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Sustainable energy in a developing world: The role of knowledgeable markets

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Wise application of knowledge in service to a vision of sustainability can guide and invigorate a global economy and global energy network dominated by the free market system. Free markets are a powerful social invention for efficient allocation of scarce resources, but in and of themselves free markets cannot and will not produce sustainability. Free markets are not generators of collective vision. Creation of visions of sustainability is what might be called a ''meta-market force,'' for it involves social, political, and cultural forces that fall outside the purview of market operation and conventional ''non-market forces.'' Once created, visions of sustainability must be translated into practice. An essential, and often overlooked, aspect of the translation process is the role of knowledge. Knowledge mediates between vision and practice. ''Sustainability knowledge'' (knowledge produced in service to the goal of achieving a sustainable civilization) must be generated, synthesized, summarized, codified, disseminated, debated, reviewed, evaluated, brokered, applied, and entrenched for a sustainability vision to take root. A gargantuan task for the twenty-first century is to harness sustainability knowledge in all sectors of the global economy.

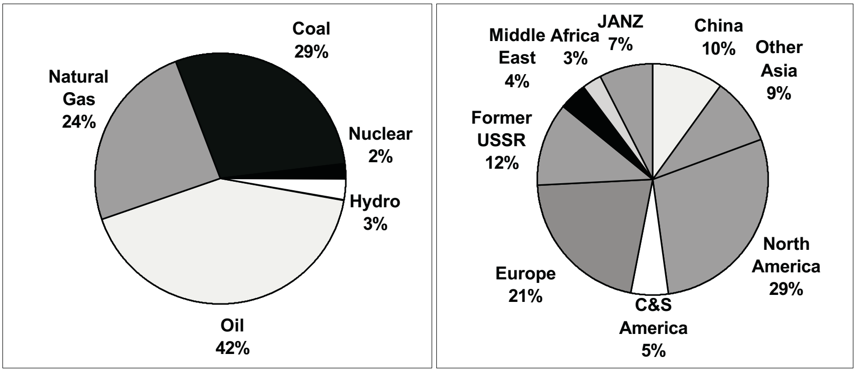
One sector is that of energy. The governing vision of sustainability in the energy sector is ''sustainable energy,'' and knowledge related to sustainable energy must be harnessed in order to attain this vision. This chapter attempts to illuminate the role of knowledge in implementing the vision of sustainable energy in the marketplace.

There is no accepted definition of "sustainability."[1] Generally, use of the term acknowledges that things are out of balance in our current practices of living on earth, and that the imbalances, if not corrected, will diminish future generations' ability to live fulfilling lives. When applied to energy, the term sustainability acknowledges that current practices of energy extraction, transformation, and use are out of balance. Sustainability, therefore, is an overarching conceptual framework for steering the human race toward balanced practices of living and energy use. The framework is composed of at least four key dimensions: preservation of ecological integrity (the natural dimension); pursuit of human justice and equity (the social dimension); maintenance of peaceful community (the political dimension); and achievement of economic efficiency (the economic dimension). This chapter focuses primarily on the environmental and economic dimensions in relation to energy use, and considers their intersection in both developed and developing countries.

Worldwide growth in energy demand: Trends and projections

Economic and social development is invariably accompanied by an increase in the need for energy and "energy services." Energy services are services – provided through the use of fossils fuels, biomass, fissionable materials, or other energy sources – that help satisfy human needs and desires. Examples of energy services are almost unlimited. They include the boiling of drinking water in Nepal, grilling of tortillas in Mexico, firing of a tea cup in Japan, welding of a Tata automobile in India, and rocketing of an F-4 Phantom off an aircraft carrier in the Persian Gulf. The form of development that is most intimately associated with vast increases in the use of energy and energy services is "industrialization."

It is rapid industrialization, combined with large populations, in low-income countries, or in countries with economies in transition, that will probably drive the biggest future increases in energy use. Historically, in industrial economies, economic growth has been positively coupled with energy use. In the decades leading up to the 1970s there was essentially a linear relationship between economic growth and energy use. Though there seems to have been a "decoupling" from a linear relationship, there is still a "positive" relationship. In other words, an increase in GDP is still associated with an increase in energy use, although the ratio between the growth in the two quantities is often less than 1:1. In the developing world, in its almost unanimous drive to industrialize, there is also a "positive" relationship, although it is difficult to characterize because of the multiple forms and levels of development.[2]



Source: British Petroleum statistics, spreadsheet file "fuelcons.wks." Here nuclear energy is counted as electricity output, not heat input; "C&S America" (Central and South America) includes Mexico; "JANZ" is Japan, Australia, and New Zealand; and "Other Asia" is all of Asia except China and Japan.

Figure 10.1. 1995 world energy use by fuel and region

As of 1995, the total amount of primary commercial fuels (including coal, petroleum, natural gas, hydroelectricity, and electricity from nuclear plants) stood at approximately 324 exajoules (EJ)[3], or about 7.74 billion tonnes of oil equivalent. Of this total, 53 per cent was used in OECD countries (sometimes referred to as the "industrialized" countries), 15 per cent in the countries of Central/Eastern Europe and the former Soviet Union, and 32 per cent in the rest of the world.[4] The "rest of the world" category includes virtually all of the lower-income countries of the world, including those in Africa, Central and South America, and much of Asia. Figure 10.1 shows the division of primary energy use in 1995 by fuel type and region or subregion, respectively. Oil accounted for the largest fraction of global energy use, followed by coal, natural gas, and primary electricity. North America was the region that consumed the greatest fraction of energy, followed by Europe, the former USSR, and China.

The global distribution of energy use has changed markedly, even over the last 10 years. Table 10.1 shows, for 1985, 1990, and 1995, the division of global primary energy use by fuel and country group. Although overall energy use in OECD countries and in the countries of Central/Eastern Europe and the former Soviet Union has grown only modestly – or even declined – over the last decade, growth in energy use in developing regions has been strong, particularly in China and other Asian countries. Note that the data in Table 10.1 do not include biomass fuels, which hold substantial shares of overall energy supply in many developing countries.

Table 10.1 World energy use trends, 1985–1995

Country group	Primary energy consumption, EJ						Fraction of primary energy consumption					
	1985											
	Coal	Nat. gas	Oil	Nuclear	Hydro	Total	Coal %	Nat. gas %	Oil %	Nuclear %	Hydro %	Total %
OECD	37.9	32.2	69.5	4.3	4.3	148.2	26	22	47	3	3	100
Eastern Europe/ former USSR	21.9	23.3	21.1	0.7	0.9	68.0	32	34	31	1	1	100
Rest of world	28.1	6.9	26.7	0.2	2.1	64.0	44	11	42	0	3	100
Total world	87.9	62.4	117.3	5.3	7.3	280.2	31	22	42	2	3	100
	1990											
OECD	39.6	36.1	76.8	5.8	4.3	162.5	24	22	47	4	3	100
Eastern Europe/ former USSR	19.9	27.7	21.2	1.0	0.8	70.8	28	39	30	1	1	100
Rest of world	34.5	10.2	33.3	0.4	2.6	81.0	43	13	41	0	3	100
Total world	94.0	74.0	131.4	7.1	7.9	314.4	30	24	42	2	3	100

	Primary energy consumption, EJ						Fraction of primary energy consumption					
	1985											
Country group	Coal	Nat. gas	Oil	Nuclear	Hydro	Total	Coal %	Nat. gas %	Oil %	Nuclear %	Hydro %	Total %
	1995											
OECD	37.9	42.4	80.4	6.9	4.6	172.3	22	25	47	4	3	100
Eastern Europe/ former USSR	13.5	22.2	12.0	0.8	1.1	49.6	27	45	24	2	2	100
Rest of world	41.1	14.4	42.7	0.5	3.4	102.1	40	14	42	1	3	100
Total world	92.6	78.9	135.1	8.2	9.1	323.9	29	24	42	3	3	100

	Average annual growth rate, 1985–1995					
	Coal %	Nat. gas %	Oil %	Nuclear %	Hydro %	Total %
OECD	0.0	2.8	1.5	4.8	0.8	1.5
Eastern Europe/ former USSR	–4.7	–0.5	–5.5	1.5	1.6	–3.1
Rest of world	3.9	7.7	4.8	8.4	5.1	4.8
Total world	0.5	2.4	1.4	4.6	2.3	1.5

Projections and scenarios of future energy use suggest that the trend of the last decade of increasing use of fuels in ''developing'' regions relative to ''industrialized'' regions is likely to continue and possibly accelerate. Table 10.2 shows ''Reference Case'' projections published by the US Department of Energy's Energy Information Administration for global energy use by fuel and region in 2005 and 2015 (USDOE/EIA 1997).

Beginning in 1995, energy use in developing regions is projected to grow at an average rate of about 3.6 per cent per year through to 2015.[5] By 2015 energy use in developing regions increases to over 41 per cent of the global total from 32 per cent in 1995. Projections by other researchers show a similar pattern.[6]

This section establishes several critical facts: growth in energy use is coupled with growth in economic activity in an industrial economy, although the coupling may not necessarily be linear; economic activity in both developed and developing countries is projected to increase in the next two decades and hence energy use is also projected to increase; and developing countries' share of global energy use relative to that of industrialized countries is projected to increase. These facts combine to suggest that coping with the global impacts (ecological, social, economic, political, and technological) of energy use poses a major challenge for the twenty-first century, and will create energy dilemmas not only for developing nations but for developed nations as well.

Can market forces in the energy sector be harnessed to achieve long-term sustainability in energy use in both developed and developing countries, and thus to mitigate or prevent the potentially devastating impacts associated with rapid economic growth? Before attempting to answer this, it is necessary to examine more closely the character of the marketplace in the energy sector.

The global ''Energy Market''

Global interdependence

One of the single most important economic changes in the world today is the phenomenal explosion in the use of free markets. There has been a dramatic shift away from ''command-and-control'' or ''centrally planned'' (socialist) economies to free market economies. Nothing better illustrates this point that the rush to free markets by the countries of Eastern Europe and the former Soviet Union, and China's experiment with free market practices. This monumental change means that the free market system, with all its goods and evils, is becoming both the world's dominant economic system and the system within which international energy relations are determined.

The explosion of free markets has intensified the phenomenon known as "global (economic) interdependence." Global economic interdependence in the energy sector is exemplified by the tremendous growth in internationally traded, financed, and produced forms of energy. It signals that in a very real sense one can talk about a global Energy Market (upper case) which ties together all energy-related market activities, whether local, national, international, or global in scale. The Energy Market stands in contrast to global energy markets (lower case) which tie together only internationally traded, financed, and produced energy. Global energy markets are a subset of the global Energy Market. The task of this chapter is to illuminate the role of knowledge in implementing the vision of sustainability in the global Energy Market. Before proceeding, however, it is necessary to examine the composition of the so-called Energy Market and its problems in dealing with sustainability issues.

Composition of the global Energy Market

The Energy Market consists of markets that encompass the buying and selling of fuels and the infrastructure within which the fuels are transformed and ultimately used to provide energy services. Energy markets range in scale from global (such as oil) to local (such as firewood). Some of the energy markets operating within the larger Energy Market are as follows.

Markets for fossil fuels

Markets for crude oil and petroleum products are global in scale, and are largely dominated by a relatively few major multinational companies and national crude oil suppliers. Coal markets are increasingly becoming global, although coal production in much of the world (including developing countries) has been traditionally state-owned. With the marked expansion of facilities for handling liquefied natural gas (LNG), the natural gas market has been shifting from primarily regional markets (using gas pipelines) to a nascent global market as well.

Markets for traditional renewable resources

Markets for biomass fuels have traditionally been local in nature, with individuals and small businesses doing the bulk of the trading. In some developing countries, markets for charcoal have become national in nature, sometimes even crossing international borders, and larger companies or cartels have sometimes become involved.

Table 10.2 USDOE/EIA projections of world energy use, 1995–2015

Country group	Primary energy consumption, EJ			Fraction of total			Average annual growth, 1995–2015
		Projections			Projections		
	1995	2005	2015	1995 %	2005 %	2015 %	
Developing Asia							
Oil	24.5	39.0	55.1	35	35	35	4.1
Natural gas	5.1	15.1	22.9	7	13	14	7.8
Coal	38.6	55.3	76.8	55	49	48	3.5
Nuclear	0.4	0.7	1.1	1	1	1	5.0
Other	1.3	2.5	3.2	2	2	2	4.5
Total	69.9	112.6	159.1	100	100	100	4.2
Other developing nations							
Oil	22.3	29.9	38.0	54	58	58	2.7
Natural gas	10.3	13.0	17.9	25	25	27	2.8
Coal	6.5	6.5	7.5	16	13	11	0.7
Nuclear	0.1	0.1	0.1	0	0	0	3.5
Other	2.0	2.1	2.3	5	4	3	0.6
Total	41.2	51.6	65.8	100	100	100	2.4
Industrialized countries							
Oil	89.5	102.0	110.9	48	47	45	1.1
Natural gas	44.5	60.5	74.1	24	28	30	2.6
Coal	38.9	41.6	44.6	21	19	18	0.7
Nuclear	6.7	6.9	5.9	4	3	2	–0.7
Other	5.9	7.6	9.2	3	3	4	2.2
Total	185.6	218.5	244.6	100	100	100	1.4

	Primary energy consumption, EJ			Fraction of total			
		Projections			Projections		
Country group	1995	2005	2015	1995 %	2005 %	2015 %	Average annual growth, 1995–2015
Eastern Europe/former USSR							
Oil	12.8	16.2	21.3	25	25	29	2.6
Natural gas	22.2	31.7	37.8	43	49	51	2.7
Coal	14.1	14.3	13.2	28	22	18	–0.3
Nuclear	0.9	0.9	0.8	2	1	1	–0.4
Other	1.1	1.1	1.4	2	2	2	1.4
Total	51.0	64.3	74.5	100	100	100	1.9
Total world							
Oil	149.0	187.2	225.2	43	42	41	2.1
Natural gas	82.1	120.2	152.7	24	27	28	3.2
Coal	98.2	117.7	142.1	28	26	26	1.9
Nuclear	8.1	8.6	7.9	2	2	1	–0.1
Other	10.3	13.3	16.1	3	3	3	2.2
Total	347.7	447.0	544.1	100	100	100	2.3

Source: USDOE/EIA, 1997. Figures for nuclear and “other” (mostly hydroelectric) fuel use were modified to reflect electricity output. Note that the USDOE/EIA energy consumption figures for 1995 are somewhat different from those published by British Petroleum – probably due to the use of different accounting practices.

Markets for conventional energy supply infrastructure

Large companies, including a number of multinational firms, dominate the provision of infrastructure for fuel extraction (coal, oil, and gas), for oil refining, for thermal, hydroelectric, and nuclear power generation, and for electricity transmission and distribution. Larger developing countries sometimes have their own industries for producing these types of equipment – particularly in smaller sizes – for both domestic use and export. Buyers of energy infrastructure have traditionally been state-owned companies or utilities, but there is a global trend toward the developers of energy facilities acting as facility owners and/or operators.

Markets for non-conventional/renewable energy supply infrastructure

The supply of infrastructure for renewable energy conversion – notably solar-photovoltaic and wind-power systems – has changed in recent years, with fewer and larger firms becoming dominant globally. Purchasers of renewable energy infrastructure vary in scale from individuals to nations.

Markets for end-use appliances and equipment

Most major electrical and gas appliances, motor vehicles, and other major energy-using devices tend to be manufactured by, or manufactured under licence to, large national or multinational corporations, while buyers are individuals/households, firms, and institutions.

Markets for energy-efficiency technologies

Sellers of energy-efficiency technologies are a combination of smaller and larger companies. Most of these devices are ultimately purchased by end-users (individuals, institutions, and businesses), although governments and utilities have sometimes played the role of ‘‘middle-man’’ in these markets.

Markets for capital

The availability of financial capital is an overarching consideration in the development and functioning of markets for fuels and especially infrastructure. In many cases, growth in demand for financing of energy infrastructure in developing countries is and will be well beyond the abilities of government and local financial institutions to provide. This means that external financing – multinational commercial and multilateral institutions – will have to fill the gap. Thus, the investment criteria of global financial institutions will play a large role in determining what type of energy systems evolve in developing countries, as well as how environmentally sustainable those systems are.

Actors in the global Energy Market

Energy sector actors in the above-described markets include the following.

Multilateral organizations and lenders

The United Nations, World Bank, Global Environment Facility, Asian, African and Inter-American Development Banks, Asia-Pacific Economic Cooperation (APEC) Forum, and other international and multinational organizations fulfil a number of roles in the energy sector of developing countries. These roles include funding research, development, and demonstration projects, providing or arranging financing for energy infrastructure, providing assistance with energy planning and energy-related economic development, tracking statistics from the energy sector, and transmitting information between various energy sector actors.

Multinational private corporations

Private corporations operating across national borders provide a substantial portion of the globally traded fuels, large energy installations, and energy demand equipment. Private corporations also play a major role in prospecting for and extracting fossil fuels, as well as in research, development, demonstration, and commercialization of new energy sector technologies. Also, industrial facilities in developing countries that are owned by multinational companies can be major demand centres for electricity and/or other fuels – thus, multinational companies can have substantial leverage in setting energy policy.

National corporations

State-owned corporations, including natural gas and electric utilities and oil and coal companies, have traditionally had a dominant role in the energy-supply sector in developing countries.

Larger private firms within nations

In some developing countries, large private firms serve as utilities and fuel suppliers, and also help shape both energy infrastructure and energy policy as suppliers of energy-using devices and as industrial/commercial consumers of fuels and energy sector equipment.

National research and development (R&D) institutions

Most industrialized nations and some developing countries have publicly and/or privately funded institutions devoted to aspects of energy technology development. Often these are organized by fuel type (such as the

Central Research Institute of the Electric Power Industry in Japan), or by other topic areas (such as the Beijing Energy Efficiency Centre in China).

National and subnational regulatory agencies

Domestic regulatory agencies are charged with setting energy and environmental standards, as well as with energy planning tasks. The regulation of energy pricing is a role often served by national agencies, although regulation in the energy sector is generally declining at present.

Non-governmental organizations

Interest groups outside of governments play various roles, including acting as advocates for consumer groups and indigenous peoples, as environmental "watchdogs," and as agents promoting (or opposing) particular energy technologies or paths.

Smaller private firms

Smaller private firms play multiple roles, including supplying technologies for energy conversion and energy demand equipment, supplying fuels such as biomass and charcoal, and consuming both fuels and energy-using devices.

"Local" communities

Local communities include state and provincial governments, cities, traditional villages, etc. These entities can act as buyers, sellers, and managers of energy. Traditional rural villages, for instance, administer traditional energy forms such as agricultural wastes, wood fuel, and charcoal produced locally, while at the same time administering industrial fuels such as electricity (in rural electrification schemes) and kerosene fuels sold in rural areas.

Individual consumers

Households and individuals are the final consumers of fuels and energy goods and services. As such, their preferences expressed via their "political votes," "monetary votes," and other economic/political actions help to determine which fuels and energy-consuming devices prevail in a particular country.

This description of energy markets and energy sector actors, while hardly complete, is sufficient to demonstrate that the operation of the marketplace in the energy sector is highly complex. The synergistic sum of all energy markets, forces that shape these markets, and actors within the markets, constitutes what is called the "Energy Market." It is this vast and loose-knit entity that must be made to function in a sustainable manner, and to which colossal amounts of sustainability knowledge must be applied in order to ensure its proper functioning.

Energy Market successes and failures

Making the Energy Market sustainable involves a two-pronged strategy – effectively deploying market forces where they do not currently exist (in other words, maximizing sustainability-directed market successes), and correcting failures in current markets (in other words, minimizing sustainability-inhibiting market failures). Knowledge has a central role in effecting both strategies. A few areas where market forces can be successfully deployed and where market deficiencies must be remedied are now discussed. The discussion proceeds from the global level to individual level.

Basic human needs

Eradication or major reduction of poverty is an essential requirement for the proper functioning of a globally sustainable economic system. Widespread poverty can undermine the global marketplace through such traumas as large-scale civil unrest, massive movements of people, or collapses of national governments. Because a market is ultimately based on considerations of economic efficiency, not human equity, even properly functioning markets have no incentive to eliminate poverty. It is up to regulators to subordinate the market to the imperative of meeting certain social sustainability criteria such as meeting basic human needs.[7] Energy markets can be created (as in the case of facilitating a switch from use of unhealthy or unsustainable traditional fuels, such as wood in deforested areas, to modern fuels, such as kerosene), and corrected (as in the case of taxing high-sulphur charcoal briquettes to encourage a shift to low-sulphur briquettes). Thus, knowledge needs to be developed and disseminated about the types and levels of energy-related needs and how best to meet them via market and non-market strategies.

Ecology and energy

Markets have failed so far to protect the earth's ecology.[8] Of all the symptoms of unsustainability in energy use, none may be more telling than the seemingly irreversible ecological impacts of energy use. It is impossible to eliminate all such impacts, but it is not impossible to keep impacts within the limits of ecological integrity. The global environmental impacts of modern energy use were first clearly recognized during the "environmental revolution" of the 1960s and 1970s. A complete rethinking of the relationship between energy use and ecological issues ensued, and led to such ideas as the "soft" energy path,[9] enhancing energy efficiency through approaches such as demand-side management,[10] and working toward a solar-based society. It is now widely accepted, if not realized in practice, that concerns about damage to ecological integrity must be considered in energy market decisions. Some of the threats to ecological integrity posed by fuel extraction, transformation, and use include global climate change, acid deposition, marine pollution, urban air pollution, water pollution, solid waste disposal, loss of biodiversity, displacement of animal/human populations, nuclear waste disposal, and nuclear weapons' proliferation. Generation and application of knowledge is a critical prerequisite for steering energy markets in the direction of ecological sustainability.

International regulation

International energy markets with no external regulation can be inefficient, environmentally destructive, and unsustainable. Regulation, if properly constructed, can provide a framework within which market forces are guided toward sustainability. The world is moving into an era of increased international regulation of energy-related sectors of the economy. For example, binding targets and timetables to reduce greenhouse gas emissions were agreed upon at the Third Conference of Parties (COP-3) of the Climate Change Convention in Kyoto, Japan, in December 1997. Also, increased global trade and the proliferation of environmental standards in different countries is forcing consideration of mechanisms like the ISO 14000 environmental certification process to ensure a level economic playing field in energy and other markets. And again, unsavoury corporate practices by some energy companies in remote areas, as well as the growing power of some multinational energy companies, are attracting regulatory attention. International regulation places a premium on accurate information and integrated knowledge.

National income accounts

Energy markets and market decisions are often significantly influenced by macroeconomic information such as is contained in national income accounts. However, the typical statistics on gross national product (GNP) and gross domestic product (GDP), as well as other macroeconomic parameters that are used to benchmark the health and wealth of an economy, do not usually measure changes in the human and environmental resource base upon which an economy is built. This deficiency can, for example, give the impression that a nation's economy is growing at a healthy rate, when in fact it is built largely upon depletion of human and environmental resources. Or it can give the impression that an economy is growing slowly when in fact it is successfully pursing socially and environmentally sustainable development. MacNeill, Winsemius, and Yakushiji (1991, 45) state the matter simply: "The introduction of indicators and appropriate revision of national accounting systems may be all that is required to correct public-sector economic decisions [which are lacking in a sustainability consciousness] in the long term, given the dominant focus of most governments on managing economic growth." The creation of "green" national income accounts can contribute to giving correct "sustainability signals" to energy markets. Green national income accounts require generation of substantial quantities of sustainability knowledge, such as sustainability indicators.

Full-cost pricing

The most important sustainability incentive in the energy sector is signalled through market prices. Full-cost pricing is the principle that producers must bear the full cost of all social and environmental damage incurred in producing and delivering a product above some minimum threshold. According to Tietenberg (1991, 214), "[i]mplementing the full cost principle would end the implicit subsidy that all polluting activities have received since the beginning of time." Full-cost pricing is similar to the "polluter pays" principle. The full-cost principle in the energy sector, as in other sectors, is knowledge intensive. It demands that the social and environmental costs of energy-related activities be made explicit, and that inappropriate subsidies are eliminated. The principle implies the imposition of "green" taxes.

"Sustainability" taxes

Even correcting unsustainable distortions in energy markets cannot take into account all external costs associated with energy production, transmission, and use. One way to correct prices is through "sustainability" taxes. Numerous taxes have been proposed and/or implemented. These include taxes on sulphur dioxide and carbon dioxide emissions, various other emission taxes, and taxes related to energy consumption levels. Emission taxes, for instance, force all polluters to face the same per-unit tax on emissions, and, if effectively employed, can result in a cost-effective (and possibly even efficient) allocation of pollution control responsibility. This outcome cannot be attained with the traditional command-and-control approach to regulation. A disadvantage of such taxes is that they put a financial burden on some firms, especially smaller firms, to the extent that they may go out of business. Similar to sustainability taxes are transferable permits or quotas schemes, such as those used in the sulphur dioxide emissions trading system enacted under the 1990 US Clean Air Act. All such tax and tax-related schemes demand high levels of information and knowledge input.

Energy planning and energy marketing

Energy planning is a tool to coordinate production and consumption of energy, and can be used either to encourage creation of new energy markets or to make current markets more sustainable. There must be a balance between free operation of markets and planning in the energy sector, and sustainability needs to become the byword in energy planning. One example of a sustainable energy-oriented planning tool is integrated resource planning (IRP). It goes without saying that knowledge plays a major role in such planning. Information on national and subnational patterns of energy supply and demand, energy resources and reserves, and technical and operating aspects of existing energy infrastructure, available in a transparent, consistent format, helps to identify opportunities for improvement of energy market operation. An example of a supplier of this type of information is ESource.[11]

Product life-cycle accounting

Energy markets are often deficient in the provision of sustainability information to large manufacturers. Sustainable energy markets require information that large manufacturers can use to make their production of goods sustainable. A promising approach for fusing economic efficiency with sustainability is product life-cycle accounting. Basically, this approach involves scrutinizing all production processes in an integrated fashion so as to identify opportunities to minimize wastes of energy and material, and in the process cut costs and pollutant emissions. Several national and multinational agencies have programmes to develop and encourage these sorts of economic/environmental "cradle-to-grave" accounting practices in industry. Needless to say, such accounting requires intense collection and organization of information and knowledge.

Sustainability information for the large consumer

Energy markets are often deficient in the provision of sustainability information to large consumers. Information on the technical (energy efficiency), environmental (pollutant emissions), and economic performance (capital and operating costs) of candidate energy technologies can help decision-makers in large organizations choose which energy supply options are suitable from a sustainability perspective. These types of data are available from equipment suppliers, regulatory agencies, and other non-governmental and institutional groups. Key issues in providing and using these data include data management, optimum usability for particular audiences, data "truthing" (making sure, for example, that manufacturers' claims are not exaggerated), and making sure that potential users are aware of information resources.

Sustainability information for the small consumer

Energy markets are often deficient in the provision of sustainability information to small consumers. Demand-side information to energy consumers (individuals, households, firms, and institutions) must be provided in order that they can make appropriate choices. Only if energy consumers have adequate information on the social and environmental ramifications of their choices of which fuels and energy-using devices to use can the promise of energy market efficiency and sustainability be fulfilled. Ways to provide environmental information to consumers include eco-labelling, "green pricing" of renewable electricity (a market-based technique for providing consumers with environmental information on their electricity bills), and information on the energy/environmental performance of a product, such as energy consumption rating systems for given types of appliances (refrigerators and air conditioners, for example).

Knowledge and sustainability in the Energy Market

Having surveyed some of the areas where energy markets succeed and fail in relation to the vision of sustainability, the chapter now turns to an examination of the role of knowledge in capitalizing on the successes and correcting the failures.

Knowledge and markets

The key question here is "How can knowledge related to sustainability be produced and incorporated into both public and private sector decision-making in ways that serve to configure, constrain, cajole, and coordinate market forces in the energy sector in the direction of a sustainable future?" Before plunging into this question, an understanding is needed of some of the elementary principles of the functioning (and "dis-functioning") of markets in relation to knowledge.

Hayek (1945, 520) succinctly stated the economic problem of society as:

> not merely a problem of how to allocate "given" resources – if "given" is taken to mean given to a single mind which deliberately solves the problem set by these "data." It is rather a problem of how to secure the best use of resources known to any of the members of society for ends whose relative importance only these individuals know. Or, to put it briefly, it is the problem of the utilization of knowledge not given to anyone in its totality.

Thus, the economic problem of society is at root a problem of knowledge. There is no one "supermind" in society that can know the total resource base and how best to use it. Thus, how do resources get valued and distributed? The free market system solves this problem by capitalizing on the fact that the two end points in economic exchange – producers and consumers – know best the terms of exchange that suit their capabilities and preferences, although each possesses only scattered and fragmentary knowledge about the other. The ragged set of knowledge known to producer and consumer meets in a decentralized decision-making forum – the marketplace – and by equilibrating supply and demand via prices results in an orderly system for "efficient" allocation of scarce resources. The catch with current knowledge that informs the marketplace, though, is that it is deficient in one major respect – it is knowledge lacking in substantial sustainability content. This can be traced to the nature of the modern market system.

The modern market system is a product of the transition from feudalism to capitalism that occurred in Europe beginning around the thirteenth century, and is fundamentally based on the "commodification" of resources such as land and labour. Polanyi (1957) called the emergence of the modern market (or Market, as he designated it), the "Great Transformation." It transformed the ways in which goods were produced, in that it vastly expanded the range of commodities that could be traded in the marketplace. Under the system of commodification born of the Great Transformation, the information (or knowledge) content of a commodity came to be quintessentially expressed in its price. It also came to be expressed in the institutional structures that defined what constituted a commodity.

However, the prices and institutions of the modern market system do not reflect even the full range of existing knowledge, let alone generate the information needed to achieve sustainability. There are spheres in which markets do not function well. The most common way of terming the dysfunctional aspects of markets is as "market failures." Some market failures were discussed earlier. One of the most common market failures is "externalities." An externality implies that there is knowledge "external" to that which is contained in a commodity's price and which has been left out in figuring the price. For the purposes of this chapter, sustainability knowledge is the key knowledge left out. But what is sustainability knowledge? And how can it be injected into the marketplace?

Sustainability knowledge and the Energy Market

To implement the vision of sustainable energy using market forces requires three more-or-less distinct sets of knowledge – knowledge related to developing energy markets, making energy markets more efficient, and making energy markets sustainable. These constitute what might be called a "knowledge" ladder to sustainable energy.

The first step in the ladder is generating, disseminating, and applying knowledge to create energy markets which would best serve the goal of sustainability. "Market creation knowledge" can be employed in those countries, especially developing countries, which do not now have energy markets or which have only embryonic markets. For example, such knowledge may be deployed to set up a stock market in which stocks in energy service companies can be traded.

The second step in the ladder is generating, disseminating, and applying knowledge to make energy markets more efficient in those countries that already possess a well-functioning market system. "Market efficiency knowledge" can be employed, for instance, to deregulate energy markets. The state of California in the United States is engaged in an experiment to deregulate the electric utility industry to make it more efficient and possibly more sustainable.

The third step in the ladder is generating, disseminating, and applying knowledge to infuse energy markets with specific sustainability goals. For example, establishing national carbon dioxide emission ceilings may help stabilize the earth's climate.

One form of knowledge that cuts across all three knowledge sets is expert knowledge. Experts and expert knowledge have a key role to play in achieving a sustainable energy future. Experts include physical scientists, social scientists, policy analysts, planners, economists, medical doctors, lawyers, engineers, etc. One grouping of experts which is particularly important to achieving sustainability is known as epistemic communities.

Epistemic communities[12]

Epistemic (related to knowledge) communities are defined as groups of experts who generate policy-oriented expert knowledge relevant to a given issue area. These communities are bonded by common criteria as to what constitutes valid knowledge (for instance, the scientific method), and a common policy project (for instance, investigating global coral reef decline). Thus, they are collectives or networks of credentialled experts who engage in a policy mission. They are not merely engaged in ‘‘research,’’ but research with a direct policy purpose. Epistemic communities are almost invariably multidisciplinary. Their level of operation may be local, national, international, or global. Their common policy project may be acid deposition in East Asia, clean coal technology in the United States, rural electrification in developing countries, or marine pollution in the Mediterranean. The essential function of epistemic communities is to generate policy-relevant knowledge on a select problem, which means they synthesize, summarize, interpret, and translate esoteric forms of technical knowledge into forms understood by policy-makers and lay people. The primary purpose of epistemic communities in the political world is to feed knowledge into the public sector to inform, among other things, decisions related to the marketplace. The relationship between epistemic communities, energy markets, and public sector governance institutions is illustrated in Figure 10.2.

Examples of energy-related epistemic communities include the Intergovernmental Panel on Climate Change (IPCC), the scientists associated with the Convention on Long-range Transboundary Air Pollution (LRTAP), and the economic and legal specialists who designed the sulphur dioxide emissions trading scheme in the 1990 US Clean Air Act. Epistemic communities exist for all three energy-market-related sets of knowledge in the knowledge ladder to energy sustainability. It is thus possible to generate a matrix of energy-sector-related epistemic communities classified in terms of knowledge type (market development, market efficiency, and market sustainability) and scale of operation (local, national, regional, global). This matrix is illustrated in Figure 10.3. One can imagine that each cell of Figure 10.3 contains the image portrayed in Figure 10.2, and that there are a vast range and number of epistemic communities parlaying knowledge between a wide variety of public and private sector institutions and actors.

To illustrate the power of epistemic communities to steer energy markets towards a sustainable path, three examples of them in action are now discussed.

The first example falls in the ‘‘regional scale/market sustainability knowledge’’ matrix cell, and relates to the development of the ‘‘critical-loads’’ approach to the acid deposition (acid rain) problem in Europe. Energy markets in Europe up until the mid-1980s did not account in any significant manner for the externalities associated with the emission of acidic substances due to fossil fuel combustion. The technique that a

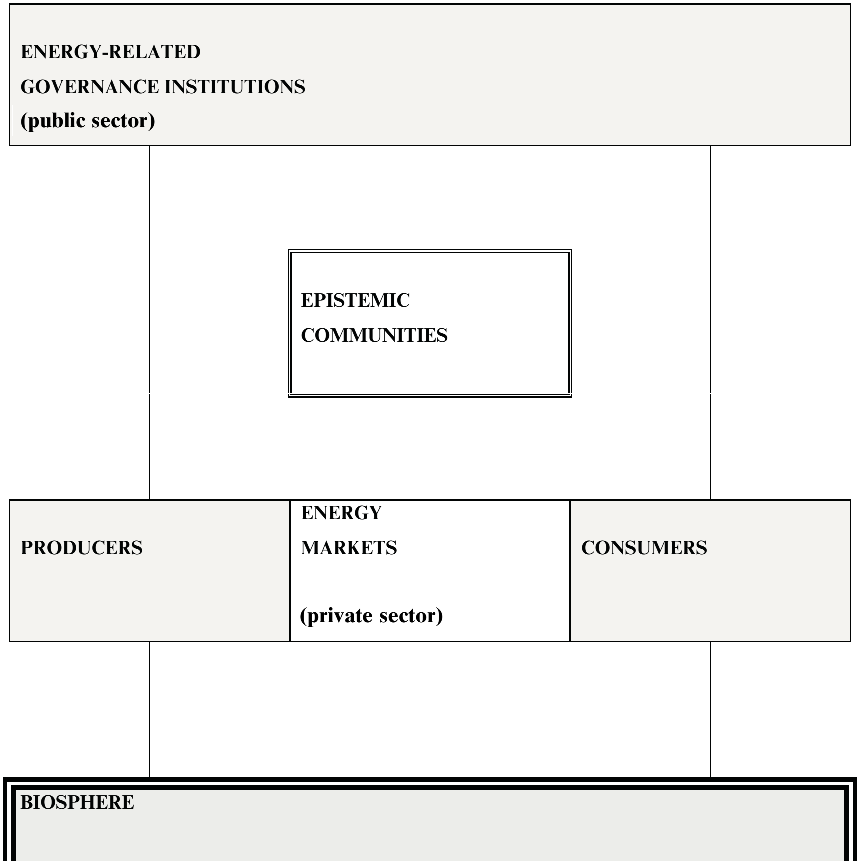


Figure 10.2. Epistemic communities, energy markets, and public sector governance institutions

European epistemic community of scientists devised to remedy this deficiency was a ''sustainable energy indicator'' called a critical load.[13]

Critical loads are but one example of a sustainable energy indicator. Such indicators have a major role to play in achieving energy sustainability. They are practical pointers, criteria, measures, standards, guidelines, or yardsticks that can be used to define and judge progress toward the sustainable energy vision. There are many types of indicators, including economic indicators such as local and national energy efficiencies per unit of economic output; social indicators such as levels of rural electrification; and environmental indicators such as carbon dioxide concentrations in the atmosphere. Because of the nature of the market system,

Knowledge type/scale	Energy market development	Energy market efficiency	Energy market substainability
GLOBAL			
REGIONAL			
NATIONAL			
LOCAL			

Figure 10.3. Knowledge and market matrix for the energy sector

it is imperative that a significant collection of quantitative sustainable energy indicators be developed. As has already been stated, the market is fundamentally based on the quantitative principle of commodification in which commodity transactions are mediated by ‘‘price’’ – a negotiated but nevertheless quantitative measure of consumer utility and producer profit. Thus, to mould itself to market dynamics, quantitative measures of energy sustainability must be generated. Much effort is already being expended in this direction. Organizations such as UNEP (in their Earthwatch programme), the World Resources Institute (in its annual *World Resources* publication), and the Worldwatch Institute (in its annual *State of the World and Vital Signs* series) are engaged in broad definition of sustainability criteria.

Science has assumed a role as arbiter of criteria of ecological sustainability, and epistemic communities have become formulators of such criteria. The formulation of the critical-loads approach by a European epistemic community associated with the acid deposition problem is evidence of this. A community of scientists related to the acid deposition problem in Europe first formed soon after the discovery of the problem in 1968. It expanded after the UN Conference on the Human Environment, or Stockholm Conference, in 1972, and was highly influential in the efforts leading to the signing of the Convention on Long-range Transboundary Air Pollution in 1979. For years the European acid deposition epistemic community cast about for an ecological sustainability criteria related to acid deposition that could be used by governments in making energy policy decisions. Although the idea of critical loads was first hit upon in Canada in the mid-1980s, it was the Europeans who seized upon it and crafted it into a policy tool. They laboured for almost a decade before it was finally accepted and formally used for the first time in the 1994 Oslo Sulphur Dioxide Protocol to the LRTAP. Since this time scientifically determined "critical loads" have become the normative base for international decision-making on the acid deposition issue in the region. Critical loads are not used to micromanage energy decisions in Europe. Instead, they provide an ecologically based tolerance of ecosystems to acidic pollutant inputs. It is left to the market to figure out how best to stay under the given tolerance level. Thus, critical loads have firmly situated themselves as an overarching framework within which regional and national energy policy decisions are made in Europe.

A second example of the power of epistemic communities to steer energy markets toward sustainability falls in the "national scale/market development knowledge" matrix cell of Figure 10.3, and relates to creation of markets for energy efficiency technologies in China. The Beijing Energy Efficiency Centre (BECon) was established in 1993 in a cooperative agreement between Chinese officials and the US Department of Energy, US Environmental Protection Agency, and the WWF. Among BECon's many activities is creating markets in China for "green lighting" technologies. An international epistemic community of green lighting experts, whose common policy objective is to generate policy-relevant knowledge for the Chinese government related to energy-efficient lighting, was instrumental in persuading the Chinese government to authorize in its Ninth Five-Year Plan a China Green Lighting Programme. The programme seeks, among other things, to create markets for energy-efficient lighting products. A key to creating such markets is technology transfer.

Technology transfer is a crucial element of the development of energy markets in developing countries. The transfer of technologies to increase energy (and economic) efficiency, reduce pollution and other environmental impacts, and generally support sustainable economic development has been touted as one way that industrialized and developing countries, working together, can address imperfections in global energy markets. Martin Bell, however, has pointed out that simply transferring technologies (hardware) is not enough (Hayes 1993). In addition to the knowledge of how to build and operate technologies, technology transfer should also provide the background knowledge, training, and organizational structure that will allow local personnel to learn about, work with, adapt, and upgrade technologies to fit local conditions better and to press worthwhile technologies into broader local use. Without this process of internalizing both technological ''know-how'' and ''know-why,'' technology transfer is unlikely to reach its full potential. It is in the transfer of knowledge – know-how and know-why – that epistemic communities have a central role to play in the creation of markets. They help create the knowledge base that is essential for new markets to function.

The international ''China green lighting'' epistemic community consisting primarily of Chinese, US, and European experts has been a sparkplug for facilitating the transfer of knowledge (in addition to hardware) in the China Green Lighting Programme. Knowledge is transferred primarily through education and training of large-scale buyers, such as operators of buildings and public facilities, in the existence and use of green lighting. The community, in addition to engaging in education and training, has also been instrumental in holding an international symposium in China on green lighting technologies and applications, establishing a China Green Lights Centre in Beijing which displays products, organizes demonstration projects, and provides guidance on major investments made by the Chinese government in the lighting manufacturing sector. In sum, the epistemic community is helping establish markets in environmentally friendly and energy-efficient lighting products in China.

The third example of the power of epistemic communities to steer energy markets toward sustainability falls in the ''local scale/market efficiency'' matrix cell, and relates to deregulation of the electric utility industry in California in the United States. In the quest for removing utility monopolies in the United States, electric utilities are the latest deregulation experiment, following the removal of regulatory barriers in the telecommunications and natural gas industries. California embarked in January 1998 on a landmark experiment that will allow companies to compete to sell electricity to residential and business customers. Arguably, a freer (or less monopolistic) market for electricity will provide more choices (among them more ''green'' choices) and help cut prices. An epistemic community consisting primarily of economists, planners, and computer programmers drawn nationwide from academic institutions, government, and business has been at the centre of the deregulation experiment. The community is providing policy-relevant knowledge to state-level and federal-level policy-makers (for instance, state legislators, Congressional representatives, the California Public Utilities Commission, the Federal Energy Regulatory Commission, and the Department of Energy). It has been responsible for generating ideas such as the independent system operator (ISO), and the power exchange (PX). The ISO functions like an air traffic controller for energy and operates the state's transmission system. The PX acts as a spot market for electricity. The ISO and PX are independent of the utilities and thereby prevent a monopoly. The complex deregulation experiment in California is knowledge intensive, not hardware intensive, and the epistemic community has provided the key knowledge to bring it to fruition.

These three examples of energy-related epistemic communities demonstrate the critical role of experts and expert knowledge in guiding energy markets toward the vision of sustainable energy. Many other examples could be given. Markets to a degree solve a coordination problem; coordination of information on preferences and capabilities between the consumer and producer. Sustainable energy markets will have to solve another coordination problem; coordination of the welter of scattered epistemic communities whose expert knowledge is essential to sustainability. This expert knowledge coordination problem will be addressed in the concluding section.

Conclusion – The United Nations and epistemic communities

Energy, environment, and markets: the thread that can tie all these components together in the fabric of civilization in the twenty-first century is the vision of sustainability and its realization through knowledge used to guide and reconstitute energy markets. Sustainable energy knowledge is a fundamental tool for resolving multiple energy dilemmas in both developed and developing countries, and for addressing these energy dilemmas in the context of a highly complex, interdependent, and synergistically dynamic Energy Market.

A substantially greater effort is justified in the energy sector to design consciously interrelated, international, interorganizational, and interdisciplinary expert knowledge systems related to sustainability. A chief component of such knowledge systems is epistemic communities. Epistemic communities need to be created, coordinated, and institutionalized in both the public and private sectors. Knowledge is both a private and a public good. As a public good, the benefits of investing in knowledge generation and management cannot be fully captured by the private sector. Hence, private entities such as consumers or firms tend to under-invest in knowledge, particularly sustainability knowledge. Without public investment in sustainability knowledge and policy instruments to incorporate such knowledge into the formulation of market decisions, markets cannot be made sustainable.[14] Institutionalization of epistemic communities has been done in the case of the IPCC associated with the Global Climate Change Convention, and the working groups and task forces of the LRTAP, for instance.

The United Nations has a valuable role to play in catalysing the creation, coordination, and institutionalization of epistemic communities. The United Nations can, for example, connect and coordinate multiple and scattered epistemic communities that operate in each of the cells in Figure 10.3. One mechanism for coordination is to construct a loose global network of sustainable energy epistemic communities linked via the Internet by "information appliances" (PCs, network PCs, Web TVs, cellular phones, satellite technology, etc.). Modern information technology has the potential for effectively coordinating multiple epistemic communities.

Some suggested forms of UN support for epistemic community creation, coordination, and institutionalization are provided below. In many cases, the United Nations is uniquely qualified to provide the suggested support.

Ongoing support for research, analysis, and scholarship

The United Nations should provide continuing support for research and scholarship on energy market development, efficiency, and sustainability. In other words, the United Nations needs to continue funding the basic work of epistemic communities – research, analysis, and scholarship.

Support for building institutional capacity for epistemic community activities

UN support for knowledge capacity-building should be ongoing in each nation, but should stress development, within each country, of a stable core of sufficient expertise (located, for example, in universities or research institutes) to allow the perpetuation of human infrastructure. In general, high levels of education are necessary for all peoples to be able to participate in the sustainability and sustainable energy debates.

Support for regional coordination of epistemic communities

The United Nations should support programmes that bring together experts from nearby countries to work together to develop and support, for example, consistent responses to market forces, environmental monitoring networks, coordinated environmental policies, and coordinated medium- and long-range evaluation of national energy paths and scenarios,[15] as well as to share information on regional energy infrastructure, resources, and plans.

Support for global information resources

Global databases and knowledge bases need to be constructed. For instance, a number of databases of energy technologies, vendors, and other energy-related documents are available around the world, but a single source of comprehensive but usable, up-to-date, unbiased, and widely available information on the technical, economic, and environmental performance of a full range of energy sector measures and technologies is still lacking. The United Nations could help to support the compilation and dissemination of such knowledge bases and databases.

In conclusion, institutionalized and coordinated networks of epistemic communities, together with associated comprehensively designed knowledge systems, need to be more fully integrated into energy markets. The fusion of networks of epistemic communities with energy markets will lead to what the authors call "knowledgeable (energy) markets." The watchword of knowledgeable energy markets will be sustainability, not blind growth. The United Nations serves as a major catalyst for creating knowledgeable energy markets.

Notes

1. The World Commission on Environment and Development defined sustainability (or sustainable development) as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, 43). The difficulty in reaching a consensus definition of sustainability, though, is demonstrated by the fact that one search of sustainable development definitions produced a list of 61 (Pezzey 1989).
2. The strong relationship between economic growth and energy use in both developed and developing countries is demonstrated by the almost linear relationship in the period from 1960 to 1990 between growth of worldwide electricity use and total global GDP; see Starr (1993).
3. One exajoule is equal to 10^{18} joules, or one billion gigajoules. An exajoule is equivalent to approximately 164 million barrels of oil, 24 million tonnes of oil, or 34 million tonnes of coal.
4. These data are from the British Petroleum (BP) website (www.bp.com), spreadsheet file "fuelcons.wks," visited on 13 August 1996. In this compilation the authors convert nuclear electricity generation to primary energy based on a direct conversion of electricity output to energy units, which is consistent with the treatment of hydroelectric energy but is different than the method used by BP.

5. Growth of energy use in developing regions is even more robust – 4.6 per cent per year from 1995 to 2015 – in the USDOE/EIA's "High Economic Growth" scenario.
6. See, for instance, IPCC (1992) and Fujime (1996).
7. Advocates of the basic-human-needs approach to development include Ghai et al. (1977) and Streeten (1981). In the area of energy and basic human needs one group of prominent advocates is Goldemberg et al. (1987).
8. Many excellent works discuss the major environmental impacts of energy use; see for example Ehrlich, Ehrlich, and Holdren (1977), Lazarus et al. (1995), and IPCC (1996a; 1996b; 1996c).
9. For example, see Lovins (1977).
10. For example, see Goldemberg et al. (1987).
11. ESource is a for-profit subsidiary of the Rocky Mountain Institute. It provides detailed, unbiased information to organizations on end-use technologies and applications. See http://www.esource.com.
12. See, for instance, Haas (1992; 1997).
13. The definition of a critical load adopted by the Executive Body of the LRTAP in 1988 is "a quantitative estimate of an exposure to one or more pollutants below which significantly harmful effects on specified sensitive elements of the environment do not occur according to present knowledge." An adjunct concept, "critical level," relates to ambient air concentrations of pollutants, not deposition values, and is defined as "concentrations of pollutants in the atmosphere above which direct adverse effects upon receptors, such as plants, ecosystems or materials, may occur according to present knowledge."
14. See Zarsky's chapter in this volume.
15. Some of the reasons for regional coordination in assembling and evaluating energy paths and scenarios include making more efficient use of regional resources, protecting regional environmental "commons," promoting trust and transparency in energy and environmental policy between countries, and learning from each other about different potential energy paths and options.

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