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Cities and Material Flows

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1. Resource Circulation on a Finite Planet

1.1 "One-way" Lifestyles since Humanity Began

It is possible to trace the history of the human race back about five million years. Since that time, humanity has exploited and manipulated nature for its own benefit and livelihood. Humans have obtained from nature the food needed to survive, and after consuming it they disposed of the organic waste in one direction --- back into nature. Humanity has raised its standard of living by making tools and using resources from nature --- wood and stone; oil and other forms of energy; and iron, copper, aluminum and other metals. Similarly, when tools were no longer needed, they were simply thrown back into nature. In short, from humanity's earliest days until the present people have lived "one-way" lifestyles --- in which the necessary materials were taken from the natural world, used, and then cast back into the natural world.

How has this one-way lifestyle been possible? It is only because the human presence on the planet was, until now, much smaller than it is now. Until recently, humanity could have described this planet as infinite and its resources impossible to deplete. "Infinite" meant that resources were in such great abundance that no matter how much was used, they would never run out. The fact that the Earth did not deteriorate significantly despite becoming the receptacle for toxic substances from humanity was thanks to the enormous self-cleansing capacity of nature. If enough time went by, nature would return to its original healthy state. In other words, we have lived on this planet under the assumption that it was like a superhero who could never fail us.

We humans have built a comfortable living on what we thought was a limitless, indestructible planet by conquering, modifying, exploiting, and plundering nature. We have cleared the forests for agricultural land, and learned the technologies to systematically produce crops. Eventually, we constructed roads and railways, and then built houses, factories, schools and hospitals near them, formed towns and cities, and dramatically increased the comfort of our daily lives. Meanwhile, we extracted natural resources such as oil, iron, copper and aluminum from the Earth's crust, and manufactured the many items required for daily life, such cars and household appliances. These all helped to bring us material abundance.

Over the two hundred-plus years that have passed since the Industrial Revolution, at the end of the eighteenth century, until the twentieth century, humanity feverishly pursued material wealth as it also developed modern technologies. The ultimate means that could be used to pursue this material wealth was a one-way economic system that depended on mass production, mass consumption and mass waste. But this system, while on one hand delivering material wealth to humanity, also brought with it the early signs of resource depletion, as the global environment became severely damaged and natural resources were consumed in huge quantity. To make matters worse, manmade chemical substances, such as those that generate endocrine disruptors, could be threatening the very continuation of the human race. As a result of pursuing a one-way life style, we have crashed into the limits of the Earth.

1.2 Lifestyles for a Finite and Vulnerable Planet

One of the main factors forcing the present generation to confront the Earth's limits is the sudden population explosion of the twentieth century. In 1700, before the Industrial Revolution, the global population was only 640 million people. By 1800 it had expanded to 890 million, and then to 1.65 billion at the start of the twentieth century. A population at this level would probably still be within the Earth's carrying capacity, but it is above this level that the problems began to appear. By 1950 the global population had risen to 2.5 billion. By 2002 it was up to 6.2 billion. Over the course of just one hundred years the global population has swelled by more than 3.5 times. The pace of growth will not stop, and the United Nations Population Fund predicts that it will rise to nine billion in about 2050. If the population continues to increase at this rate, the Earth will simply be too small for the human presence. Calculated according to the "ecological footprint" approach developed at the University of British Columbia, if all people in the world were to live like the Japanese, 1.5 more Earths would be needed.[1] To live American style, 4.5 more Earths would be needed (Table 1).

Due to the population explosion and the economic expansion driven by industrial mass production methods, from the human perspective the Earth has been transformed from being infinite and indestructible planet to a planet that is indeed finite and vulnerable. The more resources we use, the more the reserves are reduced, and eventually we will reach the end of the supply. If we continue to spew toxic substances into the natural world, we

[1] Ecological footprint: The area on the Earth required in order for one person to live sustainably, considering the consumption of resources such as food and timber, and the sequestration of carbon dioxide by forests, etc.

will pollute the air, soil and water, and threaten the very conditions required for human survival. The Earth in the 21st century has become as vulnerable as a house of cards and has a fragile existence. If we deplete our resources and cause the natural environment to deteriorate even further, the very continuation of the human race will become untenable. In order to avoid catastrophe, we must adjust our ways to recognize the finiteness of the Earth.

For this purpose, we must very quickly transform our one-way societies into resource-recycling societies, or societies with sound material flows.

1.3 Boost Resource Productivity

Figure 1 is an illustration of the conventional one-way society (expanded equilibrium society). The vertical axis shows social welfare and the level of nature utilization, and the horizontal axis shows the time scale. Social welfare could be interpreted as, for example, a lifestyle satisfaction level or the standard of living. Between the Industrial Revolution and the twentieth century, humanity increased its social welfare by exploiting nature, making life more convenient, extracting materials from the natural world, and manufacturing the things needed for living. In other words, the more nature was made accessible for exploitation and the use of materials, the higher the level of lifestyle satisfaction. Accordingly, the figure shows the utilization of nature and social welfare both increasing from the left. In other words, this figure shows the positive correlation between the two.

If this positive correlation were permitted to continue indefinitely into the future, there would be no need to challenge our one-way societies. But the finiteness of the Earth is now obvious for all to see --- in the worsening of the global environment and the depletion of resources. The one-way society as shown in Figure 1 can no longer continue.

During the 21st century, humanity must adapt itself to live with the Earth's finiteness. Humanity must not only avoid increasing the exploitation of nature, but in fact, must reduce it. On this path, there are two options. One is the contracted-equilibrium society.

Figure 2 shows a contracted-equilibrium society. Here the path is to reduce social welfare in order to reduce the amount of exploitation of nature. The course shown here has exactly the reverse of the expanded-equilibrium society in Figure 1. It involves reducing the standard of living as a means of reducing the amount of exploitation of nature. Both straight lines are declining to the right. If we are to become a contracted-equilibrium society it will not be possible to return to the lifestyles of thirty or forty years ago. But this option is more easily said than done, because people would have to be prepared for negative annual economic growth of several percent for many years into the future. Today Japan faces an unemployment rate of about 5.5%, and this is already causing major stress in society. If the goal is a contracted-equilibrium society, the unemployment rate may exceed 20 and even approach 30%. Such conditions would probably be seen as unacceptable for society. Thus, the contracted-equilibrium society is probably not feasible in the real world.

Another option is a society with sound material cycles, as shown in Figure 3. As one can see in the figure, the exploitation of nature is declining, but social welfare continues to increase. How can such as world be possible? In order to explain this, the concept of "resource productivity" is needed.

Resource productivity (P) is the social welfare (W) that can be obtained per unit of resource investment (R). This can be expressed with this formula:

$$P = W / R.$$

Resource productivity can be increased by obtaining more social welfare from less resource investment.

To illustrate, let us assume that a given society can obtain five units of lifestyle satisfaction per unit of resource investment. Now, suppose that this society, through technological innovation or lifestyle transformation, has transformed into a society that can obtain the same lifestyle satisfaction level for each 0.5 units of resource investment. The reason such as transformation is possible is that the resource productivity has doubled. If society succeeds in raising resource productivity, it is possible to reduce the exploitation of nature without reducing social welfare.

The reason that no effort was made to raise resource productivity until now is that energy and resources were thought to be limitless and their prices were set low, so there was little incentive to raise resource productivity. Instead, society increased its labor productivity and pursued economies of scale through the mass consumption of energy (oil and other forms) and other resources. Now, in the 21st century, it will be important for business and society to increase labor productivity by raising the productivity of energy and other resources.

1.4 Ten Ways to Boost Resource Productivity

There are many ways to boost resource productivity. Table 2 shows ten such ways. They include, for example, actions by corporations, lifestyle changes by individuals, and policy incentives such as institutional and tax reforms by national and local governments. What is needed for a country's economic renewal is not simply to choose one among them, but rather, to combine a variety of methods to boost overall resource productivity. The discussion below will not explain each of the ten points, but instead focus on the aspects that relate to the title of this book, "An Urban Renaissance for Japanese Cities."

First of all, it will be possible to boost resource productivity by transforming the current one-way economic system of mass production, mass consumption and mass waste disposal into a society with sound material cycles --- one that has appropriate production, appropriate consumption and zero emissions. The mass production approach produces products in large quantity through forecast-based production. But if the forecast is wrong, a large stock inventory may be left over, and as a result a large quantity may be thrown away, resulting in a huge waste of resources. Also, mass consumption is based on a throw-away culture; because things that could still be used are always being thrown away, this behavior also creates a huge waste of resources. The waste from the production and consumption phases is eventually disposed of in the natural world, so under this system, resources can only be used once. As a whole, the one-way economic system of mass production, mass consumption and mass waste has the lowest resource productivity of all economic systems.

In contrast, the circular design of an economy with appropriate production, appropriate consumption and zero emissions --- in other words a society with sound material cycles --- can create a large boost in resource productivity. The core concept of the one-way economic system is continually "making, consuming, and throwing away." In contrast, the core concept of the economy of a society with sound material cycles is "make only what is necessary, consume only what is necessary, and then recover and reuse resources from waste."

1.5 Production-on-demand Reduces Waste

At this point we must ask exactly what "appropriate production" is? Stated concisely, it is "production-on-demand" --- that is, manufacturing in response to orders received. There is no need to keep a product inventory, because production is done only to fulfill orders, and there is no need to carry a huge inventory of parts at the manufacturing stage. Production-on-demand is based on small groups of one to about six multi-skilled workers.

The production-on-demand factory uses less floor space and there is no need for warehouses to store inventory, because products are manufactured in a flexible and dynamic response to orders. Compared to factories with long conveyor belts, this type of factory is much better at conserving energy and resources.

Production-on-demand is based on the "cell production" method. In the past few years, companies such as copier makers Canon Inc. and Ricoh Company, and electronics maker Sony Corporation, have been removing the conveyor belts from their main factories and converting to the cell production method. This method differs from conveyor-belt-driven, large-lot production, by instead creating products in small quantities.

In the case of Canon, which is making a major shift to the cell production method, cells of about five people complete a task in about 15 minutes, and cells of one person complete the planned task within 90 minutes by using multi-task operations. This company calls its top-class multi-skilled workers "meisters" after the German word for master craftsman. Some meisters working alone have the skills to assemble a complete color copier in about 14 hours, using about 2,700 parts. The name of the worker is displayed inside these color copiers, which are essentially assembled by hand --- for example, "Made by Ms. Ochiai." The cell production method reminds us of the way small- and medium-sized companies make things using multi-skilled workers. But there are two key factors that are different from the earlier methods of small- and medium-sized businesses: production management based on a solid grasp of demand trends; and "supply chain management."[2]

What are the benefits of changing to cell production methods? Over four years, from 1998 through 2001, Canon removed all the conveyor belts from about 45 factories around the world, and converted to the cell production method. Over a period of four years, 18 km of conveyor belts were removed, and this eliminated the need for 540,000 square meters of space (equivalent to an area 540 by 1,000 meters).

If this area reduced was originally leased land, this reduction alone would make for a huge cost savings in leasing fees. If it was owned land, it could be sold or rented out in return for revenue. Besides these benefits, the company was also able to eliminate a large amount of warehousing that was previously needed to store products and parts, thereby reducing storage costs significantly.

By switching to the cell production method, many inefficiencies were eliminated, and over four years it was possible to reduce staff by 18,000 persons.[3] Productivity rose by 35%, and the company's total cost savings amounting to about 118.8 billion yen. On the

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2 Supply chain management is an integrated approach in which companies use information technologies (IT) between themselves and their suppliers to handle key functions, including materials procurement, product ordering and receiving, and inventory control.

3 In the table, the term "labor pool made available" refers to the number of personnel who were made redundant by the changes. The company chose not to refer to them as being redundant or "excess" employees, but rather to consider them as valuable personnel who could be employed in other divisions.

environmental dimension, the company was able to cut carbon dioxide emissions by about 7%.

1.6 Conveyer Belt Going the Way of the Mammoth

What kinds of cost reductions are possible by converting to cell production methods? The author was able to find the answer to that question at Ricoh's factory in Gotemba, Japan. The Gotemba factory started operating in October 1985 with a conveyor belt system, and for years has been producing office equipment, particularly copiers. By the second half of the 1990s, as large changes appeared in the marketplace, product inventories grew significantly since the company was still using a mass-production system. The need thus arose for a production-on-demand system directly linked to the market through proper assessments of market trends. The company started to remove the conveyor belts in 1999 and converted the factory to the cell production method.

There were huge benefits compared to the conveyor-belt style of production: (1) the work-in-process inventory could be reduced by 80%, (2) lead time (time from parts delivery to completion of the product) was reduced by a factor of five, from 325 down to 65 minutes, (3) and the factory space was reduced by a factory of three, from 1,160 to 380 square meters.

And that is not all. The equipment setup costs of 20 million yen that would have been required when subcontracting to a conveyor belt company were reduced by a factor of about seven, to merely 2.8 million yen, thanks to the expertise and know-how of the local workers. Costs of conveyor belt maintenance that would have been subcontracted outside drop to zero as employees take over this function, and the need for power to run equipment (e.g., electricity to move the conveyor) is eliminated, so large cost reductions can be expected overall.

In cases where a certain fixed number of units per day is being produced by mass production using a conveyor belt, the potential savings effect is huge. Consider for example a factory designed to produce 1,000 copiers per day. If that factory needs to reduce its production to 500 or even 300 units per day, a production system using a conveyor belt suddenly becomes very inefficient and the factory utilization rate drops considerably. If the plant construction, maintenance, and utility costs were also calculated on the assumption of 1,000 units per day, the factory could easily be operating in the red.

Large-lot production using the conveyor belt approach is not suited to small-lot production demanded by mature societies today. In a mature society people enjoy a high degree of material affluence and their tastes are diverse. As mentioned above, a mature society has sound material cycles based on the concept of making only what is necessary, consuming only what is necessary, and then recovering and reusing resources from waste. The conveyor belt system of production enjoyed 100 years of popularity, but it is not unlike the mammoth, which disappeared after it could not adapt to changes in the global environment.

1.7 Cell Production: A New Business Model from Japan

One way to describe mass production by conveyor belt is manufacturing of a *small* number of models in *large* production volumes. In contrast, the cell production method has a *large* number of models and *small* production volume. If one looks only at demand structure, this description certainly makes sense. But it is too superficial to explain the shift to cell production methods as simply a response to changes in the structure of demand. In a mature society, it is necessary to view this new system as part of a new economic system with sound material cycles, one that aims for energy conservation, resource conservation, and high resource productivity.

The economic system of a recycling-oriented society is based on sound material cycles: from appropriate production, to appropriate consumption, to zero emissions (i.e., waste is recycled), and back to appropriate production again. It responds to the demands of the new era based on making only what is necessary, consuming only what is necessary, and then recovering and reusing resources from waste. Cell production plays a part in all this.

The division of labor in the case of production by conveyor belt is based on single-task workers who participate in only one process --- such as turning screws, or attaching one part to half-finished products along the conveyor belt --- and they must basically just become cogs in the machinery. The dehumanizing nature of work arises from that reality. In contrast, under the cell production method, the local workers on the factory floor themselves arrange things in ways that are best for them, such as making or rearranging the work tables or shelving for parts as they wish. With complex products like color copiers, skilled workers assemble the parts to make the final products, and they put their own names on the product. They have greater motivation, but their responsibility is also greater. They are not part of a machine, but work as living human beings.

In the past, Japanese corporations aggressively promoted total quality control (TQC) policies, with the aim of product defect rates of zero. Workers on the production floor eagerly submitted detailed and excellent suggestions to make improvements, and the achievements of this approach were huge. In the same way, cell production also elicits suggestions from workers, and through daily improvements, companies can achieve outstanding results. But with such an approach differences can emerge between factories. There are no manufacturing processes and standard ways of doing things that exist under the conveyor belt system. In their place, there are people who apply their wisdom about creating products that consider the environment.

In October 2001, Canon surveyed 50 workers at its Ami Factory in Ibaraki Prefecture, asking their views about the conveyor belt versus cell production systems. Whereas 38.5% said they felt a "sense of achievement" under the conveyor belt system, 83.7% did so under the cell system. Whereas 32.5% said they felt "motivated in their work" under the conveyor belt system, 71.4% did so under the cell system.

The cell production method is a new "made in Japan" business model. It is no coincidence that companies like Canon and Ricoh --- quick to recognize changes in the world and alter their production methods --- are enjoying record profits these days. Japanese corporations are in the process of creating new business models that balance the environment and the economy, and are strengthening their global competitiveness --- just as when Japanese automobile makers overcame stringent new emissions regulations here (the Japanese equivalent of U.S. Air Quality Act) and then went on to expand their share of the global auto market.

2. Zero Emissions

2.1 The Pursuit of Industrial Ecosystems

Section 1 points out that in order to create a sustainable society that recognizes the finiteness of the Earth, we must shift from the one-way economic systems of the past to economic systems based on sound material cycles. To create such resource-recycling societies, it is necessary to dramatically raise resource productivity. For this, the concept of zero emissions is powerful tool.

The term "zero emissions" emerged as a concept at the United Nations University in 1993 and was first shared internationally at the "International Conference on Zero Emissions" organized by the United Nations University in April 1995. In recent years, the concept has been used more broadly than the literal meaning that "zero waste is emitted." Today the term has also taken on a broader meaning that encompasses social and economic systems --- of local communities or corporations, for example --- that are based on the assumption that the Earth is finite, that things must be used carefully and made to last a long time, and that they are recycled when their useful life is over.

Implicit in the term zero emissions is therefore the aim of efficiently utilizing limited resources and energy. The idea of the zero emissions approach was inspired by natural ecosystems. In the natural world untouched by human hands, waste does not exist. Every component of the ecosystem plays some role for some other member of the ecosystem, so no waste is ever generated.

Ecosystems consist of three components. Plants are the producers, animals are the consumers, and soil microorganisms are the decomposers and recyclers. In an ecosystem, it is only plants that (through photosynthesis) use carbon dioxide in the air and energy from the sunlight to produce useful goods (grains, fruit, etc.). Herbivorous animals eat them. Ultimately, by eating the herbivores, carnivorous animals also depend on the goods produced by plants. After plants (producers) and animals (consumers) die and return to the soil, they are completely decomposed by soil microorganisms and then become the nutrients for new production by plants. In this circular process, waste simply does not exist. In this sense, a natural ecosystem is the ultimate zero-emissions system. If we could make the contemporary industrial structure to be more like an ecosystem, we could create a new industrial structure that turns waste into resources. It might not be possible to completely eliminate waste, but we can strive to make the amount of waste continually closer to zero. Based on these concepts, the overall aim of the zero emissions concept is to create "industrial ecosystems" that mimic natural ecosystems.

2.2 Six Principles of Zero Emissions

In order to shift industrial structures toward zero emissions, it is important to respect the following six-part code of conduct:

1) Do not consume renewable resources in an amount above their capacity to renew themselves.
2) Raise the resource productivity of non-renewable resources, develop clean renewable-resource alternatives, and then the renewable amount of those alternatives can be consumed.
3) Do not emit waste in amounts that exceed nature's carrying capacity.
4) Dematerialize economic activities and lifestyles.
5) Utilize above-ground stocks effectively.
6) Internalize environmental costs and create market economies that have high

environmental efficiency.

Below is a further explanation of each part of the code of conduct.

1) Do not consume renewable resources in an amount above their capacity to renew themselves.

If logging continually exceeds a forest's pace of regeneration, in the end the forest will be destroyed. The same is true for other renewable resources. The reason that many tropical forests are being rapidly depleted is that this code of conduct is not being respected. Many experts also predict that water shortages will become a more serious problem during this century because the first principle is not being respected.

2) Raise the resource productivity of non-renewable resources, develop clean renewable-resource alternatives, and then the renewable amount of those alternatives can be consumed.

In the case of a non-renewable resource, the resource disappears in proportion to the amount that is used. But this does not mean that non-renewable resources must never be used. If a resource is used, the greatest possible effort should be made to raise its resource productivity. In addition, alternative resources should be developed, and then it is permissible to consume up to the amount of these resources produced.

3) Do not emit waste in amounts that exceed nature's carrying capacity.

If toxic waste is continually dumped into the natural world, eventually nature's ability to restore itself will be exceeded, and the global environment will steadily deteriorate. Certain problems we face today have arisen because this principle is not being respected. Examples include acid rain, ozone layer depletion, and climate change, which some consider to be the most serious environmental issue of this century. The world witnessed a population explosion during the twentieth century, and the United Nations Population Fund predicts that current population growth will continue until the mid 21st century. In order to sustain this planet, which is quickly becoming too small for the human race, we must ensure that we do not emit waste in excess of nature's carrying capacity.

4) Dematerialize economic activities and lifestyles.

As stated above, we must raise resource productivity if we are to utilize scarce resources efficiently. Dematerialization does not simply mean that we should not use resources. This term implies having a new look at the traditional materialistic market philosophy, and consider the how to use resources in ways that allow us to obtain the greatest benefits for society with the lowest possible input of resources.

In societies that are well along the path of dematerialization, the industrial structure has a high proportion of tertiary (service) industries. In some developed countries, tertiary industries account for 70 to 75% of gross domestic product. A society where this ratio has reached 90% could probably be described as a society with sound material cycles and low material dependency. The low material dependency translates into a society sustained by services, software, and information, with a high degree of value added in the economy. This type of society is more likely to be in harmony with the environment. Automobile use, for example, will shift toward rentals instead of personal ownership --- a shift that helps to promote dematerialization (Table 2).

5) Utilize above-ground stocks effectively.

In the past, developing countries had abundant underground reserves of natural resources. Many of these have been exploited over the past 100 years to support rapid economic growth. As a result, today, many underground resources have been depleted. But this does not mean that they have disappeared from the face of the Earth. They are being stored in different forms --- in manmade structures such as railways, bridges, factories, schools, hospitals, office buildings, homes, automobiles and home appliances, to name a few. These could be called above-ground stocks. Until now, many above-ground stocks were simply disposed of as waste after being used. But we must realize that these resources have been depleted, and that it is about time to stop tolerating this kind of waste. For manmade objects that have come to the end of their life and become waste, it is necessary to skillfully extract the many above-ground stocks of resources stored in them, and find ways to reuse them. To accomplish this we need ecological design. For example, we must consider at the product design stage how much of which materials are being used in which parts, how long is the useful life of parts, and when product life is over what kind of design will facilitate dismantling?

Developed countries have huge above-ground stocks of resources, and in that sense could be considered resource-rich in above-ground stocks. There are two key features of above-ground stock resources. First, if they can be properly recovered from products, they can be used (recycled) almost forever. For example, steel and copper can be recovered and reused many times, as long as they have not rusted or become degraded. Second, using above-ground stocks is a excellent way to conserve energy. For example, to produce one ton of crude steel it takes only about a third the energy to refine scrap iron in an electric furnace compared to virgin iron ore in a blast furnace. Making a ton of aluminum takes 190 times more energy to refine the ore compared to recycling --- a good reason this metal is known as "canned electricity."

Developed countries that are rich in above-ground stocks need to pay more attention to the effective use of these resources and leave more underground resources for future generations and for developing countries, which need to accumulate more above-ground stocks.

6) Internalize environmental costs and create market economies that have high environmental efficiency.

Market economies use the market to coordinate the supply and demand for goods, and this could be described as the best system for optimizing the allocation of resources. But why have market economies led to the depletion of resources and to environmental destruction? As pointed out above, there is no other explanation than that the market economy operates on the assumption that our planet is infinite and indestructible. In other words, the main cause is that costs of environmental degradation have not been internalized into market economies.

In the 21st century, the internalization of environmental costs into market economies must become an integral part of the system. For example, if we continue failing to properly deal with global warming, climate change will occur on a global scale, sea levels will rise, and agricultural land will be flooded. In order to avoid such a catastrophe, it is necessary to limit the carbon dioxide emissions that are making a large contribution to global warming. For this, it will be necessary to introduce carbon taxes and other taxes on fossil fuel consumption and to introduce economic measures to control wasteful use of resources. Many countries in Europe have already introduced carbon and energy taxes in order to limit fossil fuel use.

3. The Challenge to Create Zero-emission Societies

3.1 Creating New Industrial Chains that Utilize Waste

The United Nations University has been promoting the zero emissions approach in order support the transformation from the current industrial structure to one based on industrial ecology --- one that relies on cooperation between different industries in order to turn waste into resources. We call this the industrial cluster revolution. For example, Company B uses the waste from Company A, Company C uses the waste from Company B, Company D uses the waste from Company C, and so on. If we can create new industrial chains such as this that use waste as raw material inputs, waste emissions can approach zero. In the strictest sense, there are, of course, limits to how far one can go towards completely recycling resources, but it is indeed possible to form industrial clusters that approach zero waste output.

Some Japanese corporations have already aggressively worked to recycle waste into resources. For example, coal-fired power plants emit huge amounts of sulfur oxides (SOx) and nitrogen oxides (NOx), both of which cause acid rain. Can these waste materials be used as resources? Ebara Corporation, an environmental equipment manufacturer, tackled this question in cooperation with the Japan Atomic Energy Research Institute and Chubu Electric Power Co. They succeeded in developing the technology to convert substances into chemical fertilizers such as ammonium sulfate and ammonium nitrate, by adding ammonia to the SOx and NOx and then exposing them to a special electron beam. Meanwhile, the coal ash can be used as a raw material for making cement. Thus, if a coal-fired power plant, a fertilizer factory, and a cement factory can be located close together and interlinked, a zero-emissions type of industrial cluster can be created. These same partners, on request from Chengdu, the capital of China's Sichuan Province, built a fertilizer factory that uses SOx and NOx, beside a thermal power plant. It started operations in September 1997. Recently, Chubu Electric continued such efforts to recycle waste when at its West Nagoya Thermal Power Plant it started operations of a similar facility that uses a crude oil desulfurization process.

A growing number of industrial parks are also starting efforts to achieve zero waste. The largest industrial estate in Japan's Yamagata Prefecture is the Kokubo Industrial Park. With a total of 24 companies, including Yokogawa Electric Corporation, Matsushita Electric Industrial Co., and Fujitsu Quantum Devices, and total employment of about 5,500 workers, it is the home to factories that produce electrical equipment and electronic components, among other products. Together they emit about 7,400 tons of waste per year. They have already launched many activities, including recycling of paper waste, conversion of waste plastic into refuse-derived fuel (RDF), recycling of organic waste by collective treatment facilities, and production of products molded from used-paper pulp (e.g., for packaging and cushioning materials) (Figure 4). The park is now considering installing a gasification melting furnace in the park for the chemical treatment of waste acid and alkali, and the dismantling of used products.

In these ways, the zero emissions program of the Kokubo Industrial Park focuses on cooperation between companies within the park to recycle the waste they emit and avoid carrying industrial waste outside the park. In this process, for example, they are turning the waste paper and used paper into toilet paper and paper products molded from pulp and using preferential purchasing policies for them within the park. In addition, they are composting organic waste from the company cafeterias and the resulting fertilizer is being used in orchards in the vicinity. In return, the companies in the park give these orchards preference when purchasing peaches and other fruit.

This approach could be called the Kokubo Park Approach, and could be considered one model for efforts to achieve zero emissions at an industrial park. But despite these examples, there is still no successful example in Japan of the type of zero-emissions industrial cluster of corporations in different industries cooperating to turn waste into resources --- at least not in the strictest sense being promoted by the United Nations University.

Nevertheless, the zero emissions industrial park of small- and medium-sized companies being promoted by Kawasaki City as a strategy to address the exodus of industry along its waterfront could be considered as Japan's first real attempt at a zero-emissions style of industrial cluster. Using financial support from the Ministry of Economy, Trade and Industry (METI) and the Japan Environment Corporation, the city brought together 13 companies in different industries, particularly small- and medium-sized companies, on an area of about 80,000 square meters, to create a corporate park designed with waste recycling in mind. The total project budget was about 20 billion yen, and it started operations in the spring of 2002. The aim is to promote the recycling of waste within the park, but some challenges remain. For example, in the case of difficult-to-treat waste, because the focus is on small- and medium-sized companies, the waste cannot be handled on-site. It is melted in furnaces nearby and the fused slag is used off-site as construction material. The park still needs cooperation from off-site corporations along the waterfront.

Thus, no industrial clusters yet exist in Japan that, in the strictest sense, are actually practicing the recycling of waste through cooperation between companies in different industries within a clearly-defined zone. But this model already exists in Europe, as we will see below.

3.2 Kalundborg's Experiment with the Zero Emissions Model

Kalundborg is a city in Denmark with a population of about 20,000, located about 150 km west of the capital city, Copenhagen. It has been attracting the world's attention in recent years for being the home of an industrial park that has, in effect, already been putting the zero emissions concept into practice for many years.

As pointed out zero emissions are achieved when Company B uses as a resource the waste emitted from Company A, Company C uses the waste from Company B, and so on. If the companies in different industries can between themselves use waste as resources, the amount of waste emitted approaches zero.

At the Kalundborg industrial park, this corporate cooperation is called "Industrial Symbiosis." The industrial park consists of five corporations in different industries and one municipality, Kalundborg. The companies are Energy E2 Asnæs Power Station (electrical generation), Statoil Refinery (oil refinery), BPB Gyproc A/S (plasterboard production), Novo Nordisk A/S (pharmaceuticals manufacturing), and A/S Bioteknisk Jordrens Soilrem (soil remediation), which joined in 1998. From Kalundborg Municipality, the waterworks and energy departments are participating as partners.

This utilization of waste between companies, or resource recycling in other words, is not something that started just recently. It has evolved gradually over 30 years, and has developed into 19 projects today.

As shown in Figure 4, the original motivation for establishing the zero-emissions project at the Kalundborg industrial park was simply to boost profitability. It was simple: by cooperating they would all benefit. The cooperative relationship started with the utilization of waste heat and wastewater.

For example, the steam coming from the Energy E2 Asnæs Power Station during power generation is sold to Statoil Refinery and Novo Nordisk A/S. The steam is used at the oil refinery as a heat source to warm pipes, and at Novo Nordisk A/S as a heat source for sterilizing the raw materials for pharmaceuticals manufacturing. Meanwhile, Statoil Refinery is selling cooling water back to the Energy E2 Asnæs Power Station. The cooling water is used at the refinery for refining oil, and at the power station as cooling water for boilers. The water changes state between gas and liquid as it circulates between the companies.

The supply of gypsum from the Asnæs Power Station to BPB Gyproc A/S is also an easy-to-understand example of resource recycling. Gypsum is a byproduct of the flue-gas desulfurization process at the power plant. It is used as a raw material at BPB Gyproc A/S. Until this project began, the company was importing natural gypsum all the way from Spain. By using gypsum from the power plant, however, it was possible to make huge savings on transportation costs. Not only that, the quality of the gypsum from the power plant was high, and the supply was reliable. For the power plant, this arrangement meant revenues from the sale of gypsum.

The industrial symbiosis at Kalundborg had its beginnings from the fact that almost 40 years ago, the Statoil Refinery was drawing huge amounts of water from nearby Lake Tissø (Figure 4). Later, this activity expanded into an experiment to create a closed system, to make raw material inputs out of the waste that was being emitted from the factories and town, such as coal ash, gypsum, sludge, waste heat, steam, and effluent, etc. Heated water from the power plant is now being used for a district heating system, as well as for fish farming (it is warmer than seawater). Today about 100 tons of trout are being harvested each year from the fish farm.

Through this experiment in industrial symbiosis at Kalundborg the cooperative relationships have expanded over the years, and their effective use of waste will probably continue to expand in the future. To date, the experiment in industrial symbiosis has brought huge benefits for each of the companies in terms of business performance.

On this point, E. Pederson, director of the Kalundborg industrial park's Industrial Development Association, says "We have invested a total of about U.S. 75 million dollars to date into Industrial Symbiosis. In return, the cost savings and revenues of all partners are about a cumulative 1.6 billion dollars compared to the situation had we not started Industrial Symbiosis. In the past few years alone, the returns have been 15 million dollars per year." He adds, "The experiment in Industrial Symbiosis started for purely economic reasons --- in other words, the pursuit of profits. There was not one iota of concern about the environment or about avoiding resource depletion. We were surprised that we were attracting attention in recent years as a model of a resource-recycling economy. When we were told that we were on the leading edge of a new era, this became a huge encouragement for us."

They are proving that resource recycling from waste --- in other words, the zero emissions approach --- is economically sound, and their case will continue to be a useful reference for initiatives around the world.

3.3 Sweden's Växjö Municipality Attempts to Go Fossil Fuel Free

The next case has no direct connection with zero emissions, but it is worth mentioning here, as any efforts to address the reality of the planet's finiteness cannot succeed without the efficient use of sustainable resources. Sweden's Växjö Municipality, which is aiming to create a "compact city," has declared that it will break free from unsustainable fossil fuels, and is showing signs of success on the path to create a fossil-fuel free community.

Växjö is a key city in the country's Smaland region, about 450 km southwest of Sweden's capital city of Stockholm. With a population of about 74,000, it is a quiet country town surrounded by forests. The reason it began to attract attention was its Fossil-Fuel Free Declaration in November 1996, a year before the historic Kyoto Conference that let to the adoption of the Kyoto Protocol, an international treaty aiming to tackle the issue of climate change.

Sweden's energy sources in 1999 included fossil fuels (38.2%, mostly oil), nuclear power (34.6%) hydropower (11.5%), and biomass (15.1%), with a little less than the remaining amount (less than 1%) coming from waste heat utilization and electricity imports. The major sources of electricity were nuclear and hydro power, with fossil fuels accounting for only a small proportion. Fossil fuels such as oil were mostly being used in the transportation sector, and for heating in this country known for its long, cold winters. As one can see from this energy breakdown, for Sweden to go fossil-fuel free its strategy must be based on changing the energy sources used for heating and in the transportation sector.

In 1974, Växjö started using its district heating system, which relied completely on petroleum as its energy source (Figure 5). In 1979, petroleum provided 100% of the energy for heating, but starting in 1980s, the ratio of biomass increased gradually to 80% in 1995, compared to 20% for petroleum.

3.4 Inspired by Agenda 21

How did Växjö become the first municipality in the world to declare its goal of going fossil-fuel free? There were a number of factors. First, the dependence on oil imports presented too great of a risk in the case of sudden events like the outbreak of war. The town had already suffered through two oil supply shocks in the past, and in a country with long, cold winters, heating is a matter of survival. Fortunately, this town, surrounded by forests, is endowed with wood biomass, which raises the opportunity to make use of biomass as an energy source instead of petroleum. The heat efficiency of biomass is only about 20% that of petroleum, but this disadvantage can be overcome through technological innovation, and experiments in the 1980s have opened up the huge potential for biomass.

The second factor was that the town was inspired by Agenda 21 (the global action plan for achieving sustainable development), which was adopted at the UN Conference on

Environment and Development (UNCED, or Earth Summit) in Rio de Janeiro in 1992. As Agenda 21 stresses the importance of local governments in environmental protection, the town established the Växjö Agenda 21 Committee, which reports directly to the mayor. In Sweden, environmental non-governmental organizations have a respected status in society, and with comprehensive cooperation from the Swedish Nature Foundation, the committee prepared concrete scenarios of environmental strategies for the town. The idea of going fossil-fuel free was included as a core concept in this process.

3.5 Cut CO_2 Emissions by 50%

The third factor was the supportive mood in the world for efforts to address climate change, in the year before the Kyoto Conference. By replacing petroleum with cleaner, renewable energies such as biomass, town planners realized that it would be possible to suppress emissions of carbon dioxide and contribute significantly to efforts to fight global warming. If the town made a fossil-fuel free declaration before other cities, it would be covered in the media and enjoy a boost in its reputation. Based on this assessment, the town issued the fossil-fuel free declaration and took the lead in a new era.

Speaking about the development of scenarios to promote efforts to go fossil-fuel free, Sara Nielson, the coordinator of the city's Agenda 21 Committee said, "We concentrated on presenting concrete targets that any citizen could understand." The main target was "to cut CO_2 emissions in half in 2010 compared to 1993." The Kyoto Protocol uses 1990 as its base year, but this town did not have accurate statistics on carbon dioxide emissions before 1993. As a result their base year is different by a few years, but their figure is clearly ambitious compared to the 6, 7, and 8% reductions in the official commitments of Japan, the United States, and the European Union, respectively, under the Kyoto Protocol.

3.6 Co-generation Companies Betting on Wood Biomass

The foot-soldier of efforts to go fossil fuel free was Växjö Energy Ltd. (VEAB). Though it is 100% owned by the Växjö Municipality, it is purely a profit-seeking company. There are many companies of this type of in Sweden. They are different from quasi-governmental corporations in Japan. Those in Sweden adhere to the general objectives of the municipality, but they are private companies in which the management is allowed to conduct profit-seeking activities. The business of VEAB is primarily cogeneration (combined heat and electricity supply systems) and the district heat and hot water supply. Heat supply is based on a system of heating water in boilers and supplying it to homes and businesses via a piping system.

At present, the main plant has the capacity to produce 38,000 kilowatts of electricity and has the capacity to supply 66,000 kilowatts of heat. In addition, the company has small-scale cogeneration systems at Växjö Airport and various locations in the city. There are 74,000 persons in the district served by the company, of whom about 50,000 (25,000 households) live in urban areas. The company provides about 30 to 40% of household electricity requirements, with the remainder being provided by other utility companies.

Of the15,500 apartments in the district, 14,000 (90%) are supplied by the district heating system, but only 1,700 (20%) of the 9,500 detached homes are receiving heat supplied by the company. Most of the detached homes are in the suburbs, and installation of a piping system for district heating there will raise costs. Nevertheless, because centralized district heating would save energy in the long run compared to independent heating for each house, the company's policy is to install district heating pipes to as many houses as possible.

3.7 Biomass Also Being Promoted for Detached Homes

At present, over 80% of detached homes have their own household heating system. The main energy source is petroleum (only a few use electrical heating systems). For the town to go fossil-fuel free, it will be necessary for these homes to switch from petroleum to biomass. The city authorities are promoting conversion by offering subsidies for this purpose. The conversion costs amount to about 700,000 yen. This is not exactly a small sum of money, but because the city subsidizes 25% of this amount, the actual burden on owners is just over 500,000 yen. Meanwhile, the price of biomass is not subject to taxation, so it is cheaper to use. Thus, the annual energy costs of biomass use will be considerably lower than for petroleum, allowing owners to recover their investment in ten years, after which the difference means pure savings.

The author toured a private suburban home that had converted from petroleum to biomass. In the boiler room, instead of a fuel tank, there were four white bags containing wood pellets (16 kilograms per bag). This fuel is easy to ignite, and the chimney could be used with no change from the time when petroleum was used. One inconvenience, if it could be called that, is that the wood biomass fuel receptacle must be refilled manually. But a system is being devised to do the refilling automatically, so this problem will be solved in due course. In contrast to petroleum combustion, no nitrogen oxides or sulfur oxides are emitted in the chimney smoke in the case of biomass fuel, giving the owner some satisfaction that he was helping to protect the global environment.

Some detached homes are also testing the installation solar heaters for room heating, and solar collectors for water heating. For these installations, 35% of the cost is subsidized. The author has some question about how much the proponents can expect from using solar collectors in a place with Sweden's short hours of sunlight and long winters, but was impressed with their bold spirit to try anything with the potential to help them go fossil-fuel free.

3.8 Peat: A Non-renewable Resource

Figure 5 shows the energy shift from petroleum to biomass in the town. Peat makes up a large proportion of the town's fuel, as it is considered to be a form of biomass. But starting in the 1990s the town debated whether or not peat was a *renewable* form of biomass, and concluded that it is not. Today, most of the wood biomass being used in the town's heat supply and cogeneration consists of sawdust from sawmills, bark, branches and cuttings from logging operations, but about 10% still comes from peat. Reducing the use of peat further remains as a future task for the town.

3.9 Taxation Also Provides Major Support

To systematically promote the conversion from fossil fuels to wood biomass as an energy source for district heating, one cannot ignore the strategic role of selective taxation (by both national and local governments) on energy sources. Figure 6 shows the taxation by energy source used in the district heating supply. Petroleum, liquefied petroleum gas (LPG) and natural gas are all subject to a high energy tax, carbon tax, and sulfur tax, etc. Meanwhile, biomass is not taxed at all. As a result, the energy cost per kilowatt-hour for biomass is about one-third that of petroleum, and only one-quarter that of LPG. It is not difficult to imagine that with such price differentials in the taxation system, there is a huge incentive for the use of biomass.

After issuing the fossil fuel free declaration, Växjö city raised its biomass dependency to 95% by 2000 for its heat supply sector (the remaining 5% was still provided by petroleum). One could say that the town has almost achieved its goal of going fossil-fuel free in this sector.

3.10 Transportation Sector Still a Challenge

Figure 7 shows the trend in carbon dioxide emissions per capita in Växjö. In the energy supply sector, due to the bold conversion from petroleum to biomass, carbon dioxide emissions per capita have been cut in half from 20,000 tons in 1990 to less than 10,000 tons today. In contrast, the emissions from the transport sector have increased. This trend is partly due to an increase in car use, but it shows that the town has been making less progress in going fossil-fuel free in transportation compared to the heating sector.

As part of its fossil-fuel free strategy, in recent years Växjö has been aggressively promoting low emissions vehicles such as ethanol-powered and electric cars. In addition, in order to keep cars out of the city center, the city is working on various projects to completely redesign the downtown core's transportation systems, by encouraging cycling, converting intersections from being car-friendly to pedestrian-friendly, and creating car-free streets. The results are not yet evident in the statistics, however. Evidently, a breakthrough in the transportation sector will be the biggest challenge Växjö will face as it aims to go completely fossil-fuel free by 2010.

Table 1: Ecological Footprint in the World

Country	Population (person)	Ecological Footprint (ha/person) (A)	Available Areas (ha/person) (B)	Debt for the Environment (ha/person) (A-B)
World Total	5,744,872,000	2.85	2.18	0.67
Japan	125,769,000	5.94	0.86	5.08
USA	269,439,000	12.22	5.57	6.66
Germany	81,909,000	6.31	2.48	3.83
China	1,232,456,000	1.84	0.89	0.96
New Zealand	3,720,000	9.54	15.80	-6.26
Ethiopia	56,789,000	0.85	0.68	0.18
Bangladesh	120,594,000	0.60	0.08	0.52
Brazil	161,533,000	2.60	11.56	-8.96

(Source) WWW, *Living Planet Report 2000*, Ministry of Environment, *Annual Report on the Environment in Japan 2001*.

Table 2: Way to the Higher Resource Productivity

1.	Mass Production, Consumption, Waste => Appropriate Production Size, Zero Emissions for Consumption
2.	Disposable Products => Long Life Products
3.	Large and Heavy => Compact and Light
4.	3R (Reduce, Reuse, Recycle)
5.	Privately-owned => Rental
6.	Innovation (Improvement of Energy-efficiency)
7.	Introduction of IT to Economy: Non-digital Goods => Digital Goods
8.	Tax Reform: Tax Levy to 'Bads,' Tax Reduction to 'Goods'
9.	Improvement of Lifestyle
10.	Centralized Society => Decentralized Society

Figure 1: "One-way" Type Society

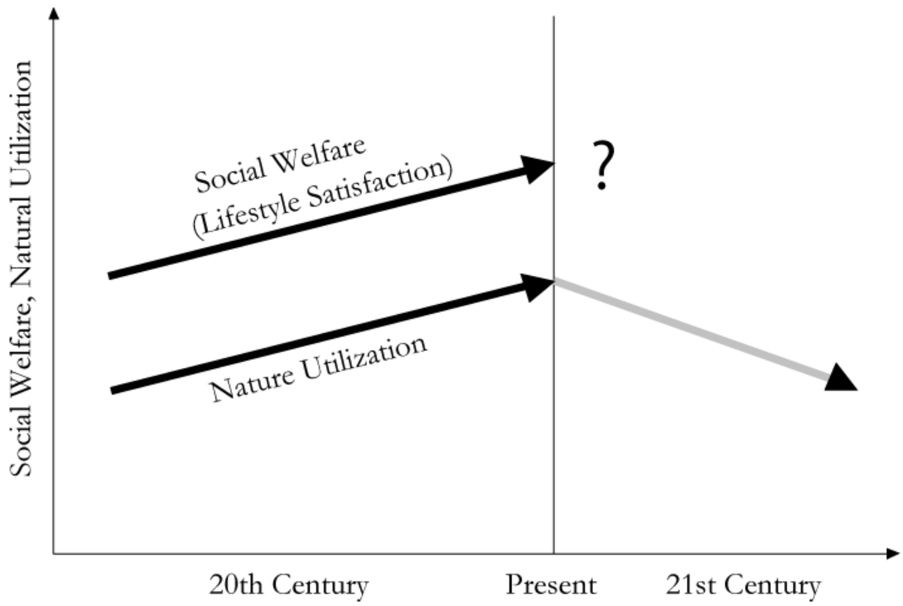


Figure 2: "Contracted-equilibrium" Type Society

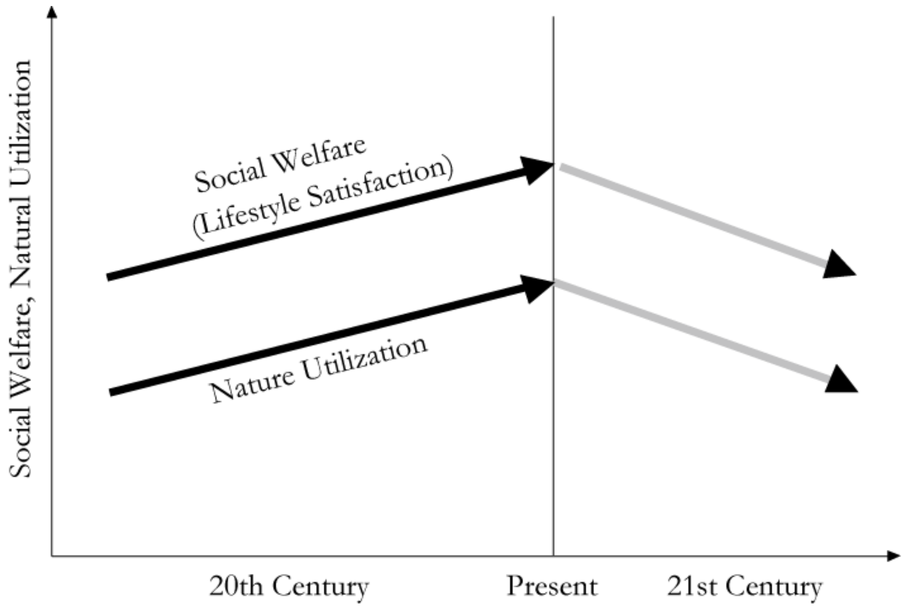


Figure 3: Recycling Based Society

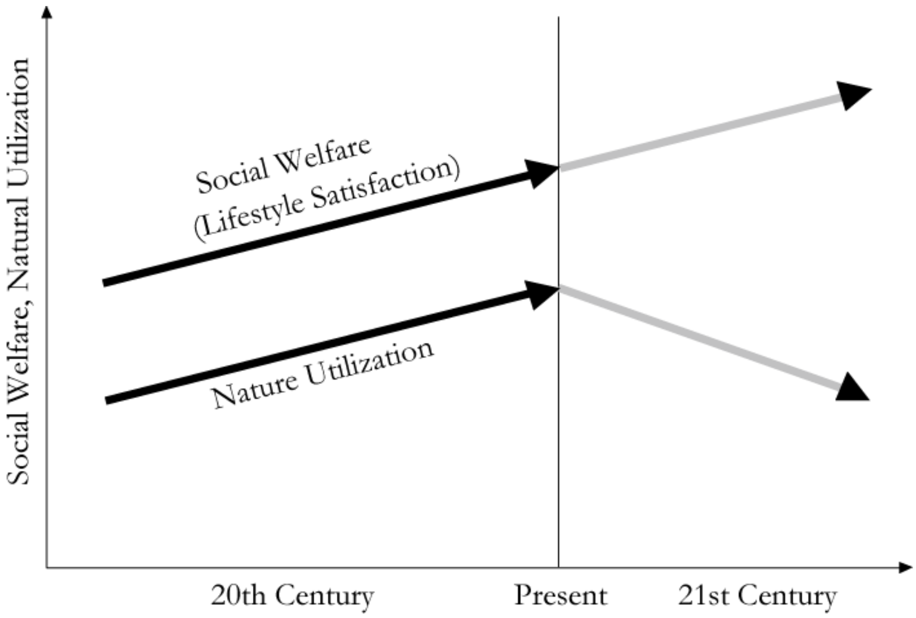


Figure 4: Kalundborg Industrial Park

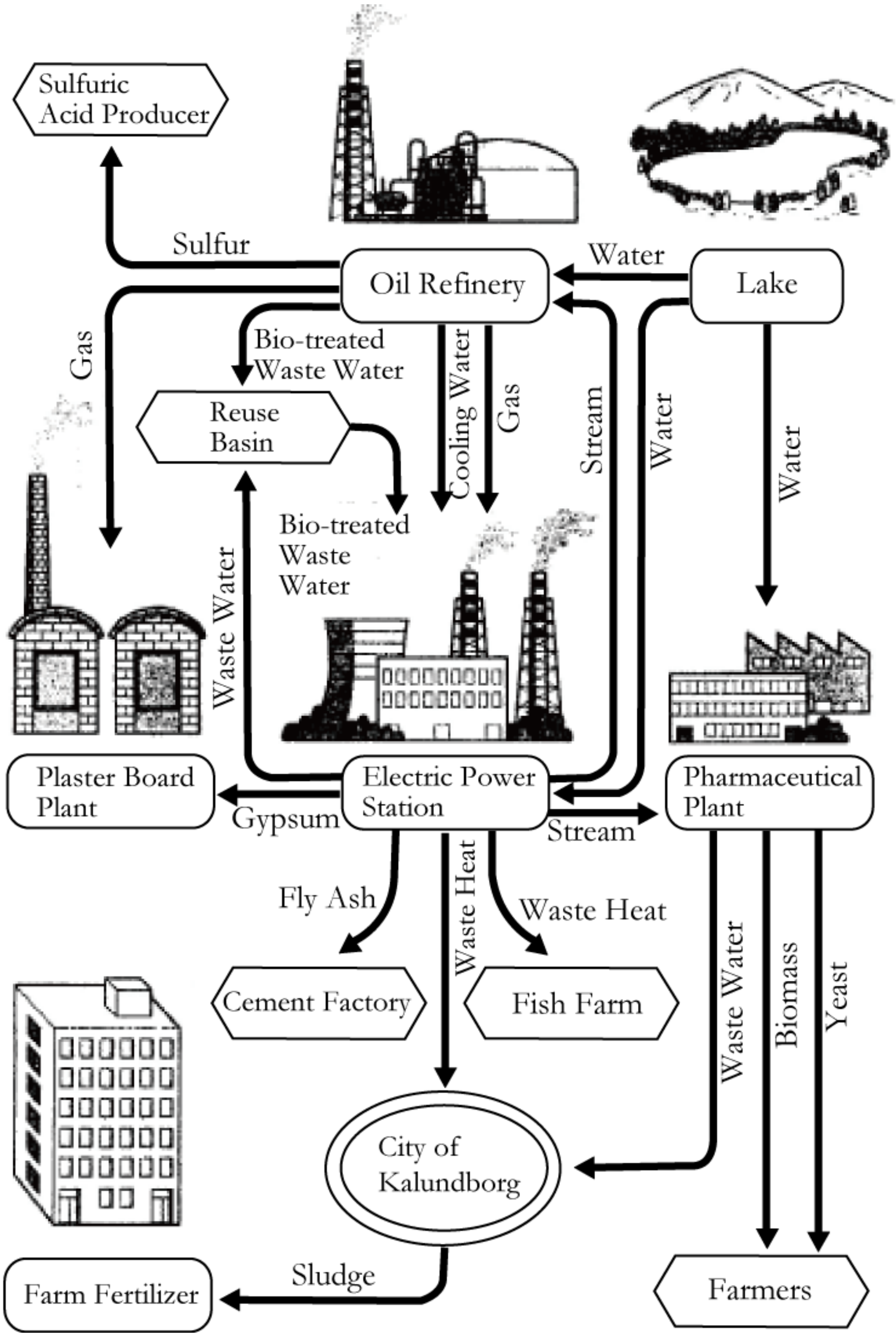
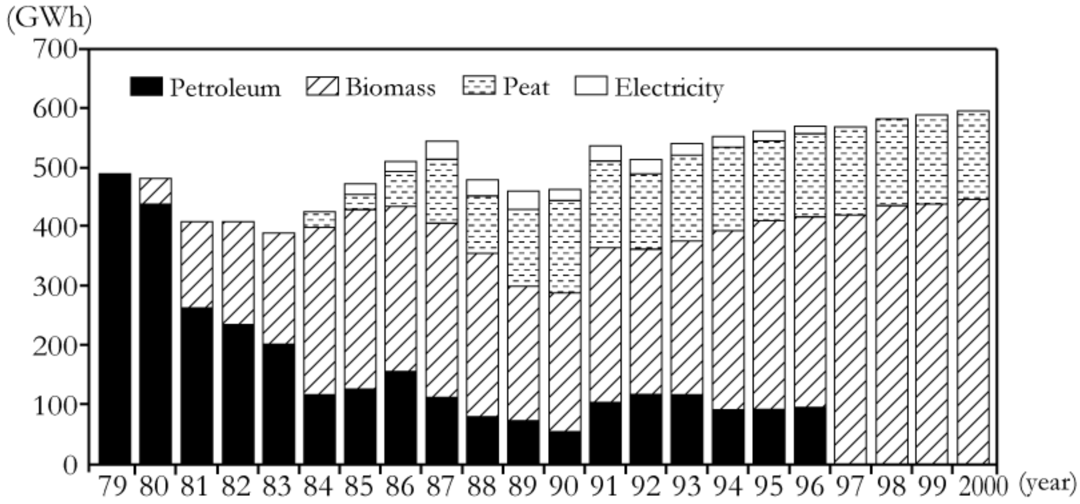
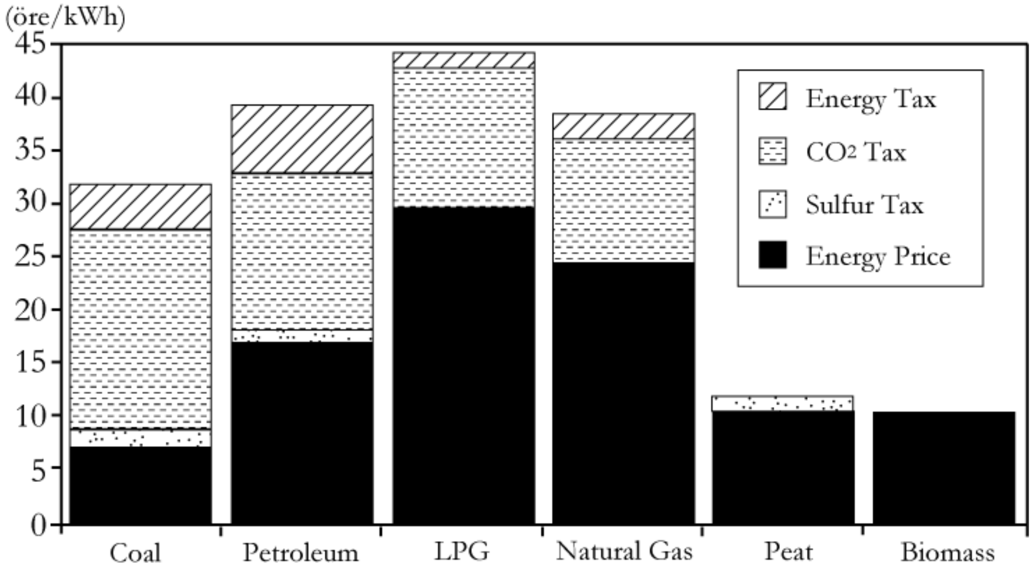


Figure 5: Shift of Energy Source in Växjö (1979-2000)



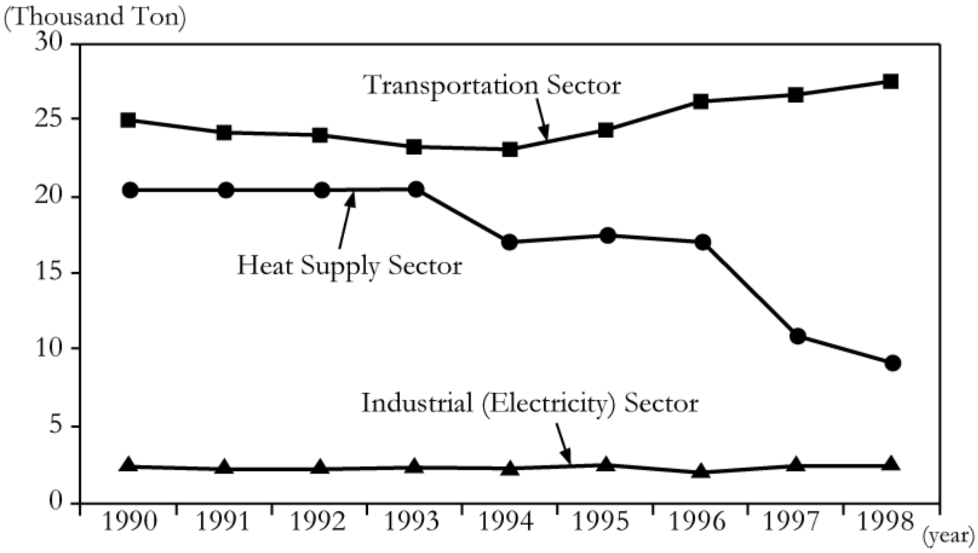
(Note) Peat is included in biomass.
(Source) Växjö Energy Ltd. (VEAB).

Figure 6: Taxation by Energy Source Used in District Heat Supply



(Note) 1 krona = 100 öre (1krona is approximately 12.5 yen equivalent).
(Source) Växjö Energy Ltd. (VEAB).

Figure 7: Trend in CO_2 Emissions per capita in Växjö



(Source) City of Växjö.