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energy choices that empower human beings, with appropriate technologies and reasonable technology-transfer policies. We must produce energy in a way that is compatible with Earth's ecosystems and that preserves the planet's chemical and climate conditions for generations to come.

Understanding Our Current Energy Situation

"The time has come for societies to move from the romance with nature to a pragmatic redesign of our economic system inspired by eco-systems" (Pauli, 2010). When seeking to define a better energy policy, it is difficult to manage (and find the right balance among) the huge number of variables involved. Policy decisions must encompass all sectors, taking into consideration their energy impacts and the new models of production that may be needed. This challenge is particularly relevant for the food sector, where it is often easy to fall into the trap of considering food and energy as trade-offs, rather than considering energy as one of the main inputs and outputs of the whole food chain.

Seeking Alternatives to Oil

As a source of energy, oil is transportable and easy to use. It also forms the basis for many industrial chemicals. Since the beginning of the twentieth century, these characteristics have made oil one of the most important commodities in the world. Despite the centrality of oil to current industrial development, however, data provided by the International Energy Agency reveal the unsustainability of the petroleum-based model:

- From 1999 to 2011, the price of crude oil rose by over 400 percent, from \$17 to over \$80 a barrel.
- Many experts forecast that world oil production will reach its maximum no later than 2030 and then begin declining rapidly, in accordance with the "peak oil" predictions of geoscientist M. King Hubbert.
- The current level of oil consumption is over 30 billion barrels annually, with projected yearly increases of as much as 2.5 percent.
- The new oil reserves being discovered in any given year often amount to only about one-quarter to one-half of the oil consumed, meaning that oil reserves are being depleted rapidly; even with improvements in extraction methods, the world's demand for oil is outpacing the supply.

Much of the oil being produced today comes from areas of geopolitical conflict and instability. In addition, the scarcity of oil has forced petroleum companies to explore areas that are increasingly less accessible. Clearly, there is a pressing need to restructure our economy so that it can become less dependent on oil, especially in strategic sectors. In pursuing energy alternatives, however, it is important to follow a systemic approach. Otherwise, in solving old problems, we will simply create new ones. To be genuinely sustainable, renewable technologies and strategies must be introduced within a context of systemic planning that integrates them into natural and agricultural processes, with efforts at the local, regional, and global levels. The complexity and magnitude of the challenges facing sustainable development are immense. Although achieving sustainability has been on the international agenda for decades, much work remains to be done. At the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 15), held in Copenhagen in December 2009, all participant states agreed on the importance of poverty alleviation and working toward sustainable production and consumption, including product and energy policies. In order to achieve these goals, states must integrate their efforts at the local, regional, and global levels with frameworks that fulfill sustainable development criteria. Many technology and strategy options exist for the design and implementation of sustainability initiatives. However, a more integrated and well-coordinated approach is required if

sustainable technologies are to be used exclusively and if meaningful levels of economic, social, and environmental equity are to be achieved. As made clear in the following discussion, our current efforts at finding energy alternatives fall far short of what is needed.

Solar Panels Over the Fields

Solar panels transform the sun's rays into useful energy and/or heat for human consumption. Sunlight can be converted directly into electricity using photovoltaic technology or indirectly using methods such as solar thermal power. Since the mid-1990s, the use of photovoltaics has accelerated because of concerns about global warming, supply issues with oil and natural gas, and the improving economic position of photovoltaic power relative to other energy sources. This technology has become a cornerstone of the new sustainable energy model. With an average increase of more than 20 percent each year since 2002, photovoltaics also represent one of the world's fastest-growing energy technologies. By the end of 2010, the cumulative generating capacity of global photovoltaic installations had surpassed 40,000 megawatts (REN21, 2011). Despite these successes, there are growing concerns about the intensive and centralized employment of photovoltaic technology, which can involve large areas of agricultural land, especially in Europe. Most of the installed photovoltaic power is concentrated away from urban areas. Cities—where half the world's population currently lives and where 75 percent of world energy production is consumed—generally have few photovoltaic installations. Because of market incentives, solar companies often build large-scale solar farms on rented agricultural land. This practice can potentially damage prospects for agricultural operations and sustainable food development. It can also result in very significant environmental impacts, such as loss of soil permeability (less penetration of rainwater), suppression of biological activity (due to continuous loss of radiation in areas shaded by solar panels), and acceleration of desertification, which in turn can increase hydrological imbalances. Moreover, many economists believe that large-scale solar projects detrimentally impact the financial sustainability of farm production, especially at the local level.

Wind Farms

Use of wind power (particularly in the form of wind turbines) is also increasing rapidly. By the end of 2010, the worldwide capacity of wind-powered generators was 196.7 gigawatts (GW). Energy production was 430 terawatt-hours (TWh), which represents about 2.5 percent of worldwide electricity usage (World Wind Energy Association, 2011). Capacity has more than doubled in the past three years. The total amount of power that could economically be extracted from wind sources greatly exceeds current world power use from all sources. Globally, an estimated 72 terawatts (TW) of wind power could potentially become commercially viable (Archer & Jacobson, 2005). In 2008, average global power consumption from all sources was about 15 TW ("A Survey of the Future of Energy," 2008). Wind power also involves drawbacks. Wind farms can create noise, visual impacts, and other effects on the environment, raising barriers to social acceptance at the local level. These issues do not diminish the value of wind power as an important source of renewable energy, however. Even though wind farms may create visual and other impacts, the land where they are located typically can still be used for purposes such as farming and cattle grazing. This is true even where trees may need to be cleared around tower bases, especially for installation sites on mountain ridges. One of the main arguments against the installation of wind turbines involves the danger they pose to birds. Many studies, however, indicate that the number of birds killed by wind turbines is negligible when compared to the millions that die annually as a result of other human-related causes, such as vehicular traffic, hunting, electric power

transmission lines, and high-rise buildings (see, e.g., Kingsley & Whittam, 2005; Langston & Pullan, 2003).

Hydropower Stations

Hydropower, which creates electricity from the force of moving water, represents another important renewable energy source. One major benefit of hydroelectric plants is that they do not directly produce carbon dioxide emissions. Even though some carbon dioxide is emitted during their construction, hydroelectric stations generate lower levels of greenhouse gases than any other energy source (Paul Scherrer Institut, 2005). Nonetheless, problems arise when we try to exploit this resource without considering the surrounding territory. One of the main impacts created by hydropower stations involves alteration of the landscape surrounding dams and their water-storage reservoirs. Construction of hydropower dams typically requires vast areas of land. But large tracts of barren land are not available in most parts of the world. As a result, developers must remove plants, animals, and human settlements before a hydro-power dam can be constructed. This causes extensive damage to local ecosystems, undermining the ecological balance. The food chains of micro- and macro-organisms can be disturbed, sometimes causing the extinction of entire species. Other negative aspects involve changes in the physical character of water. Hydropower turbines increase water temperatures, leading to loss of water through vaporization. In addition, the oxygen content of the water decreases. Oxygen is vital to aquatic organisms, and its absence can lead to many negative consequences—including, in the worst case, widespread anoxia. Finally, it has been noted that, in tropical regions, hydropower reservoirs can produce substantial amounts of methane. When water is stagnant for long periods of time, the plants present in it begin to decompose. This decomposition process releases methane, a very potent greenhouse gas.

Using Crops as Biofuels

In recent years, increasing attention has been devoted to the potential of biofuels as sources of renewable energy, particularly in light of increases in the price of oil and petroleum products. Two major types of biofuels being produced today are biodiesel and bioethanol. Biodiesel is produced from vegetable oils (including soybean, sunflower, rapeseed, and jatropha), animal fats, or recycled greases. It typically is used as a diesel additive to reduce the levels of particulates, carbon monoxide, and hydrocarbons emitted by diesel-powered vehicles. In addition, pure biodiesel is available in Europe. Bioethanol, which is made by fermenting components of plant materials, is produced mainly from sugar cane and starch crops. It is most widely used in the United States and Brazil, where it typically serves as a gasoline additive. The feedstocks used for biofuels often are grown on land that otherwise would be used to produce food crops. According to many in the scientific community, the increased demand for biofuels has put significant pressure on food supplies by displacing production of grains and other crops. Some argue that biofuels contributed heavily to the food crisis of 2008–2009, when prices for commodities such as corn, soybeans, and wheat increased sharply. Worldwide, almost half the population suffers from severe resource constraints that make it difficult for them to adapt to higher food prices. Some are forced to spend as much as 80 percent of their income on food. When food costs increase, many go hungry. Observers also question whether producing fuel from plant matter is energy efficient and sustainable. Some studies suggest that the amount of energy needed to produce certain biofuels (especially corn-based ethanol) exceeds the energy contained in the fuel itself—although other studies dispute this contention. It is also important to consider a range of other factors associated with biofuel production, including how much carbon dioxide is absorbed by growing feedstock plants and the quantity of emissions generated during biofuel

production and transport. As Lester Brown points out, converting the entire grain harvest of the United States to etha-nol would produce less than 20 percent of the fuel required to run the nation's automobiles (Brown, 2009). Considering this fact, does it make sense to turn our agricultural fields into a big fuel tank? Recently, research has focused on the produc-tion of second-generation biofuels (from nonfood crops, crop residues, and waste), as well as on third- and fourth-generation versions (from algae and bio-/thermochemical processes, respectively). Nonetheless, first-gen-eration biofuels still re-main the most widely used because they can be utilized in existing vehicles, they can be distributed within the existing infrastructure, and they are seen as genuine alternatives for replacing at least some diesel and gasoline use (Randelli, 2009).

Nuclear Energy

In 2009, about 14 percent of the world's elec-tricity was derived from nuclear power (World Nuclear News, 2010). The United States pro-duces the most nuclear energy in absolute terms, with nuclear power providing 19 percent of the electricity consumed in the country (United States Energy Information Administration, 2010). France produces less nuclear energy overall but derives a higher percentage of its electricity from nuclear power (about 80 percent) than any other country (Beardsley, 2006). In the European Union as a whole, nuclear energy provides about 30 percent of electricity (Eurostat, 2007). Proponents of nuclear power say it repre-sents a sustainable energy source that can reduce carbon emissions. But increased use of nuclear energy faces a number of problems:

- high costs (the cost of constructing a nuclear power plant can reach \$2,000 per kilowatt);
- length of time required to put nuclear power plants into service (too slow for transitioning away from fossil fuels);
- lack of sufficient uranium supplies (the amount of uranium available is probably in-sufficient for long-run nuclear power genera-tion) (Consoli, 2010b);
- concerns about the environmental, health, and safety issues posed by nuclear power plants;• potential security risks related to nuclear pro-liferation; and
- difficulties associated with the long-term management of nuclear waste.

Moreover, critics argue that nuclear power is not actually a low-carbon electricity source if the whole nuclear fuel chain is considered. Studies show that the fossil-based energy required to ex-tract, gasify, enrich, transport, and store uranium produces the same level of emissions as a natural-gas power plant for a comparable amount of energy (Caldicott, 2006). Thus, nuclear power be-comes far less attractive as an energy source when we consider the full life cycle and the whole en-tropic impact of the energy process, rather than focusing on one isolated stage of that process.

Hydrogen as Part of the Energy System

Even though hydrogen is the most abundant element in the universe, it amounts to less than 1 percent of the gas on earth. The most common source of hydrogen is water. Hydrogen is also present in the earth's crust, where it is combined with other elements in various compounds. It is found in organic matter, fossil fuels (including natural gas), and methane. Commercial hydrogen can be produced by several methods, including natural gas reform-ing, coal gasification, and water electrolysis. Currently, the cheapest way to produce hydro-gen is to use oil or other fossil fuels. It has been estimated that about 97 percent of commercial hydrogen is produced from fossil sources (with the rest obtained mainly through water electroly-sis). Generating hydrogen from fossil fuels leads to the emission of large quantities of carbon di-oxide, a greenhouse gas. Although hydrogen is not a primary energy source (like

natural gas, oil, and coal), it can be valuable as an energy vector (or carrier) and as a storage vehicle for energy produced by renewable sources. As a vector, hydrogen allows the transfer of energy in space. When used for storage, hydrogen can transfer energy in time, allowing consistent flows of energy to be created from intermittent sources like wind and solar. When hydrogen is produced from traditional energy sources, it is inefficient from a thermodynamic point of view because generating it requires more energy than is available in the hydrogen itself. However, producing hydrogen via electrolysis from renewable energy sources offers an efficient way of harnessing renewable electricity that is produced at off-peak times, when it would otherwise be wasted. In this case, hydrogen production represents a net gain, not a loss. According to Jeremy Rifkin, hydrogen offers a “universal” storage system that can facilitate our use of renewable, solar-based sources of energy. Rifkin expands on these ideas in his books *The End of Work* (1995) and *The Empathic Civilization* (2009). Currently, significant research is being done on hydrogen technologies, especially fuel cells. In the European Union, European Commission-led programs have created a partnership with hydrogen industrial groups, the European Hydrogen Joint Technology Initiative (JTI). The initiative aims in part to produce hydrogen from renewable energy sources in order to complete the energy cycle using intermittent renewable energy sources.

Minimizing Energy and Material Waste: The Food Supply Chain

The life cycle of any product involves many different stages and components. From extraction of raw materials through production, distribution, sale and purchase, consumption, and disposal, energy and materials flow through the system, shaping its environmental, social, and economic sustainability. During this life cycle, energy and material resources typically are wasted at many stages. The food system offers an important case in point. The imbalance between the excess food supply in Western countries (which is large enough to feed the entire world) and food scarcity in developing countries points up the inefficient allocation of energy in the system—inefficiency that translates into a problem of an inequality in food distribution and waste generation. In this context, it would be useful to think of supplying food as an inclusive system, not a series of separate stages. Considering the relevant criteria (such as food miles, the supply chain, biological requirements, and fair production) in a holistic and balanced way (Tecco & Fassio, 2008) would create a situation where the right amount of food is produced with the right quantity of energy. In such a system, the inevitable “waste” outputs of one process could become inputs to another. The priority here is not to obtain energy from waste. Rather, it is to rethink the productive and distributive system in a way that minimizes waste production. In the discussion that follows, we offer some ideas for pursuing such a systemic approach.

The Systemic Approach: Changing Our Perspective on Efficiency and Technology Innovation

“In our society we face situations, analyze cause-effect phenomena, solve technical problems, study strategies ‘per spot,’ using a linear approach. This is not innovation” (Bistagnino, 2009). We need to change the usual way we think. Innovation resides in the way we look at problems. We have to be aware that we are working within a system where special care in planning needs to be devoted not only to products, but also to the processes that generate them and the system they relate to—a system incorporating social, cultural, and ethical values. Within industry, linear processes of development affect perceptions of reality. These processes, which are based upon cause-effect relationships, generate huge quantities of waste, from the start of the manufacturing process through the product’s “end of life.” In order to avoid this waste of resources, we must broaden our focus from an exclusive emphasis on

products and their life cycle. We must instead move toward understanding and developing the complex relationships that spring from the production process.

Broadening Our Focus

Design that focuses on individual products inevitably creates waste and environmental problems. Even when the planning process seeks to coordinate multiple factors (including functional, technical, symbolic, cultural, and production issues), the solutions tend to be specific to the product itself and generally overlook larger or systemic effects. We must widen this narrow focus in order to diminish our ecological footprint and create a more sustainable economic path. In order to achieve a broader focus, we need to adopt Systemic Design—an approach that seeks to create not just industrial products, but complex industrial systems.

Understanding Systemic Design

Systemic Design aims to create sustainable systems in which material and energy flows are designed so that waste from one production process becomes input to other processes, preventing waste from being generated. As explained in the book *Design Sistemico* by Luigi Bistagnino, Systemic Design allows us to:

- outline and plan the flow of material from one system to another, within ongoing metabolism processes that reduce the ecological footprint and generate a superior economic flow;
- plan and optimize all the constituent parts of an ecosystem for coherent and mutual evolution; and
- manage and encourage reciprocity in dialogue among the many different players throughout all development phases.

Energy/Food Communities

Systemic production of energy implies the creation of “energy communities” in parallel with “food communities,” where producers and consumers of both food and energy operate together in small-scale production processes within a distributed model, moving away from the culture of consumerism. Those companies and territories that are able to adopt this approach can achieve a “prime mover” position.

Principles of Systemic Design

Systemic Design is a holistic approach that analyzes all the implications, causes, consequences, and negative externalities of each energy process. Although this sounds complex, the basic principles of Systemic Design are fairly simple:

- the outputs of each system become inputs for another system;
- the relationships thus developed generate an open system (as opposed to the closed systems created by linear planning);
- these open systems are self-supporting and self-reproducing, and they evolve together;
- the operational context is prioritized; and
- the relationship between humans and their surroundings is at the heart of the design project.

These principles engender an extremely dynamic and complex relational system that becomes more cohesive as the connections among the parts develop. As a result of its varied and interrelated activities, the system becomes autopoietic (that is, it acquires self-generating strength). Many studies have sought ways to save energy in different fields, from food production to city planning. Systemic Design goes further, and involves choices at the individual and cultural levels. Certainly, large-scale industries play a significant role in energy-efficiency and technology innovation. However, the innovation they pursue must go

beyond the development of new products. We need to reexamine the way we view key issues and seek space for innovation within ourselves. The first step toward transformative innovation requires us to identify how much our choices and actions are shaped by a consumerist culture. This approach can reduce what economists call “negative externalities” to their lowest possible level.

Creating a Multidisciplinary

If companies and localities want to achieve a prime mover position, they would be well advised to adopt a holistic, 360-degree approach to analyzing causes, consequences, and implications. From this perspective, it is fundamental to pursue a “multidisciplinary vision,” bringing together the many different areas of scientific knowledge that reflect the real dynamics and functioning of nature. To accomplish this, we must start with a wide-ranging survey that encompasses all local resources in order to define the operational context. This means understanding the stakeholders involved; the incoming and outgoing flow of energy and material (input and output); the logistics of people, work, and goods; the services and products delivered to the marketplace; and the territory as a physical, social, and cultural space where exchanges of goods and services take place. The systemic model of production prefers to rely on local resources rather than “importing” resources from external, distant locations. By using outputs from one system as inputs for another system, it triggers a virtuous collaboration among productive processes (agricultural and industrial), natural processes, the surrounding territory, and the community. In this way, the systemic model creates an open relational web that revitalizes the locality and capitalizes on its main strengths and qualities. The analysis of inputs and outputs must be both quantitative (so that we understand the amount of resources moving through the system) and qualitative (so that we know exactly what we have at our disposal). This analysis enables us to develop a clear idea of:

- the resources we need, including their features and origins;
- the processing wastes and rejects within the system, including their specific qualities and their final destination; and
- what occurs throughout various processes (comparing specific differences between inputs and outputs).

The understanding we develop holistically embraces the whole process and allows us to perceive the interwoven relationships that exist within the system we are analyzing. The depth of insight we achieve through holistic analysis also shows why simply focusing on individual parts of a system is useless: It ignores obvious links among component parts and fails to capitalize on the dynamism of the whole.

Promoting Productive Growth

Adopting the Systemic Design approach can lead to exponential growth in productive capacity. As a result, the locality may be able to produce new material goods, offer new services to its citizens, and ultimately increase the number of jobs. By fully exploiting an area’s resources, we can encourage development that prioritizes the local dimension and spawns self-sustained processes of energy production and supply (Bi-stagnino, 2009).

The Socially Responsible Model of Consumer-Producer

Traditionally, companies’ product-design concerns have focused on how to sell the largest number of goods to the biggest possible market. It is a top-down idea of consumerism, and views purchasers simply as the end-users of products. By contrast, a systemic approach evaluates the opportunities inherent in products in relation to social evolution and human well-being. It considers the user of a product as a key actor who plays a leading role within

the complex production system. Because the systemic approach sees users/consumers as “embedded” in the economic and productive system, they are perceived as making active decisions about products and purchases—a role that goes far beyond passive “consumption.” From this point of view, a factor such as energy use becomes a key variable in user/consumer decision making as an indicator of a product’s quality. Greater awareness allows each purchaser to better recognize, value, appreciate, and choose products. At the moment of purchase, a person who is aware of the environmental problems that products can cause (such as the loss of bio-diversity) can no longer be defined merely as a “consumer.” By conscious action, he or she can decide to attribute more value to one product than to another. The purchaser can even recognize himself as being an ally of the company that produces the product. He thus becomes part of the production process, becoming and discovering himself as a “prosumer” rather than a mere consumer (Ceppa, Fassio, & Marino, 2008). Even the most fully aware and environmentally committed purchasers can have only a limited impact, however. While development of energy-efficient products may help us conserve natural resources, it is shortsighted to believe that we can continue our current wasteful life-style with the help of new products. Instead, we urgently need to change our thinking and behaviors. Such fundamental change is more difficult than creating a new product line, but it nonetheless is crucial to explore approaches that can challenge predominant consumption patterns. Systemic Design methodology can support the evolution of a new economic model with different productive and cultural relationships. This new model favors long-term sustainability over maximization of economic growth, and networks of interdependent activities and cooperative development over competitive advantage for individual entities (Hawken, Lovins, & Lovins, 1999).

Guidelines and Policies for a Holistic System

Theoretical Guidelines

In moving toward a more holistic system, policymakers must address certain basic concerns (such as ensuring food security and meeting the needs of growing populations) while promoting sustainable production methods that do not deplete material and energy resources or cause damage to the environment. Those who make policy decisions need a systemic approach in order to manage the complex web of actors and components inherent in a distributed energy model. Systems thinking can provide a clear vision for adequately connecting all the “moving parts.” By contrast, failing to consider the linkages among all disciplines leads to a fragmented policy agenda (Wijkman, 2008).

■ Improving on Current Approaches to Sustainability Policy

Systemic Design has clear advantages over two commonly used strategies for promoting sustainability: the sector-based approach and the local, “bottom up” approach. The sector-based approach, which often encourages public-private partnerships within specific sectors or industries, can create valuable sustainability initiatives. This approach has important drawbacks, however. One key problem is that it may be difficult to involve parties who do not identify themselves with the specific sector—and this can lead the partnership to neglect major emitters and energy users. For instance, if we consider agriculture as a sector by itself, we may fail to include parties who transport the food that is produced by agricultural activities, since they would be viewed as belonging to another sector (transportation). Such a fragmented view can lead to delays or duplication of effort, ultimately resulting in a larger expenditure of resources. By contrast, the systemic approach would view both sectors as part of the “food system.” On the other end of the strategy spectrum is the local, bottom-up approach. Interventions that are specifically tailored to small, local populations can create

benefits for the communities they serve, but such programs tend to have limited reach and short lifespans. In many cases, these programs lack substantial financial support and cannot scale up effectively because they find it difficult to relay their message and teach their methods to stakeholders at the regional or national level.

■ Towards a Territorial Approach

A territorial approach to sustainability incorporates the advantages of both the sector-based and local approaches, while broadening the benefits that are achieved. By incorporating local culture, it allows people to feel a sense of ownership and identify with policy interventions, while mobilizing them to contribute and participate. Local cultures can be characterized as forms of “intellectual property” that allow local rural economies to impose some level of control over social and economic development. The territorial approach encourages participation by people from all segments of society and across all social and economic groups. Even though these populations may share the same overall culture, they can bring expertise from many different disciplines. Truly sustainable development can be achieved with diversification and localization of energy sources and systems if the adverse impacts of each energy system are sufficiently small to be kept within the tolerance limits of the environment. The combination of energy resources needed to attain an optimal energy supply may vary based on the territorial region and local conditions, which in turn are influenced by local practices, resources, and environment. The territorial approach seeks to establish energy communities along with food communities, empowering farmers and those who understand the dynamics of sun, water, and land to become the principal actors in energy processes.

■ Material and Energy Resource Networks

Mainstream private and public stakeholders follow the profit motive in their utilization of material resources as they aim for sustained economic growth. Such an approach is not inherently bad since it spurs creativity and allows the market to utilize human and natural resources to add value, thus creating wealth. However, the current system fails to fully quantify environmental opportunity costs or “charge” them to the material resources that are being used. Thus, the prices paid for material resources do not reflect their full cost. Because such resources are in effect priced too cheaply, producers have no clear incentive to use them more efficiently and see no immediate need to switch to alternative, greener processes. Given the increasing evidence of environmental degradation and climate change, it seems clear that we have not sufficiently accounted for the real costs of the vast material resources consumed and transformed globally on a daily basis. In the case of food production, two key material resources that require special attention are land and water. The availability of these resources is constantly changing due to human activities and environmental effects. Ensuring efficient use of material resources requires us to develop systems that allow a single resource to serve multiple functions, thus reducing the need for additional inputs (Campagnaro, 2008). One of the most important changes that can be made to our current market system is for government and the private sector to ensure that the actual costs of material resources are accounted for by curtailing subsidies and limiting the distortion created by private-sector “entitlements” to public goods. Once the true cost of material resources is actually accounted for, buyers and consumers will look for other, less expensive alternatives on the market. If these alternatives do not exist, market actors will create new options (such as recycling of used materials), internally linking business models across multiple companies that can tap into each other’s input and output systems. An ideal system would also generate positive feedback, where one or more by-products (or other materials that are now perceived as “waste”) would become new material resources for other processes, in turn fueling further generation of material resources. In many cases, these practices require little capital

investment or process modification for systemwide adoption. Even within a single energy system, system resilience and energy security can be greatly increased with distributed and dispersed power generation (Barbero, 2010). Additionally, there is an immense opportunity for organizations to network with one another in order to take advantage of more cyclical and systemic use and reuse of energy resources. There is a growing practice of linking business units or enterprises to take advantage of synergies. Greater attention and support via knowledge networks is needed to spread a more systemic form of business and organizational management.

■ Networks of Local Know-How

Since much of the knowledge about energy and material networks is held by local communities, it is essential for policy decisions to draw from these networks, so that people associated with or working in these communities can disseminate local knowledge further to networks at different levels. This will help build synergistic linkages between local populations (who have traditional knowledge) and experts (who have technical expertise in areas such as the natural sciences). It has been shown that interventions or technologies that incorporate traditional knowledge are more readily adopted. However, care must be taken to balance this merger of new and old, and local stakeholders need to play an active role in the transformation process. Local knowledge should be shared at the regional, national, and international levels.

■ Moving Toward a Decentralized Structure

Traditionally, organizations have taken a centralized approach in managing their operations. That is, organizations try to control inflows, outflows, revenues, and expenditures independently of outside factors in order to maximize success and profitability. From a single-company point of view, it is understandable that management would attempt to control as many aspects of the production cycle as possible in order to limit costs, increase revenues, and ensure positive returns. However, as information becomes more accessible via global communications portals (which are rapidly expanding through increased use of the Internet and other telecommunications media), the way in which organizations grow and govern themselves is changing. New, less costly opportunities to connect and share not only ideas, but also business functions, are expanding rapidly. As a result, many companies are now adopting a more decentralized organizational structure in which greater innovation and growth take place at all facility sites and organizational levels. Personal and business networks (both formal and informal) are also on the rise, and will play an increasingly important role for organizations. The key to success for a decentralized, integrated organizational structure is the ability to share and tap into information and knowledge. Within the food system, improving networks that increase access to knowledge in the area of sustainable food production, processing, marketing, and consumption can have a substantial effect on what consumers demand and how farmers and food processing companies produce for the end market. In her book *The Future of Knowledge* (2003), author Verna Allee summed up many of these changes:

We are finally realizing that those old enterprise models and management tools are simply inadequate for the world we are in now. As a whole society, we now need to hone our ability to live and thrive in a world where the adversarial stances between society, business, and political systems no longer make sense. (p. 7)

Practical Policies for Networked Systems

■ Output Becomes Input

As in nature, what is not used by a system should become raw material for the development and survival of someone/something else. In the production process, the waste (output) of a system becomes an opportunity (input) for another system, creating new economic opportunities and new jobs. In this sense, waste is a renewable energy source like wood and biomass. It can be combined with perpetual energy sources (solar, wind, or water) to produce green power. Using something that is considered waste as a starting point is particularly valuable. Since the waste would otherwise have been disposed of, putting it to use yields a high relative benefit. It is also important to introduce flexible energy technologies and design integrated energy-system solutions. Technological changes alone are not sufficient to generate sustainable development. For this reason, it is crucial to encourage complementary land use and alternative farming systems that create positive feedback (systems that recycle material resources to generate additional resources). In rural locations or areas of agricultural production, practical policy ideas include the following:

- Provide incentives and appropriate technologies for farmers to adopt soil and water conservation practices. Agroforestry can prevent further degradation of soil resources and replenish nutrients, while supporting mixed uses of livestock and crops such as fruit trees that could diversify/generate income for farmers who adopt these practices.
- Encourage the adoption of irrigation technologies that improve water-use efficiency, such as drip and micro-irrigation.
- Invest in large-scale production of biochar through pyrolysis of residues from agricultural, forestry, and animal wastes. Biochar helps retain soil nutrients and fertilizers. It can be used for carbon sequestration, allowing carbon to be stored in soil for hundreds of years. It also significantly reduces soil emissions of nitrous oxide, a particularly powerful greenhouse gas. Currently, programs in Brazil and the Democratic Republic of Congo are encouraging farmers to transition from “slash and burn” to “slash and char” in order to increase crop yields and decrease adverse environmental impacts. Biochar production has the potential to lower atmospheric concentrations of carbon dioxide by eight parts per million or more over the next 50 years. In urban areas, practical policy ideas include the following:
 - Mandate practices such as citywide composting, which can decrease greenhouse gas emissions from landfills and provide material resources that can be recycled back into the food system.
 - Invest in basic infrastructure for water conservation. Simple installations for harvesting rainwater from roofs and built surfaces could generate water for use in urban and peri-urban agriculture.

■ Strengthening Networks and Relationships

It is important to consider more broadly all the networks of components that make up the food and production systems, including the materials (resources) and energy that are used, captured, and stored throughout different stages of the product life cycle. Understanding the pattern of material and energy flow (and looking at where it can be improved) can allow us to find entry points for designing more sustainable systems. The availability of energy can promote development within a territory. Moreover, an energy system that is integrated with its local area can strengthen relationships among different actors, from institutions to private-sector companies and communities. Collaborative design helps create awareness and heightens the level of commitment on the part of each co-designer. Involving the private sector can encourage direct dialogue with subnational authorities and open new markets that create additional financial resources for sustainability projects. Governments should

encourage active investment from the private sector, especially for eco-innovations and the transfer of green technologies. Such investments can be presented as win-win-win relationships: In addition to improving environmental sustainability, they can allow companies to be socially responsible and establish their credibility in the community. These projects can create economic gain for the region and the people of the community. It is crucial to build knowledge networks through education and research. According to the United Nations Educational, Scientific and Cultural Organization, universities now offer more than 9,000 areas of specialization. But there are very few in-depth programs dedicated to studying transdisciplinary connections and systems thinking. Supporting programs of interdisciplinary studies and systems design would help train professionals to adopt a systems approach in thinking about sustainability.

■ Towards Autopoiesis

In nature, systems are autopoietic and self-maintaining. They sustain themselves by reproducing automatically, thus allowing them to define their own paths of action. Each system is naturally led to create balance and preserve its independence. If we would start to think in terms of autopoiesis in the food system, we might find it possible to allocate the flow of material and energy efficiently and distribute it equally. An energy system that is independent from other countries or regions, basing its operations on resources available in the local area, is both strong and flexible. Such a system can adapt easily and quickly if conditions in the territory change (Barbero, 2010). To create this type of system, it is important to open the flow of knowledge in multiple directions by encouraging and supporting cross-border, regional networks that facilitate information exchange. Policy-makers need to ensure transparency in the decision-making process and open sharing of knowledge at all levels. In the European Union, the Lisbon Strategy launched an effort to create a “competitive and dynamic knowledge-based economy.” In the developing world, associations such as the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) play an important role. FANRPAN, which operates across multiple countries in Africa, utilizes innovative methods (such as theater) to teach farmers in rural Mozambique and Malawi about better agricultural practices, while also encouraging interregional discussion on issues such as agriculture policy and climate change.

■ Act Locally

Like ecosystems, human-created systems are deeply influenced and shaped by their habitat. Using the resources available in the local area, new opportunities can be created by increasing people's participation and reducing the barriers to adaptability. In this context, it is important to understand the tensions that can arise from different perspectives on energy issues. Citizens often view energy as a basic resource that they are entitled to use for their own benefit and self-improvement. From government's point of view, however, energy represents a common resource that is important to society as a whole. For citizens, energy is a consumer right; they want access to plentiful energy that is safe for the environment and not harmful to people's health. For regional and national governments, energy involves complex geopolitical strategies. For companies, energy is a source of profit that contributes to economic growth. We think it is preferable to encourage territory-specific approaches to energy production and diversification of energy sources. Each local area can present its own unique challenges, which can vary depending on the territory's level of development. For example, a recent report published by the United Nations Food and Agricultural Organization (FAO) indicated that in many developing countries, wood fuels are still widely used for household cooking and heating, as well as for the processing of food and cash crops, including coffee, tea, tobacco, and coconuts. In these communities, it is important to find ways of

managing sustainable energy generation from wood biomass, while also making improvements in equipment such as wood stoves. In addition, it is crucial to explore other means of harnessing bioenergy in order to avoid overreliance on a single energy source. Policymakers and administrators should facilitate sound resource use at the local level through utilization of information technologies. Governments should take advantage of advances in geographic information systems (GIS), satellite imaging, and communication technologies (such as the Internet and mobile phones) to collect and communicate up-to-date information pertinent to agricultural production. Providing timely information on weather and soil moisture can allow farmers to optimize their use of material resources, such as fertilizers and water. Such integrated information technology systems are already being used in Australia and in some parts of sub-Saharan Africa.

■ **Humans and Their Communities: At the Center of the Systemic Project**

In today's society, the "consumer product" has become the fulcrum of a values paradigm. Concerns about economic well-being and aspirations to social status shape consumption choices in a negative way. By contrast, the systemic approach questions the present economic and industrial model, proposing a new paradigm where social, cultural, ethical, and ecological values are at the center of each production process. Citizens consume energy, but they give back in the form of social and collective intelligence. Supporting programs of interdisciplinary studies and systemic design would help train professionals to adopt a systems approach in thinking about sustainability. Governments should engage systems approach-trained professionals in the policymaking process.

Conclusion

The adoption of systemic production and a human-centered approach (including more innovative capture and generation of energy) offers great potential for creating more sustainable production and food systems for the planet. Systemic Design generates local economic development, thus establishing the conceptual base and the analytical skills that are needed to create local and regional economic change. Consumer demands reflect both positive and negative behavior. On the positive side, consumers consciously demand higher-quality and greener products. On the negative side, consumers often choose passively, basing their decisions primarily on low prices. Changes in behavior will be required in order to encourage private companies, the food industry, and governments to adopt a more systemic way of operating. Expanding consumer awareness via enhanced knowledge networks will be key to changing consumer behavior globally. Designing food and production policies for a sustainable future requires careful consideration of the multifaceted issues involved, as well as the interconnections among them. In order to achieve viable networks, it is crucial to develop a multidisciplinary vision that brings together a wide variety of skills. This will facilitate the emergence of a new culture of sustainable innovation, with processes inspired by the dynamic operations of nature. In particular, in the field of renewable energy, the creation of sustainable infrastructures and agile energy systems can spur the development of entire regions. Green energy that is produced in small plants and distributed throughout the territory can promote both economic success and sustainability. Such agile systems can become a new paradigm for both energy efficiency and energy security at the regional or even national level (Barbero, 2011). When the linkages between materials, energy, people, and knowledge are mapped out clearly, efficient pathways toward sustainability become apparent, showing us how to use (and reuse) un-tapped resources. Utilizing these networks, we can innovate collectively to create systems that are beneficial to both people and the environment.

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