Energy and food production with a Systemic Approach"



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## Energy and Food Production With a Systemic Approach

In the discussion that follows, we sug-gest a new and in-novative approach to sustainable pro-duction of energy and food. We also offer concrete poli-cies for addressing a range of problems and difficulties associated with our current production model.

### About This Article

We begin with a discussion of energy issues, noting some basic problems with dependency on fossil fuels. We also survey the energy situation as it exists today, including efforts to find alter-native and renewable energy sources, especially related to food production.As the discussion makes clear, today's econ-omy is based on a linear approach that wastes energy and material resources at many stages of the production process. We highlight the need for a new strategy that abandons this approach in favor of an interrelated and holistic methodol-ogy: Systemic Design. Systemic thinking sees production as a com-prehensive system, not a series of disconnected stages. From this viewpoint, by-products and waste are not simply discards. Instead, they are "outputs" that can be used productively in other processes. Systemic thinking in design aims to unite economic, social, cultural, and environmen-tal demands. This approach can em-power human be-ings in their re-lationship with nature, production, and the environment (Bistagnino, 2009). In the final sections of this article, we offer some guidelines and practical policies that can be used to promote holistic development that is genuinely sustainable.

### Entropy and Fossil Fuels

On the planet we inhabit, energy flows from the sun, abundantly and consistently. Over the last 200 years, however, we seem to have forgot-ten that this energy flow follows precise rules that are unchangeable and need to be respected if we want to preserve the biochemical conditions necessary for the survival of the human species. These crucial rules involve entropy and the second law of thermodynamics. According to these laws, when energy is used to transform mat-ter, it becomes progressively more disordered and diminished in quality—producing pollution and, in Earth's biosphere, climate change. How does nature transform matter through the energy flowing from the sun? Nature does not burn anything, but instead produces energy and life through thermochemical processes such as photosynthesis. Burning fossil fuels has introduced an en-ergy production system based on combustion rather than thermochemistry. Consuming these fuels, which were cre-ated as deposits of carbon hundreds of millions of years ago, has accelerated the entropic processes on the planet. Climate change, pollution, and health hazards are only the consequences of an energy model based on combustion rather than thermochemical processes.

### Oil as a Nonfuel Resource

Oil is a valuable substance that should be used as a raw material for chemicals and pharmaceuti-cals, not burned as a source of energy. As Angelo Consoli recently noted, "it is incredible that in the year 2010 we are continuing to produce en-ergy by combustion processes when human intel-lect and technology have developed more natural and less destructive models" (Consoli, 2010a). The continuing reliance on fossil fuels is the result of bad economic choices and poor research strategies. We have invested enormous sums pursuing oil and nuclear energy instead of devel-oping solar and hydrogen technologies, which could lead the world in another direction. If we had respected the law of entropy, by now we could have small and efficient solar panels that would be affordable to all people living in the southern regions of the world, where solar radia-tion is strongest. It is time for energy choices that empower human beings, with appropriate technologies and reasonable technology-transfer policies. We must produce energy in a way that is compat-ible 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 pol-icy, 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 rel-evant 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 commodi-ties in the world. Despite the centrality of oil to current industrial development, however, data provided by the International Energy Agency re-veal 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 produc-tion 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 extrac-tion 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 petro-leum companies to explore areas that are increas-ingly less accessible. Clearly, there is a pressing need to restruc-ture 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. Oth-erwise, 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 chal-lenges facing sustainable development are im-mense. 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 allevia-tion 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 sus-tainable development criteria. Many technology and strategy options exist for the design and implementation of sustain-ability initiatives. However, a more integrated and well-coordinated approach is required if sus-tainable 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 cur-rent 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 use-ful energy and/or heat for human consump-tion. Sunlight can be converted directly into electricity using photovoltaic technol-ogy or indirectly using methods such as solar thermal power.Since the mid-1990s, the use of pho-tovoltaics 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 photo-voltaic installations had surpassed 40,000 mega-watts (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 cur-rently lives and where 75 percent of world energy production is consumed—generally have few photovoltaic installations.Because of market incentives, solar compa-nies 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 permea-bility (less penetration of rainwater), suppres-sion of biological ac-tivity (due to continu-ous loss of radiation in areas shaded by solar panels), and accelera-tion of desertification, which in turn can increase hydrological imbal-ances. 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 En-ergy Association, 2011). Capacity has more than doubled in the past three years.The total amount of power that could ec-onomically 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 instal-lation 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 gener-ate 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 altera-tion of the landscape surrounding dams and their water-storage reservoirs. Construction of hydropower dams typically requires vast areas of land. But large tracts of bar-ren 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 exten-sive 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 tropi-cal 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 decom-position 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 prod-ucts. Two major types of biofuels being produced today are biodiesel and bioethanol. Biodiesel is produced from vegetable oils (in-cluding soybean, sunflower, rapeseed, and jatro-pha), animal fats, or recycled greases. It typically is used as a diesel additive to reduce the levels of particulates, carbon monoxide, and hydrocar bons emitted by diesel-powered vehicles. In addi-tion, 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 com-modities 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 sus-tainable. Some studies suggest that the amount of energy needed to produce certain biofuels (es-pecially corn-based ethanol) exceeds the energy contained in the fuel itself—although other stud-ies 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 trans-fer of energy in space. When used for storage, hydrogen can transfer energy in time, allowing consistent flows of energy to be created from in-termittent sources like wind and solar. When hydrogen is produced from traditional energy sources, it is inefficient from a thermo-dynamic point of view because generating it requires more energy than is available in the hy-drogen itself. However, producing hydrogen via electrolysis from renewable energy sources offers an efficient way of harnessing renewable electric-ity that is produced at off-peak times, when it would otherwise be wasted. In this case, hydro-gen 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 Commis-sion–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 extrac-tion of raw materials through production, dis-tribution, 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 feel the en-tire world) and food scarcity in developing countries points up the inefficient alloca-tion of energy in the system—inefficiency that translates into a problem of an inequal-ity 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 prob-lems. 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 incorpo-rating 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 prod-uct's "end of life." In order to avoid this waste of resources, we must broaden our focus from an ex-clusive 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 inevitability creates waste and environmental problems. Even when the planning process seeks to coordinate multiple factors (including func-tional, technical, symbolic, cultural, and produc-tion 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 pro-cess becomes input to other processes, preventing waste from being generated. As explained in the book Design Sistemico by Luigi Bistagnino, Sys-temic Design allows us to:

• outline and plan the flow of material from one system to another, within ongoing me-tabolization processes that reduce the eco-logical footprint and generate a superior eco-nomic flow;

• plan and optimize all the constituent parts of an ecosystem for coherent and mutual evolu-tion; 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 con-sumers of both food and energy operate together in small-scale production processes within a dis-tributed 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 an-alyzes all the implications, causes, consequences, and negative externalities of each energy process. Although this sounds complex, the basic prin-ciples 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 sys-tems 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 dy-namic and complex relational system that be-comes more cohesive as the connections among the parts develop. As a result of its varied and in-terrelated activities, the system becomes autopoi-etic (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 in-volves choices at the individual and cultural levels. Certainly, large-scale industries play a significant role in energy-efficiency and technology innova-tion. 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 econo-mists call "negative externalities" to their lowest possible level.

**Creating a Multidisciplinary**

VisionIf companies and localities want to achieve a prime mover position, they would be well ad vised to adopt a holistic, 360-degree approach to analyzing causes, consequences, and implica-tions. 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 con-text. This means understanding the stakeholders involved; the incoming and outgoing flow of energy and material (input and output); the logis-tics 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 "import-ing" resources from external, distant loca-tions. By using out-puts 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 fea-tures 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 in-puts and outputs).

The understanding we develop holistically embraces the whole process and allows us to per-ceive the interwoven relationships that exist within the system we are analyzing. The depth of insight we achieve through holis-tic 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 capac-ity. As a result, the locality may be able to pro-duce 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 rela-tion 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 recog-nize himself as being an ally of the company that produces the product. He thus becomes part of the production process, becoming and discover-ing himself as a "prosumer" rather than a mere consumer (Ceppa, Fassio, & Marino, 2008). Even the most fully aware and environmen-tally 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 behav-iors. Such fundamental change is more difficult than creating a new product line, but it nonethe-less is crucial to explore approaches that can chal-lenge 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 de-velopment over competitive advantage for indi-vidual 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 promot-ing sustainable production methods that do not deplete material and energy resources or cause damage to the environment. Those who make policy decisions need a sys-temic 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 en-courages public-private partnerships within spe-cific sectors or industries, can create valuable sustainability initiatives. This approach has im-portant 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 con-sider 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 sub-stantial financial sup-port 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 incor-porates 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 owner-ship 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 partici-pation 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 con-ditions, which in turn are influenced by local practices, resources, and environment. The territorial ap-proach seeks to estab-lish energy communi-ties along with food communities, empow-ering 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 stakehold-ers follow the profit motive in their utilization of material resources as they aim for sustained economic growth. Such an approach is not inher-ently 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 environ-mental 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 alterna-tive, greener processes. Given the increasing evidence of environ-mental degradation and climate change, it seems clear that we have not sufficiently accounted for the real costs of the vast material resources con-sumed 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 gov-ernment and the private sector to ensure that the actual costs of material resources are accounted for by curtailing subsidies and limiting the distor-tion created by private-sector "entitlements" to public goods. Once the true cost of material resources is ac-tually 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 posi-tive 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 gen-eration 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 advan-tage 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 net-works 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 work-ing 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 cen-tralized approach in managing their operations. That is, organizations try to control inflows, out-flows, revenues, and expenditures independently of outside factors in order to maximize success and profitability. From a single-company point of view, it is un-derstandable that management would attempt to control as many aspects of the production cycle as possible in order to limit costs, increase rev-enues, and ensure positive returns. However, as information becomes more accessible via global communications portals (which are rapidly ex-panding 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 adopt-ing 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, in-tegrated organizational structure is the ability to share and tap into information and knowl-edge. Within the food system, improving net-works that increase access to knowledge in the area of sustain-able food production, processing, marketing, and consumption can have a substantial ef-fect on what consum-ers 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 sys-tem 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 com-bined with perpetual energy sources (solar, wind, or water) to produce green power. Using some-thing 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 en-ergy technologies and design integrated en-ergy-system solutions. Technological changes alone are not sufficient to generate sustainable development. For this reason, it is crucial to encourage comple-mentary 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 technolo-gies for farmers to adopt soil and water con-servation 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 tech-nologies that improve water-use efficiency, such as drip and micro-irrigation.

• Invest in large-scale production of biochar through pyrolysis of residues from agricul-tural, forestry, and animal wastes. Biochar helps retain soil nutrients and fertilizers. It can be used for carbon sequestration, allow-ing carbon to be stored in soil for hundreds of years. It also significantly reduces soil emis-sions of nitrous oxide, a particularly power-ful 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 con-centrations 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 com-posting, 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 con-servation. 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 devel-opment 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 commit-ment 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 finan-cial resources for sustainability projects. Govern-ments 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 environ-mental sustainability, they can allow companies to be socially responsible and establish their cred-ibility in the community. These projects can cre-ate 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 sys-tems thinking. Supporting programs of interdis-ciplinary 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 repro-ducing 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-bor-der, regional networks that facilitate informa-tion exchange. Policy-makers need to ensure transparency in the de-cision-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 Analy-sis Network (FANRPAN) play an important role. FANRPAN, which operates across multiple coun-tries 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 chal-lenges, which can vary depending on the ter-ritory's level of devel-opment. For example, a re-cent 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 mak-ing 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 fa-cilitate sound resource use at the local level through utilization of information technologies. Governments should take advantage of advances in geographic information systems (GIS), satel-lite imaging, and communication technologies (such as the Internet and mobile phones) to col-lect 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 mate-rial 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 Projec**

tIn today's society, the "consumer product" has become the fulcrum of a values paradigm. Concerns about economic well-being and aspira-tions to social status shape consumption choices in a negative way. By contrast, the systemic ap-proach questions the present economic and in-dustrial 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 pro-fessionals to adopt a systems approach in think-ing 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 in-novative capture and generation of energy) offers great potential for creating more sustainable pro-duction 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 re-quired 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 emer-gence of a new culture of sustainable innovation, with processes inspired by the dynamic opera-tions 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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**Silvia Barbero** holds a PhD in productive systems and industrial design from Politecnico di Torino. She currently is a research fellow at the Department of Architectural Planning and Industrial Design, Politecnico di Torino, where she also serves as an adjunct professor (teaching "Environmental Requirements of Industrial Products") in the degree program in virtual and graphic design. Her professional and academic work focuses on application of systemic design in industrial production and environmental sustainability. She can be reached at silvia.barbero@polito.it.
**Franco Fassio** holds a PhD in the history of architecture and urban planning with a specialization in culture of design from Politecnico di Torino. At present, he serves as a research fellow and contract professor ("Systemic Approach for Gastronomy" and "Gastronomic Events with Reduced Environmental Impact") at the Università Degli Studi di Scienze Gastronomiche (University of Gastronomic Sciences) in Pollenzo, Bra, Italy. His work focuses on gastronomic production, environmental sustainability, and green events planning. He can be reached at f.fassio@unisg.it.