Asia-Pacific Environmental Innovation Strategies (APEIS)
Research on Innovative and Strategic Policy Options (RISPO)
Strategic Policy Options

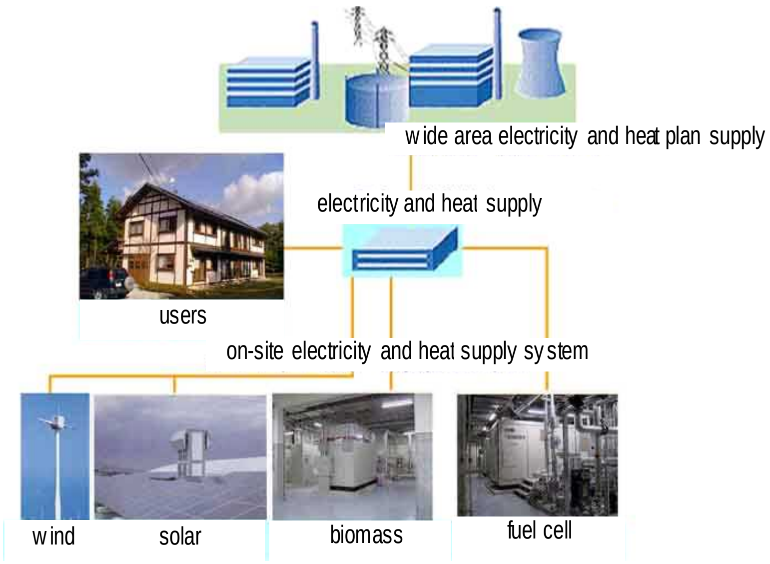
I. Title of sub-theme:
Promotion of biomass energy

II. Title of strategy:
Strengthening energy security

III. Title of strategic policy option:
Promoting biomass-based hybrid renewable energy system

IV. Brief description of the policy option (Summary):

This strategic policy option suggests the installation of hybrid renewable energy supply systems based upon biomass, especially in the urban areas where for various reasons the potential for development of stand-alone renewable energy systems is limited.



Source: University of Kitakyushu

Figure 1. Biomass-based hybrid energy supply system

Although renewable energies such as solar and wind are becoming popular in countries which emphasise clean energy development in national energy policy, they face some limitations in terms of market development, mainly because of high initial cost and fluctuating power generation strongly affected by climatic conditions, low intensity, and seasonal variance.

In order to resolve these problems, biomass energy can be combined with other renewables to form a hybrid energy system. Such combinations can make use of the best of each, while offsetting weaknesses (Kidani 2001). This idea basically attempts to establish an optimal energy system as a whole, synthesising various renewable energy sources, and simultaneously improving the quality and availability of power (Figure 1).

Extending this idea is a borderless compound energy system which uses multiple energy sources beyond the borders of sectors or countries, called a virtual power plant (see Section XII, "Virtual Power Plant"). This idea of linking various components into a distributed power supply is already in practice in some countries As Figure 2 illustrates, two or more distributed power supply systems located in different places can function like one plant through the use of a communication network.

- **Objectives:**
  To stabilise clean energy supply in urban areas by enhancing biomass-based hybrid renewable energy systems

- **Environmental Areas:**
  Climate change, Air pollution, Urban environment

- **Applicable geographic area and socio-economic conditions (where):**
  Geographic conditions:
  - Urban and semi-urban areas where grid energy supply systems are close, or biomass energy resources are rich.

  Socio-economic conditions:
  - Potential users may be found in a variety of sectors including agriculture, manufacturing, and power generation

- **Stakeholders (by whom, for whom):**
  By whom: Combined energy systems require multiple partners to link the biomass energy system with other renewable energy systems. Various stakeholders including central and local governments, private corporations, non-governmental organisations (NGOs), and local communities need to be involved.

  For whom: End users, including industry located in urban and semi-urban areas

- **Time span (by when):**
  The policy is expected to have both short and long term effects, depending upon the combination and technologies to be utilised.

  Even though individual renewable energy technologies have been well developed, sectoral regulations to encourage social acceptance are crucial to remove obstacles for hybrids and policy implementation.

- **Expected impacts:**
  Environmental impacts: Biomass-based hybrid renewable energy systems can make the energy system less dependent upon fossil fuels, and contribute to reduction of negative environmental impacts such as air pollution and global warming, etc.

  Socio-economic impacts: Biomass-based hybrid renewable energy systems can offer market entry strategies for renewable energy technologies that cannot currently compete with the lowest-cost traditional energy. This may lead to not only creation of industry clusters and various employment opportunities, but also contribute to the revival of local economies.

V. Background (Rationale):

There are several reasons behind the promotion of biomass-based hybrid renewable energy systems. One reason is that solar and wind power, which are subject to climatic variation, lead to energy production that is by and large unstable. This being the case, there is the hope that biomass energy, of which there is a great potential resource, could solve the problem.

Another reason is that power plants of renewables such as solar and wind, require huge investment for facility development, compared to biomass energy. It is not realistic to be able to supply clean energy from only solar and wind, to meet energy demands in urban areas. Various kinds of renewable energies need to be utilised effectively in order to meet increasing energy demands.

VI. Critical instruments:

Design, planning and management: Optimal mixture

Although a biomass-based hybrid energy system is able to provide both heat and electric power, it is important to be connected to related energy systems, which enable optimal performance by uniting individual energy systems, such as heat collecting systems, a heat transfer system, thermal storage, a heat exchange system, and a power generation system. In order to materialise such functions, it is necessary to pay attention to whether the energy system is an optimal mixture (safe, controllable, durable, reliable, economically feasible, environmentally-friendly, etc.), and take into account data about weather conditions.

Such an energy supply system basically combines not only wind and solar energy systems, but also other renewable energy systems as a whole, supported by cyclic substances such as rainwater, household waste, and wastewater residue. In the case of wind and solar energy systems, where power outputs fluctuate according to natural conditions, appropriate storage batteries would likely need to be installed. Combinations of various renewable energy systems are basically the best way to raise energy efficiency. The important thing is to assess each location for maximizing the power output of the system, while at the same time keeping it cost effective through the proper balance of power sources.

Some studies suggest the AHP (Analytic Hierarchy Process) as a useful method that enables assessment of an optimal energy mix. By evaluating the policy impacts comprehensively, and taking into account local knowledge, a reasonable consensus can be created to realise the optimal mix (see Section XII, “Analytic Hierarchy Process”).

Regulatory instruments: Deregulation and regulatory arrangement

Because of the nature of the hybrid energy system which integrates various power resources, its development may create conflicts among the regulations that have jurisdiction over the individual resources, and run into obstacles in its promotion in combination with other energy systems. Deregulation and regulatory arrangements are very instrumental in promoting an energy mix.

As the electric power industry in a country becomes deregulated, more cost-effective electric power supply systems which have power sources close to users become popular. As the Japanese case indicates, for example, the conventional regulations related to the energy supply system were a barrier to utilising biomass energy, which provides both electricity and heat, because fuels for emergency electric power sources were limited to liquid fuels such as light oil and heavy oil, under the Law on Special Measures for Promotion of the Utilisation of New Energy. Gaseous fuels were not allowed for electric power. However, the Japanese Agency of Natural Resource and Energy accepted utilisation of gaseous fuels including natural gas for electric power generation along with deregulation and amendments to this and related laws.

As a result, co-generation systems which were more efficient than conventional energy generation were aggressively promoted in both industrial and commercial sectors.[1] Japan's case shows that regulatory arrangements are crucial in the promotion of integrated energy systems for effective use.

Economic instruments: Feed-in Tariff

A feed-in-tariff requires grid operators to buy electricity from biomass energy driven hybrid energy systems at premium prices, and at the same time ensures grid access for electricity generated with hybrid systems. In fact, this instrument would be central to support development of hybrid renewable energy systems.

However, since a feed-in tariff is not as effective at ensuring profitability for biomass energy compared to wind power, remuneration by feed-in tariff alone is not sufficient to motivate investors to overcome the barriers connected with the development of the biomass-based hybrid energy system (e.g., line connection and facility development). Therefore, the feed-in-tariff should be supported by some additional economic instruments such as a subsidy, soft loan, and the like for successful implementation. The most important thing is that the instrument is feasible both in the regulated as well as in the liberalised electric market.

According to a study on this system, European countries with minimum price standards showed a larger and faster growth of renewable energy technologies, compared with other European countries having implemented renewable portfolio standards.[2]

Economic instruments: Portfolio standard

Renewable Portfolio standard (RPS) is a very popular instrument in European countries and is expected to increase demand of biomass-based electricity production. It is imperative that a framework of laws be established to ensure successful implementation of RPS policy and that a system of independent verification be used to track biomass electricity generation and regional quotas.

An important component of the RPS policy is green certificates, which is an instrument for integrating market mechanisms into an incentive-based certificate policy (see Section XII "Green Certificate"). Green certificates serve as an easily ascertained indicator that can show that electricity comes from biomass resources generated by a certain facility. The RPS policy introduces the competitive mechanism of green certificate trading for establishing the conditions under which biomass resources are favoured by promoting the rational utilisation of regionally distributed resources, and reducing electricity generation costs.

The competitive market mechanism of green certificates trading plays a crucial role in promoting renewable electricity generation at a lower cost when used to meet regional quotas. It is also indispensable to establish an objective accounting and tracking system, and information management system, to ensure the successful operation of green certificate trading. The PRS helps to establish the principle of consumer cost sharing of the electricity price margin.

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[1] A cogeneration system uses two effective forms of energy (i.e., electricity and heat) from one energy source, and is generally high in energy efficiency (total energy efficiency typically more than 70-80%). Cogeneration using biomass or natural gas is seen as an attractive option in many cases, as it is efficient and produces little emissions of NOx, CO_2 and SOx free.

[2] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (http://www.bmu.de/english/fset8@O.htm).

Economic instruments: Public subsidies

As Figure 1 illustrates, hybrid renewable energy systems are a kind of network system which connect remote and different energy systems. A hybrid energy system may require a large amount of investment, especially for in-line connection between the different energy systems and facility development. These costs are a financial disincentive to individual renewable power plants. In order to solve this problem, it is critical to reduce the initial costs that result in high prices of electricity and energy, taking into account available public subsidies and scale of hybrid energy systems.

Financial support from the public sector is critical for reducing the financial burdens of individual power plants. However, public subsidies are not always available, especially in developing countries. A possible solution for accessing public subsidies could to develop hybrid renewable energy systems in conjunction with other important activities, such as disaster prevention. At the same time, in order to minimise the size of subsidy required, the optimal scale of the hybrid energy system should be considered.

Awareness/capacity building: Information exchange among local authorities

As mentioned in the **Design, planning and management** section, whether such biomass-based hybrid energy systems can realise an optimal situation for energy efficiency is dependent upon local characteristics. It is often difficult in practice to select the most appropriate renewable energies from the various options. However, successful and unsuccessful cases in other areas or countries may give useful guidance to identify what is the best combination of renewable energies.

Information exchange among industries and local authorities needs to be enhanced so as to promote similar systems in other places where such systems do not exist. Information technology-based databases, lectures and symposia would be good ways[3] to raise the awareness of key local people and authorities.

VII. Impacts of the policy option

a. Impacts on the driving forces for environmental degradations

This hybrid renewable energy system attempts to promote biomass energy together with other renewable energies, instead of fossil fuel energy, which contributes to local and global environmental problems. As the result of the promotion of this energy system, energy consumption of fossil fuels could be reduced. At the same time, air pollutants and greenhouse gases which stem from fossil fuel energy use also could be mitigated.

In addition, by combining heat, power system and highly-efficient devices (fuel cells, advanced materials, cooling systems, etc.) in a hybrid system, overall energy efficiency can be greatly improved, and energy conserved, when compared with individual technologies (Burch 2001).

b. Impacts on the environment and socio-economic conditions

Hybrid renewable energy systems can be designed to maximise the use of renewables, which results in a system with lower emissions than traditional fossil-fuel technologies, as many cases show.

3 New Energy Foundation (http://www.nef.or.jp/info/teigen.html)

The case of the University of Kitakyushu in Japan[4] is a good example that shows the clear benefits to both the environment and socio-economic aspects, even with a small-scale hybrid energy system on a university campus. The Environmental Energy Center of the university installed a fuel cell (200 kilowatts) and natural gas cogeneration (160 kilowatts), as an alternative energy source, in order to supply both electricity and heat for air conditioning and hot-water at the university.

A hybrid energy system, including a photovoltaic system (150 kilowatts) installed on the roof of the research building of the Department of International Environmental Engineering, generates power of 510 kilowatts for use at the university. Together with the active utilisation of exhaust heat in this system, a substantial reduction of energy consumption and CO_2 emissions can be expected, as the case of the University of Kitakyushu indicates in Table 1.

Table 1. Energy consumption and Life Cycle (LC) CO_2 emissions of university hybrid system

Energy system installed	Energy-saving effect	$LCCO_2$ reduction effect (over 15 yrs)
(1) Natural exhaust by solar chimney	216 Gcal/yr (0.9%)	141t-C (0.9%)
(2) Pre-cooler and warmer by underground pit	221 Gcal/yr (0.9%)	144t-C (0.9%)
(3) Photo voltaic system	368 Gcal/yr (1.6%)	217t-C (1.4%)
(4) Fuel cell＋gas engine (natural gas based co-generation)	1,278 Gcal/yr (5.5%)	416t-C (2.6%)
(5) Temperature variation system (10-degree differential cold and warm water supply for air conditioning)	485 Gcal/yr (2.1%)	317t-C (2.0%)
Total	2,568 Gcal/yr (11.0%)	1,235t-C (7.8%)

Source: The Environmental Energy Centre, University of Kitakyushu

In addition, hybrid renewable energy systems can create new market opportunities for emerging renewable energy technologies before they are mature (Burch 2001). This may lead to the creation of industry clusters and various employment opportunities, and also stimulate local economies.

VIII. Evaluation of the policy option (- Analysis A-)

a. Sustainability:

As Table 2 indicates, in terms of generalised energy costs of each renewable energy source, most of energy cost is relatively higher than that of conventional energy system. However, a hybrid renewable energy system combining heat, power system and highly-efficient devices (fuel cells, advanced materials, cooling systems, etc.) can greatly improve overall energy efficiency and conserve energy for the hybrid system when compared with the stand-alone technology (Burch 2001). Financial sustainability might be still one of the challenges but can be improved so as to attract a number of concerned agencies, such as local governments and enterprises, to be involved.

b. Equity:

For the areas where grid-connection is distant and people cannot access electricity, a

4 The University of Kitakyushu (http://www.env.kitakyu-u.ac.jp/ja/ecopage/ecocampuspage4/ecopage_4o/4o.html)

decentralised or on-site hybrid renewable energy system is a useful means to provide more equal access to the local people. At the same time, hybrid energy system development where electricity is not available can help mitigate regional economic disparities.

c. Efficiency:
A hybrid energy system can be designed to achieve desired attributes at the lowest acceptable cost, which is the key to market acceptance. To mobilise a biomass-based hybrid energy system helps increase energy security in a economically efficient manner.

As a case in the United State indicated, a hybrid energy system could reduce electricity costs for the town's residents by cutting diesel fuel consumption for power generation (Burch 2001).

d. Effectiveness:
For areas where a connection to the electrical grid is not available, a decentralised hybrid energy system could be a good solution to supply energy in an economically and ecologically sustainable way.

This kind of micro-grid energy system which is close to users contributes to a reduction of inequity in access to electricity in local areas with less cost.

e. Relevance:
Higher reliability of energy systems generally can be accomplished with redundant technologies and/or energy storage. Hybrid energy systems typically include both, which can simultaneously improve the quality and availability of energy. Thus, the hybrid systems strongly support this objective which addresses the problem of sustainable energy supply or energy security due to increasing energy demand and current insufficient accessibility. It is relevant to the policy goal.

IX. Implementation Issues:

New energy efficient conversion technology or energy systems may have significant impacts on social aspects such as people's behaviour and work patterns in daily life. Social acceptance of this system in the local area would be a vital issue for implementation.

X. Applicability and limitation:

This energy system is largely subject to characteristics such as awareness and willingness of stakeholders as well as climatic conditions and economic situations. A successful case in one place is not necessarily replicable in another. It is very important to examine the best mixture of various energy systems from possible combinations, carefully considering local situations. In particular, this system can address limitations in terms of fuel flexibility, efficiency, reliability, emissions and/or economy.

This concept of hybrid energy systems can be applicable in rural area as well, as in the case of wind and solar energy systems that have been introduced prior to biomass energy. By comparison, biomass energy is cheaper than the other renewable energy. In rural areas where biomass resources are not rich enough, this system may not be appropriate.

XI. Related Good Practices:

N/A

XII. Related Analytical Background Paper(s) (- Analysis B -):

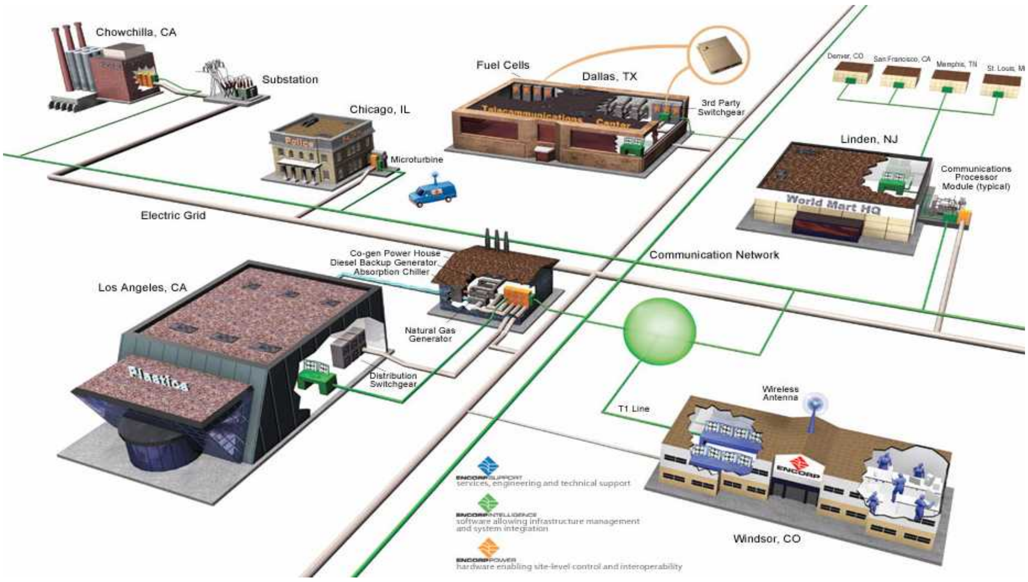
1. Virtual Power Plant[5]

Like a simple network of personal computers, the Virtual Power Plant links together seldom-used standby and emergency backup generators at hospitals, universities, manufacturers, office towers, and other facilities. This network of “mini” power plants allows utilities and high-energy users to draw additional power from these on-site sources as needed.

Traditionally, today’s power is generated by large coal or nuclear power plants and distributed to consumers via a network of aging transmission and distribution lines, much like the spokes of a bicycle wheel. Encorp’s Virtual Power Plant combines today’s IT technology, such as low-cost computers and networking technology, with innovative Encorp software and controls to move beyond the old “one-way” power-distribution system. The Virtual Power Plant incorporates Encorp’s renowned Gold Box to introduce two-way communication between the company, its remote locations and the utility. Companies that use the Virtual Power Plant create a reliable network of remote power plants that they control. With Encorp’s Generator Power Control-or Gold Box - providing the brains, companies can

- monitor various power parameters to determine the system efficiency,
- receive instantaneous signals from the utility when additional power is needed,
- pre-schedule downtime for preventative maintenance, and much more.

The Virtual Power Plant is "technology-neutral" by design, which means its software can communicate with any and all types and brands of power generation technology (i.e., diesel or gas engine/generator sets, gas turbines, micro-turbines, fuel cells, wind, hydro, and energy storage) in any combination or mode of operation. The Virtual Power Plant is truly an open-protocol end-to-end design, with the capability to interface with commercial building automation systems, industrial energy management systems, and utility grid control systems. The Encorp Virtual Power Plant is transforming the power generation industry.



Source: ENCORP (http://encorp.com/default.asp)

Figure 2. Virtual power plant

[5] Encorp (http://www.encorp.com/content.asp?cmsID=41)

2. AHP (Analytic Hierarchy Process)

Designed to reflect the way people actually think, the Analytic Hierarchy Process (AHP) method was developed in the 1970s by Dr. Thomas Saaty, while he was a professor at the Wharton School of Business, and continues to be the most highly regarded and widely used decision-making theory not only in energy sectors but also other sectors.

The AHP method is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons, then synthesising the results, the AHP methodology not only helps decision-makers arrive at a best decision, but also provides a clear rationale that it is the best.

There are many cases for which this model was applied for decision-making in the renewable energy sector, since technologies of renewable energy are strongly affected by many influencing factors and constraints. The AHP method provided a comprehensive framework for performing the prioritization of energy mix policy in a scientific and systematic manner considering various influential factors.

According to the Japanese case study that was conducted using samples in both urban and rural areas of Japan (Hiromatsu 2003), the biomass-based hybrid energy system is relatively more applicable for rural areas, compared with urban areas mainly due to rich biomass resources.

3. Cost comparison between various renewable energies and conventional energies

As Table 2 indicates, the generalized energy cost of various renewable energies estimated by the New Energy Council shows that renewable energy which uses waste is the least costly.

Table 2. Cost comparison between various renewable energies and conventional energies

Type of renewable energy	Cost	Conventional energy	
		Cost (comparison with fees)	type
Solar	0.5 -1 USD/kWh	2.5-6 times	Electricity
Wind	0.03-0.2 USD/kWh	2-3 times	Boiler power generation
Waste	0.08-0.1 USD/kWh	1.5- 3 times	Boiler power generation
Co-generation (industry)	0.08-0.1 USD/kWh	1.5 -3 times	Boiler power generation
Co-generation (household)	0.1-0.2 USD/kWh	4 times	Boiler power generation
Fuel cell	0.3 USD/kWh	4 times	Boiler power generation

Source: Advisory Committee for Energy, Subcommittee on Renewable Energy (Jan. and Oct. 2000)

4. Green Certificates

Green certificates are increasingly seen by governments around the world as a means to support renewable energy production. Sometimes formally called a TREC (tradable renewable energy certificate), a green certificate is issued to producers as proof that a certain amount of energy has been generated from renewable sources. Producers can also sell their green certificates separately from the electricity, thus gaining additional revenue. Potential buyers include generators unable to produce enough green electricity to meet a pre-determined obligation. The style of development of green certificate systems varies widely around the world.

Green certificates represent the environmental value per unit of green electricity produced that may have been generated in different regions, using a diverse set of technologies. Each provincial electricity company may fulfil its quota by purchasing local renewable energy electricity, and by purchasing green certificates from other provinces that have already met their specific quota. The electricity company will adopt specific options by comparing the price of a green certificate and the marginal cost of developing local biomass.

In the course of production, firms, seeking the largest profit, will choose the best resources and technologies to accomplish their quota. If local resource availability is poor and the marginal production cost is higher than the price of green certificates, they will choose to purchase the green certificate from a region where the marginal cost is lower. From a macroeconomic point of view, renewables will tend towards optimisation as trading of green certificates is a way to promote the most cost-effective resource use and reduce overall energy costs.

Some European countries have already taken steps, either voluntarily or based on national legislation, to use a certificate-based system to increase renewable energy production to fulfil targets set by the EU's renewable directive and the Kyoto Protocol. In Asia, Japan finalised details for a green certificates scheme in 2003, while China has included a scheme in its tenth five-year plan covering 2001-2005. In the United States the implementation of renewable portfolio standards (RPS) schemes-introduced in 12 United States so far, forms the basis for green certificate trading. While each scheme varies in detail from state to state, RPS basically sets out net electric sales requirements of renewable energy for power producers in relation to their total energy supply. RPS schemes could help introduce diverse energy supplies in the United States and cut down dependence on exported fossil fuels.

References

Gary D. Burch. 2001. Hybrid Renewable Energy Systems, U.S DOE Natural Gas/Renewable Energy Workshop, August 21, 2001.

Elkarmi, Fawwaz, and Isam Mustafa. 1993. Increasing the utilization of solar energy technologies (SET) in Jordan. Pages 978-984: Energy Policy, Volume 21, Issue 9, pp 978-984.

Hashimoto, Sachihiko . 2003. National Institute of Science and Technology Policy, Construction of the electric power supply system using the decentralised power supply- Construction of the energy supply system according to the local characteristics (in Japanese). (http://www.nistep.go.jp/achiev/ftx/jpn/stfc/stt025j/0304_03_feature_articles/200304_fa02/200304_fa02.html)

Hiromatsu, Takeru. 2003. Research on the optimum energy mix, considering the regional characteristics (Chapter 2), Report on Research Committee on Energy and Environment: Engineering Advancement Association of Japan (ENAA), 2002 (in Japanese).

Kablan, M. M. 2004. Decision support for energy conservation promotion: an analytic hierarchy process approach, Energy Policy, Volume 32, Issue 10, ppPages 1151-1158.:

Kidani, Osamu. 2004. Biomass - Bioresources and Environment,-. Page 88: CORONA PUBLISHING, CO., LTD (in Japanese), p. 88..