ENERGY SAVINGS THROUGH CHANGES IN LIFESTYLES AND ECONOMICS

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Contents

Summary

The article discusses how to reduce the energy system's load on the life-support system by using energy more efficiently and by switching to renewable energy resources. Discussions on energy efficiency are organized around the energy-chain model which illustrates how the raw, primary energy is converted through three main links: the supply technology, the end-use technology, and personal lifestyles, into the ultimate end, a general welfare. Energy efficiencies have no inherited environmental problems and are, generally, superior to any energy supply option.

The major options for higher efficiencies are in the lifestyles and the end-use technologies, since efficiency of supply technologies is already relatively high. The importance and principles of aiming for more energy efficient lifestyles are discussed in broad terms. For the end-use technologies, hard facts, demonstrated by examples, suggest potential for using energy several times more efficiently than at present. In short, it is possible in the course of half a century, to offer everybody on Earth a joyful and materially decent life with a per capita energy consumption of only a small fraction of today's consumption in the industrialized countries of the world.

Over the period 2000 to 2050, a total switch to renewable energy sources for supply is possible, but renewable energy sources can also cause severe environmental problems if exploited intensively. This stresses the need for first aiming for a low energy consumption. Examples of renewable energy supply options are described and discussed by their technology, potential, economics, and environmental impacts.

Finally, some principles for integrating and optimizing the whole energy chain are outlined with the aim of fulfilling people's needs satisfactorily with low environmental impact. This can be obtained if individuals and societies are dedicated to pursue that overall goal and adjust lifestyles, economies, and technologies appropriately. Materially, people's daily lives need not deviate much from today's European average standard, but in terms of economic thinking the necessary changes can appear quite challenging.

1. Introduction

Anthropogenic global warming is mainly caused by CO_2 emission which is dominated by the CO_2 generated when burning fossil fuels (see *Anthropogenic Climate Influences*). The energy sector is responsible for roughly half of the greenhouse effect and the resulting global warming. Consequently, development in energy systems must play an essential role in mitigating global warming (see *The Intergovernmental Panel on Climate Change*). In aiming for a sustainable development there are, however, many other energy-related environmental and resource problems to be faced (see *Methane Emission Reduction and Food Supply* and *Chlorofluorocarbons (CFCs) and their Substitutes*).

Since all kinds of energy supplies cause environmental problems, some more, some less, it seems reasonable to first look for ways to use less energy. Using less somehow seems to indicate suffering and hardship, but this need not be the case. The technologies that consume energy can be made much more efficient. However, the technical improvements need to be combined with lifestyles that are also energy efficient in the sense of providing satisfying and joyful lives to all people with a low consumption of goods and services, since all sorts of consumption imply some energy use, direct or indirect. Obviously, the global population is responsible for the environmental problems, and a low population density should also be part of any life-support system policy in all parts of the world.

Although substantial energy savings can be achieved, there will always be a need for some energy supply. This supply must increasingly come from CO_2-neutral, renewable energy sources, since nonrenewable sources like fossil fuel and nuclear energy by definition are unsustainable and should be applied only in a planned transition.

This article will give an overview of the options for living well with low, environmentally benign energy consumption, assuming that technology and social structures are adapted to that goal (see *CO2-mitigation and Adaptation Options*).

It should be noted that, in the following, energy consumption does not include the metabolic energy in food consumed by humans.

2. Energy System Models and Concepts

The use of energy takes place within a system of technologies. When analyzing the environmentally sustainable options of future energy systems, it is useful to stretch the meaning of the energy system concept to include all the elements from the natural energy resource to the human energy welfare or satisfaction, from the ultimate means to the ultimate end. Consequently, the study of energy systems involves many different disciplines including engineering, planning, sociology, economics, and biology.

2.1. Energy Chain Model

Figure 1 shows what is termed the "energy-chain model" consisting of the links which step-by-step convert the natural energy resource, "primary energy," into "energy welfare." Environmental impact is in most cases associated with the activities at the bottom where the primary energy exploitation depletes natural resources, generates pollution, and in other ways interferes with nature. At the upper end, the term energy welfare is used to denote the ultimate purpose of the energy system, such as satisfaction. The efficiency of the whole energy chain can now be defined as the energy welfare obtained divided by the primary energy exploited. Later, the environmental impact from using the different types of energy resources will be discussed, but first the potential for using primary energy efficiently is considered. The energy chain model in Figure 1 serves as a basis for this.

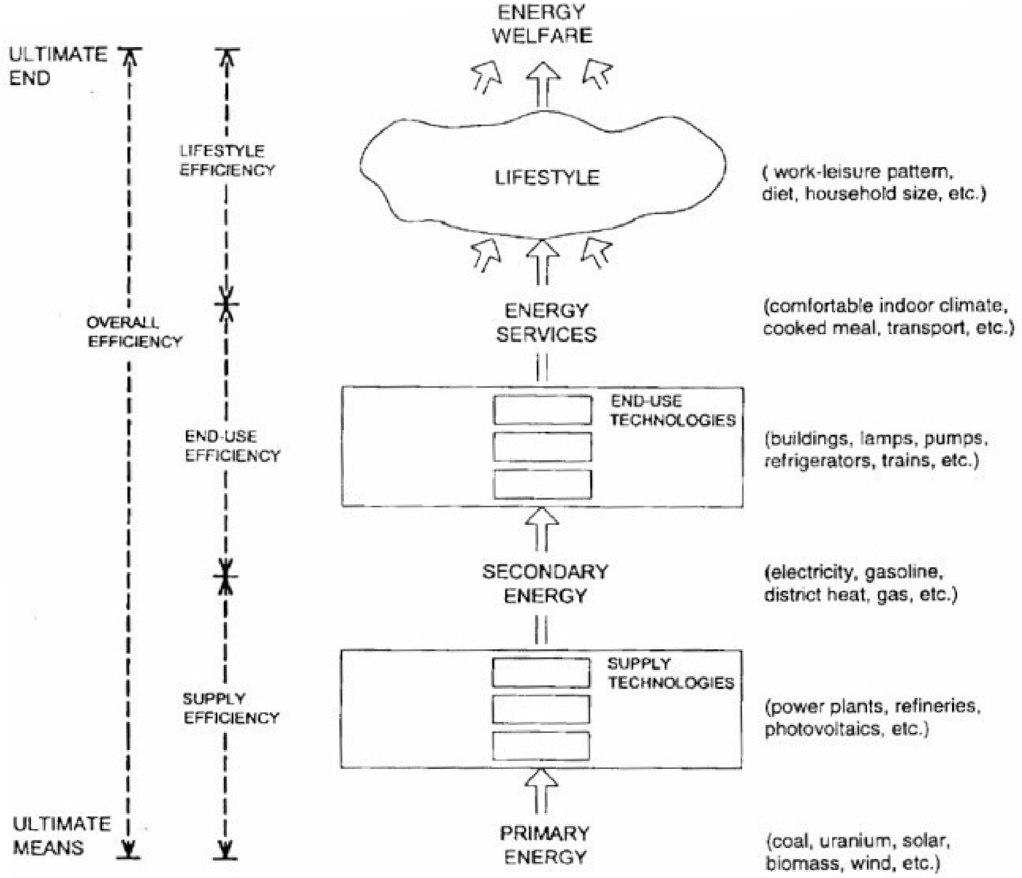

Figure 1. The energy chain

In the following we will briefly define and explain the single links in the chain, starting at the bottom.

2.2. Technological Links in the Energy Chain

Primary energy sources are nonrenewable sources like crude oil, coal, natural gas, and uranium, as well as renewable energy sources, mainly solar radiation and its many derivatives: hydropower, wind, biomass, etc.

By means of supply technologies like power plants, oil refineries, gasifying plants, windmills, photovoltaic systems, solar collectors, and furnaces, primary energy is converted into what is termed secondary energy, or sometimes, "energy ware." These are more refined forms of energy, which are typically sold on the market to the end users. Secondary energy includes electricity, district heat, fuel wood, diesel oil, charcoal, bottled gas, piped gas, gasoline, and kerosene.

By means of end-use technologies, the secondary energy is further converted into "energy services." End-use technologies include a huge variety of technologies such as whole buildings, pumps, refrigerators, trains, and ventilation systems. End-use technologies provide the energy services that constitute the physical output people want, as when a washing machine turns energy (plus water and detergent) into the "energy service" of clean clothes.

Energy services consist of things such as comfortable indoor temperatures, warm meals, convenient transport, cold beverages, refrigerated food storage space, water supply, and thousands of other services at home as well as at work, and in school and other locations. Energy services cannot normally be measured in energy units, but rather need other physical units, such as square meter of floor space at a comfortable temperature, kilograms of clothes cleaned, liters of cooled storage space available. But the energy services are all in different units and consequently, they cannot directly be added up. As a result, it is not easy to express a total end-use efficiency for one household, institution, or country.

There are various ways to overcome these problems of adding energy services as well as quantifying and measuring end-use efficiencies. Some of the measures rely on gross domestic products (GDP), expressed per capita, or income per capita. Others rely on a concept of "frozen efficiencies" to determine the overall development in energy services for a nation, for instance. But the difficulties in quantifying indicate that we are moving into a softer area of science, as described in the following.

2.3. The Soft End of the Energy Chain

The main lesson to be learned from looking at the energy-chain model in Figure 1 is that energy is of no direct value to human beings, not even secondary energy. Only when this secondary energy is turned into energy services can people draw some physical benefits from the energy chain. These services roughly express people's material standard of living.

The extent to which an increase in material standard of living leads to a higher satisfaction depends on cultural values, the living standard already obtained, and many other aspects of lifestyle. This link is illustrated by a bag-shaped element in Figure 1 indicating that, contrary to the previously described "hard" technical systems, we are here considering "soft" factors. The term "lifestyle" is used to mean how people have organized their daily life and how they live it. Lifestyle is to a large extent determined by the political and economic frames provided by society as well as by environmental conditions. Consumption is an essential element of lifestyle, both composition and amount of consumption. But working patterns, household sizes, diet, and leisure activities are also important threads in the interwoven web of a lifestyle.

It might offend some people to talk about the efficiency of a lifestyle. On the other hand, hardly anybody could argue against the two targets: (a) to make people satisfied and happy in any positive sense of this energy welfare concept, and (b) to do it with a minimum of environmental damage. The ratio of this energy welfare to the energy services consumed constitutes what is here understood as "lifestyle efficiency." Obviously, it is very difficult to quantify this efficiency, but it would be an expression of ignorance to exclude such soft aspects from considerations when analyzing the potential for using less energy.

While the flow of energy and services goes from the bottom to the top in the energy chain model, Figure 1, the analyses and planning is better off by starting at the top. It makes little sense to investigate how much energy could possibly be supplied before analyzing how much or how little is needed. Sections 3, 4, and 5 provide descriptions and discussions of the various links in the chain, starting at the top.

2.4. Means and Ends in Energy Systems

The purpose of the whole energy system, as illustrated in Figure 1, is to meet some ultimate human ends. The cost of achieving this is the exploitation of some natural resources, which are the ultimate means. Hence, the overall efficiency can be defined as the ratio of the ultimate ends to the ultimate means. These considerations apply to the economy in general, but unfortunately, economists tend to forget the two extremes in the chain, the ultimate costs and the ultimate benefits.

Attention in present economics is focused on a small part of the chain, namely the elements to which a monetary value can easily be ascribed and fed into statistical tables, mathematical equations, and computer models. Hence in energy policy, to provide secondary energy like electricity often becomes an end in itself, even though it is nothing but a means for providing energy services. Likewise, the energy service level, which is an expression of the general material welfare, is often seen as an end in itself rather than a means for higher ends. In the chain there are several such intermediate ends that serve as intermediate means for the next step.

The part of the energy chain in which optimization is taken seriously by economists is roughly extending only from the exploitation of resources by supply technology to the sale of secondary energy. In this part, market economy has resulted in reasonably efficient systems. The resources like sunshine, oil reserves in the ground, etc., are not ascribed any value in themselves. In the upper end, the economic optimization is left to the consumers who, however, in today's complicated industrialized societies are poorly prepared and informed to make the best choices. This is, for instance, demonstrated in Section 3 by the many options for the end user to using energy more efficiently.

3. The Effect of Energy Savings on Lifestyles and Economics

Often economic policy as well as economic theory is implicitly based on the assumption at present trends in industrialized societies suggests a more balanced and differentiated picture. This question is essential, because only an economy with satiation at some stage of development can provide a basis for a future sustainable society. With unlimited growth in demand for energy services and other consumption, energy consumption as well as its environmental impact will in the long run also continue to grow without limits. Despite the immense options for efficiency gains from better technologies, energy consumption cannot be decoupled from growth in energy service, and hence in the economy. Only for finite periods can this decoupling appear to exist because energy consumption and the economy can temporarily grow at different rates.

3.1. Preindustrial Economic Development

Only for brief periods has humankind been preoccupied with expansion in production and consumption as a goal. The present period of growth started with industrialization a couple of centuries ago. But the conscious political emphasis on growth in GDP has barely existed for fifty years. Today the euphoria of industrial success has led to a drive for eternal growth. Often this drive is erroneously perceived as an expression of human nature.

In ancient societies, affluence meant to be able to fulfill all ones needs and wants and still have time left. The key factors here are the level and types of desires and the attitude towards work. If the desires are unlimited spare time is impossible. Stone Age people often had a lifestyle of affluence in the sense of having excess time to relax, enjoy life, etc., a pattern still found in countries or regions that people from industrialized countries often denote as “undeveloped” or “underdeveloped.”

Also in Europe up until the Middle Ages people often lived a relaxed life with all basic needs well satisfied. Population growth, however, later lead to a too high exploitation of the natural life-support system. The basic element in this system, the forests, were then cut at an unsustainable rate which led to their depletion. This triggered governmental actions for the forest environment that, with its supply of fuel wood, fodder, food, and materials, formed the foundation for the economy. Harder work was seen as essential for solving the problems in Northern Europe. In the course of a few centuries an alliance with the church managed to introduce the Protestant ethic of hard work and frugality as the proper way to live. In the Western world, hard work is still a dominant social value and from there it is spreading to other cultures around the world. In today’s industrialized countries, this value of work is expressed, for instance, in policies of “creating jobs” rather than “creating welfare.”

3.2. Growth, Development, and Satiation Today

Pioneers in economic thinking considered growth in the gross domestic product, or GDP, as only a temporary phase in an economic development. The visions of economists like J. Stuart Mills in the mid-nineteenth century and J.M. Keynes around 1930 implied the satisfaction of people’s need for a joyful life without totally exploiting the natural environment. In recent decades, Nobel Prize laureates in economics Jan Tinbergen and Trygve Haavelmo have clearly expressed that economic growth in the affluent industrialized nations must come to a halt. Only then will the rest of the world have a chance to offer its people a decent life within the carrying capacity of the environment. Today, the industrialized part of the world does have the production technology that could fulfill a vision of a sustainable and decent life for every human being. But the economies seem to be guided by an invisible fist in a global contest of obtaining the highest GDP per capita. Consideration for energy consumption and the general environment is, at best, ranked second.

Fortunately, the claim for eternal growth, which is usually embedded in the present economic policy, is not founded in an eternal greed of people. Actually, there are several indications that in countries with a high material standard of living and with relatively high solidarity and equity, people’s values are turning away from what eternal growth in consumption and production can offer them, namely hard and distressing work and increased monetary wealth. Surveys in Northern Europe point towards a majority preferring less work to more consumption. Also labor market negotiations have increasingly shown that more leisure to enjoy life is higher on the labor rank and file's agenda than is higher pay. Similar trends towards satiation have been observed in the USA at different times in the 1900s. So far, however, such trends have not been welcomed but rather overruled by various government actions, including restriction of advertisement, limitation of shopping hours, tax policies that increase inequity in income and work, etc.

Most economists would agree that GDP is a very poor indicator of welfare, which it was actually never meant to be. GDP counts only what is produced and only the part that is counted in monetary terms. Cures and repairs after accidents and disasters count positively in GDP, while preventive measures like the longevity of durable goods tend to lower GDP, even though the goods continue providing the same service. From a real economic point of view, the output from the goods is the service they provide and with longer lifetime of the goods this is achieved at a lower input of resources, but also with a lower GDP. Similarly with energy savings, where cost effective increases in energy end-use efficiency allow the provision of the same services with lower energy input, but also a lower GDP. In a quest for one single indicator and without a better metric, economists and mainly politicians continue to use GDP as a measure of human welfare. Researchers have attempted to correct GDP for some of the more obvious absurdities as those mentioned above. Indicators based on such adjustments of GDP have over the recent decades shown a steady decline in a more real economic welfare in USA and other affluent industrialized nations, while at the same time GDP increases. With such macro-level analysis about a general decline in welfare from the increasing GDP in mind, the micro-level GDP satiation described above should not come as a surprise.

3.3. Derived Needs and Consumption

Most needs for energy services are not really basic needs like water, food, and shelter. Rather, needs for energy services are derived from the environment human find themselves in, either natural or artificial. The need for transportation is an example of such a derived need.

The high productivity of today's industrialized economies is partly due to specialization based on money exchange. People need transportation to get to work to produce and to earn money. Afterwards, they have to go to another place to buy food and other consumer goods and services. Parallel to this, products have to be transported around to various specialists and finally to the shops and home from the shops. A reduction in energy consumption for transportation can be achieved not only by improving the end-use efficiency of providing transportation (person-km and Mg-km), as described in Section 4.7, but also by reducing the need for transportation. Since growth in consumption and growth in GDP have so far been the overriding goals of governments, there has been essentially no incentive to encourage a reduction in the need for transportation.

Ivan Illich was the first of several to point out that, from an overall basic economic consideration, it is not cost effective to use a private car. If the time the owner spends at work to earn money to buy it, to pay the taxes, gasoline, parking, etc., is added to the time spent driving the car, the mean speed in kilometers traveled per hour is lower than when riding a bicycle. Similar calculations can be made for other goods, bought on the argument of saving time, but paid for by many hours of work.

3.4. Lifetime of Durable Goods

The so-called durable goods like furniture, clothes, cars, and computers are not always very durable when expressed in terms of their mean useful lifetimes. If this were a technical durability question only, almost all of these goods could be designed, without significant extra cost and energy input in production, to be used twice as long or more, if wanted. This would save roughly half of the energy used to produce these goods, as described in Section 3.2.

In industrialized affluent countries, long before clothes and furniture are worn out they are replaced by new fashions that satisfy some social and psychological needs. The same applies to cars, computers, and kitchens, where functional obsolescence also plays a significant role. There can be cases where an accelerated replacement makes some environmental sense, as when an old, very inefficient refrigerator is replaced by a new, more efficient model. But this is a temporary stage of development towards a sustainable life-support system. The general environmental rule should be to keep goods as long as they serve their basic purpose properly.

When the physical energy services are consumed for the purpose of satisfying nonmaterial needs, the result can often be poor. Social and psychological needs, like self-esteem and security, can be well satisfied with friendship, education, and other nonmaterial methods, or attempts can be made to satisfy them with more powerful computers, bigger cars, the latest fashion in clothes, larger houses, and other material goods. The materialistic culture that has increasingly dominated the industrialized countries is characterized by extending material consumption to satisfy nonmaterial needs.

If the social and psychological needs could be satisfied by more appropriate means, there would be substantial options for saving energy as well as other resources by extending the lifetime of durable goods, especially if repair is facilitated in the production and in the general economic structure.

3.5. Efficiency through Sharing

The per capita need for energy services in the domestic sector is closely related to household size. In affluent industrialized countries, mean household size is decreasing, approaching two persons, with the most common size being one person. This makes the utilization of various energy services like space heating, lighting, and refrigeration quite inefficient as compared, for instance, to a household with four to eight persons who can share many services. The same pattern is observed in transportation where heavy and energy-demanding vehicles often carry just one person.

One of the driving arguments behind this trend away from sharing is higher individual freedom, but the hidden cost is a loss of freedom through long, distressing working hours and a loss of social benefits from sharing. More sharing holds substantial potential for increasing lifestyle energy efficiency. But as discussed in the section following, the present structure of the economy in most countries tends to counteract an efficient lifestyle.

3.6. Sustainable and Efficient Welfare Economy

Energy efficiency of lifestyle and economics in the energy chain is a measure of how much satisfaction people get from the energy services consumed (see Figure 1). The sharing of goods and extension of their lifetimes discussed above are examples of lifestyle efficiency improvements that could be quantified in a focus on the primary purposes of purchasing new clothes, furniture, and cars. Such steps could lower the production of durable goods and hence the whole GDP and its energy consumption. Unemployment can be prevented by also sharing the work through shorter working time. In light of the growing trends towards preferring less work rather than more consumption, all of these steps are consistent with a general satiation economy.

Changing the path to environmentally sustainable development is a dramatic transition in economic thinking, but not necessarily a dramatic transition in daily lifestyle. Today, the economic systems in affluent industrialized regions are in danger of developing a purpose of their own, turning GDP and consumption into ends rather than means of fulfilling people's needs. One explanation of this trend has been the high value ascribed to work which makes work an end rather than a means for obtaining certain goods and services. Fortunately, however, these values seem to be giving way among the general public in many industrialized countries.

Also, the perception of economics as a system of its own, independent of the environment, must be revised. Ecological economics is a rather new school of economics, based on the fact that economics is a subsystem of the total environmental system, and is dependent on it for sources of energy and materials as well as for sinks of waste. The most important implication of this thinking on the energy planning is that the flow of energy must be constrained to a level below the environmentally maximum acceptable supply from renewable energy sources. As discussed in Section 5, this is a quite different perception than the presently dominant one that is based on using stocks of nonrenewable energy sources at whatever rate is required by the economy.

To summarize, there are clear indications that eternal expansion of material consumption is neither desired by the public nor possible. Recognizing these facts and adjusting economic policies to them could substantially lower the demand for energy services.

4. End-Use Efficiency Savings

The secondary energy delivered by the supply system can be electricity, district heat, gasoline, charcoal, etc. (see Figure 1). These are also termed energy wares, referring to the fact that this is the form in which energy is usually sold as a ware to the consumer or end user. From this retail trade point onward, the end-users play a key role in how efficiently, or inefficiently, the secondary energy is utilized to provide the desired energy services.

4.1. Historical End-Use Efficiency

End-use efficiency has been improved over the centuries. Before industrialization the per capita consumption of primary energy for domestic uses, usually in the form of fuel wood, was often higher than in a well-equipped household today. The reason was that end-use technologies for cooking and keeping warm indoors in cold regions were surprisingly inefficient, mainly because the end-use technologies consisted of leaky and poorly insulated buildings and open fireplaces. Extremely inefficient candles and oil lamps provided lighting. Transportation and soil cultivation were performed by draught animals, and by human power, and often with quite inefficient heavy carts and tools. The few early industries producing iron, glass, salt, bricks, and pottery used an energy input of fuel wood in ways that were an order of magnitude less efficient than present methods.

In Europe, population growth spurred deforestation, depriving people of their abundant access to sustainable flows of renewable materials and energy. Necessity is the mother of invention, however, and over the centuries shortages of energy have taught people to utilize energy still more efficiently. Stoves replaced open fireplaces and saved typically three-quarters of fuel wood. Steel parts made carriages and agricultural tools like plows easier to pull, which saved more than half the energy consumed.

4.2. Further Options for End-Use Efficiency Improvements

It could be argued that the lesson from history is that further improvements of end-use technology will be invented and implemented whenever necessary. First, however, one should remember that the environmental problems we are facing today do not necessarily affect the people who have caused them and that this situation makes acting in time less likely. Second, energy technologies today are closer to theoretical limits of efficiency. Third, earlier inventions were typically not ready “in time,” but appeared only after immense human suffering. Fourth, with today’s rapid growth in consumption of resources, shortages and crises will not leave much time for inventing new technologies as necessary. It is essential not only to look ahead but also to act before the last call.

Improvements of efficiency by a factor of three, four, or more are still possible in industrialized countries. But millions of people today are living under materialistically poor conditions in which energy use is even more wasteful than in industrialized nations. In both cases, most of the saving options seem to be cost effective.

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Biographical Sketch

Jørgen S. Nørgård (or Jorgen S. Norgard) has worked since 1972 on energy planning for a humane and environmentally sustainable future. Most of this work has taken place at his present workplace, the Technical University of Denmark, from which he received his PhD in physics and mechanical engineering. For some years before his university studies, he worked as a farmer and a mechanic. After receiving his PhD, he spent more than two years in the USA, half at Dartmouth College in New Hampshire studying methodologies for long-term dynamic analyses.

Norgard's research and teaching have been interdisciplinary, emphasizing the environmental and economic importance of keeping energy consumption low by means of technical efficiency increases as well as by adopting appropriate lifestyles and economic structures. The methods and energy-saving options he has pointed out and developed in numerous publications have increasingly been recognized internationally. He has been appointed to governmental committees and boards on energy issues, and has also worked with various nongovernmental organizations internationally as well as in Denmark.

Over the years, Norgard has been invited to many parts of the world as a speaker and advisor on energy planning. For twenty years, he has been a member of the Balaton Group, a worldwide association of one hundred environmental researchers and managers which meets annually at Lake Balaton in Hungary. He has published numerous books, essays, and scientific papers, mostly in English and Danish, and he participates in daily debate in written and electronic media about the direction of future development.