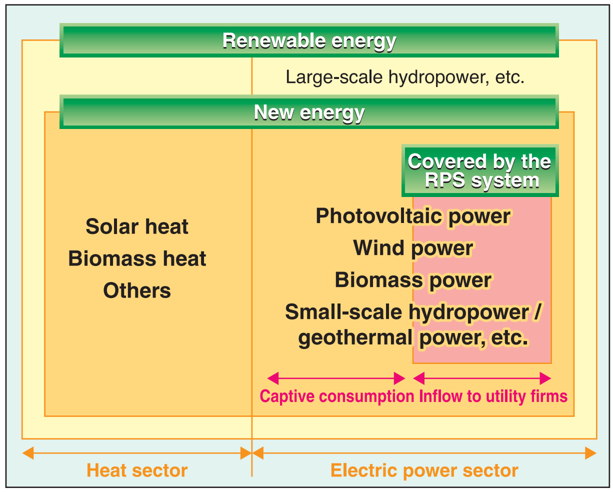
High Hopes for Biomass as New Energy Source

By Yamaji Kenji

Chart 1 Revised definition of new energy in Japan



Source : *Agency for Natural Resources and Energy*

1. Biomass's Role as New Energy Source

Japan's law intended to promote the use of new energy treats supply- and demand-side new energy sources in a mixed manner. But in 2006, through discussions at an advisory panel to the Ministry of Economy, Trade and Industry, new energy sources were defined as part of renewable forms of energy. Those which were earlier seen as demand-side new energy were categorized into innovative uses of energy and energy saving. But these renewable forms of energy do not include existing ones that have been already used on a commercial basis such as large-scale hydroelectric power generation, and those that are considered to be far from practical use such as ocean energy. As a result, as shown in *Chart 1,* the sources of new energy that Japan should make efforts to develop were defined as solar heat, photovoltaic power, wind power, biomass power / heat, small-scale hydropower / geothermal power, and "others." The supply of energy by these new sources accounted for only about 1.8% of Japan's primary energy needs in fiscal 2003. The Japanese government has set the goal of raising the figure to about 3% in fiscal 2010 (see *Table 1*). Meanwhile, in the electric power field, as shown in *Table 2,* the supply of power generated by renewable energy sources, including these new forms, accounted for about 10% of Japan's total electric power generation – a level comparable to those of the United States and European countries.

Since the Kyoto Protocol came into force in 2005, advanced countries have accelerated their efforts to reduce greenhouse gas emissions. In Japan, the government decided in April 2005 to promote the use of renewable energy which emits no carbon dioxide (CO_2). The decision was taken by the Ministerial Meeting on Promotion of Comprehensive Energy Measures.

Besides being effective in combating global warming, the new energy sources emit fewer air pollutants and are environmentally compatible. In addition, the renewable sources will help improve energy-hungry Japan's energy security because they are domestically produced.

Moreover, the use of natural energy sources such as biomass will help materialize the idea of "local production for local consumption" and is also expected to help revitalize local economies. In other words, the new energy sources are locally available, decentralized ones. This decentralized characteristic of biomass and other forms of new energy has the potential of transforming the composition of the country's future energy system.

Table 1 Actual / targeted use of new energy in Japan

		FY 2003	FY 2010 Targets
Power generation sector	Photovoltaic power	210,000 kl (860,000 kw)	1,180,000 kl (4,820,000 kw)
	Wind power	276,000 kl (678,000 kw)	1,340,000 kl (3,000,000 kw)
	Waste / biomass power	2,137,000 kl (1,739,000 kw)	5,860,000 kl (4,500,000 kw)
Heat use sector	Solar heat	690,000 kl	900,000 kl
	Waste-based heat	1,610,000 kl	1,860,000 kl
	Biomass heat	790,000 kl	3,080,000 kl *1
	Untapped energy*2	42,000 kl	50,000 kl
	Black liquor, scrap wood, etc.*3	4,780,000 kl	4,830,000 kl
TOTAL (Ratio to primary energy supply)		**10,540,000 kl** (1.8%)	**19,100,000 kl** (around 3%)

Note : *Breakdowns in the power generation and heat use sectors are rough targets. (The figures were revised in 2005.)*
**1 The figure includes biomass-derived fuel (500,000 kl) in transport-use fuels.*
**2 Untapped energy includes snow-and-ice cryogenic energy.*
**3 Black liquor, scrap wood, etc., are part of biomass energy. The figure partially includes those used for power generation. The figure for black liquor, scrap wood, etc., is an endogenous model estimate because it depends on the level of production of paper and pulp.*

Source : *Agency for Natural Resources and Energy*

Table 2 Percentages of renewable energy used in power generation sector

(%)

	Japan	Europe (EU-15)	United States
Hydroelectric	8.2	10.1	6.9
Geothermal	0.33	0.2	0.37
Biomass	1.21	1.38	1.34
Wind power	0.09	1.62	0.28
Photovoltaic	0.09	0.02	0.01
TOTAL	9.9	13.3	8.9

Note : *Power output includes that for captive consumption.*
Source : *Agency for Natural Resources and Energy (for Japan); "Energy Balances of OECD Countries 2003-2004," International Energy Agency (for others)*

2. FY 2010 Targets: Greater Biomass Share

As indicated in *Table 1,* the Japanese government plans to cover about 3% – or 19.1 million kiloliters in oil equivalent – of the country's primary energy supply with supply-side new energy in fiscal 2010. Of the new energy supply, the amount of photovoltaic power is set at 1.18 million kiloliters and that of wind power at 1.34 million kiloliters, both in oil equivalent. This means that the targeted power output capacity will be 4.82 million kilowatts for photovoltaic power and 3.00 million kilowatts for wind power. The reversal in the figures of power capacity and oil equivalent between photovoltaic power and wind power stems from a gap in their anticipated capacity factors. This is because the capacity factor for wind power is larger than that for photovoltaic power. When using natural energy, the operation of energy facilities is affected by natural conditions such as sunshine and wind force.

Meanwhile, target figures for the new energy were revised in March 2005. The main points of the new figures, which revise the targets set in 2001, include a sharp cut in the target for solar heat whose use has been sluggish in recent years and a boost in the targets for biomass and waste-disposal heat. But there was no change in the total targeted amount for all new energy sources. The targeted amounts of energy supply from biomass and waste in fiscal 2010 are 5.86 million kiloliters in oil equivalent for power generation, 1.86 million kiloliters for waste heat, 3.08 million kiloliters for biomass heat (including 500,000 kiloliters for automobile fuel), and 4.83 million kiloliters for black liquor, scrap wood and others. In total, the amount is set at 15.63 million kiloliters in oil equivalent. Those figures indicate the importance of biomass in the use of new energy because the main component of waste is biomass.

3. Challenges Facing Biomass Energy Cells

Biomass falls behind solar batteries and wind power in terms of public recognition but is in reality a mainstay source of new energy. As *Table 1* indicates, the combined amount of waste and biomass power generation was 2.14 million kiloliters in oil equivalent in fiscal 2003. In addition, the use of biomass heat came to 790,000 kiloliters and that of waste heat 1.61 million kiloliters. On top of them, about 4.8 million kiloliters of energy from black liquor and scrap wood originated from biomass sources.

Biomass resources exist in varied forms, posing a challenge in their use as energy. Moreover, biomass resources have already been widely used as food, paper and wood materials and are less recognized as an energy source. This is one of the reasons for the slow pace of biomass use as a source of energy.

The forms of biomass that can be used as energy are of great variety. There are also a variety of biomass-use technologies ranging from combustion to thermochemical and biochemical conversion. In general, relatively dry biomass resources, such as wood whose water content is low, are suitable for combustion or thermochemical conversion, while biochemical conversion is better used for food-derived biomass resources that contain more water. But this theory does not necessarily apply to new technologies, such as hydrothermal reaction.

Table 3 shows a matrix of relationships between various biomass resources and energy-conversion technologies. It also shows the current state of development of those technologies. Needless to say, more combinations of energy technologies, including fuel cells, are possible to use as energy such fuels as synthetic gases, methane and ethanol that are produced out of thermochemical and biochemical conversion.

Meanwhile, it is also important to develop technologies to acquire, collect and transport biomass resources that scatter across the globe widely and thinly, though this is not covered by *Table 3*. It is also needed to devise some innovative ways of collecting and transporting biomass resources that are voluminous and take much space. Along with the development of technologies to convert biomass resources into chip, pellet and slurry forms, improvements in social systems such as collection and transport systems in regional communities are expected to play a key role.

The use of biomass resources is diverse, ranging from food, fiber (materials such as paper and wood) and livestock feed to fertilizers and fuel. They are called the biomass 5Fs, after their initial letters. And the value of using biomass resources comes down roughly in that order. In fact, the use of biomass resources as energy or fuel is a relatively less valuable way to use them. Therefore, from an overall point of view, biomass resources must be first put to higher-value use and then used for other purposes in a phased manner.

As mentioned earlier, it is important to compare the resource value of biomass when using it as energy or for other purposes. (In the case of waste, the minus value of disposal costs needs to be considered.) From the standpoint of resource economics, biomass based on waste that has disposal costs is most advantageous. In this case, however, environmental costs are required when using it as energy. Moreover, unused resources such as wood left over on forest land are economically attractive. But as biomass resources are bulky, transportation and storage costs need to be studied carefully.

Biofuels, particularly bioethanol, have recently drawn attention as automobile fuel. In this case, the earlier mentioned diversity of biomass resources needs to be considered. Current biomass resources used as bioethanol materials are sugarcane in Brazil and corn in the United States. This is because ethanol is produced from sugar or starch using current technologies. But thinking of the future of biomass resources, the use of edible biomass resources would run into a conflict of interest with the supply of food. In addition, such use would not pay from the viewpoint of resource economics. We need to aim at establishing technologies to produce ethanol from cellulose, which is more universal and rich as a biomass resource. Meanwhile, a large amount of energy is required to produce ethanol, notably in the dehydration process. If fossil fuels are used in this process, the value of biomass as non-fossil resources will

Table 3 Matrix of relationships between biomass resources & energy conversion technologies

			Biomass resources										
			Wood biomass		Paper biomass	Herb biomass			Manure, sludge		Food waste	Others	
						Meadow grass, waterweed, seaweed		Agricultural residue				Sugar, starch	Plant oil
		Dry / Wet	D	D	D	D	W	D	W	W	W	W	W
		Examples	Wood left over on forest land, forest thinnings, sawing remainders	Construction/ demolition waste	Waste paper	Meadow/ napier grass	Ulva, water hyacinth	Corn, paddy straw, rice husk, straw	Livestock excreta	Sewage/ excreta septic sludge	Food-processing/ kitchen/ fishery-processing waste	Sweet potato	Cooking oil waste/ rapeseed/ palm oil
Conversion technologies	Combustion	Direct-combustion boiler	◎	◎	◎			○		◎			
		Direct-combustion power	◎	◎	○			○	△		◎		
		Fuel solidification	◎	◎				○		○	◎		
		Mixed-combustion power	◎	◎				○	△	○	◎		
	Thermochemical conversion	Melting/gasification	○	◎				○					
		Fixed-bed gasification	◎	○				◎					
		Fluidized-bed gasification	○	○				◎					
		Entrained flow gasification	○	○		○		◎					
		High-BTU gasification	○	○		○		◎					
		Fast pyrolysis	◎	○	○	○	○	○	○	○	○		
		Slurry-converted fuel	○	○	○	○	○		△	○	○		
		Direct liquefaction	○	○	○	○	○		△	○	○		
		Supercritical water gasification	○			○	△			○	○		
		Supercritical methanol treatment	○		○								○
		Carbonization	◎	○	○	△	△			○	○		
		Esterification											◎
	Biochemical conversion	Methane fermentation	△			△	◎		◎	◎	◎		
		Ethanol fermentation	○	○	○			○			○	◎	
		Acetone-butanol fermentation									○	◎	
		Hydrogen fermentation			○	○	○	◎	○	○	○	○	

The table is a matrix showing the state of technologies for converting various biomass resources into energy.
◎: practical use achieved ○: in the development phase (including demonstration in a pilot plant) △: in the feasibility study phase

Note : *This matrix shows examples of introduction and of R&D, compiled from the source shown elsewhere. It is short-sighted to judge that items with no mark in this table have no compatibility between resources and technologies.*
Source : *"Basic survey on introduction of new energy, survey on policies for use and diffusion of biomass energy," Japan Institute of Energy, published in May 2005*

sharply decline. It is important not only to improve energy efficiency of bioethanol but to establish a system to use biomass energy for the production of bioethanol.

Meanwhile, in addition to ethanol, other biofuels include bio-diesel fuel (BDF) produced from vegetable oils and fats and biomass-to-liquid (BTL) fuel produced through thermochemical conversion. (BTL fuel is produced after thermally decomposing biomass into synthetic gas and then into liquid.) In Europe, where diesel-powered vehicles are popular, BDFs such as fuel from rapeseed oil are already used. Palm oil has also attracted attention as a BDF material. From a long-range perspective of demand and supply of fuel for transportation use, BTL fuels are expected to play a key role because they can be used for diesel engines and aircraft.

4. From "Technology-Push" to "Market-Pull"

Not only technological development but diffusion and spread are important to promote the use of new energy. In recent years, major countries have shifted their focus in their new-energy policies from the conventional "technology-push" type led by research and development efforts to what is called "market-pull" that is backed by economic incentives. In addition, to promote the introduction of new energy into the market, these countries have come to put more focus on actual new-energy supplies, in a departure from the conventional assistance to initial investment, such as subsidies and tax reductions. For example, Japan's renewable portfolio standard (RPS) law requires utility firms to procure a certain level of new energy-originated electricity and create an artificial market. The law is intended to promote competition between renewable energy sources to efficiently introduce new energy. Some countries impose requirements to mix a certain amount of biofuel into automobile fuel in an effort to create demand and to help promote the use of new energy.

In many cases, biomass is economically advantageous among new energy sources. But it is difficult to select the best way of utilizing biomass resources as energy because they vary in form. To promote the use of biomass as energy, a market-pull type policy is considered to be more effective and efficient than promoting the development of a particular technology because such a policy would aim at creating demand systematically, helping promote competition among various biomass use systems, and stimulating their technological development and introduction. JS

Yamaji Kenji is professor, Department of Electrical Engineering, School of Engineering, University of Tokyo.