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Energy Security and Sustainability in Japan

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Japan is the third largest energy consumer in the world. Presently it consumes nearly 461 Mtoe of primary energy per year and is projected to consume so annually till 2040. But meeting energy demand has always remained a challenge for Japan as it is one of the weakest nations among the developed countries in terms of energy security. It lacks significant domestic reserve of energy resources, and its hydroelectricity production is not plenty. So Japan has to rely on imports of oil, coal, natural gas, etc. to power the nation. This dependence on foreign resources makes the energy sector of Japan fragile and exposed various risks. The authors in this paper introduce the contingent and structural risks in the energy sector in Japan. This paper argues that to maintain its overall development and reduce energy dependence on others, Japan has to explore the non-conventional and renewable energy options like wind energy, ocean energy, geothermal energy, photovoltaic energy and biomass energy along with the skillful utilization of waste energy and energy cascading possibilities. Towards the goal of energy sustainability, nuclear energy may play an important role in Japan in the foreseeable future.

Keywords: Energy, development, foreign resources, contingent and structural risks, renewable energy.

1. Introduction

Japan's energy consumption doubled every five year during Post-WWII period of a rapid industrial growth into the 1990s. By 1976, Japan was consuming 6 percent of global energy supplies with only 3 percent of the world's population (Dolan and Worden, 1994)[1)]. Presently, Japan is the third largest economy and energy consumer in the world. It consumes about 461 Mtoe of energy per year and is projected to consume nearly the same amount of primary energy annually till 2040 (Table 1).

But achieving energy security has become a vital challenge for Japan over time. By energy security, we accept the goal of securing “adequate energy at reasonable prices necessary for the people's lives, and economic and industrial activities of the country" (Toyoda, 2012)[2)]. Unfortunately, Japan is one of the weakest nations among the developed countries in terms of energy security, having only 19 percent of energy self-sufficiency (15 percent from the nuclear power) before the 2011 Fukushima accident. The situation looks grim by the fact that Japan lacks significant domestic reserves of oil, coal, natural gas and other energy resources, including uranium for energy production. The river-based hydroelectricity generation is not plenty. So Japan has to rely on import of these resources to power the nation. This dependence on foreign resources made Japan's energy sector fragile and exposed to two kinds of risks - contingent risks and structural risks. While the former may happen in the form of political events in the supplier countries like wars, riots, embargo, terrorist acts or accident, the latter impacts through the structural change or imbalance at the demand side and/or supply side. The 2011 earthquake and tsunami caused damage to nuclear reactors forced a nationwide shutdown of all plants due to fear about the release of radioactive material, exposing further the energy vulnerability of Japan.

So developing a self-sufficient energy infrastructure to generate and supply energy to sustain its economic development has remained a strategic concern for Japan. To maintain and energize its overall development and reduce energy dependence on others, Japan has to explore the non-conventional and renewable energy options like wind energy,

ocean energy, geothermal energy, photovoltaic energy and waste and biomass energy. But there is every likelihood that towards the goal of Japanese energy sustainability, nuclear energy will play a significant role till the foreseeable future.

This is a descriptive study that has six more parts. Part two has been devoted to examining the link between economic growth and energy consumption. This also looks at the sectoral demand for energy. Part three identifies various risks Japan faces towards its energy security. Part four deals with the energy scenario of Japan for next few decades. Part five examines the growing role of different renewable energy sources in that future. Part six discusses energy cascading process. Part seven concludes the paper.

2. Economic Growth and Energy Use and Supply Scenario in Japan

Like any other economy in the world, the economic growth in Japan needed the support of the energy over a long period of time. At present, Japan is the third largest economy and energy consumer in the world. It saw the peak of energy use in 2007 when total energy use reached 525 Mtoe. That came down to 481 Mtoe in 2012 due to earthquake and tsunami in March of 2011.

Indeed, the relationship between GDP growth and use of energy can't be missed any economy in the world. Though Japan achieved the status of the second economy in 1968, the economic growth in the 1970s and 1980s made it one of the spectacular post-war success stories. The economic success was duly supported by the energy sector during this period. Figures from 1 to 3 have been prepared to show the amount of GDP Japan attained against the total amount of energy used and supplied for that economic accomplishment. The GDP in the figures has been expressed in Japanese ¥ trillion and energy in 10^{13} kcal for the period.

Figure 1 shows the real GDP and use of energy used in aggregate and rate of growth of the both from 1975 to 2012. The size of the economy from 1975 to 1990 increased by ¥216 trillion, from about ¥225 trillion to ¥441 trillion (in 2005 price). Unsurprisingly, this growth in economic size was matched by the growth in energy use as well, reaching from 466 (10^{13} kcal) from 343 (10^{13} kcal) during the period. But since then both the pace of economic growth and growth of energy use declined substantially mainly due to the price bubble burst in the economy in the 1990s. The Tsunami and earthquake in 2011 brought the use of energy further down to the level of 1992. The rate of growth for them followed a similar pattern during the period.

Figure 2 depicts the share of energy consumption by important sectors of the economy from 1965 to 2012 and highlights the shifting structure of energy consumption. This may be indicative of the changes in Japanese economic activities as well. An investigation indicates that during this period a large number of Japanese manufacturing industries has been relocated to China, Malaysia, Thailand and other countries which may have caused a decline in the industrial energy consumption. On the other hand, the domestic transport sector has grown with the consumption share, from 17.6 percent to 25.1 percent during the period. Similarly, the massive urbanization of Japan has led to higher consumption of energy by the residential users as well.

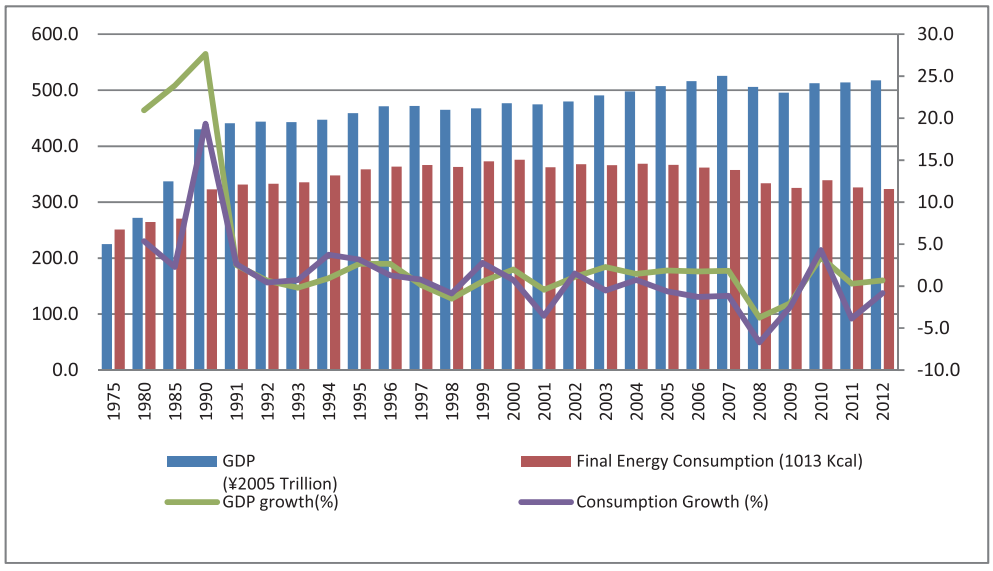
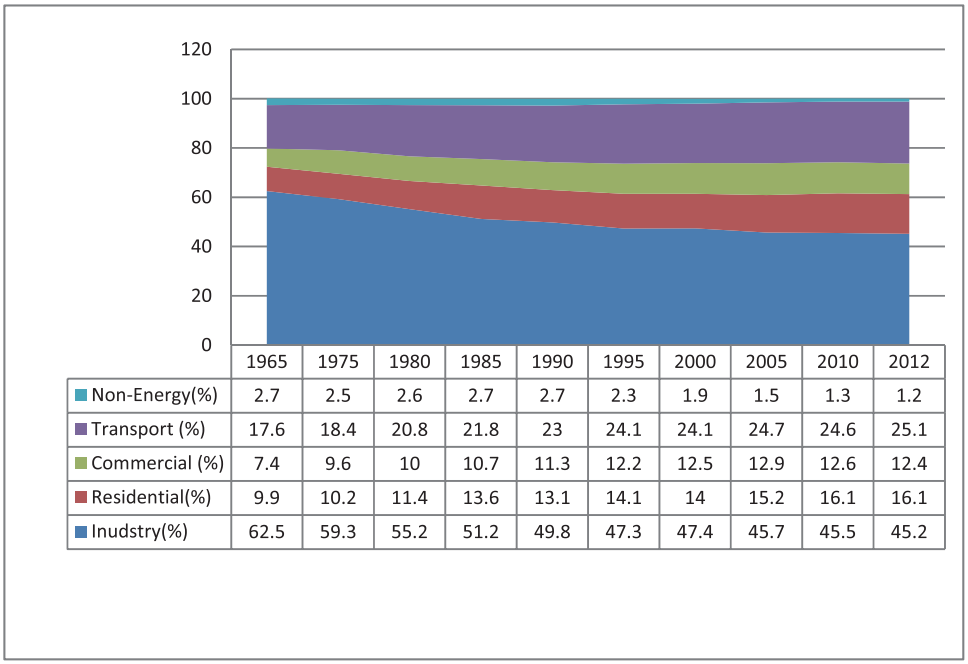


Figure 1: Aggregate and Rate of Growth of GDP and Use of Energy, Japan (1975-2012).

Source: Constructed. Data from The Energy Conservation Center, EDMC- Handbook of Energy and Economic Statistics, 2014.[3)]



	1965	1975	1980	1985	1990	1995	2000	2005	2010	2012
Non-Energy(%)	2.7	2.5	2.6	2.7	2.7	2.3	1.9	1.5	1.3	1.2
Transport (%)	17.6	18.4	20.8	21.8	23	24.1	24.1	24.7	24.6	25.1
Commercial (%)	7.4	9.6	10	10.7	11.3	12.2	12.5	12.9	12.6	12.4
Residential(%)	9.9	10.2	11.4	13.6	13.1	14.1	14	15.2	16.1	16.1
Inudstry(%)	62.5	59.3	55.2	51.2	49.8	47.3	47.4	45.7	45.5	45.2

Figure 2: Sectoral Share of Energy Consumption (1965-2012).

Source: Constructed. Data from The Energy Conservation Center, EDMC- Handbook of Energy and Economic Statistics, 2014.

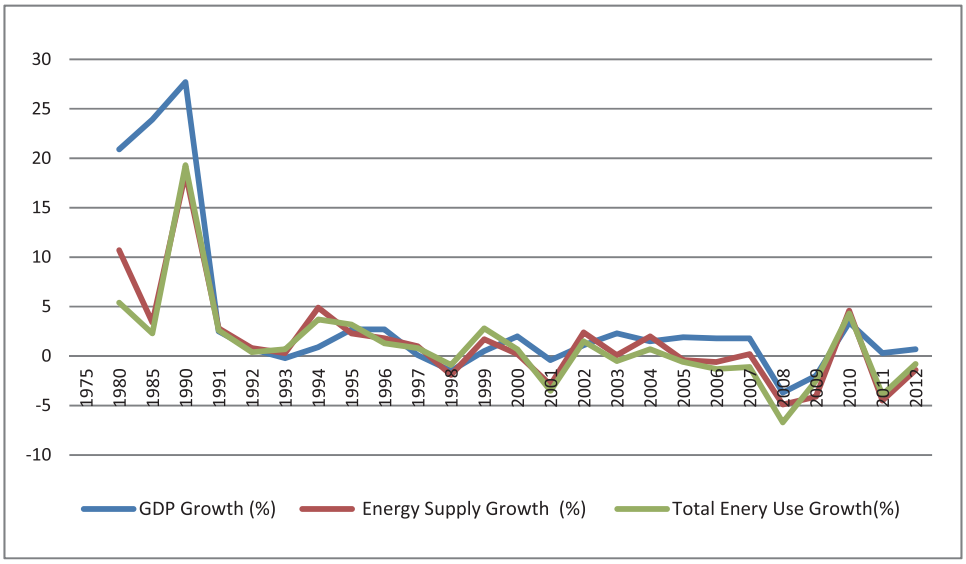


Figure 3: Growth of GDP, Energy Supply and Energy Use (1975-2012).

Source: Constructed. Data from The Energy Conservation Center, EDMC- Handbook of Energy and Economic Statistics, 2014.

The supply side also has seen changes during the period of our discussion. In line with the increase in GDP, supply of primary energy fluctuated over time. After a continuous rise in supply up to 1997, the supply side saturated and from 2004 aggregate supply line of energy has been declining. A number of factors might have affected this including a bleak prospect of any real growth of demand from any individual sector. The population figure could be an important

barometer in this regard. The link between population and economic and production activities, consumption of everything, use of infrastructural facilities, various services and utilities is unmistakable. The energy sector can't be an exception.

The overall growth rates of GDP, primary energy supply, and final energy consumption in Figure 3 reinforces the observations we have already made in this section. The trend lines are sloping downward for all of them.

3. Energy Dependency and Contingent and Structural Risks

To bring a sort of par to its economic development, Japan should have achieved a substantial level of energy security by this time. But yet Japan is fragile in terms of energy security. In fact, it never reached more than 21 percent of energy self-sufficiency, that too back in 1998. As an aftermath of the 2011 tsunami and earthquake that forced Japan to shut down all nuclear power plants, the local share of energy production nosedived to 11 percent, making Japan more dependent on foreign resources for energy production.

To make the matter worse, Japan lacks significant domestic reserves of resources for energy reduction. The river-based hydroelectricity production is not plenty. So Japan has to rely on import of these resources to power the nation.

Figures 5, 6 and 7 have been drawn to depict the state of energy insecurity of Japan. This dependency is indicative of various risks towards its energy security.

Figure 5 shows the share of different sources of primary energy supply in Japan. Coal, oil, and natural gas have emerged as the significant sources used for primary energy production. Without domestic supply sources, Japan has to depend on external players for all these resources and has to pay a huge bill for energy generation every year for their importation. Indigenous resources like river based hydraulic power, nuclear energy, and renewable energy sources are also used for energy production. In 2011, oil was the single largest source of energy supply, constituting about 39 percent of all, followed by natural gas (23.3 percent) and coal (22 percent). Sources like hydraulic power (3.4 percent), nuclear energy (4.2 percent) and renewable energy sources (7.8 percent) contributed the rest.

That underscores the importance of external factor for the energy sector of Japan. Since 1975, Japan never could achieve more that 21 percent of its energy supply (1998) domestically. Though the position improved a bit in the 1980s, Japan never could show the promise that it would achieve a satisfactory level of self-reliance in the energy supply. The setback of 2011 left Japan further behind in the goal for achieving energy security.

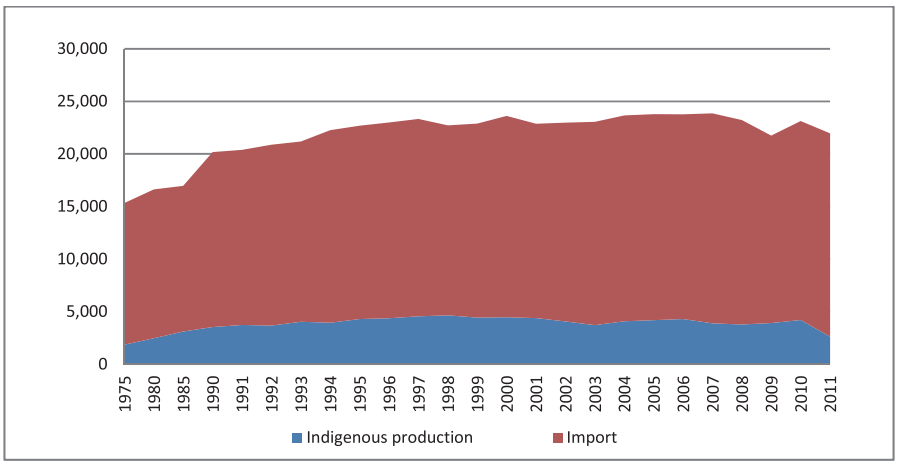


Figure 4: Japanese External Dependency, 1975-2011 (in Petajoules).

Source: Constructed. Data from The Energy Conservation Center, EDMC-Handbook of Energy and Economic Statistics, 2014.

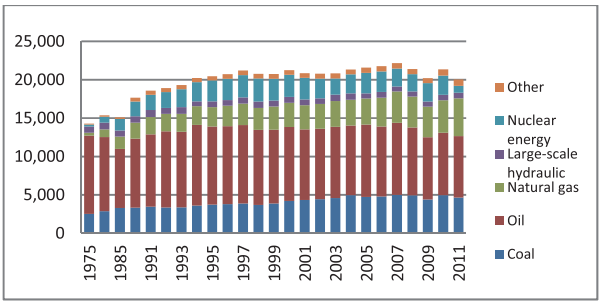


Figure 5: Share of Various Sources in Primary Energy Supply (1975-2011, in petajoules).

Source: Constructed. Data from the Statistical Yearbook of Japan, 2013.[4)]

That brings to the fore the possible risks an economy like Japan may face when it is so much exposed to external sources of energy supply. Figures 6 and 7 show Japanese oil and gas import dependency on external sources. In fact, Japan holds strategically a fragile position as it faces both contingent risks as well as structural risks emanating from various sources of energy. Both these risks can trigger a crisis to the supply chain of resources that are used for energy generation, particularly by Japan. Indeed, the risk factors are increasing in terms of number, scale, and complexity.

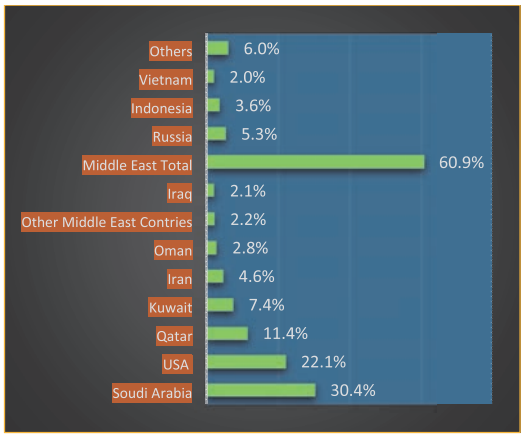


Figure 6: Share of Japan's Fossil Fuel Import, Crude Oil FY2012 (21103 x10^7 liter)

Source: Constructed. Data from Statistical Yearbook of Japan, 2013.

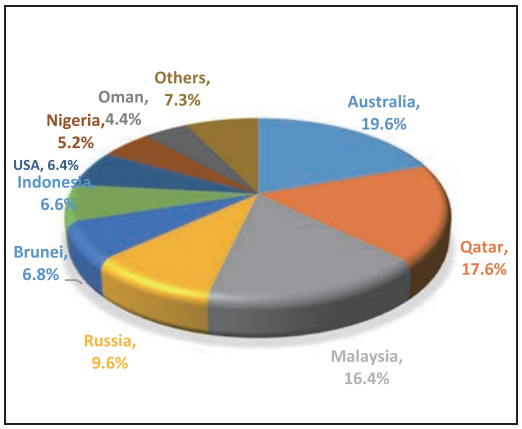


Figure 7: Natural Gas Import, FY2012 (8687x10^7 kg)

Source: Constructed. Data from Statistical Yearbook of Japan, 2013.

As we know, contingent risks are unpredictable events that could directly threaten energy supply may pose contingent risks. Political actions by consumer nations are another source of this risk. The long ridding oil sanctions on Iran and the uncertain state of sanctions on Russia are examples of this risk. Another source that can be any accident and disruption in the supply chain, one of which may be evolving in the South and East China Seas. These risks look to have potential to affect the Japanese energy sector directly through supply cut or price escalation any time.

Similarly, structural risks include embargos imposed by producers for economic or political reasons, the strengthening of producers' marketing control, environmental ramifications of excessive fossil fuel consumption and lack of energy infrastructural development (Koyama, 2006)[5)]. So, various structural factors of economic and political origins can affect both the demand and supply sides of Japanese energy resources of importance. The demand scenario of energy resources is changing rapidly because of the emergence of China, India, and other energy deficient countries as the competition for energy is getting stronger. The supply side can also develop reluctance to sell needed materials, as exemplified by, in a bit different context, the stoppage of sale of rare earth by China to Japan soon after the East China Sea island dispute emerged in 2012. Moreover, energy resources that are relevant to Japan are depleting fast at their origins.

In fact, Japan has, thus far, remained nearly an eternal case of energy insufficiency since its economic march began after the WWII. The Great East Japan earthquake and nuclear power point accident in 2011 have further

Table 1: Primary Energy Consumption of Japan and Some Selected Countries (In Mtoe).

Country	Reference Scenario					Advanced Technology Scenario				
	Historical		Projection			Historical		Projection		
	1990	2011	2020	2030	2040	1990	2011	2020	2030	2040
Japan	439 (5.0)	461 (3.5)	466 (3.1)	449 (2.6)	425 (2.2)	439 (5.0)	461 (3.5)	446 (3.1)	402 (2.5)	361 (2.1)
China	871 (9.9)	2728 (20.8)	3433 (22.6)	4009 (22.9)	4423 (22.5)	871 (9.9)	2728 (20.8)	3212 (22.2	3499 (22.1)	3649 (21.6)
India	317 (3.6)	749 (5.7)	1011 (6.6)	1403 (8.0)	1896 (9.7)	317 (3.6)	749 (5.7)	918 (6.4)	1202 (7.6)	1585 (9.5)
S. Korea	93 (1.1)	260 (2.0)	290 (1.9)	309 (1.8)	310 (1.6)	93 (1.1)	260 (2.0)	284 (2.0)	292 (1.8)	282 (1.7)
Indonesia	99 (1.1)	209 (1.6)	301 (2.0)	413 (2.4)	547 (2.8)	99 (1.1)	209 (1.6)	306 (2.1)	416 (2.6)	534 (3.2)
World	8782 100	13113 100	15216 100	17517 100	19642 100	8782 100	13113 100	14449 100	15825 100	16910 100

Source: Constructed. Data from The Energy Conservation Center, EDMC- Handbook of Energy and Economic Statistics, 2014.

aggravated the future energy scenario. Though the safety of nuclear power plants will remain an important concern, the fact that it has developed a fairly high nuclear power infrastructure which are still commercially viable. It will require a huge commitment of fund to dismantle them prematurely. Thus using them as an alternative source before a viable renewable energy source is put as a replacement. To overcome this situation, Japan should draw next plan to ensure energy supply to sustain its economic progress as well as make itself significantly self-reliant.

4. Future Energy Requirement Scenario

A line of consolation is that the energy scenario for the future indicates that energy consumption in Japan has already reached a plateau, and there is little possibility of going it further up till the mid of the 21st century. In fact, the demand for energy is going to decline in all future projections. This is in the line of emerging industrial context and population estimation. Japan seems to have passed its economic prime and is facing a process of hollowing out of the manufacturing sector because of their overseas relocation and closing down. Moreover, its population is declining at an accelerated rate.

Table 1 has been constructed to highlight two scenarios - Reference Scenario and Advanced Technology Scenario - of energy consumption for a number of countries, viz. Japan, China, India, South Korea and Indonesia. Of the scenarios, the former has been used to make the future energy consumption based on the past and present trend of use of energy. But in case of the advanced technology scenario, the impact of using energy efficient technology in building, transportation, industry, commerce, etc. has been factored into the projection. Interestingly, in both the situations, Japan is the only country projected to experience decline in energy consumption in the coming decades. On the other hand, China, India, and Indonesia are going to face increasing demand for energy as their economies are expected to grow during the time. In the table, parenthesis figures indicate the percentage share of energy consumption of a country against the world's total of 100. Ironically, the decrease in energy consumption in Japan, though not indicative of economic expansion or development, may bode well towards the goal of energy its security and sustainability by attaining a satisfactory level of domestic energy generation.

5. Exploration of Renewable Sources for Energy Security

The promise for self-sufficiency in energy in Japan lies in the development of a vibrant new and renewable energy sector. And the trend might be setting in the sector. At the same time, it has to go for energy cascading and integration. As compared to other OECD nations, electricity and other end-use energy prices in Japan seem to be the highest in the region thereby energy efficiency and energy cascading options are countless.

Table 2: Electric Power Generated By New and Renewable Energy, 1990-2011(In Terajoules).

Fiscal Year	Total	Natural Energy			Geothermal power generation	Refuse use	
		Photovoltaic cell generation	Wind power generation	Biomass power generation		Refuse fired power generation	Industrial wasted electricity recovery use
1990	107,385	12	-	-	16,246	16,861	74,266
1995	144,510	2.2	12	-	29,416	25,987	89,094
2000	167,414	16	968	-	29,868	41,984	94,578
2005	196,282	11	15,409	-	28,335	60,056	92,471
2008	188,523	100	25,663		23,950	59,549	79,262
2009	184,593	131	31,166	-	24,880	58,929	69,487
2010	300,647	190	34,290	116,241	22,784	48,684	78,458
2011	316,049	526	39,659	122,545	23,284	52,125	77,911

Source: Constructed. Data from Statistical Yearbook of Japan, 2013.

Table 2 reveals that between 1990 and 2011 electricity power generated by new and renewable energy sources nearly trebled. Primary sources among them have remained the biomass power generation, industrial wasted electricity recovery use, refuse fired power generation, wind power generation, and geothermal power generation. Photovoltaic cell generation is a minor source in this category.

6. Energy Cascading and Integration

In a simplified general equilibrium model Goto (1995)[6] has researched cost-effective technical options currently available or possible ones into the future. In this model, least cost technologies are adopted as they become economically feasible. Energy savings take place as soon as the technology is replaced with a new one.

In a conventional power plant, the power generation efficiency is about 38 percent, and the remaining 62 percent of thermal energy is thrown to the ambient. Heat is the final formation of energy that flows from high to low temperature.

To utilize 100 percent energy of primary energy sources, it is inevitable to introduce the cascaded energy utilization concept in the energy sector. Cascaded energy utilization involves fully harnessing the heat produced by fossil fuel combustion, from its initial 1700°C down to near ambient temperatures, with a thermal 'down flow' of heat analogous to the downward flow of water in a cascade (Kashiwagi et al. 2001).[7] In order to foster the energy cascading option, Hayakawa et al. (1999)[8] investigated the regional energy saving potential by cascaded use of waste heat in energy intensive industries, taking into account the actual local industrial structure in Japan. Results showed that the energy consumption can be reduced up to 71 percent in Mie prefecture by heat cascading. According to the energy flow in the optimized combination in Mie prefecture, high-temperature waste heat in the ethylene industry is adequately supplied to electricity demand in the cement industry through condensing turbines.

But if we look at the total energy requirement of Japan, these sources are still insignificant. So the role of nuclear power seems to have not ended yet. Indeed, Japan has to utilize nuclear power as a bridging source and at the same time invest more in the renewable energy sources. The alternative options open to Japan for its drive for energy self-sufficiency as it miserably lacks the conventional resources that are generally used for energy generation.

7. Conclusion

The tentative picture of Japanese energy future makes it easier to design and implement an energy plan that is formulated on available engineering and rich technology. Creating them as viable alternatives or replacements of the set up that is heavily dependent on external resources would help Japan in a number of ways.

Firstly, it will save an enormous amount used to for importing resources used for energy supply and thus will reduce any trade deficits due to their imports.

Secondly, Incentive to the local production should create a big, vibrant economic sector, contributing to the production and employment. Though initial investment requirements could be high, the long-term nature of the demand for the energy service should adequately compensate for the investment.

Thirdly, given the contingent and structural risks involved to the energy fragility, Japan can and should strive for

energy security, and that could be achieved by developing alternative domestic sources of energy generation.

Lastly, but not the least, to sustain and even to further the level of economic development Japan has already achieved, it needs uninterrupted sources of energy supply. Dependency at the present rate can't ensure that sustainability. A satisfactory level of self-reliance may ensure that economic future for Japan.

So any Japanese energy sufficiency should be based on the development of a vibrant new and renewable energy sector. The sooner Japan achieves the goal, the better.

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