Environmental Project No. 807 2003
Miljøprojekt

Whole-Systems Framework for Sustainable Consumption and Production

Beatrice Anarow, Catherine Greener, Vinay Gupta,
Michael Kinsley, Joanie Henderson, Chris Page and Kate Parrot
Rocky Mountain Institute

Danish Environmental Protection Agency
Danish Ministry of the Environment

Contents

1 A FRAMEWORK FOR THE IMPLEMENTATION OF SUSTAINABLE CONSUMPTION AND PRODUCTION 5

1.1 THE CALL FOR A FRAMEWORK OF PROGRAMS 5
1.2 THE CALL FOR BETTER MODELS 5

2 A WHOLE-SYSTEMS APPROACH TO SUSTAINABLE PRODUCTION AND CONSUMPTION 7

2.1 REFRAMING PRODUCTION-CONSUMPTION MODELS: THE INVESTMENT, PRODUCTION, CONSUMPTION, WASTE CYCLE 7
2.2 CYCLES WITHIN THE IPCW SYSTEM 9
2.2.1 The Production and Consumption Cycle 9
2.2.2 The Investment Cycle 9
2.2.3 The Waste/By-product Cycle 9
2.3 WHOLE-SYSTEMS THINKING 10
2.3.1 The Whole-systems Approach 10
2.3.2 Green Buildings 11
2.3.3 Integrated Pest Management 11

3 PROGRAMS THAT SUPPORT WHOLE-SYSTEMS APPROACHES TO SUSTAINABILITY 13

3.1 PROGRAM ONE: INCORPORATE SYSTEMS THINKING INTO UN PROGRAM DESIGN AND DELIVERY 13
3.1.1 Objectives 13
3.1.2 Background 13
3.1.3 Anticipated Outcomes 14
3.1.4 Program Activities 14
3.2 PROGRAM TWO: SUPPORT THE WIDESPREAD USE OF INTEGRATED ECONOMIC AND ENVIRONMENTAL MODELING TOOLS. 15
3.2.1 Objectives 15
3.2.2 Background 15
3.2.3 Anticipated Outcomes 17
3.2.4 Program Activities 17
3.3 PROGRAM THREE: REFINE, STANDARDIZE, AND CONSISTENTLY APPLY SUSTAINABILITY METRICS TO PROGRAMMATIC INTERVENTIONS 18
3.3.1 Objectives 18
3.3.2 Background 18
3.3.3 Anticipated Outcomes 20
3.3.4 Program Activities 20
3.4 PROGRAM FOUR: CREATE AWARENESS OF "SUSTAINABLE INVESTMENT" PRACTICES AS THE NECESSARY COMPLEMENT OF SUSTAINABLE PRODUCTION AND CONSUMPTION PRACTICES. 21
3.4.1 Objectives 21
3.4.2 Background 21
3.4.3 Anticipated Outcomes 21
3.4.4 Program Activities 21

4 PROGRAMS THAT PROMOTE GREEN DESIGN AND INFRASTRUCTURE 23

4.1 PROGRAM FIVE: BUILD THE GLOBAL CAPACITY OF ONLINE RESOURCES IN GREEN DESIGN 23
4.1.1 Objectives 23
4.1.2 Background 23
4.1.3 Anticipated Outcomes 24
4.1.4 Activities 24
4.2 PROGRAM SIX: GREEN DESIGNS AND RETROFITS FOR UN BUILDINGS 25
4.2.1 Objectives 25
4.2.2 Background 25
4.2.3 Anticipated Outcomes 26
4.2.4 Program Activities 27
4.3 PROGRAM SEVEN: ENCOURAGE ADOPTION OF "DECENTRALIZED INFRASTRUCTURE" 28
4.3.1 Objective 28
4.3.2 Background 28
4.3.3 Activities 29

5 REGIONAL DEVELOPMENT PROGRAMS 31

5.1 PROGRAM EIGHT: ESTABLISH A COALITION OF DEVELOPED AND DEVELOPING ISLAND NATION-STATES TO FOSTER ENERGY INDEPENDENCE AND INCUBATION OF PIONEER HYDROGEN ECONOMIES. 31
5.1.1 Objectives 31
5.1.2 Background 31
5.1.3 Anticipated Outcomes 32
5.1.4 Program Activities 32
5.2 PROGRAM NINE: "LEAPFROG" NEW ENVIRONMENTAL REGULATIONS PAST OUTDATED COMMAND AND CONTROL MODELS TO INTEGRATED, FLEXIBLE ONES. 33
5.2.1 Objectives: 33
5.2.2 Background 34
5.2.3 Anticipated Outcomes: 35
5.2.4 Program Activities: 35
5.3 PROGRAM TEN: DEVELOP INITIATIVES IN CHINA TO ASSIST IN DEVELOPMENT OF SUSTAINABLE ENTERPRISES AND THE TRAINING OF SUSTAINABILITY LEADERS. 35
5.3.1 Objectives 35
5.3.2 Background 35
5.3.3 Anticipated Outcomes 38
5.3.4 Activities 38

6 CONCLUSION 41

7 ENDNOTES 43

1 A Framework for the Implementation of Sustainable Consumption and Production

1.1 The Call for a Framework of Programs

The 2002 World Summit on Sustainable Development's Plan of Implementation recorded its delegates' recommended actions for achieving global sustainable development. Chapter three of the Plan calls for a shift away from patterns of unsustainable consumption and production and for the creation of a ten-year framework of programs to bring the requested actions into fruition.

The UN, individual governments, and the private sector have environmental initiatives of almost every imaginable type and form: educational, technological, monitoring, financial, development-based, production-focused and more. Yet the World Summit on Sustainable Development[i] and the UNEP DTIE *Global Status 2002: Sustainable Consumption*[ii] concur: the combined effect of these programs has fallen short of achieving our goal of global sustainability.

1.2 The Call for Better Models

New models and methodologies that integrate sustainable consumption and production are key to successful sustainability efforts. The "Way Forward" section of UNEP's *Global Status 2002: Cleaner Production* prioritizes the integration of cleaner production and sustainable consumption efforts in its list of "elements to facilitate greater implementation of Cleaner Production." [iii] The report lists three necessary steps to achieving this integration, notably, "the development of methodologies which help in simultaneously addressing the issues related to Cleaner Production and Sustainable Consumption." [iv]

The corollary UNEP report, *Global Status 2002: Sustainable Consumption,* elaborates. The report identifies modeling as one of six strategic areas that need development in future sustainable consumption efforts. Strategic Area Three calls for:

> Finding a more appropriate conceptual schema for describing the essential elements of systems of production and consumption, allowing for more complexity of elements and interactions than the two-sided 'consumption' and 'production', but still simple enough to assist analysis and intervention.[v]

This paper proposes a whole-systems model that expands on conventional consumption-production models by describing the linked cycles of unsustainable investment, production, consumption, and waste. Whole-systems models are more complete and are therefore better situated to identify **coordinated networks** of strategic interventions in an effort to move beyond interventions that only affect one part of a system. This paper will then recommend programmatic responses based on the work the Rocky Mountain Institute has developed in the areas of whole-systems thinking, *Natural Capitalism*, manufacturing efficiency, and alternative energy and energy systems. Our programs are organized into three groups: Systems Thinking, Green Design, and Regional Development.

The Four Principles of Natural Capitalism

1) Radically Increase Resource Productivity.
2) Shift to biologically inspired production models (Biomimicry).
3) Move to a solutions-based business model.
4) Reinvest in natural and human capital.

-From *Natural Capitalism*

2 A Whole-Systems Approach to Sustainable Production and Consumption

2.1 Reframing Production-Consumption Models: The Investment, Production, Consumption, Waste Cycle

Success in the global efforts to shift towards sustainable consumption and production depends on an accurate and comprehensive model of the systems of consumption and production. Starting with such a model, it becomes possible to study the complete life cycle of a particular environmental problem; to discover where in the life cycle effective interventions can be made; and to produce metrics to measure the effectiveness of interventions.

The **Investment, Production, Consumption, Waste** (IPCW) cycle that this paper proposes (see diagram) is a more complete situation model than conventional production-consumption models.

The IPCW cycle shows that:

1> **Investment** uses financial and natural capital to create production capacity.
2> **Production** makes goods (and often waste) using additional financial and natural capital (operating costs and raw materials, for example).
3> **Consumption** takes goods and turns them into profits and (usually) waste.
4> **Waste** remains.

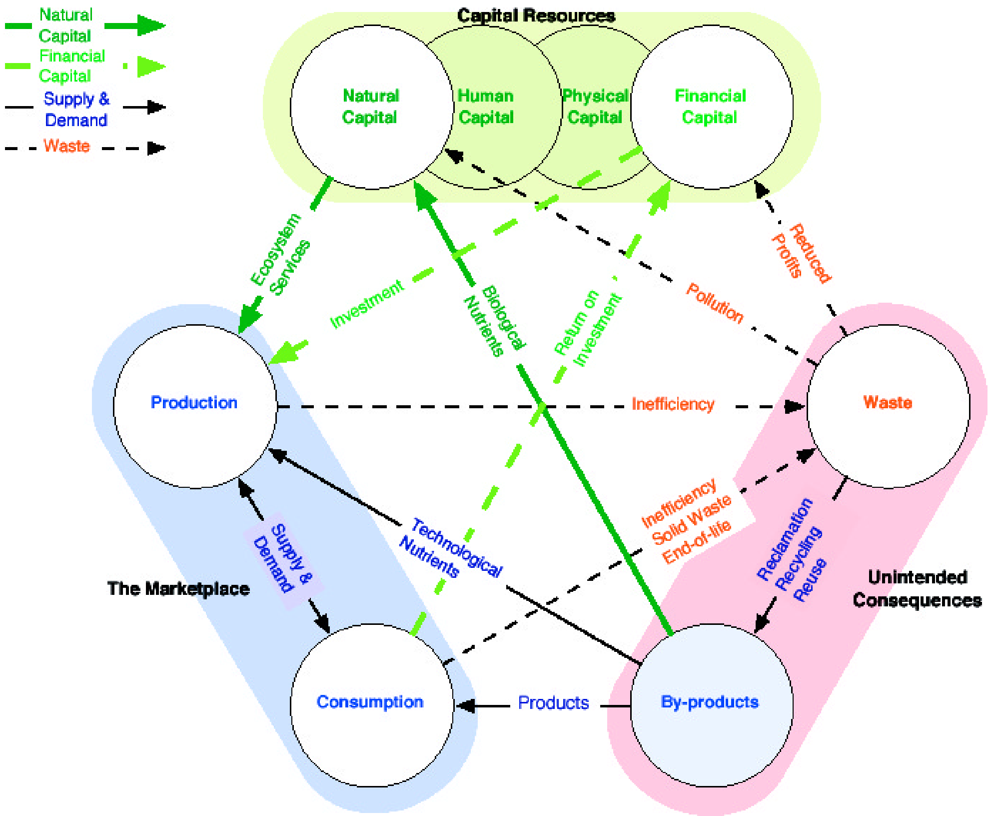

Fig. 1: IPCW Diagram

Diagram Key

- **Natural Capital** represents natural resources, such as coal and oil, living systems and ecosystem services.[vi]
- **Financial Capital** is cash, investments, and monetary instruments.[vii] In this diagram it also represents those who manage and control these resources.
- **Human and Physical Capital** are vital parts of the model developed in *Natural Capitalism*.[viii] They have been de-emphasized in this diagram for clarity.
- **Production** represents all of the infrastructure and systems that provide goods and services.
- **Consumption** is an abstraction that represents all market demand, including that of individuals, companies, and governments. "Consumption" also is the process of satisfying that demand by consuming goods and services.
- **By-products** are outputs of a system that could have been waste, but can be reused, usually instead of extracting further natural resources.
- **Waste** includes inefficient processes, residue, pollutants, and outputs from production that have no other further use in the IPCW cycle ("terminal waste"). It also includes resource depletion through over-consumption, such as the degradation of farmland through poor agriculture.
- **Arrows** represent the flow of resources, in various forms (money, goods, natural resources, waste) between these six nodes.

2.2 Cycles within the IPCW System

The IPCW system is complex. Highlighting three sub-cycles in the system makes it easier to understand.

2.2.1 The Production and Consumption Cycle

Current sustainable production and sustainable consumption programs target the production and consumption cycle. As consumers purchase goods and services, they influence what manufacturers create. As manufacturers produce new products and advertise to the public, they attempt to create or shape consumer demand.

This cycle can be influenced by actions that influence both consumers and producers, including:

- making sustainable products cheaper and unsustainable products more expensive (through pollution taxes, for example),
- promoting efficient production methods,
- working with (or legally compelling) manufacturers to phase out unsustainable products, and
- educating consumers (*e.g.*, product labeling).

2.2.2 The Investment Cycle

Investors supply capital to projects that they believe will give them a good return on their investment. These projects then interact with the production/consumption cycle, and if successful, return profits on the original investment.

In the natural capitalism model, natural resources are part of the capital invested in projects. Their associated costs needs to be internalized and their value incorporated into accounting methodologies. As such, reinvesting in natural capital should be a matter of course.[ix]

The investment cycle can be influenced by actions including:

- investment incentives,
- investor education,
- calculation and inclusion of currently externalized costs,
- making sustainability performance visible (using tools like the Global Reporting Initiative),
- risk assessments and valuation methods, and
- differential taxation (feebates) that reward sustainable projects and penalize unsustainable projects.

2.2.3 The Waste/By-product Cycle

In the waste cycle, natural resources are used in production to make goods (and waste). Goods are then consumed, causing more waste.

Conventional consumption and production both generate waste, which leads to an ever-increasing demand for natural resources and an increase in pollution. In contrast, sustainable production and consumption systems produce very little waste. Often they convert some “waste” streams into marketable by-products and reinsert them back into the system.

The waste cycle can be influenced by sustainable production and consumption, including:

- clean and efficient production methods,
- encouraging products and services designed for reuse and recycling, and
- prevention of externalization of waste removal, handling, and storage costs.

Most current interventions focus on one of these three cycles in isolation. However, whole-systems thinking suggests that a more unified approach may produce significantly better results.

2.3 Whole-Systems Thinking

2.3.1 The Whole-systems Approach

The two *Global Status 2002* reports each call repeatedly for new conceptual schemata to move beyond current approaches. Individually, today's global, national, and local interventions are not producing adequate progress towards sustainability. Interventions are often made without support from a comprehensive whole-systems model, and without sufficiently accurate system metrics for feedback.

Whole-systems thinking recognizes that a problem is created by every part of the system in which the problem is embedded, and that the problem can be addressed in any and every part of the system.

This approach focuses on interactions between the elements of a system as a way to understand and change the system itself. Whole-systems thinking pays close attention to incentives and feedback loops within a system as ways to change how a system behaves.[x]

Whole-systems thinkers see wholes instead of parts, interrelationships and patterns, rather than individual things and static snapshots. They seek solutions that simultaneously address multiple problems.[xi]

Respected whole-systems theorist Donella H. Meadows lists nine places to intervene in a system, in increasing order of impact: numbers (subsidies, taxes, standards), material stocks and flows, regulating negative feedback loops, driving positive feedback loops, information flows, the rules of the system (incentives, punishment, constraints), the power of self-organization, the goals of the system, and the mindset or paradigm out of which the goals, rules, and feedback structures arise.[xii] In Meadow's hierarchy, altering numbers—adding five percent more money to a program budget, reducing unemployment by half a percent—are the least effective form of intervention. Altering mindsets—traditional industrialization leads to prosperity, waste is inevitable, centralized projects mean progress—is the most effective form of intervention. Effective change means tinkering with intervention strategies and parts of the system until something works.[xiii]

Whole-systems thinking can produce effects that would be unattainable with more linear approaches because it is often a closer fit to the reality of the situation. Two examples, from architecture and agriculture, showcase the benefits of whole-systems approaches.

2.3.2 Green Buildings

Green building techniques successfully deliver better buildings with lower construction costs, fewer natural resource demands, and lower operating costs by understanding the whole system in which a building operates.

Traditionally, when making a decision about how much to invest in energy-efficient building technologies or how fuel-efficient a car should be, we automatically assume incremental levels of savings for our efforts. One should install extra insulation in a house, the reasoning goes, until the cost per extra fraction of an inch of extra thickness is equal, but not more than, the extra savings on the heating bill. While this is common thinking, this reasoning ignores whole-systems thinking.

For example, a PG&E demonstration building in Davis, California contains neither a furnace nor an air conditioning system in a climate where summer temperatures sometimes reach 45 Celsius. The creators designed away the need for active temperature control systems by combining improvements in the key components of the house—shell insulation, thermal mass, and internal appliances. Double-thick insulation and super-efficient windows prevent unwanted heat from entering the house; efficient lights and appliances release very little heat inside; and double drywalls create sufficient thermal mass to store coolness through the hottest part of the day. Whole-systems thinking yielded energy savings and passive cooling far in excess of what any single improvement could have achieved on its own.

With furnace and air conditioning gone, the need for associated infrastructure such as ductwork, pipes, controls, and wiring were also drastically reduced, creating more space for people inside the building. Beyond the lack of heating and cooling machinery, energy-efficiency measures reduced the energy demands of space conditioning, water heating, lighting, and refrigeration energy by 75% compared to a conventional home. Greater up-front costs for some components of the building quickly paid for themselves with "big savings that were cheaper than little ones."[xiv]

2.3.3 Integrated Pest Management

Integrated Pest Management (IPM) is an outstandingly successful application of whole-systems, life-cycle-based thinking to a practical problem: controlling (mainly agricultural) pest populations. Although IPM was once a radical departure from the then-standard “spray-and-pray” approach to pest control (*i.e.*, apply pesticides and hope for population reduction), its successes have brought it to the mainstream.[xv]

IPM operates by building a detailed understanding of the system in which pests appear, by:

- understanding the whole life cycle of the pest species in question, including what supports the population, reproductive cycles, and points in the life cycle where populations can be reduced by an intervention,
- monitoring the pest populations at every stage of the life cycle, and
- precisely defining population levels at which pest populations require action.

By applying a system that includes metrics and a life-cycle model, many small, strategic interventions can cumulatively result in excellent pest control. Successful IPM reduces the problem at every stage of its life cycle so that threshold pest populations simply never appear. The individual interventions of an integrated pest management system are ineffective on their own. IPM works because it uses these individual interventions in response to carefully measured feedback from the system it seeks to change. If one intervention is less effective than anticipated, the other interventions in the system are increased in intensity or new interventions are introduced until the system is back on track.

While whole-systems thinking does not automatically yield sustainable production and consumption systems, *sustainability cannot be achieved in the absence of whole-systems thinking*. An environmental health and safety employee charged with enforcing hazardous waste disposal regulations, but otherwise given no authority, will rarely be able to enact innovative and cost-saving ways of eliminating hazardous waste on the front end. An engineer tasked with cooling a building after the architect has drawn the final floor plans will not be able to suggest changes to lighting systems, aspect, or materials that could reduce the size of the HVAC system or eliminate it altogether. The farmer constrained by market demand may not be able to choose to cultivate a variety of crops, remaining chained to a pesticide-dependent monoculture.

Action on conventional models of sustainable production and consumption tends to emphasize interventions at the production and consumption stages of the cycle. To be effective, however, interventions must be considered for every stage.

The programs outlined below suggest multiple intervention points in the areas of Systems Thinking, Green Design, and Regional Development.

3 Programs that Support Whole-Systems Approaches to Sustainability

3.1 Program One: Incorporate systems thinking into UN program design and delivery

3.1.1 Objectives

Develop capacity within the UN to use whole-systems, integrated problem-solving to design its programs.

Develop capacity within the UN to teach these problem-solving techniques to its various clients.

3.1.2 Background

For generations, engineers, scientists, and managers prepared themselves to solve complex problems by becoming increasingly specialized—by reducing problems to their constituent parts and focusing their attention on each part. As a result, for instance, architects design a building, mechanical engineers devise its heating system, lighting designers draw up plans for illumination, and interior designers plan the resulting spaces. This separation of design functions and professions often results in inefficient design, construction delays, oversized heating systems, higher costs, and unnecessary environmental impacts.

Sidebar: Operation Cat Drop

Lack of whole-systems thinking can result in more important consequences than poor building design; it can also result in serious unforeseen problems. In Borneo in the 1950s, the World Health Organization (WHO) attempted to solve the problem of malaria afflicting the Dyack people. Their simple solution was to spray DDT to kill mosquitoes. The operation was considered a success until the thatch roofs of most houses started falling down. It was determined that the DDT also killed wasps that had previously preyed on thatch-eating caterpillars. Without the wasps, the caterpillars were rampant and ate the roofs of the village houses.

WHO then discovered a worse problem: the DDT built up in the food chain, poisoning insects that were eaten by lizards which, in turn, were eaten by cats. As the cats died, rats proliferated, and the area was faced with outbreaks of sylvatic plague and typhus. WHO eventually enlisted the Royal Air Force to parachute 14,000 live cats into Borneo. If WHO had considered the implications of spraying DDT from a whole-systems perspective, this entire fiasco might have been avoided and a more appropriate solution sought.

-*Natural Capitalism, p. 155-156*

Whole-systems thinking, an alternative to counter-productive, linear problem-solving, was described at length in section 2.3.

Whole-systems ideas have specific and practical design and problem-solving applications. For example, Rocky Mountain Institute conducts intensive workshops based on integrated whole-systems thinking. It has used its technique in scores of circumstances for design or redesign of buildings, land parcels, communities, petrochemical plants, food and industrial processing facilities, and even refugee shelters. Results have included attractive, functional, and profitable design, plus significant reductions in energy consumption, cost, waste, environmental impacts, and resource inputs.

3.1.3 Anticipated Outcomes

- Lower cost, more effective, and more efficient UN programs with fewer unintended consequences, including environmental impacts.
- Understanding among UN personnel and leaders of the value of integrated, whole-systems design.

3.1.4 Program Activities

3.1.4.1 Short term

- Test the value of integrated, whole-systems design in one department of the UN (the capacity-building branch of the UNEP, for example) by contracting appropriate organizations to:

    - conduct intensive workshops with UN personnel to help design or redesign certain selected UN programs,

- teach selected UN personnel whole-systems problem-solving techniques, and
- teach UN personnel to teach whole-systems problem-solving techniques to selected UN clients.

- Monitor and study the results of this pilot program.

3.1.4.2 Medium Term

- Expand the use of whole-systems design and training to additional UN programs, based on tests conducted in the short term.

- Integrate whole-systems design into the development of UN programs.

- Integrate the teaching of whole-systems thinking into appropriate client-delivery programs.

3.1.4.3 Long Term

- Require the use of integrated whole-system thinking in the design and delivery of all UN programs.

3.2 Program Two: Support the Widespread Use of Integrated Economic and Environmental Modeling Tools.

3.2.1 Objectives

Foster the further development of predictive models that promote the understanding of the interactions between the economy and the environment.

In particular, focus on simulation tools to support decisions that have large environmental effects: government policy, investment, and product design.

Promote research into using computer models to help design, support, and monitor other environmental programs, particularly those that operate together across different levels of the investment, production, consumption, and waste system.

3.2.2 Background

Computer simulation of environmental problems supported and informed the strategies that scientists and policymakers developed to combat the erosion of the ozone layer. Such models today encourage political action on greenhouse gas emissions by forecasting the effects of global warming.[xvi]

Computer modeling is one essential tool for breaking through what is superficially "known" about systems to understand the dynamics of the system itself. This kind of preconception-challenging approach can improve the quality of mental and social models. It is by changing these models that real change is effected.[xvii]

Computer modeling of our economic and environmental systems can demonstrate the benefits and feasibility of sustainable consumption and sustainable production. Accurate and widely accepted models can provide a basis for implementing system-wide changes and can help target programs for maximum effect.

Widespread Deployment of Existing Tools

The current generation of economic/environmental modeling tools are under-used. Many product designers do not have access to environmental assessment tools, the training to use them properly, or a legislative requirement to produce impact statements. Small and/or poor governments do not have indigenous computer modeling expertise or the resources to develop it, yet must still make decisions about the impact of environmental programs.

Targeted Development of the Next Generation of Tools

The current generation of simulation tools model a single dimension of complexity each: one tool models macroeconomics and another, new products. There is a need for a new generation of tools that performs simulations like these across domain boundaries—tools, for example, that can help a product designer see the waste management or capital requirements of his organization's products, or help an economist to make the case for decentralizing the electrical infrastructure of a nation by modeling the economic gains.

In particular, there is a need for tools that can model the combined effects of actions at different levels. Most environmental problems are being simultaneously addressed at financial, educational, cultural, and technical levels. Effective modeling tools need to be able to simulate program effects on each of these levels and sum the effects into a picture of the whole system. Tools like these could help design a new generation of environmental intervention programs that focus on multiple levels of action within a single modeling and monitoring framework.

An Overview of Current Modeling Programs:

Macroeconomic Modeling: Support for Governments and International Agencies

The GEM-E3 model, developed by the European Commission, analyzes the macro-economy and its interactions with energy systems and the environment. This system models each nation individually, with data reflecting taxes, consumption, investment, and import/export activity. The model is sufficiently specific to allow fine-grained analyses of policy options and effects[xviii].

For example, this model was used to compute the likely economic impacts of different CO_2 emission-reduction strategies in Switzerland. The results indicated the secondary economic benefits of using a domestic carbon tax rather than buying CO_2 permits on the international market.[xix]

Industrial Life-Cycle Analysis: Support for companies

The "Economic Input-Output Model for Environmental Life Cycle Analysis" by the Carnegie Mellon University Green Design[xx] combines a variety of U.S. government data on environmental impacts and economic interdependencies. Researchers can use the model to calculate the total cumulative environmental and economic impact of economic activity in some 485 different economic areas, such as "Commercial Fishing" or "Air Freight."

For example, the EIOLCA simulation reports that $1 million of spending on "book printing" (one of its 485 economic categories) will release 4.3 million metric tons of CO_2. All the different emission sources for each economic category are shown individually, so it is clear that "paper production" and "transport" account for almost half of the emissions in the book printing process.

Product Life-Cycle Analysis: Support for Product Designers
Product life-cycle analysis tools, such as the SimaPro[xxi] system, help designers understand the impact of their products.

SimaPro, for example, maps a product as a set of inputs (such as 0.4 kg injection-molded plastic, 0.1 kg steel, 300w power consumption) that are individually rated for environmental impact using pre-defined assessment tables. The system produces a simple analysis of a proposed design. In this instance, it shows that the major environmental impact of this product will come from its power consumption over the lifetime of the product.

3.2.3 Anticipated Outcomes

- Enhanced awareness and use of product-design and life-cycle-analysis tools throughout industry.
- Broader awareness of simulation as an important step in environmental decision making processes.
- A more refined match between available tools and needs for simulation services.
- Accelerated development of decision-support tools to help design and model environmental initiatives and impacts at all levels.

3.2.4 Program Activities

3.2.4.1 Short term

- Study opportunities to extend the use of economic/environmental modeling tools across governments, private enterprise, and education.
- Index available tools and create a map of needs and the tools needed to address them.
- Collect information on unmet needs for simulation services, paying particular attention to needs which can be met with existing tools (for example, identify governments without the resources to use models like GEM-E3 to help them design their own policies). Also gather requirements for a new generation of simulation systems.

3.2.4.2 Medium term

- Design and implement support programs to help deploy simulation tools for sustainable production and sustainable consumption programs. For example, train designers in life-cycle assessment technologies.
- Support the use of models like GEM-E3 for study of technological and policy changes in the private sector. For example, GEM-E3 can report the effect of investment programs and cleaner production systems on environmental impacts.
- Support the development of simulation models of UN environmental and development programs within the context of systems like GEM-E3 in order to help refine program goals.

3.2.4.3 Long Term

- Support the development of tools that model international, regional, national, and private-sector actions in the economic/environmental system within a single simulations framework. Integrated models should be developed to coordinate programs at all of these levels.

3.3 Program Three: Refine, Standardize, and Consistently Apply Sustainability Metrics to Programmatic Interventions

3.3.1 Objectives

Increase the efficient and effective use of quantitative program assessment to assist sustainability activities.

Require that UN-funded projects estimate their total environmental benefit and measure this against the appropriate metrics. If results vary significantly, investigate.

Fully use current metrics where available and, as a secondary goal, create new metrics that can more accurately and succinctly measure sustainability.

3.3.2 Background

Measuring the effect of environmental programs requires data. Quantitative measurements of the relative severity of our environmental impact can help greatly with mitigation efforts, as was evidenced in the highly-effective global action to phase out CFC production. Similar success has been achieved, though far less spectacularly, in the political effects of studies on greenhouse gas emissions.

The integrated-systems approach requires that researchers understand the projected outcomes of particular actions and have the ability to measure these projections against the results, so that when the two do not correspond, researchers can determine why, and use this feedback to continually refine the intervention system. This approach requires metrics and data.

Researchers and policymakers are at the very earliest stage of this kind of precision in understanding and managing environmental problems. Although there are innumerable sustainability programs, initiatives, proposals, and agendas, the difficulties of assessing the concrete results of any action on the status of the entire system has contributed to the limited success of efforts in the field. Two emerging metrics, one for companies and the other for products, offer new data to help assess program impacts.

The Global Reporting Initiative
The GRI[xxii] is an important milestone in the journey towards providing accurate, public sustainability data for companies. Though it has reached only an early stage of development, the GRI has widespread support and may well succeed in making sustainable-business information as reliable and available as financial data.

The Integrated Product Policy
Another promising initiative is the European Union Integrated Product Policy.[xxiii] The IPP is a well-designed program with a broad set of goals. It

proposes whole-systems interventions in order to increase adoption of green products in the marketplace.

One of the IPP initiatives provides life-cycle analysis for a broad spectrum of products. Two promising projects, the *External Environmental Effects Related to the Life-Cycle of Products and Services*[xxiv] and the parallel *Information Database on Environmental Aspects of Products And Services*[xxv] will provide a large, available, standardized pool of sustainability information about products and the consumption of products.

Using GRI, IPP and similar data

Though these new sources of data are all in the early stages of adoption, they are an encouraging development that should be supported. As the GRI, IPP, and similar metrics are more widely used, national/international and sector/sub-sector sustainability indices can be computed, giving us a sustainability metrics that are as easy to quote as a nation's GNP.

In the measurement of metrics, it is important to consider the appropriate use of scale. Aggregate national data from individual countries, for example, rarely reflects the considerable gap between rich and poor that often exists within a nation's boundaries, nor does it reflect the wide variations in pollution, resource scarcity, or quality of life. Aggregate national data can therefore lead to misguided policy decisions or might overlook "hot spots" that could best benefit from intervention. It also may lead to less accurate information being included in predictive models.[xxvi] In countries where decisions on environmental policy are made at the state, county, province, or town level, national aggregate data may not provide the level of information necessary to make the best decisions. Local data gathering may be less prone to reporting error than when the host nation collects and reports the information.[xxvii]

By engaging local people in gathering information for metrics (through, for example, Rapid Rural Appraisal techniques), more accurate, finely grained information can be gathered and translated into models and decision-making. Such techniques can also provide more accurate information to feed into predictive models used to map regional, national, and global trends.

Future programs (and networks of programs) can set specific targets in terms of the indices computed from this new metric data. In keeping with an emphasis on setting numerical goals for the performance of systems of programs, such indices can be used to review resource allocation and retarget sustainability efforts into areas with the greatest results. The number of programs that can be assessed in this way will grow as more and better data become available.

However, there are some situations where an over-emphasis on metrics can be counterproductive, such as:

- when measurement creates time delays or barriers to timely, appropriate action, as in the precautionary principle;
- when the intervention targets have outcomes that are too difficult or expensive to measure (for example, some kinds of public awareness programs);
- when metrics cannot provide the same level of discrimination as the judgment of an experienced professional. For example, the success of

some educational initiatives for indigenous peoples is often measured in gradual shifts in attitudes or openness to new ideas.

In these instances, the correct measuring instrument is not a metric, but a wise and experienced human being. The cultivation and training of such individuals is also a goal of this program (see also Program One, section 3.1).

3.3.3 Anticipated Outcomes

- Greatly increased understanding of the effectiveness of sustainability interventions.
- Resulting refinement and innovation in programs.
- Creation of data to support effective whole-systems intervention using coordinated networks of programs.
- Greater public awareness of sustainability indices.

3.3.4 Program Activities

3.3.4.1 Short Term

- Index data sources for easy accessibility and use.
- Monitor emerging publication standards and encourage their use.
- Identify environmental problems for which new metrics, or better application of existing metrics, would provide concrete benefits.
- Promote the use of goal-oriented intervention-program design, and gather data on "missing metrics" or metric failures from program evaluations.

3.3.4.2 Medium Term

- Begin work on information technology aspects of data access and exchange.
- Gather data that indicates problems or gaps in current metrics.
- Encourage funding bodies to direct funding to programs whose success or failure is measurable based on available indices.
- Build public awareness of sustainability indices and research concrete actions to support and integrate indices with such initiatives as consumer labeling.
- Facilitate the creation and standardization of new metrics by forming networks among interested researchers. Attempt to avoid clashes of standards by early integration.

3.3.4.3 Long Term

- Integrate full use of environmental benefits measured against appropriate metrics into funding cycles.
- Encourage the adoption of metrics-based legislation where appropriate.

Support the consolidation of sustainability metrics as a part of business life

3.4 Program Four: Create Awareness of "Sustainable Investment" Practices as the Necessary Complement of Sustainable Production and Consumption Practices.

3.4.1 Objectives

- Develop the model and practice of sustainable investment as a complement to sustainable production and sustainable consumption models and practices.
- Foster the understanding of sustainable investment as an important missing ingredient in transitioning economies to sustainability.

3.4.2 Background

Sustainable investment is the natural parallel of sustainable consumption and sustainable production. The precise definition of sustainable investment may take years to establish, considering that both sustainable production and sustainable consumption are still being defined. However, the eventual definition of sustainable investment should certainly include multiple-bottom-line reporting, environmental impact analyses of investment portfolios, and the development of concepts like zero-emissions capital management.

A UNEP DTIE Sustainable Investment program would not replicate efforts already being made by the UNEP Financial Initiatives program, or by initiatives such as the GRI. Rather, the SI program would focus on applying work from these initiatives to support existing Sustainable Production and Sustainable Consumption Programs. An SI program would work to form a three-way partnership between investment, production, and consumption approaches to sustainability. It would help connect the financial world with the needs of Sustainable Production and Sustainable Consumption Programs and attempt to build awareness of such issues in the investment sector.

3.4.3 Anticipated Outcomes

- Development of parallel sustainability concepts for investment, consumption, and production.
- Support of sustainable investment as a peer to sustainable production and sustainable consumption concepts and practices.
- Greater effectiveness of other interventions through better understanding of this vital area.

3.4.4 Program Activities

3.4.4.1 Short Term

- Research starting a UNEP DTIE Sustainable Investment program.
- Hold a conference to define the purview of such a program, raise awareness, and recruit support.
- Foster awareness in the sustainable consumption and sustainable production communities about their relationship with sustainable investment.

3.4.4.2 Medium Term

- Start a UNEP DTIE Sustainable Investment Program.
- Integrate sustainable investment into combined activities of SC and SP programs on an equal footing.
- Work closely with initiatives like GRI and green development groups to support SC and SP programs with investment.

3.4.4.3 Long Term

- Fully integrate sustainable consumption, production, and investment approaches in sustainability programs.

4 Programs that Promote Green Design and Infrastructure

4.1 Program Five: Build the Global Capacity of Online Resources in Green Design

4.1.1 Objectives

Support and develop easily accessible sources of information on green design.

Develop frameworks that are interactive and practically useful to the non-technical green-design practitioner.

4.1.2 Background

A growing number of companies are seeking to design products and processes that are non-toxic in their manufacture and use; use a minimum of materials and energy; and are part of a system that enhances rather than depletes the earth. McDunough-Braungart green chemistry principles, the principles of natural capitalism, and the guidelines for biomimicry (see sidebar) all offer whole-system design frameworks for the creation of cleaner, less polluting products and production systems in all types in all industries.

Sidebar: Biomimicry Principles

Biomimicry encourages us to ask in response to all design problems, "What would Nature do here?" and to follow nature's ability to function in a closed-loop, nontoxic, sustainable manner. Below are some guidelines:

Nature runs only on sunlight.
Nature uses only the energy it needs.
Nature fits form to function.
Nature recycles everything.
Nature rewards cooperation.
Nature banks on diversity.
Nature demands local expertise.
Nature curbs excesses from within.
Nature taps the power of limits.

(From *Biomimicry: Innovation Inspired by Nature*. p.7. Janine Benyus, 1997. William Morrow and Company, New York, New York.)

These frameworks encourage product designers and engineers to employ nature’s principles of efficiency and zero waste. Biologists and ecologists that study organisms and ecosystems are quite familiar with nature’s repertoire of intelligent designs and strategies, but rarely do they get to share their knowledge with engineers and designers. Furthermore, manufacturers in the developing world do not always have easy access to the intelligent designs that do exist, those that can achieve ten- or hundred-fold resource savings at *lower* cost.

The reason for these gaps is not so much a lack of information, but a lack of access to information. What is needed is a library that bridges this language chasm and makes literature and solutions based on the principles of natural systems accessible to designers and engineers.

An open library of designs for refrigerators, lighting, heating, cooling, motors, and other systems will encourage manufacturers, particularly in the developing world, to leapfrog directly to the most sustainable technologies, which are much cheaper in the long run. Manufacturers will be encouraged to use the efficient designs because they are free, while inefficient designs still have to be paid for. The library could also include green chemistry and biological solutions to industry challenges, for example enzymatic reactions that could be used in place of energy, and chemical-intensive processes or nontoxic paint pigments for cars and buildings. This library should be free of all intellectual property restrictions and open for use by any manufacturer, in any nation, without charge.

4.1.3 Anticipated Outcomes

- Enhanced adoption of advanced, efficient product design, particularly in the developing world.
- Reduction of energy demand (and corresponding reallocation of some grid and generation investments).
- Enhanced adoption of smaller, decentralized, sustainable power sources due to reduced demand.
- Reduction of human and ecosystem toxicity, and reduction in solid waste.

4.1.4 Activities

4.1.4.1 Short Term

- From existing sustainability database projects, identify online databases of sustainability products and practices to support and to collaborate with in dissemination of green design information.[xxviii] All data should be linked to related UN database resources.
- Support development of a reference catalogue of designs for environmentally sound products and production systems, resources for acquiring them, and best whole-systems design practices.

4.1.4.2 Medium Term

- Carefully monitor adoption.
- Build networks of manufacturers who are using the designs to share infrastructure costs associated with implementation and further refinement.
- Encourage the use of tools such as the US EPA's TRACI, which translates complex toxicological and life-cycle assessment data into information that designers and engineers can readily use to make business decisions.
- Build networks of manufacturers using the designs to share infrastructure costs associated with implementation and further refinement.
- Support initiatives by companies to work with their supply chains and customers to create new, innovative products and services through the use of life-cycle assessment data and the creation of multi-stakeholder partnerships to reduce toxicity and improve energy efficiency.

4.1.4.3 Long Term

- Conduct long-term studies on the impact of the products; use this data to further refine designs and encourage adoption.

4.2 Program Six: Green Designs and Retrofits for UN Buildings

4.2.1 Objectives

Demonstrate the benefits of green building design and energy-efficient end-use equipment to citizens, policymakers, and the construction industry through green retrofits of existing UN buildings and green construction of new UN buildings.

Increase the rate of diffusion of green technologies.

Reduce UN costs and environmental impacts.

Provide a healthy working environment for UN personnel.

4.2.2 Background

Showcasing innovative green technologies in high-visibility UN buildings encourages awareness and adoption of these innovations on a broader scale. Research in the area of innovation-diffusion demonstrates that more people adopt innovations faster if they are innovations that they can observe, obsere, and test before committing themselves to, and that have a perceivable relative advantage over existing technologies.[xxix] By giving citizens a chance to see, test, and notice the advantages of a UN green building, the UN can help to accelerate adoption of such ideas throughout society.

The Many Benefits of Green Building:
From reflective roofs, CFLs, and super-efficient windows to flexible access floors, personal comfort controls, and photovoltaics, a wealth of new technologies is adding function, value, and high performance to today's buildings.

Well-designed green buildings often cost no more to build than the alternatives (if not less) because resource-efficient strategies allow for the downsizing of more costly mechanical, electrical, and structural systems.

Green buildings save money throughout their life cycle. They are energy efficient, saving from 20 to 50% of energy costs through integrated planning, site orientation, energy-saving technologies, on-site renewable energy-producing technologies, light-reflective materials, natural daylight and ventilation, and downsized HVAC and other equipment. A raft of other resource- and money-saving devices that continue to pay throughout the building's life cycle includes: natural landscaping, water-saving equipment, low-maintenance materials, salvaged construction debris, and smart building controls.

Green buildings generally provide higher-quality work environments, principally because of daylighting and the lack of off-gassing from toxic building materials. This, in turn, generally translates to greater employee job satisfaction and higher work productivity. Eight documented case studies show that productivity gains from green design can be as high as 16 percent.[xxx]

Short-term Results:
While building green from day one offers best chances for maximum efficiency and breakthrough levels of energy savings, retrofits can also yield excellent results. Installing daylighting and energy efficiency measures in one California office building yielded 75% energy savings and a 45% reduction in worker absenteeism.[xxxi] Analysis of a green retrofit of a 20-year-old Chicago building already in need of remodeling revealed that changing the renovation design to a whole-systems approach could dramatically improve comfort, quadruple energy efficiency, and cost about the same as normal renovations.[xxxii] Simply screwing in compact florescent lamps saves 75 to 80% of the electricity used by an incandescent bulb; reduces the labor of replacing them because they last 8 to 13 times longer; and places less of a load on a building's cooling system because of no heat from incandescent bulbs.[xxxiii]

4.2.3 Anticipated Outcomes

- A heightened awareness of the benefits of green buildings and energy-efficient equipment by UN workers and citizens who interact with showcased buildings.
- Increased and accelerated adoption of green building technology by other members of society.
- Tangible support for new efforts by UN efforts to encourage green building in developing countries, for example, by the UNEP International Environmental Technology Centre[xxxiv].
- Healthy working environment for UN personnel; increased staff productivity; reduced absenteeism.
- Reduced capital costs of new buildings; reduced operating costs of existing UN buildings; reduced resource consumption and environmental impact of UN buildings.
- Improved public relations, both internationally and with the buildings' neighbors.

4.2.4 Program Activities

4.2.4.1 Short Term

- Develop a policy for the greening of UN building, including energy efficiency in buildings and equipment, green building materials, waste reduction, water efficiency, and buildings' relationships to surrounding neighborhood. The policy could include green-building criteria, including:
  -more energy is generated by the building than used
  -water leaves the building cleaner than it enters
  -indoor air quality is healthy
  -building achieves a given rating on a standard green-building rating systems (such as LEED, Leadership in Energy and Environmental Design, a green building rating system from the U.S. Green Building Council).
- Develop metrics and target a performance objective for each policy category. (e.g. electricity use per square foot).
- Inventory existing UN facilities.
- Implement rapid, low-to-no-cost retrofits in all UN buildings (e.g., compact florescent bulbs, water-saving faucets).
- Pick several buildings to pilot extensive retrofits that will make the most visible statement.
- Conduct integrated, whole-systems design workshop for each type of building to be retrofitted. Include building-users on workshop design team along with designers and engineers.

4.2.4.2 Medium Term

- Retrofit targeted buildings.
- Monitor results.
- Develop longer-term retrofit program.
- Develop green-building program for new building construction.
- Continue to retrofit existing buildings worldwide.
- Involve in each building retrofit process, key elements of local construction industry.
- Coordinate retrofit and new-construction program with other UN programs to influence and train the construction industry in various countries. For example, conduct UN-sponsored technology seminars inside the retrofitted buildings. These efforts should continue into the long term.

4.2.4.3 Long Term

- Provide green-building educational materials for building visitors and on UN websites
- Develop educational materials comparing before-and-after retrofit costs and benefits.
- Expand green design programs now being developed by UNEP International Environmental Technology Centre.[xxxv]

4.3 Program Seven: Encourage Adoption of "Decentralized Infrastructure"

4.3.1 Objective

To encourage the adoption of "Decentralized Infrastructure" (defined below) to reduce or remove the need for costly and resource- and capital-inefficient centralized infrastructure.

This program involves a mix of prototyping, education, investment, and public relations.

4.3.2 Background

Centralized infrastructure such as power stations often require extremely large capital investments and many years to build. In many cases these same services can be provided via a mixture of demand-reducing end-use efficiency (such as insulation and efficient appliances) and local, small-scale resource provisioning (for example, solar panels). The resulting avoided cost represents a crucial but widely unrecognized source of capital, particularly for the developing world.

As an example, the manufacture of end-use, energy-saving technologies such as compact-florescent lamps (CFL) or super-efficient windows takes around a thousand times less capital than expanding the electricity supply. Furthermore, capital from demand reduction is returned ten times faster than it would be for building new electrical infrastructure. Combined with the lower capital requirements, a CFL plant is 10,000 times more efficient than expanded infrastructure. [xxxvi]

By reducing demand, power stations and other forms of infrastructure can be built smaller, closer to the end-user, or eliminated entirely. Shifting to a demand-reduction model can provide people with services they want and need in a manner that consumes fewer resources, is flexible and sustainable, and costs less. Historically, providing power and water to large and rapidly growing populations often necessitates huge development projects. These can be expensive, requiring money from multinational lending institutions; can generate tremendous environmental damage and displacement of people; can under-perform expectations; and, by the nature of their size, are inflexible to changes in demand. While the generation of much-needed jobs is often an attractive feature of such projects, in the long run they may be less sustainable than smaller, more efficient, flexible, and regionally appropriate modes of delivering the same services.

Two terms, "decentralized" and "distributed," are used (roughly) interchangeably to describe this form of infrastructure. The case for distributed electricity infrastructure is exhaustively demonstrated in *Small Is Profitable* by A.B. Lovins, *et al.*[xxxvii]

Decentralized infrastructure in developed countries

Developed countries can also leverage the benefits of distributed generation as a flexible, cost-effective alternative to replacing aging, centralized energy infrastructures. By reducing overall energy consumption, and thus reducing demand at "the end of the pipe" the distributed generation system mitigates the need to build new energy capacity. In situations that demand a reliable, uninterrupted supply of energy or water, such as data centers or hospitals, decentralizing and distributing the source of both improves source security, reduces the chance of interruption, and allows for better control over locally appropriate efficiency measures.

Decentralized Infrastructure Housing

Housing construction often requires six different kinds of centralized infrastructure (potable water, wastewater treatment, stormwater management, electricity, gas, and communications) before construction can start. These costs are often externalized; that is, they are not included in the prices of the residences. In contrast, Decentralized Infrastructure Housing (DIH) provides all of these essential services, using such features as energy efficiency, photovoltaic generation, composting toilets, and a raft of other emerging sustainable technologies.

Obstacles

Because Decentralized Infrastructure Housing actually looks very different from conventional housing, adoption is problematic—despite the fact that actual quality of life for residents may be higher and total-systems development costs significantly lower.

Likewise, large, centralized development projects that supply energy and water often represent an enormous sunk capital cost that makes energy and water cheap to the end-user. In such cases, incentives to reduce energy consumption may be extremely low for government, utilities, and the individual citizen. Intervention, then, must happen at both the building level, and at the level of planning how infrastructure services are provided in the first place.

4.3.3 Activities

4.3.3.1 Short term

- Analyze and model (see program two, section 3.2) the costs and benefits of centralized infrastructure development versus programs that incorporate decentralized infrastructure for different nations, taking into account job generation, specific regional concerns, and net economic and environmental impact.

- Gather regionally appropriate case stories and data describing the economic benefits of decentralized infrastructure and make them available via the Internet, particularly in conjunction with existing sustainable practice websites.

- Develop education materials comparing decentralized infrastructure costs with centralized, capital-intensive ‘traditional’ systems.

- Encourage development of policies favoring decentralized infrastructure in multinational lending organizations, and for groups that supply microloans.

- Encourage use of decentralized infrastructure in aid and relief efforts that provide housing in the wake of displacement or disaster—for temporary, longer-term, and permanent shelter.

4.3.3.2 *Medium term*

- Conduct UN-sponsored technology introduction and training seminars on decentralized infrastructure and Decentralized Infrastructure Housing (DIH).
- Educate civil leaders and politicians (particularly finance ministers) on the possibilities of freeing up huge amounts of development capital with the adoption of decentralized infrastructure. Provide nation-specific projects and support regional champions in order to do so.
- Develop large-scale training programs for energy-efficiency retrofits and decentralized infrastructure housing that teach skills and generate jobs.[xxxviii]
- Educate private-sector contractors and developers on DIH benefits.
- Build UN-sponsored model homes with examples of decentralized infrastructure that ordinary people can tour, in order to gain public acceptance.
- Support the construction of model projects that can be documented and evaluated to provide evidence for the success of the system.
- Find opinion-leaders to endorse or use DIH to remove any stigma associated with a new kind of housing.
- Particularly in developed countries, encourage the establishment of national zoning and building code standards that encourage, rather than hinder, decentralized infrastructure.[xxxix]

4.3.3.3 *Long term*

- Establish a multilateral agreement to promote efficiency in energy and building materials and to phase out of universally inefficient materials and devices.

- Establish multilateral agreements in support of appropriately sized development projects that supply resources efficiently and sustainably to those they are meant to serve; are flexible and modular; generate local jobs; have a reduced impact on the planet; and do not saddle the nation or region with unreasonable debt.

5 Regional Development Programs

5.1 Program Eight: Establish a coalition of developed and developing island nation-states to foster energy independence and incubation of pioneer hydrogen economies.[xl]

5.1.1 Objectives

Promote the development of self-sufficient, sustainable energy infrastructures for developing and developed island nation-states.

Create an international network for the exchange of decentralized sustainable energy ideas, technological expertise, innovation, enterprise incubation, and strategies to between all island nation-states - big and small, developing and developed.

Address unique economic, environmental, and security needs of island-states through cutting edge strategies and technologies such as energy efficiency, distributed generation, and alternative energy, with a particular attention to hydrogen.

Use activities as an opportunity to incubate and "jump start" transitions to sustainable energy sources and the hydrogen economy that will in the future benefit "late adopter" non-island nations as well.

5.1.2 Background

Island nation-states have a particular stake in developing an autonomous energy structure. Fossil fuels, particularly oil, generally have to be imported from long distances. This can pose both a security risk and an unwanted expense. Eighty-eight percent of Hawaii's energy is currently produced from oil. In 2000, Iceland spent $185 million on oil imports. By 2005, it is predicted that 92 percent of oil imports to the Asia-Pacific region will come from the Middle East. Political volatility, trade disagreements, threats to traditional shipping routes, price fluctuations—all pose potential threats to fossil-fuel dependent economies in general and island nation-states in particular.[xli] Climate change, with the risks of rising seas, increased flooding, and volatile weather patterns, poses more immediate dangers to islands than to landlocked nations.

Smaller developing island nation-states already have networks for examining sustainability issues, including energy, through the UN-supported Small Island Developing States Network (SIDS).[xlii] Combining the focused efforts of developed and developing island nations of all sizes towards the achievement of self-sufficient, renewable energy infrastructures is a logical next step.

In particular, island nation-states with growing economies are uniquely suited to the benefits of hydrogen-generated energy. Unlike imported oil, hydrogen can be produced locally from a flexible range of energy sources. Hydrogen produced from renewable fuel sources offers a means for both weaning the world from its fossil fuel habit and slowing global warming. Hawaii, Singapore, Japan, and Iceland have already invested considerable time and resources into moving towards sustainable energy — including the development of a hydrogen economy. Sixty-seven percent of Iceland's energy already comes from emissions-free geothermal heat and hydroelectric dams; this could provide a carbon-free energy source for hydrogen production.[xliii]

By pooling their intellectual capital, a diverse body of island nations could share and capitalize on technology developments, best practices, and innovative indigenous knowledge.[xliv] Developed island nations who are already creating new energy technologies could foster the development of demand for such products from their developing island partners, thus creating additional market pull for an emerging industry. By placing themselves on the cutting edge of energy sustainability, island-states could achieve competitive advantage and early market penetration in a field that will become more lucrative when non-island states join in later, thus providing the leaders with a boost to their national economies.

Beyond eliminating economic and environmental liabilities, shifting to hydrogen could create an additional competitive industry for early adopters. Hawaii is examining the possibility of tapping into its abundant geothermal, wind, and solar energy reserves to become an *exporter* of energy—shipping hydrogen around the Pacific to energy-hungry nations. One of the later phases of Iceland's sophisticated hydrogen transition plan involves the export of hydrogen to Europe.[xlv]

By recognizing the threats of continued dependence on fossil fuel to their own survival, and seizing the opportunities to be had by switching to cleaner, decentralized hydrogen, island economies may lead the way technologically and politically for the rest of the world, acting as early adopters and catalysts for transition to sustainable energy infrastructures on a global scale.

5.1.3 Anticipated Outcomes

Increased sustainability and security for member island nation-states due to self-sufficiency of energy.

Accelerated development of technologies and strategies that support energy self-sufficiency, distributed generation of energy, and alternative energies, including hydrogen fuel cells.

Creation of new export opportunities for member nations in the form of cutting edge energy technology, carbon trading, and the sale of green energy to other nations.

Increased flow of ideas and technical support on energy matters between developed and developing island nations, to the mutual benefit of both.

5.1.4 Program Activities

5.1.4.1 Short term

- Hold a conference to network developed and developing island nation-states of all sizes in the exchange of ideas around creating sustainable, autonomous energy infrastructures.

- Provide cutting-edge training and technical support to island nation-state members in the areas of energy efficiency, distributed generation, alternative energy, and hydrogen energy infrastructures.

- Support aggressive energy-efficiency training and programs within member states, to reduce the total energy demand prior to development of new energy infrastructure. Develop roadmaps for legislation and incentive systems to promote energy conservation and efficiency, modifiable for individual nation-states but drawing upon ideas and expertise of the entire alliance.

5.1.4.2 *Medium term*

- Create incentives for developed island nations to share technology expertise with less developed nations.

- Encourage engagements between island nation-states and private industry for development of innovative energy solutions.[xlvi]

- Investigate and develop markets for trading carbon offsets to other nations. Create a pool of carbon credits for smaller nations to increase the size of a saleable block of offsets.

- Carefully monitor and document progress, including energy savings, payback time, successes, and failures. Make the information freely available and visible, both as an information exchange for member nations and encouragement to other interested parties.

5.1.4.3 *Long term*

- Set a goal of carbon-free, energy autonomy for all member nation-states, with an additional goal of net export of energy for some.

- Provide technical support and consulting services to non-island nations seeking insight in developing energy autonomy and hydrogen economies.

5.2 Program Nine: "Leapfrog" new environmental regulations past outdated command and control models to integrated, flexible ones.

5.2.1 Objectives:

Encourage the development of international-, national- and regional-level environmental regulations that are flexible, innovation-friendly, and rigorous.

Examine means of encouraging sustainable production practices via the standards, guidelines, and regulations of international trade organizations in ways that are equitable and do not interfere unreasonably with the efficient flow of free trade.

5.2.2 Background

United States environmental regulation—mostly crafted in the 1970s—was command-and-control focused. It was also fragmented into control of pollution by media (e.g., the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act); and focused upon implementation of government-designated best available technology (BAT). While such regulation served its purpose at the time, it no longer represents the best model for governments to encourage sustainable practices. Developing countries without existing regulatory models should certainly not look to current US models for guidance. Rapid innovations in technology, increasing globalization, and changing scientific data require that the environmental regulation of the future must look drastically different if we are to achieve radically improved sustainability.

Historically, European countries have cultivated more creative regulation designed in collaboration with industry. European states have been more willing to enact regulations that place end-of-life responsibility for products with corporations. But even Europe needs to join an accelerated global adoption of integrated regulations that push for more and more sustainable methods of production and consumption, rather than merely complying with the status quo.

In his *Harvard Business Review* article "Green and Competitive: Ending the Stalemate," Michael Porter provides guidelines for creating innovation-friendly regulations (see sidebar)[xlvii]. While there is no universal design model for regional environmental regulation, this provides some useful landmarks in crafting legislation.

The WTO

On a global scale, change at the level of trade organizations could also be highly beneficial. Currently, the World Trade Organization allows its member nations to bar free trade from other nations based upon the quality of the end *product* in question, but does not allow the *process* by which a good is produced to affect its tradability status.[xlviii] But increasingly, it is evident that processes can negatively affect the quality of an end product —particularly food—in unanticipated ways. There is also considerable evidence that the processes themselves can have adverse effects with global impact. For example, conventionally grown cotton accounts for a large percentage of pesticide use on the planet; trade guidelines supporting organic cotton could provide a significant global leverage point to alleviating related problems of water pollution and health problems. To the extent that production practices threaten to impair ecosystem services and agricultural productivity, sustainable processes can contribute positively to the continued, long-term health and prosperity of international trade. An unintended consequence of current WTO regulation is the protection of externalization of ecological costs associated with product production by barring the consideration of those costs in assessing import tariffs.

Efforts to objectively identify reasonable process criteria to regulate trade on goods should be accelerated. Specific processes that offer the greatest potential for positive global impact on the environment should be identified and prioritized as recommendations to the trade organizations. While there is perhaps legitimate concern that such criteria could be imposed as a disguised trade barrier to benefit an international trade organization member, this concern exists in all trade regulations and must be successfully balanced against the benefits of allowing nations to control their imports.

5.2.3 Anticipated Outcomes:

- Increased efficacy and decreased bureaucracy in domestic and international environmental regulations.

- Increased compatibility between policies designed to foster free trade and economic growth and those designed to promote sustainability.

5.2.4 Program Activities:

5.2.4.1 Short term

- Support an independent body to research and identify sustainable process criteria suitable for trade regulation and likely to create maximum positive global environmental impact.

5.2.4.2 Medium term

- On a regional and national level, identify opportunities for the application of feebates[xlix] and heavy differential taxation of inefficient end-use devices as a means of promoting the use of resource-efficient technology in industry.

5.2.4.3 Long term

- Conduct research into how regional, national, and international environmental regulations could be integrated and standardized to a level that would do more to encourage sustainable processes and promote global and economic prosperity.

5.3 Program Ten: Develop initiatives in China to assist in development of sustainable enterprises and the training of sustainability leaders.

5.3.1 Objectives

Support China's development of sustainable production and consumption practices.

Encourage "leapfrogging" ahead of outdated, polluting methods of production and consumption to cutting-edge technologies and practices that offer both greater sustainability and opportunities for global market competitiveness.

5.3.2 Background

With one-fifth of the world's population within its borders, China presents serious environmental challenges and, at the same time, a key leverage point in the promotion of sustainable consumption and production. China contains nine of the top ten most polluted cities on the planet.[l] China mines and burns a billion tons of coal a year—a quarter of the world’s supply. Three-quarters of the country’s energy needs are met by coal.[li] Though China currently trails the United States in overall greenhouse gas emissions, current trends suggest that they will hold the number one position by 2020.

Although the ecological pressures are daunting, the opportunities are enormous as well. Energy intensity in the Chinese economy has been steadily decreasing, owing to investment in energy efficiency and improved technology;[lii] recent research concluded that a shift in rice cultivation practices has drastically reduced China's methane emissions for the past two decades.[liii] In anticipation of the 2008 Olympics, the central government has pledged to reduce coal consumption in Beijing by one half and to eliminate the problem of dust storms in the city. Studies indicate that switching from coal to natural gas in China would likely reduce total industrial carbon output by as much as fifty percent. A shift from coal to natural gas would both reduce carbon output and address the significant air quality problems that plague China's urban areas.[liv]

In support of China's ongoing efforts to move towards sustainability, the international community should look for opportunities to support and encourage national leadership and both private and state enterprises in adoption of whole-systems sustainability practices in China.

For these reasons, we recommend aggressive efforts to include China in many of the activities outlined in other programs presented in this document.

In particular, China's need for jobs, large rural population, and rapidly industrializing economy all make it an excellent candidate for "leapfrogging" technologies. Growing a cutting-edge infrastructure that features hydrogen generation, radically increased resource efficiency, and flexible, decentralized energy will benefit China and the planet financially and environmentally.[lv] Conversely, trying to raise the standard of living for 1.4 billion people using 1920s Pittsburgh-style coal-based energy systems and business-as-usual industrial practices would be disastrous not only for China but for all global communities as well.

Leapfrogging: the Case of the Chinese Refrigerators

OECD countries have the greatest responsibility in achieving major efficiency technology gains; they are the best equipped to achieve them. Yet, it is also of great import to appreciate the responsibility and opportunity of developing nations to learn from the experience of OECD countries and leapfrog to greatest resource efficiency. Consider, for example, the sad story of Chinese refrigerators.

When the government decided people should have them, more than a hundred factories were built, and the Beijing households owning a refrigerator rose from 2% to 62% in six years. But through inattention, the refrigerators were built to an inefficient design. An effort to promote development instead created crippling shortages of both power and capital. The officials to whom this was pointed out said the error would not, if they could help it, be repeated: it had taught them that China can afford to develop only by making energy, water, and other kinds of resource efficiency not just an add-on program but the very cornerstone of the development process. Otherwise, the waste of resources will require so much and so costly supply-side infrastructure that too little money will be left to build the things that were to use those resources

This importation of inefficient technologies to developing nations coupled with an ever-increasing population hungry for a higher quality of life or basic necessities to survive is leading to great human despair. It is leading to greater energy use, it is moving capital from humanitarian services to expanding capital intensive energy infrastructure, despite the availability of efficient technology as exemplified in the story of the Chinese refrigerators.

(From *Least Cost Climate Stabilization*, Amory Lovins and Hunter Lovins, 1991, p.52)

One method of supporting the leapfrog effect is the incubation of enterprises manufacturing sustainable products in a sustainable manner. Sustainable products —particularly alternative energy devices such as photovoltaic panels and energy-efficiency end-use products such as compact florescent lamps — offer multiple advantages to developing nations. They reduce dependence upon older, unsustainable practices and they avoid the need to develop costly infrastructure. They can generate much-needed jobs, sometimes in lieu of jobs in less sustainable industries. New enterprises can build on some early inroads that are already in place. For example, China is already a major producer of compact florescent bulbs.

One danger in incubating these manufacturing processes in China and other developing countries has already surfaced in early projects currently online. Manufactured sustainability products (such as, for example, PV panels sold in Kenya) often vary drastically in quality[lvi], frustrating the user, impeding technology diffusion, and hindering the "leapfrog" effect. A considerable investment of income is lost when a product with poor quality control under-performs or breaks down quickly. Efforts to encourage the enterprises manufacturing green products in countries like China should continue, but attention must be paid to ensuring high quality and proper implementation via technical support and quality-monitoring guidelines.

Sustainable production enterprises also should be decentralized where practicable in order to help stabilize communities stressed by high unemployment. In some parts of India, for example, fabric parts for jeans are sold and assembled by local tailors, reducing cost and providing local industry and jobs.[lvii]

5.3.3 Anticipated Outcomes

- Reduction of dependence upon fossil fuels to meet national energy demands.

- Decreased dependence upon centralized modes of energy supply

- Cultivation of enterprises that create jobs, market opportunities, and promote sustainability on a regional and national level.

5.3.4 Activities

Create multiple programs and initiatives in China, some new, some incorporated into existing development projects.

Apply programs 5, 6, and aspects of 8 to China.

5.3.4.1 Short term

- Provide technical and financial support for projects that shift users from coal to natural gas. Studies indicate that this switch would likely reduce total industrial carbon output by fifty percent.

- Create a resource-efficiency extension program, on the model of agricultural extension, at the local level. These "nomads with compact florescent lamps" could provide advice on efficient use and sustainable production of power, especially in rapidly developing municipalities.

5.3.4.2 Medium term

- Create programs to educate policy makers, teachers, media, and business and government leaders on the benefits of "leapfrogging" technology and the disadvantages of a fossil-fuel-dependent, resource-inefficient development path. Base the information on China-relevant stories and statistics.

- Influence future leaders by incorporating whole-systems thinking (project #1) and green design (project #5) into the curriculum of engineering, science, planning, architecture, and business programs at China's top universities.

- Via online resources and training at universities, encourage information exchange that promotes leapfrog technologies (i.e., advanced, competitive, sustainable production processes that create jobs and achieve improved quality of life) and discourages the adoption of outdated, inefficient production models.

- Aggressively encourage China's shift to a hydrogen economy before it develops an extensive transportation and energy infrastructure based on the internal combustion engine and centralized, fossil-fuel-dependent power generation.

5.3.4.3 Long term

- Encourage the adoption of sustainable technologies by fostering and supporting new enterprises that seek to manufacture them in China. Develop an infrastructure supporting the incubation, development, and quality monitoring of sustainable technology manufacturing enterprises. [lviii]

6 Conclusion

It is easy enough to speak in terms of discarding linear thinking, seeing the system as a whole, identifying leverage points, intervening effectively, and measuring accurately. It is an entirely different matter to implement such behavior on the ground.

The suggestions in this paper offer ideas for achieving the goals of more sustainable production and consumption systems. The integration of agencies, shifting of mindsets, and leveraging of funds necessary to make these goals a reality are obviously difficult. We have not addressed some of the most obvious and urgent places to intervene—population, for instance— because they are outside of Rocky Mountain Institute's areas of expertise.

The recommendations we have made emphasize the power of information, opportunities for drastic increases in resource efficiency in buildings and infrastructure, and the need for integrated interventions. Some of the short-term ideas, such as compact florescent light bulb retrofits in UN buildings, may offer gratifying immediate payback. Many other proposed ideas will require a broader understanding of sustainability and inter-agency coordination to implement.

All our suggestions stem from the axiom that the whole is greater than the sum of its parts. Our recommendations can be summarized as follows: understand the investment, production, consumption, and waste cycles in which any environmental problem is embedded; target interventions at multiple points in the cycle, measure the impact of these interventions; and adjust further interventions accordingly. The promise of transformation through whole systems thinking has been demonstrated on a small scale in agriculture and green building design. It is now imperative that we realize its potential on a global scale.

7 Endnotes

1. United Nations, *Report of the World Summit on Sustainable Development Johannesburg, South Africa, 26 August– 4 September 2002* (New York: United Nations, 2002), page 3.

2. C. Ryan, *Global Status 2002: Sustainable Consumption* (Paris: United Nations Environment Programme, Division of Technology, Industry and Economics, Production and Consumption Branch, 2002), p. 5.

3. P. Modak, *et. al., Global Status 2002: Cleaner Production* (Paris: United Nations Environment Programme, Division of Technology, Industry and Economics, Production and Consumption Branch, 2002), p. 121.

4. Ibid.

5. Ryan, 2002, p. 8.

6. P. Hawken, A.B. Lovins, and L.H. Lovins, *Natural Capitalism: Creating the Next Industrial Revolution* (Boston, New York, and London: Little, Brown and Company, 1999), p. 4.

7. Ibid.

8. Ibid.

9. Ibid., p. 19.

10. J.W. Forrester, “System Dynamics: the Foundation Under Systems Thinking,” delivered at the Sloane School of Management, MIT, Cambridge, MA, June 8, 1999.

11. P. Senge, *The Fifth Discipline* (New York: Currency/Doubleday, 1990), pp. 68–70.

12. D.H. Meadows, “Places To Intervene in a System,” *Whole Earth Magazine*, Winter 1997.

13. Meadows adds a final place to intervene: transcending mindsets altogether.

14. Lovins, *et. al.*, *Factor Four: Doubling Wealth, Halving Resources* (London: Earthscan Publications Limited, 1997), p 15–17.

15. R. Norris, *et. al., Concepts in Integrated Pest Management* (NJ: Prentice Hall, 2003).

16. R.B. Gagosian, “Abrupt Climate Change: Should We Be Worried?” Whitepaper presented to the World Economic Forum, Davos, Switzerland January 27, 2003.

17. J.W. Forrester, “System Dynamics and the Lessons of 35 Years,” in *The Systemic Basis of Policy Making in the 1990*, ed. K. De Greene, p19

18. P. Capros, *et. al.*, “European Union: the GEM-E3 General Equilibrium Model, *Economic & Financial Modelling* 4: 51-160 (1997).

19. O. Bahn, “GEM-E3 Switzerland: Databases Update and Further Insights,” *PSI Scientific Reports*, Volume V, General Energy (2000).

20. C. Hendrickson, A. Horvath, S. Joshi, and L.B. Lave, "Economic Input-Output Models for Environmental Life Cycle Analysis" (Pittsburgh: Carnegie Mellon Green Design Initiative, 1998).

21. Available from Pré Consultants bv, Plotterweg 12, 3821 BB Amersfoort, the Netherlands

22. Global Reporting Initiative website: www.globalreporting.org/

23. Integrated Product Policy website: http://europa.eu.int/comm/environment/ipp/home.htm

24. BIO Intelligence and O2 France, “Life-Cycle of Products and Services.” Study began in December 2001.

25. http://europa.eu.int/comm/environment/ipp/eex_ta.pdf

26. BIO Intelligence Service SA, “Information Database on Environmental Aspects of Products And Services.” The initial phase is due to finish in Spring 2003. http://europa.eu.int/comm/environment/ipp/gpp_ta.pdf

27. M. Auffhammer and R.T. Carson, “Forecasting China's Carbon Dioxide Emissions: A View Across Provinces,” University of California San Diego white paper. October 7 2002. http://econ.ucsd.edu/seminars/china.pdf

28. See, for example, the *Washington Post* argument that China underreported its carbon emissions: .J. Pomfret,"Research Casts Doubt on China's Pollution Claims,"*Washington Post*, 15 August, 2001, p. A16.

29. Two external possibilities are the Best Practices Database (www.bestpractices.org) and the Global Sustainable Solutions Database at MIT (http://gssd.mit.edu/GSSD/gssden.nsf).

30. E. M. Rogers, *Diffusion of Innovations* (New York: The Free Press, 1995), pp. 15–16. The full list of criteria for diffusion of innovations is: relative advantage over existing technologies; compatibility with

existing ways of doing things; observability; a low level of complexity; and trialability.

31. J. Romm, U.S. Department of Energy and W. Browning, Increasing Productivity Through Energy-Efficient Design, Greening the Building and The Bottom Line (Snowmass, CO: RMI, 1994).

32. Hawken, *et. al.*, 2000, p.89.

33. Hawken, *et. al.*, 2000, p. 120

34. A.B. Lovins and L.H. Lovins, "A Bright and Simple Idea,"*Whole Earth*, Fall 2002, p.12.

35. UNEP-IETC and International Council for Research and Innovation in Building and Construction, *Agenda 21 for Sustainable Construction in Developing Countries, A discussion document* (New York: UN, 2002). www.unep.or.jp/ietc/Focus/Agenda%2021%20BOOK.pdf.

36. Ibid.

37. A.B. Lovins and A. Gadgil, "Negawatt Revolution: Electric Efficiency and Asian Development" (Snowmass, CO: RMI, 1991), p. 2.

38. A.B. Lovins, *et. al.*, *Small Is Profitable* (Snowmass, CO: RMI, 2002).

39. See, for example, training in Curitiba, Brazil, *Natural Capitalism*, p. 302.

40. See, for example, the Renewable Energy Mitigation Plan (REMP) in Pitkin County, Colorado. Houses that exceed an allotment for total energy consumption are taxed by the regional governing body. Money from the taxes is pooled into a fund that supports microloans to residential energy efficiency and alternative energy projects. http://www.newrules.org/environment/climateaspen.html

41. For additional information on hydrogen economies, see A.B. Lovins and B. Williams, "A Strategy for the Hydrogen Transition," 10^{th} annual U.S. Hydrogen Meeting, National Hydrogen Association, Vienna, Virginia, 7–9 April, 1999. Available at http://www.rmi.org/images/other/HC-StrategyHCTrans.pdf.

42. S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157,* August 2001, p. 6.

43. www.sidsnet.org

44. S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157,* August 2001, p. 6.

45. Iceland plans on becoming the first carbon-free economy within the next two decades, beginning by conversion of its buses, cars and even its

fishing fleet to hydrogen fuel cells. See Finnur Sveinsson Nomik, "A Transition to the Hydrogen Economy: A Strategy for Sustainable Development in Iceland by April 2000" (WWF International paper). In January 2002, the University of Hawaii opened a fuel-cell test facility in Honolulu in partnership with private corporations and the Department of Defense, supported by over $2 million of federal funding. Japan's Ministry of Economy, Trade and Industry has set a target for the number of fuel-cell vehicles in use in 2010 at 50,000 and 5 million by 2020; in Tokyo, hydrogen refueling stations are being set up to supply a fleet of fuel-cell cars.

46. S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157,* August 2001, p. 5.

47. This is already occurring in Iceland. Shell Hydrogen, DaimlerChrysler, and Norsk Hydro have entered into a joint venture with Icelandic consortium Vistorka to create the Icelandic New Energy Co. Ltd. (See WWF International paper, "A Transition to the Hydrogen Economy: A Strategy for Sustainable Development in Iceland by Finnur Sveinsson Nomik April 2000, p.4). BP and DaimlerChrysler have committed to supplying hydrogen fueling stations and hydrogen cars to Singapore by as early as 2004. ("BP to build Singapore stations for hydrogen cars," Reuters News Service, 23 October 2001.)

48. "Green and Competitive: Ending the Stalemate," *Harvard Business Review* September–October 1995, reprint 95507.

49. The WTO acknowledges the following on its site, "One area where the Trade and Environment Committee needs further discussion is how to handle—under the rules of the WTO agreement on Technical Barriers to Trade—labeling used to describe whether *the way a product is produced* (as distinct from the product itself) is environmentally-friendly. "Beyond the Agreements: The environment — a new high profile," *Trading into the Future: The Introduction to the WTO* website. www.wto.org/english/thewto_e/whatis_e/tif_e/bey4_e.htm (accessed 25 January 2003).

50. Feebates include financial disincentives that may take the form of a levy on equipment that is performing below a given standard that ideally equates to best in class. Feebates also include financial incentives to purchase equipment performing above the standard. These come in the form of a rebate.

51. World Resources Institute, "Urban Air Pollution Risks to Children: A Global Environmental Health Indicator" (Washington, D.C.: World Resources Institute, 1999) p. 5.

52. United States Energy Information Administration, "China's Energy Demand Now Exceeds Domestic Supply," *Country Energy Profile: China* webpage, October 1997, www.eia.doe.gov/emeu/cabs/china/part2.html, p. 2.

53. "Second Analysis Confirms Greenhouse Gas Reductions in China", National Resources Defense Council, October 2001, p.1. National Resources Defense Council, "Second Analysis Confirms Greenhouse Gas Reductions in China," October 2001, p.1. www.nrdc.org/globalWarming/achinagg.asp#note6
54. "Shifts in Rice Farming Practices in China Reduce Greenhouse Gas Methane," Goddard Space Flight Center Media webpage, 19 December 2002. www.gsfc.nasa.gov/topstory/2002/1204paddies.html.

55. http://www.wri.org/china/climate.htm

56. For example, 60 percent of rail transport in China is devoted to transporting coal long distances from source to user. "China's Energy Demand Now Exceeds Domestic Supply", For example, 60 percent of rail transport in China is devoted to transporting coal long distances from source to user. "China's Energy Demand Now Exceeds Domestic Supply," www.eia.doe.gov/emeu/cabs/china/part2.html p.1

57. See, for example, "Field performance measurements of Amorphous Silicon Photovoltaic Modules in Kenya"in *Conference Proceedings, American Solar Energy Society (ASES)*, Madison, WI, June 16-21, 2000. See also, "Evaluation of Energy-Saving Options for Refugees," UNHCR (United Nations High Commission on Refugees), 2001. www.unhcr.ch/cgi-bin/texis.

58. M. Baghai, S. Coley, D. White, C. Conn, and R. McLean, "Staircases to Growth", *McKinsey Quarterly* 4:39–61 (1996).

---

[i] United Nations, *Report of the World Summit on Sustainable Development Johannesburg, South Africa, 26 August– 4 September 2002* (New York: United Nations, 2002), page 3.
[ii] C. Ryan, *Global Status 2002: Sustainable Consumption* (Paris: United Nations Environment Programme, Division of Technology, Industry and Economics, Production and Consumption Branch, 2002), p. 5.
[iii] P. Modak, *et. al.*, *Global Status 2002: Cleaner Production* (Paris: United Nations Environment Programme, Division of Technology, Industry and Economics, Production and Consumption Branch, 2002), p. 121.
[iv] Ibid.
[v] Ryan, 2002, p. 8.
[vi] P. Hawken, A.B. Lovins, and L.H. Lovins, *Natural Capitalism: Creating the Next Industrial Revolution* (Boston, New York, and London: Little, Brown and Company, 1999), p. 4.
[vii] Ibid.
[viii] Ibid.

[ix] Ibid., p. 19.
[x] J.W. Forrester, "System Dynamics: the Foundation Under Systems Thinking," delivered at the Sloane School of Management, MIT, Cambridge, MA, June 8, 1999.
[xi] P. Senge, *The Fifth Discipline* (New York: Currency/Doubleday, 1990), pp. 68–70.
[xii] D.H. Meadows, "Places To Intervene in a System," *Whole Earth Magazine*, Winter 1997.
[xiii] Meadows adds a final place to intervene: transcending mindsets altogether.
[xiv] Lovins, *et. al.*, *Factor Four: Doubling Wealth, Halving Resources* (London: Earthscan Publications Limited, 1997), p 15–17.
[xv] R. Norris, *et. al.*, *Concepts in Integrated Pest Management* (NJ: Prentice Hall, 2003).
[xvi] R.B. Gagosian, "Abrupt Climate Change: Should We Be Worried?" Whitepaper presented to the World Economic Forum, Davos, Switzerland January 27, 2003.
[xvii] J.W. Forrester, "System Dynamics and the Lessons of 35 Years," in *The Systemic Basis of Policy Making in the 1990*, ed. K. De Greene, p19
[xviii] P. Capros, *et. al.*, "European Union: the GEM-E3 General Equilibrium Model, *Economic & Financial Modelling* 4: 51-160 (1997).
[xix] O. Bahn, "GEM-E3 Switzerland: Databases Update and Further Insights," *PSI Scientific Reports*, Volume V, General Energy (2000).
[xx] C. Hendrickson, A. Horvath, S. Joshi, and L.B. Lave, "Economic Input-Output Models for Environmental Life Cycle Analysis" (Pittsburgh: Carnegie Mellon Green Design Initiative, 1998).
[xxi] Available from Pré Consultants bv, Plotterweg 12, 3821 BB Amersfoort, the Netherlands
[xxii] Global Reporting Initiative website: www.globalreporting.org/
[xxiii] Integrated Product Policy website: http://europa.eu.int/comm/environment/ipp/home.htm
[xxiv] BIO Intelligence and O2 France, "Life-Cycle of Products and Services." Study began in December 2001. http://europa.eu.int/comm/environment/ipp/eex_ta.pdf
[xxv] BIO Intelligence Service SA, "Information Database on Environmental Aspects of Products And Services." The initial phase is due to finish in Spring 2003. http://europa.eu.int/comm/environment/ipp/gpp_ta.pdf
[xxvi] M. Auffhammer and R.T. Carson, "Forecasting China's Carbon Dioxide Emissions: A View Across Provinces," University of California San Diego white paper. October 7 2002. http://econ.ucsd.edu/seminars/china.pdf
[xxvii] See, for example, the *Washington Post* argument that China underreported its carbon emissions: .J. Pomfret,"Research Casts Doubt on China's Pollution Claims,"*Washington Post*, 15 August, 2001, p. A16.
[xxviii] Two external possibilities are the Best Practices Database (www.bestpractices.org) and the Global Sustainable Solutions Database at MIT (http://gssd.mit.edu/GSSD/gssden.nsf).
[xxix] E. M. Rogers, *Diffusion of Innovations* (New York: The Free Press, 1995), pp. 15–16. The full list of criteria for diffusion of innovations is: relative advantage over existing technologies; compatibility with existing ways of doing things; observability; a low level of complexity; and trialability.

[xxx] J. Romm, U.S. Department of Energy and W. Browning, Increasing Productivity Through Energy-Efficient Design, Greening the Building and The Bottom Line (Snowmass, CO: RMI, 1994).
[xxxi] Hawken, *et. al.*, 2000, p.89.
[xxxii] Hawken, *et. al.*, 2000, p. 120

[xxxiii] A.B. Lovins and L.H. Lovins, "A Bright and Simple Idea,"*Whole Earth*, Fall 2002, p.12.

[xxxiv] UNEP-IETC and International Council for Research and Innovation in Building and Construction, *Agenda 21 for Sustainable Construction in Developing Countries, A discussion document* (New York: UN, 2002). www.unep.or.jp/ietc/Focus/Agenda%2021%20BOOK.pdf.
[xxxv]Ibid.
[xxxvi] A.B. Lovins and A. Gadgil, "Negawatt Revolution: Electric Efficiency and Asian Development" (Snowmass, CO: RMI, 1991), p. 2.
[xxxvii] A.B. Lovins, *et. al.*, *Small Is Profitable* (Snowmass, CO: RMI, 2002).
[xxxviii] See, for example, training in Curitiba, Brazil, *Natural Capitalism*, p. 302.
[xxxix] See, for example, the Renewable Energy Mitigation Plan (REMP) in Pitkin County, Colorado. Houses that exceed an allotment for total energy consumption are taxed by the regional governing body. Money from the taxes is pooled into a fund that supports microloans to residential energy efficiency and alternative energy projects. http://www.newrules.org/environment/climateaspen.html
[xl]For additional information on hydrogen economies, see A.B. Lovins and B. Williams, "A Strategy for the Hydrogen Transition," 10th annual U.S. Hydrogen Meeting, National Hydrogen Association, Vienna, Virginia, 7–9 April, 1999. Available at http://www.rmi.org/images/other/HC-StrategyHCTrans.pdf.
[xli] S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157*, August 2001, p. 6.
[xlii] www.sidsnet.org
[xliii] S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157*, August 2001, p. 6.
[xliv] Iceland plans on becoming the first carbon-free economy within the next two decades, beginning by conversion of its buses, cars and even its fishing fleet to hydrogen fuel cells. See Finnur Sveinsson Nomik, "A Transition to the Hydrogen Economy: A Strategy for Sustainable Development in Iceland by April 2000" (WWF International paper). In January 2002, the University of Hawaii opened a fuel-cell test facility in Honolulu in partnership with private corporations and the Department of Defense, supported by over $2 million of federal funding. Japan's Ministry of Economy, Trade and Industry has set a target for the number of fuel-cell vehicles in use in 2010 at 50,000 and 5 million by 2020; in Tokyo, hydrogen refueling stations are being set up to supply a fleet of fuel-cell cars.
[xlv] S. Dunn, "Hydrogen Futures: Towards a Sustainable Energy System," *Worldwatch Paper #157*, August 2001, p. 5.
[xlvi] This is already occurring in Iceland. Shell Hydrogen, DaimlerChrysler, and Norsk Hydro have entered into a joint venture with Icelandic consortium Vistorka to create the Icelandic New Energy Co. Ltd. (See

WWF International paper, "A Transition to the Hydrogen Economy: A Strategy for Sustainable Development in Iceland by Finnur Sveinsson Nomik April 2000, p.4). BP and DaimlerChrysler have committed to supplying hydrogen fueling stations and hydrogen cars to Singapore by as early as 2004. ("BP to build Singapore stations for hydrogen cars," Reuters News Service, 23 October 2001.)

[xlvii] "Green and Competitive: Ending the Stalemate," *Harvard Business Review* September–October 1995, reprint 95507.

[xlviii] The WTO acknowledges the following on its site, "One area where the Trade and Environment Committee needs further discussion is how to handle—under the rules of the WTO agreement on Technical Barriers to Trade—labeling used to describe whether *the way a product is produced* (as distinct from the product itself) is environmentally-friendly. "Beyond the Agreements: The environment — a new high profile," *Trading into the Future: The Introduction to the WTO* website.
www.wto.org/english/thewto_e/whatis_e/tif_e/bey4_e.htm
(accessed 25 January 2003).

[xlix] Feebates include financial disincentives that may take the form of a levy on equipment that is performing below a given standard that ideally equates to best in class. Feebates also include financial incentives to purchase equipment performing above the standard. These come in the form of a rebate.

[l] World Resources Institute, "Urban Air Pollution Risks to Children: A Global Environmental Health Indicator" (Washington, D.C.: World Resources Institute, 1999) p. 5.

[li] United States Energy Information Administration, "China's Energy Demand Now Exceeds Domestic Supply," *Country Energy Profile: China* webpage, October 1997, www.eia.doe.gov/emeu/cabs/china/part2.html, p. 2.

[lii] "Second Analysis Confirms Greenhouse Gas Reductions in China", National Resources Defense Council, October 2001, p.1. National Resources Defense Council, "Second Analysis Confirms Greenhouse Gas Reductions in China," October 2001, p.1.
www.nrdc.org/globalWarming/achinagg.asp#note6

[liii] "Shifts in Rice Farming Practices in China Reduce Greenhouse Gas Methane," Goddard Space Flight Center Media webpage, 19 December 2002. www.gsfc.nasa.gov/topstory/2002/1204paddies.html.

[liv] http://www.wri.org/china/climate.htm

[lv] For example, 60 percent of rail transport in China is devoted to transporting coal long distances from source to user. "China's Energy Demand Now Exceeds Domestic Supply", For example, 60 percent of rail transport in China is devoted to transporting coal long distances from source to user. "China's Energy Demand Now Exceeds Domestic Supply," www.eia.doe.gov/emeu/cabs/china/part2.html p.1

[lvi] See, for example, "Field performance measurements of Amorphous Silicon Photovoltaic Modules in Kenya"in *Conference Proceedings, American Solar Energy Society (ASES)*, Madison, WI, June 16-21, 2000. See also, "Evaluation of Energy-Saving Options for Refugees," UNHCR (United Nations High Commission on Refugees), 2001. www.unhcr.ch/cgi-bin/texis.

[lvii] M. Baghai, S. Coley, D. White, C. Conn, and R. McLean, "Staircases to Growth", *McKinsey Quarterly* 4:39–61 (1996).