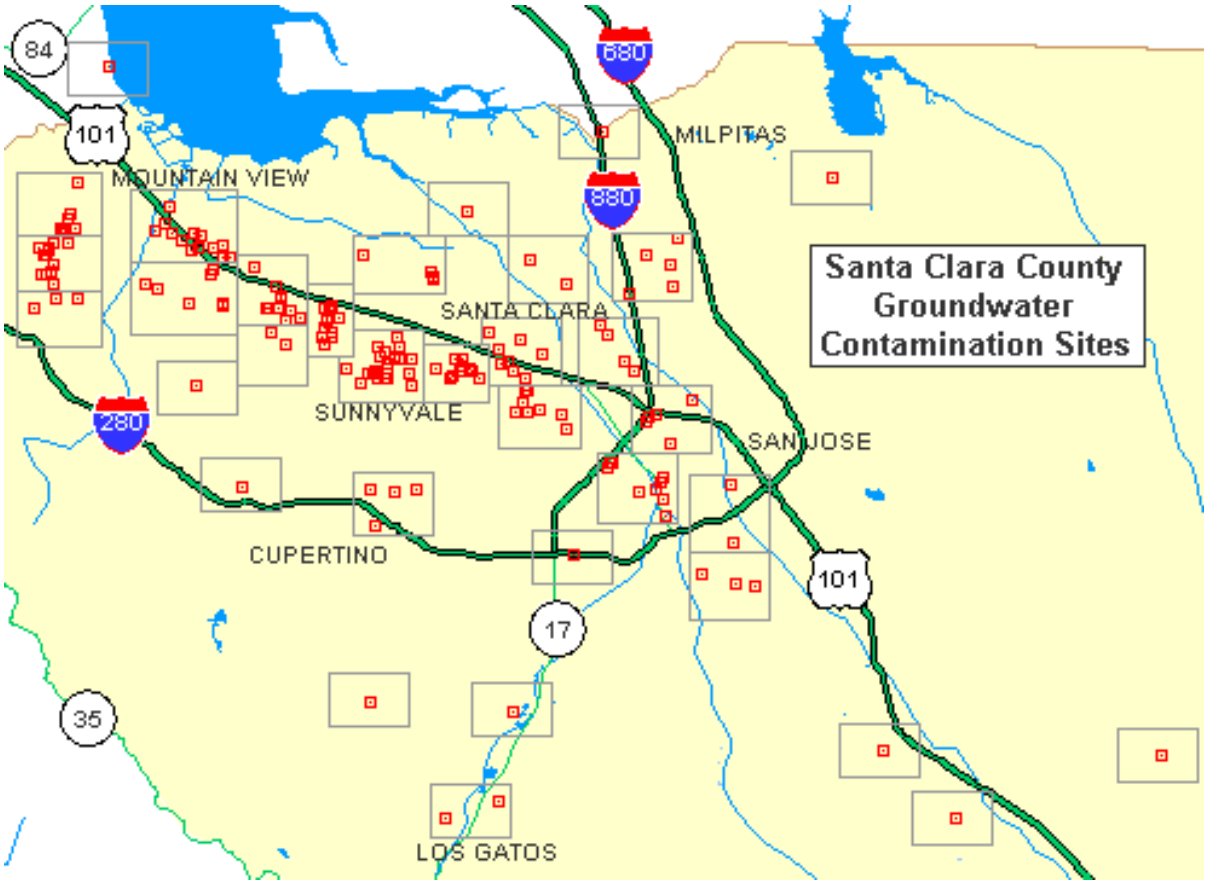
Water pollution is perhaps the most recognized environmental impact of high tech production. In the1980's Silicon Valley newspapers featured headlines such as, "Clean Industry Dirty Water" and "Toxics in our Water."[93] Currently, Santa Clara County is home to a greater number of U.S. Environmental Protection Agency-recognized "Superfund" sites—a descriptor given to the nation's most contaminated areas, eligible for federal "superfund" money—than any other county in the country. Of the 29 Superfund sites in Santa Clara County, 20 were directly related to the electronics industry.[94]

The issue at most of these sites is extensive groundwater contamination from semiconductor manufacturing. In addition to the Superfund sites, 94 groundwater pollution sites in Santa Clara County are also the direct result of the high tech industry, with some contamination extending in long "plumes" for miles in length and over 100 feet depth.[95]

Figure 15 presents a map, created by SVTC, illustrating the location of groundwater contamination in Santa Clara County. This map, located on the SVTC website, has interactive capabilities, as well as specific data on polluted sites.

Figure 16 offers a demographic overlay and shows the location of the groundwater contamination relative to the Latino population in the Silicon Valley. This map reveals that the contaminated sites are frequently located in areas with higher densities of Latinos and African-Americans, people with lower median-incomes, and renters. (For more demographic maps visit: http://www.svtc.org/ecomaps/svtc_maps/demographics/latino.htm.[96]) The data for both maps is from the California Regional Water Quality Control Board.

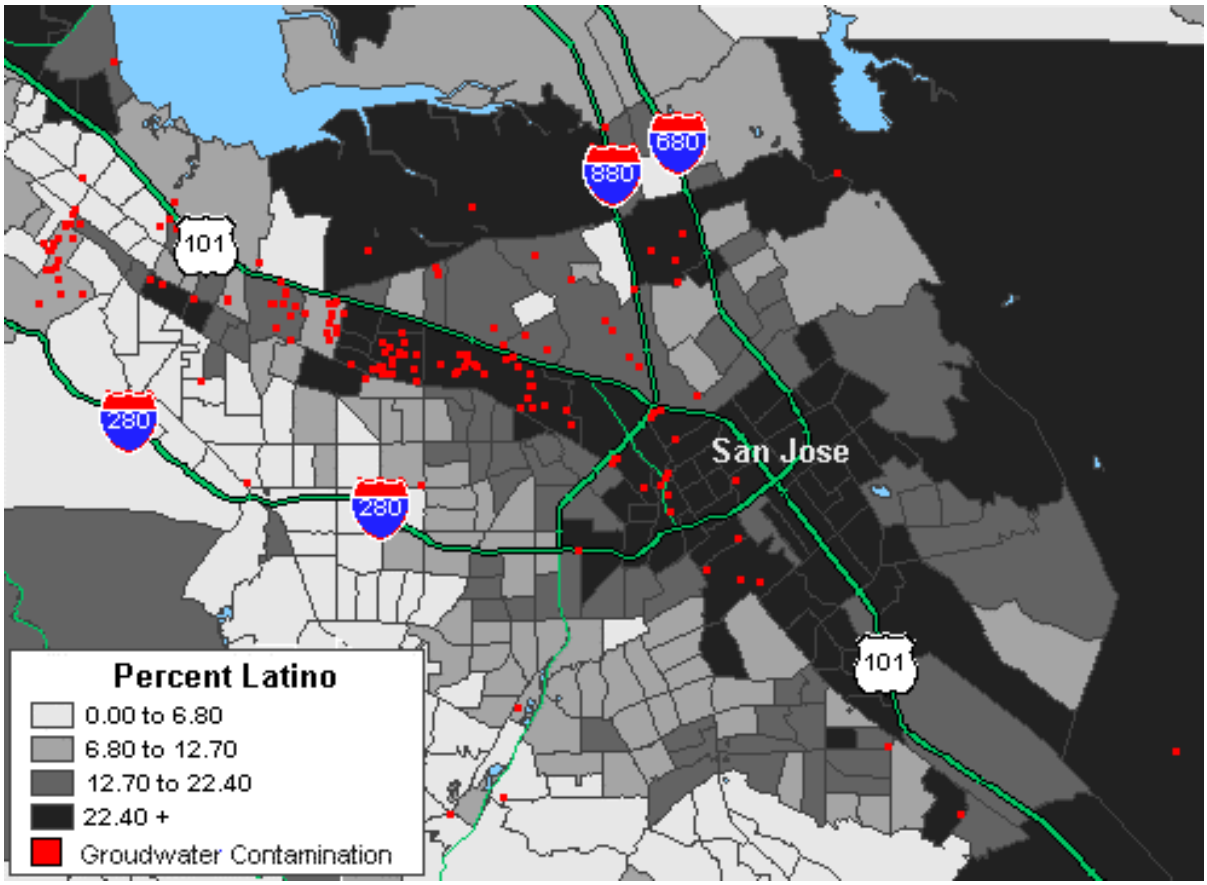
Figure 15. Groundwater Contamination Sites in Santa Clara County, California



NOTE: Each red square represents a groundwater contamination site, based on data from the California Regional Water Quality Control Board.

(Source: http://www.svtc.org/ecomaps/svtc_maps/maps.htm)

Figure 16. Silicon Valley Groundwater Contamination and Latino Population Density



NOTE: Each red square represents a groundwater contamination site, based on data from the California Regional Water Quality Control Board.

(Source: http://www.svtc.org/ecomaps/svtc_maps/demographics/latino.htm)

- **Creation of electronic waste**

  Both the hazardous and non-hazardous waste at the end of a high tech product's use—often referred to as "e-waste"—presents environmental concerns. In the U.S. only 14% of computers are recycled or remanufactured, with the remaining 86% going to hazardous waste landfills (46%), solid waste landfills (25%), and incineration facilities (15%).[97]

  Additionally, electronic waste is being exported to India, China and other developing countries with lower environmental standards and oversight. A 2002 report by the Silicon Valley Toxics Coalition and Basel Action Network estimated that between 50% and 80% of electronic waste is shipped to developing countries.[98] Figure 17 outlines some of the environmental problems associated with the rising amounts of electronic waste.

  Several companies, however, are offering limited take back and recycling programs, although many have a fee. In addition, programs such as Hewlett Packard's toner cartridge recycling are making progress in the direction of "closing the loop" for high tech equipment. Remanufacturing is also being explored, and companies such as XEROX tout their multi-million savings from remanufacturing equipment.[99]

  Rolltronics is trying to achieve the goal of being cradle-to-cradle. Recycling and reusing their product and also manufacturing it with greater energy efficiency.

Figure 17. Electronic Waste[100]

By the year 2005, one computer will become obsolete for every new computer put on the market. Studies estimate that the number of obsolete computers in the United States will soon be as high as 315 to 680 million units, resulting in more than a billion pounds of lead and millions of pounds of cadmium, mercury and other toxic materials.

The increasingly rapid evolution of technology has effectively rendered many items disposable after a relatively short period of time. Consumers no longer take a malfunctioning toaster, VCR or telephone to a repair shop. Replacement is often easier and cheaper than repair. And while these ever improving gadgets provide many benefits, they also carry a legacy of waste.

Electronic waste (e-waste) includes a broad and growing range of electronic devices that are disposed of, such as computers, monitors, TVs, stereos, cellular phones, and personal electronic devices. E-waste already constitutes from 2% to 5% of the United States' municipal solid waste stream and is increasing rapidly. According to the U.S. Environmental Protection Agency, in 1997 more than 3.2 million tons of e-waste ended up in U.S. landfills.

Over the last several years, no product has epitomized the problems posed by obsolete electronics as the personal computer. Today's computer industry innovates very quickly, bringing new technologies and upgrades to market on the average of every 18 months. Thus, the average life span of a personal computer has shrunk to two years. Currently, Californians buy more than 2.2 million new computer systems each year, and this number is growing exponentially. (Thus far, about 50% of US households own a computer.)

Analysts estimate that more than 6,000 computers become obsolete in California every day. These machines are either tossed out with the trash and subsequently landfilled by trash collectors, often illegally. Many are stored in attics and garages. Consumers have, on average, two to three obsolete computers in their garages, closets or storage spaces. U.S. government researchers estimate that three-quarters of all computers ever sold in the country remain stockpiled, awaiting disposal. The National Safety Council reported in 1999 that only 11% of discarded computers were recycled, compared with 28% of overall municipal solid waste.

Computers, televisions and other e-waste contain materials and components that could be recycled. However, one of the problems is the lack of collection incentives and recycling infrastructure, as well as the high cost of material collection, handling and processing. The costs of recycling often outweigh the value, especially due to costs of handling toxic materials.

Lastly, an immense problem that has been brought to light recently by SVTC's report "Exporting Harm," is that of exporting old IT equipment to developing nations.[101] Thousands of people in Asia are in the "recycling" business, breaking down old computers and technology equipment for parts, often burning and disposing hazardous materials. One effect of the unregulated operations is groundwater contamination, including, as reported in the *New York Times*, "alarming levels of heavy metals that corresponded directly with metals most commonly found in computers."[102] The report also describes the frequent child labor practices in the recycling industry.[103] All of these factors should be addressed in creating a sustainability-oriented high tech enterprises.

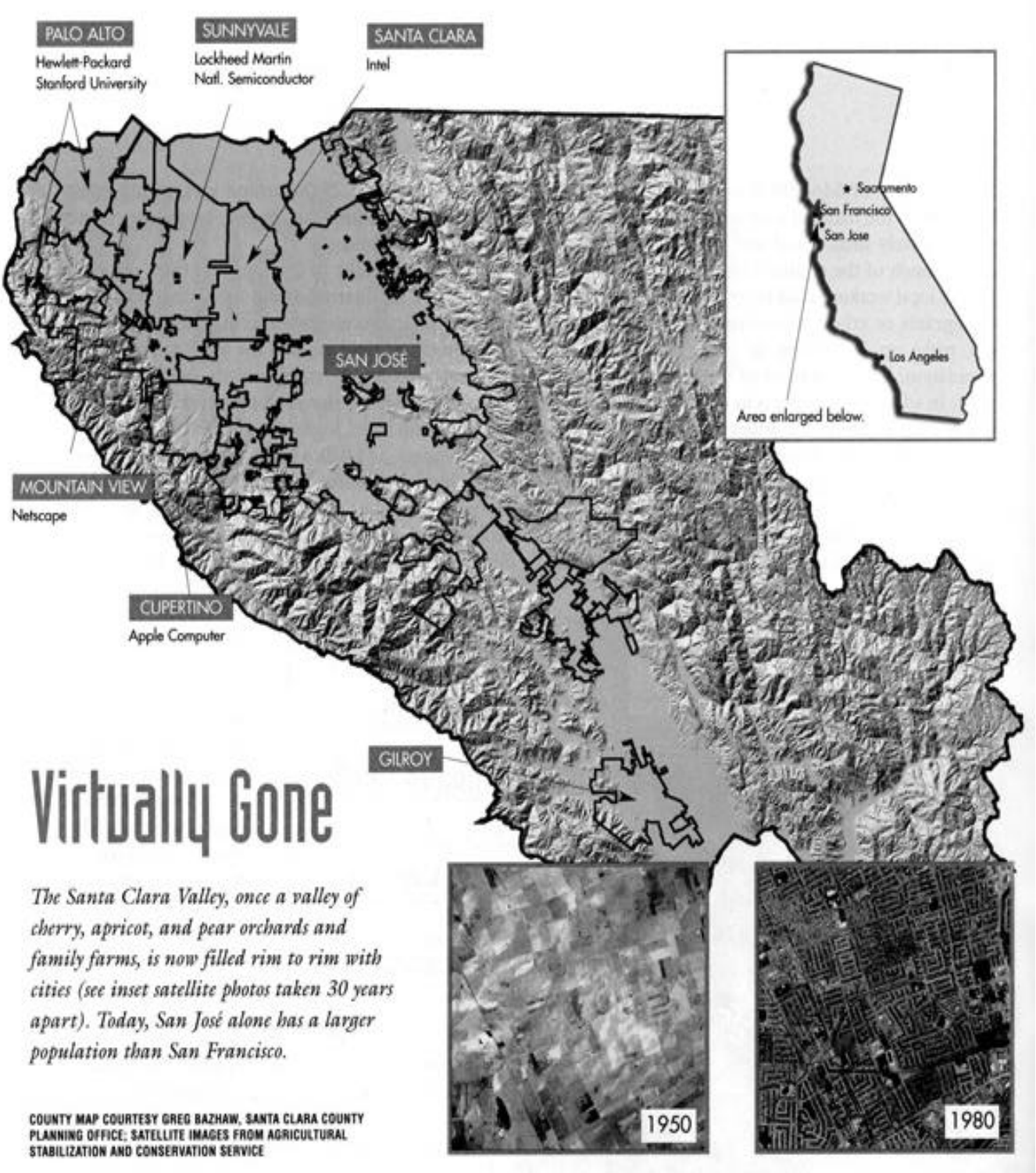
(Contributed by: Silicon Valley Toxics Coalition (for more information see: http://www.svtc.org))

- **Urban Sprawl**

Fifty years ago, the Santa Clara Valley was home to the some of the world's most fertile soil and large quantities of produced prunes, apricots, and cherries. Today, from Highway 101, many would get the sense of Santa Clara County as a congested parking lot. Almost the entire valley floor and much of the hillsides have been converted to industrial and office parks. In 1999, the Greenbelt Alliance ranked Santa Clara County second among the nine Bay Area counties in terms of "most land at risk of development".[104] Figure 18 illustrates the dramatic change in the Silicon Valley landscape in the past 50 years.

The sudden growth of the Valley threatens the quality of life for all residents, leading to smog, sprawl, housing shortages, and an overwhelmed educational system. In addition, the traffic congestion costs drivers over $1.25 billion annually and has a major impact on air quality,[105] which in turn affects human health issues.

Figure 18. The Changing Landscape of the Silicon Valley Region, California



(Source: Sachs, Aaron. 1999. "Virtual Ecology: A Brief Environmental History of Silicon Valley." *WorldWatch.* (January/February).; Reprinted courtesy of the WorldWatch Institute. http://www.worldwatch.org)

3.4 The Natural Step Framework and the Information Technology Sector

The beginnings of a sustainability assessment process is presented in the preceding sections of this report, by explaining sustainability and its relevance to both business in general, and a sector in particular.

The Natural Step (TNS) Framework was developed in response to the need for clarity in how to integrate complex ecological and social factors and dynamics into decision-making. The Natural Step's System Conditions offer principles to guide sustainability-oriented decision-making and assist in developing pathways forward.

Supported by scientists internationally—and described as an "operating system" for sustainability—TNS' Framework provides a common basis from which to understand the fundamental conditions of sustainability. Thus, it offers a standard and accepted baseline for sustainability, while also facilitating decision-making. These overarching principles and approaches are part of a broader set of tools for understanding and applying sustainability concepts to businesses.[106]

The Natural Step Framework has been applied and extensively used in a range of businesses, including, Nike, CH2MHill, IKEA, Collins Pine Company, and Scandic Hotels. Each of these companies has sought to stop the cycle of continually reacting to environmental problems and to become more pro-active by improving operations and, in some cases, rethinking strategy. Businesses have realized results that been measured in several ways, ranging from improved environmental performance through millions of dollars in cost savings.[107]

The Natural Step's four system conditions can be used to analyze information technology as a tool in developing a sustainable society. While there are many obstacles and challenges, there is also much potential for IT to reinvent itself.

SECTION 4: IT in a Sustainable Future

> "There is undoubtedly a rapid progression to greater focus and accountability on corporate sustainability or the environmental and social issues. With this comes the need to engage with stakeholders and demonstrate performance and transparency….
> Failure to address the issue will result in greater cost, not least in relation to reputation, and could even lead to organizations not being allowed to operate….
> To add business value, organizations need to integrate environmental and social strategies into their core business strategy in a proactive and innovative manner."
>
> - *PricewaterhouseCoopers 2000*[109]

As a growing number of multinational corporations are assessing how to become more focused on sustainability issues, the IT sector has an opportunity to become a sustainability-oriented solutions provider, both for its clients and for its own operations. The question is what efforts will be first undertaken in exploring integration of its products and practices with those of sustainability. As Klaus Fichter, a technology and sustainability analyst, asks:

> "Will *homo connecticus* lovingly stroke over his computer touch screen, be beamed via the World Wide Web around the globe in a matter of seconds and get all the jobs done effortlessly, cheaply, in real time and of course using a minimum of energy resources and without any side-effects? Is that the new economy – clean, pollutant free and gentle on resources?"[110]

As is clear from the preceding pages, this vision is far from reality. This final section offers a vision of a sustainability-oriented IT sector.

If the IT sector begins to strategically consider the context in which 21st century business will be conducted, a whole new set of options emerge. John Seely Brown, chief scientist at XEROX, offers one view of the future:[111]

> "Roughly 15 years into the 21st century, the social computing stage morphed into a period called ecological or symbiotic computing. Structural matter (atoms) and computing (bits) became inseparable. Zillions of sensors, effectors and logical elements (made of organic and inorganic materials) were interconnected via wireless, peer-to-peer technologies, producing smart, malleable stuff used to build smart appliances, buildings, roads and more…. In a way, the inorganic world took on organic properties, using computing to transparently modulate responses to the environment."

Although realization of this vision may seem distant, companies can begin by devising the IT systems, and technology for, sustainable energy, transportation, and resource use. All of these issues represent issue areas that, if addressed, could become enormous business opportunities. For example:

> How can IT enable product designers to "grow" solutions within a design space that does not just take into account nature, but uses sustainability principles in the way we use specific concepts like gravity, heat, and tension?

How can IT enable more sustainable manufacturing and delivery models?

How can IT facilitate new, sustainability-oriented business models to be created?

How can IT enable new materials to be developed and cycled in sustainable ways?

What are the new ways that IT can extend the human ability to adapt, learn, ask questions, and find answers?

How can IT help us to consider factors that are farther into the future, deeper into the past, which affect the dynamics between ourselves and the planet-wide system in which we live?

With these points in mind, a vision for IT in 2020 is a sector that:

- Designs and creates new technology services that are characterized as:

  being free of persistent organic pollutants, heavy metals, and toxic, persistent, and bioaccumulative ingredients,

  cycling materials through "closed loop" processes, and

  operating on solar energy.

- Manufactures using solar energy
- Invests in eliminating the digital divide and providing access for all people, while respecting cultural differences and cultural needs
- Operates on continually developing, open source software models that prolong life of machines
- Produces machines that can be upgraded with new technologies
- Establishes operations in developing nations that embody (and improve on) the practices in Europe and North America
- Ensures the health and safety of all workers and communities

These steps may be beyond the capacity of any single company, but all firms do have roles to play and areas in which to start. As more businesses, non-profit organizations, and government agencies take the first steps, coalitions can form and difficult, cross-cutting problems can be addressed. The ecological and social impacts of the high technology sector can be greatly reduced through a combination of product and business (re)design, closed-loop systems, and regional planning and policy More importantly, the sustainability-based *opportunities* are wide open to hardware and software innovation and entrepreneurship.

Hardware tools, such as sensors and controls, can improve eco-efficiency, record ecosystem information, and monitor inventories. Software has enormous potential for integrating sustainability principles into supply chain management and enterprise resource planning, sustainable product design, as well as both information capture and management. Finally,

internet and communications technology can being used in new ways to connect people to better understanding ecological and social dynamics.

Since nature is itself a large information system, the potential to change business will become unleashed when the IT sector begins to work with nature and towards sustainability. With a vision to the future, and an understanding of sustainability, the IT sector is equipped to innovate for a more sustainable world.

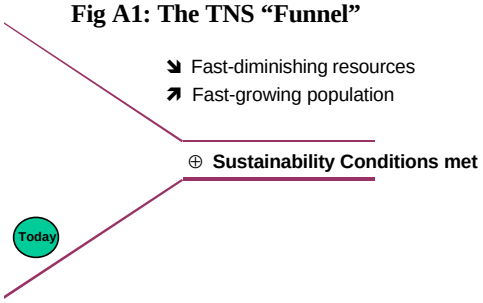
APPENDIX A: THE NATURAL STEP FRAMEWORK

About Sustainability and Sustainable Development

Increasing demands upon, and depletion of, natural resources, accelerating levels of global pollution, and growing concerns about the impacts of businesses on society are not new problems.

Neither are they avoidable. These factors will increasingly constrain the 'freedom to operate' of organizations and society at large. The Natural Step (TNS) uses the metaphor of "the funnel" to describe the tightening of these constraints, and the pressures to become more sustainable (Figure A1). Sustainable development addresses these challenges proactively, based upon a sound understanding of what sustainability means.

Fig A1: The TNS "Funnel"



A sustainable system is one that can continue indefinitely. A sustainable society is one that does not impair or overload the life-support systems that provide for its needs. A sustainable product, process or organisation is one that respects nature's non-negotiable limits and the rights of those with whom it interacts, however remotely. It is that basic and, at the same time, remote from common practice today.

All too often, problems are addressed reactively, using technical means to cure symptoms and not address core issues. True sustainable development goes a long way beyond merely complying with basic environmental and social obligations, and differs from traditional 'end-of-pipe' solutions to pollution and social concerns. Rather, sustainable development addresses issues "upstream," early in the decision-making process, such that the pursuit of business does not systematically create the kinds of social and environmental problems that will, sooner or later, harm business performance and reputation.

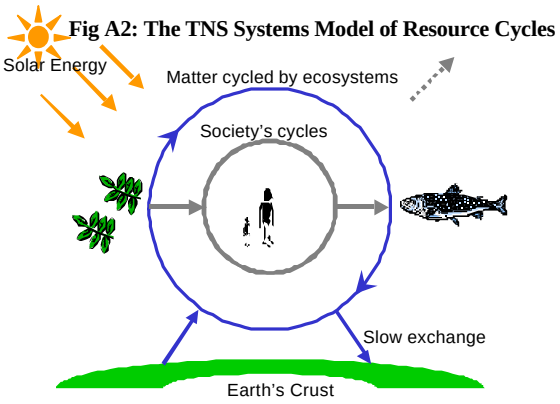
How does one move from concept to practice, and begin applying these concepts to the messy world in which we live? If we chase them back far enough, it is easy to see that businesses ultimately depend upon natural and human resources including for example, energy, timber, clean air and water, as well as the ingenuity and labor of people who converts these natural resources into economic goods. We all share the same world, and therefore our activities inevitably affect that same world and all those living within it.

Since sustainability challenges are unavoidable, sustainable development is also possibly the greatest business opportunity of the age. It is firstly essential to acknowledge that the Earth's ecosystems, upon which we are fully dependent, operate in ways that it is possible to define using science and ultimately determine what is and what is not sustainable. The Natural Step's approach to sustainable development is based upon a systematization of these scientific principles.

The Natural Step Framework

The Natural Step (TNS) Framework presents a set of principles and strategic tools based on the scientific principles governing the Earth's ecosystem, the inherently sustainable system that supplies all our needs. At the heart of the TNS Framework is a science-based systems model of this sustainable Earth system (Figure A2). The Framework defines what sustainability means and helps organisations integrate sustainability factors into their decision-making processes.

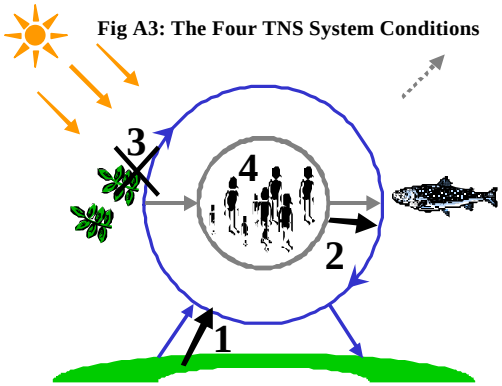
Fig A2: The TNS Systems Model of Resource Cycles



It can also be used to explore the sustainability implications of today's products and processes, and the measures that must be undertaken to make them more sustainable. The TNS Framework comprises four elements:

A. **Sustainability awareness** comprises an understanding of the issues and the conditions that must be met in the "mouth" of the funnel. The TNS Framework includes four necessary System Conditions for sustainability stemming from the science-based systems model. These four TNS System Conditions are illustrated in Fig A3 and listed below:

Fig A3: The Four TNS System Conditions



In the sustainable society, nature is not subject to systematically increasing…

1. *…concentrations of substances extracted from the Earth's crust*
2. *…concentrations of substances produced by society*
3. *…degradation by physical means*

and, in that society. . .

4. *…human needs are met worldwide.*

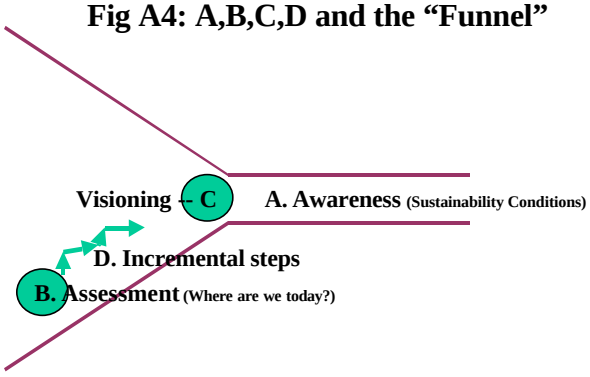
B. On the basis of these four necessary System Conditions of sustainability, one is then in the position to undertake a **Baseline Sustainability Assessment** of a organization or operation.

C. Having used the System Conditions to determine an organization's present state, the system conditions can also be a helpful tool in creating a **clear vision** for a sustainable enterprise.

D. Backcasting is a process by which one determines the incremental steps to take in moving toward this vision from where an organization is today. This approach differs radically from the more common technique of *forecasting*, which is an extrapolation from today's knowledge, situation, and trends to predict the future. Although yielding short-term gains, forecasting overlooks the inevitable changes and discontinuities with current trends that will arise through sustainability pressures. Incremental steps derived from backcasting acknowledge current constraints to full sustainability (for example, limits to capital investment or the readiness of the market). However, they also reflect the progressive steps that can be made today, from which further future steps can be taken to lead along a clear path towards the vision of full sustainability.

The steps for applying the TNS framework are illustrated in the context of "the funnel" in Figure A4. Together, they help define in unambiguous terms what sustainability means, and provide a readily-understandable framework to get to grips with the practicalities of sustainable development. This approach enables the integration of sustainable development into strategic planning, communication of complex ideas, the sharing of these concepts with partners and across social sectors, and making strategic judgements about the steps needed to move towards a more sustainable future.

Fig A4: A,B,C,D and the "Funnel"



Endnotes

[1] Wilsdon, James and Paul Miller. 2001. "Digital Futures: An Agenda for a Sustainable Digital Economy" in Wilsdon, James (editor). *Digital Futures.* London, England: Earthscan: 2.
[2] Hart, Stuart. 1997. "Beyond Greening: Strategies for a Sustainable World." *Harvard Business Review.* 75(1): 67-68.
[3] Funk, Karina. 2002. "Performance and Sustainability Over the Long Haul." *Perspectives on Business Innovation.* Issue 7 (http://www.cbi.cgey.com/pub/docs/sustainability_and_performance.pdf)
[4] Hart, Stuart and Milstein, Mark. "Global Sustainability and the Creative Destruction of Industries." Sloan Management Review. (Fall 1999): 24.
[5] Hart, Stuart. 1997. "Beyond Greening: Strategies for a Sustainable World." *Harvard Business Review.* 75(1): 66-76; Hawken, Paul, Amory Lovins, and L. Hunter Lovins. 1999. *Natural Capitalism: Creating the Next Industrial Revolution.* Boston: Little and Brown Company; Senge, Peter and Goran Carstedt. 2001. "Next Industrial Revolution." *Sloan Management Review.* (Winter): 24-38.
[6] http://www.hp.com/e-inclusion/en/index.html
[7] Holliday, Chad. 2001. "Sustainable Growth, the DuPont Way." *Harvard Business Review.* (September): 129-134.
[8] For examples, see: Altomare, Mary and Brian Nattrass.1999. *The Natural Step for Business.* British Columbia, Canada: New Society Publishers; Haverman, Mark and Dorfman, Mark. 1999. "Breaking Down the 'Green Wall: Early Efforts at Integrating Business and Environment at SC Johnson." *Corporate Environmental Strategy.* 6 (1): 4-13 Hoffman, Andrew J. 2000. "Integrating Environmental And Social Issues Into Corporate Practice." *Environment.* 42 (5); Halme, M. and J. Niskanen. 2001. "Does Corporate Environmental Protection Increase or Decrease Shareholder Value? The Case of Environmental Investments." *Business Strategy and the Environment.* 10: 200-214; Holliday, C. 2001. "Best Practice Sustainable Growth, the DuPont Way." *Harvard Business Review.* (September): 129-134.
[9] A UK study by Innovation through Partnerships showed that the core of innovation is a dynamic and resilient relationship between a company and its stakeholders (www.innovation-partnership.org).
[10] Numerous organizations have cut operational costs through sustainability-oriented practices. For example, 3M saved more than $810 million since 1975 through its "Pollution Prevention Pays" program (www.3m.com/profile/evt/3t.html) and Interface saved more than $165 million between 1994 and 2000 by reengineering production and redesigning processes to reduce waste (www.interfaceinc.com).
[11] A study by Cone-Roper found that 86% of consumers have a more positive image of a company if they see it doing something to make the world a better place (E. Creyer and W. Ross, "The Influence of Firm Behavior on Purchase Intention: Do Consumers Really Care About Business Ethics?" *The Journal of Consumer Marketing* 14(6) 1997). A DePaul University study found that the average reputation score for a company with a strong commitment to business ethics was between 4.7% and 6.7% higher than for companies without this commitment (C. Verschoor, "A Study of the Link between a Corporation's Financial Performance and Its Ethics," *Business and Society* 1998).
[12] According to an ICF Kaiser study, "both an improved environmental management system and improved environmental performance result in significant reductions in a firm's Beta," reducing systematic risk about 13% and, along with it, reducing cost of captial from 13% to 12.34% (see S. Schaltegger and R. Burritt, *Contemporary Environmental Accounting: Issues, Concepts, & Practice* (Greenleaf 2000)). A study on the effects of the Superfund in the United States found that 62.5% of banks analyzed had rejected loan applications because of the possibility of environmental liability (Schaltegger and Burritt). Following allegations that Talisman Oil was helping to finance human rights abuses in Sudan, a large number of pension funds publicly divested their stock of the company ("Halting Sudan's Slavery and Slaughter," *Boston Globe*, November 8, 1999).
[13] A Rutgers University study found that firms applying "high performance work practices" have a 7.05% decrease in employee turnover with a $3,814 increase in profits per employee (see M. Huselid, "The impact of human resource management practices on turnover, productivity, and corporate financial performance," *Academy of Management Journal* 38(3), 1995). A Students for Responsible Business study found that 82.7% of MBA respondents would choose an offer for a more socially responsible company if the salaries offered were equal and more than 50% were willing to take a lower salary to work for a company with a good SD reputation (M. Albion, *The Future of Socially Responsible Business: MBA Students Speak Out* 1996).
[14] An IFC Kaiser study, this one of 330 companies within the S&P 500, found that a 50% improvement in environmental management systems and environmental performance resulted in a 13.2% decrease in Beta, a measure of sensitivity of stock used by analysts (P. Ameer, S. Feldman, and P. Soyka, *Does Improving a Firm's Environmental Management System and Environmental Performance Result in a Higher Stock Price?* For IFC Kasier, November 1996).
[15] Wackernagel M. and W. Rees. 1996. *our Ecological Footprint.* Philadelphia, Pennsylvania: New Society Publishers.
[16] http://www.oit.doe.gov/bestpractices/motors/
[17] Green Business Letter (November 2000).
[18] Benyus, Janine. 1997. *Biomimicry.* New York, New York: William Morrow and Company.
[19] http://www.att.com/telework/artlib/congress_testimony.html
[20] Personal communication, August 24, 2001.
[21] Cramer, Jacqueline and Ab Stevels. 2001. "The Unpredictable Process of Implementing Eco-efficiency Strategies," in Charter, Martin and Ursulat Tischner. (editors.) *Sustainable Solutions.* London, England: Greenleaf Publishing: 327.
[22] U.S. Department of Energy, Best Practices Case Study. http://www.oit.doe.gov/bestpractices/pdfs/weirtonm.pdf
[23] Caldwell, Bruce. 1999. "Reverse Logistics." *Information Week.* (April 12) http://www.informationweek.com/729/logistics.htm

[24] http://www.att.com/telework/
[25] Hawken, Paul, Amory Lovins, and L. Hunter Lovins. 1999. *Natural Capitalism.* New York, New York: Little, Brown and Company: 152
[26] http://www.sfcarshare.org
[27] http://wriws1.digitaldividend.org/wri/app/navigate?_form=desktop&_action=Projects
[28] http://www.hp.com/e-inclusion/en/
[29] Cramer, Jacqueline and Ab Stevels. 2001. "The Unpredictable Process of Implementing Eco-efficiency Strategies," in Charter, Martin and Ursulat Tischner. (editors.) *Sustainable Solutions.* London, England: Greenleaf Publishing: 327.
[30] U.S. Department of Energy, Best Practices Case Study. http://www.oit.doe.gov/bestpractices/pdfs/weirtonm.pdf
[31] Caldwell, Bruce. 1999. "Reverse Logistics." *Information Week.* (April 12) http://www.informationweek.com/729/logistics.htm
[32] http://www.att.com/telework/
[33] Burrows, Peter. 2001. "The Era of Efficiency." Business Week. (June 18): 92
[34] http://www.rmi.org/sitepages/pid386.php
[35] http://prius.toyota.com/technology/control.html
[36] Clean Edge. 2001. "Clean Tech: Profits and Potential." (http://www.cleanedge.org/)
[37] Kelly, Henry. 1999. "Information Technology and the Environment: Choices and Opportunities." *Information Impacts Magazine.* (October) (http://www.cisp.org/imp/october_99/10_99kelly.htm)
[38] Quote of Vinod Khosla, partner with Kleiner Perkins Caufield & Byers, in Luc Hatlestad. 2001. "On the Shoulders of Giants." *Red Herring.* (May 1-15): 170-174.
[39] U.S. DOE, Office of Industrial Technologies. 2000. *Best Practices Management Case Study.* (December)
[40] http://www.bsr.org
[41] Caldwell, Bruce. 1999. "Reverse Logistics." Information Week. (April 12) (http://www.informationweek.com)
[42] Cohen, Nevin. 1999. "Greening the Internet: Ten Ways E-Commerce could Affect the Environment and What We Can Do." *Information Impacts Magazine.* (October).
[43] http://www.ce.cmu.edu/GreenDesign/
[44] http://www.aei.org
[45] Benyus (1997).
[46] Johnson, Steven. 2001. *Emergence.* New York, New York: Scribner.
[47] http://www.biosgroup.com
[48] Hafner, Katie. 2001. "Better Networks: Look to Nature" *New York Times*. (September 13): D1-D6.
[49] Kurzweil, Ray. 1999. *The Age of Spiritual Machines*. New York, New York: Penguin Books.
[50] http://www.parc.xerox.com/projects.html
[51] Sheats, James. 1999. "Information Technology and Sustainable Development." In Dorf, Richard C. 2001. *Technology, Humans, and Society: Toward a Sustainable World.* San Diego, California: Academic Press.
[52] Hawken, Paul, Amory Lovins, and L. Hunter Lovins. 1999. *Natural Capitalism.* New York, New York: Little, Brown and Company: 152
[53] http://www.sfcarshare.org
[54] http://wriws1.digitaldividend.org/wri/app/navigate?_form=desktop&_action=Projects
[55] http://www.hp.com/e-inclusion/en/
[56] For more information on: Conservation International's GIS mapping projects see: http://www.biodiversityscience.org/xp/CABS/research/gis/gisprojects.xml, TaraHaat: http://www.tarahaat.com/index_english.asp, LINCOS: http://www.lincos.net/html/eng/menu.html Greenstar: http://www.greenstar.org/ SustainIT: http://www.sustainit.org Department of Energy: http://www.oit.doe.gov/bestpractices/databases.shtml , Ecos: http://www.ecostech.com/pages/products.html
[57] For more information, please contact the Center for Precision Agricultural Systems, Washington State University.
[58] http://www.sap.com/solutions/plm/keycapabilities/ehs.asp
[59] http://www.cool-companies.org/energy/debunk.cfm
[60] http://www.nemi.org/Roadmap/00highlights.html
[61] Arensman, Ross. 2001. "The Greening of Technology." *Electronic Business.* (May): 97-102.
[62] Gaither, Chris. 2001. "Intel and Two Smaller Rivals Plan New Energy-Saving Chip Lines." *The New York Times.* (October 16).
[63] Ladou, J. and T. Rohm. 1998. "The International Electronics Industry." *Journal of Occupational and Environmental Health.* 4 (1): 1- 18. and Byster, L. and T. Smith. 1999. "High-tech and Toxic." *FORUM for Applied Research and Public Policy.* 14 (1): 69- 75.
[64] Ladou, J. and T. Rohm (1998).
[65] Silicon Valley Toxics Coalition. 2002. "Why Focus on Computers?" San Jose, California: Silicon Valley Toxics Coalition. http://www.svtc.org/cleancc/focus.htm
[66] Intel changes process chemistry up to 45 times a year at their fabrication plants. (Mazurek, Jan. 1999. *Making Microchips.* Cambridge, Massachusetts: The MIT Pres: 27).
[67] Norr, Henry. 2002. "Is Chip Industry Really Ready to Confront Health Issue?" *San Francisco Chronicle.* (March 25). http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2002/03/25/BU238107.DTL

[68] Scientific Advisory Committee of the Semiconductor Industry Association. 2001. "Cancer Risks Among Wafer Fabrication Workers in the Semiconductor Industry." University of Massachusetts at Lowell. Available at: http://www.svtc.org/hu_health/sac_recom.pdf
[69] Semiconductor Industry Association. 2002. "Semiconductor Industry Association To Implement Health And Safety Review For Fabrication Workers." (Press Release) San Jose, California: Semiconductor Industry Association. (March 20) http://www.semichips.org/pre_release.cfm?ID=216
[70] Mazurek (1999).
[71] Weber, J. and M. Parrish. 1992. "Implications of IBM Study on Miscarriages." *Los Angeles Times.* (October 13).
[72] Smith, Ted and Leslie Byster. 1998. "The Challenges of Environmental De-regulation in the Era of Globalization." *Semiconductor Fabtech.*(Edition 7).
[73] She, Jianwen et al. 2001. "PBDEs In the San Francisco Bay Area: Measurements in Harbor Seal Blubber and Human Breast Adipose Tissue." *Chemosphere.*(IN PRESS).
[74] Environmental Finance Center. http://www.greenstart.org/efc9/
[75] Californians Against Waste Foundation, Green Capital, Silicon Valley Toxics Coalition Campaign for Responsible Technology, and The Materials for the Future Foundation. 2000. *Poison PCs and Toxic TVs*. San Jose, California: Silicon Valley Toxics Coalition: 12-13. (http://www.svtc.org)
[76] Benson, Mitchel. 1986. "Pact Reached in Tainted Water Dispute" *San Jose Mercury News.* (July 4)
[77] Working Partnerships USA. 2001. *Everyone's Valley: Inclusion and Affordable Housing in Silicon Valley*. Policy Briefs: Silicon Valley Equity Series (June).
[78] California Technology Stock Letter. (March 16, 2001): 4.
[79] Joint Venture: Silicon Valley Network. *2001 Silicon Valley Index.* San Jose, California: Joint Venture: Silicon Valley Network. http://www.jointventure.org/resources/2001Index/2001home.html
[80] Joint Venture: Silicon Valley Network. *2002 Silicon Valley Index.* San Jose, California: Joint Venture: Silicon Valley Network. http://www.jointventure.org/resources/2002Index/index.html
[81] Joint Venture: Silicon Valley Network. *2002 Silicon Valley Index.*
[82] Sachs, Aaron. 1999. "Virtual Ecology: A Brief Environmental History of Silicon Valley." *World Watch.* (January/February): 12- 21. And: U.S. Census Bureau: http://quickfacts.census.gov/qfd/states/06/06085.html
[83] Working Partnerships USA. 2001. *Everyone's Valley: Inclusion and Affordable Housing in Silicon Valley*. Policy Briefs: Silicon Valley Equity Series. (June)
[84] Joint Venture: Silicon Valley Network. *2001 Silicon Valley Index*
[85] Joint Venture: Silicon Valley Network. *2001 Silicon Valley Index*
[86] Bridges.org. 2001. "Spanning the Digital Divide" http://www.bridges.org/spanning/chpt2.html#_Toc515100154
[87] Wurman, Richard Saul (ed.) 2001. *Understanding USA.* Newport, Rhode Island: Ted Conferences Inc.
[88] OpNet: http://www.opnetwork.org/, Mentor Girls: http://www.mentorgirls.org/, Plugged In: http://www.pluggedin.org/
[89] California Technology Stock Letter. (March 16, 2001): 4.
[90] Mazurek (1999): 48.
[91] Mazurek, Jan. 2000. "The High Tech Sector and the Environment in the New Millennium: Performance, Prescriptions and Policy." Oakland, California: California Global Corporate Accountability Project.
[92] Environmental Protection Agency Toxics Release Inventory http://www.epa.gov/tri
[93] http://www.svtc.org/resource/keynews.htm
[94]The Electronics Industry Good Neighbor Campaign (EIGNC). 1997. *Sacred Waters: Life-Blood of Mother Earth.* http://www.svtc.org/resource/pubs/execsum.htm. Pg. 27.
[95] EIGNC 1997: 23 and 36.
[96] For information on the SVTC Health and Environmental Justice program, please see: http://www.svtc.org/envhealth_just/index.html.
[97] Arensman, Russ. 2001. "The Greening of Technology." *Electronic Business.* (May 1)
[98] Basel Action Network and Silicon Valley Toxics Coalition. 2002. *Exporting Harm: The High Tech Trashing of Asia*. San Jose, California: Silicon Valley Toxics Coalition. http://www.svtc.org/cleancc/pubs/technotrash.pdf
[99] http://www.usaep.org/scem/case2.htm
[100] Californians Against Waste Foundation *et al.* (2000).
[101] Basel Action Network and Silicon Valley Toxics Coalition. 2002.
[102] Markoff, John. 2002. "Technology's Toxic Trash Is Sent to Poor Nations." *The New York Times.* (February 25).
[103] Basel Action Network and Silicon Valley Toxics Coalition. 2002: 16, 19, 21, and 25. http://www.e-insite.net/eb-mag/index.asp?layout=articlePrint&articleID=CA72724
[104] www.greenbelt.org/pdf_files/GMAP1.pdf
[105] Working Partnerships USA. 2001. *Everyone's Valley: Inclusion and Affordable Housing in Silicon Valley*. Policy Briefs: Silicon Valley Equity Series. (June)
[106] For example see, Anderson 1998, Hawken *et al.* 1999, McDonough and Braungart 1998, von Wizsaker *et al.* 1997, Wackernagel and Rees 1996.
[107] Nattrass and Altomare. 1999. *The Natural Step for Business.* Gabriola Island, British Columbia: New Society Publishers.
[108] Romm, Joseph. 1999. *The Internet Economy and Global Warming.*

Annadale, Virginia:The Center for Energy and Climate Solutions. http://www.cool-companies.org

[109] Price Waterhouse Coopers (PWC). 2000. Creating Business Value Through Corporate Responsibility: Sustainability Strategies and Reporting for the Goal Industry. London, U.K.: Price Waterhouse Coopers.

[110]Fichter, Klaus. 2000. "Sustainable Business Strategies in the Internet Economy." http://www.green-ecommerce.com/Fichter/Fichter.htm

[111] Brown, John Seely. 2001. "Where Have All the Computers Gone?" *Technology Review.* (January). http://www.technologyreview.com/magazine/jan01/print_version/brown.html