English Summary

Study of Potential for the introduction of Renewable Energy

As a 2009 project, the Ministry of Environment appointed Ex Corporation Environmental & Urban Planning, Research and Consulting, Itochu Techno-Solutions Corporation, Pacific Consultants Co., Ltd., and Asia Air Survey Co., Ltd. to carry out an study entitled “Study of Potential for the introduction of Renewable Energy” (hereinafter referred to as the “Potential Study”). The details of this study are discussed here.

In this Potential Study, energy resources which can be estimated theoretically but do not take into account various limiting factors (such as land application or application technology) are defined as “potential”; whereas, feasible energy resources where various limiting factors concerning energy collection (extraction) and application are taken into consideration and which are estimated after creating a scenario (assumption) for limiting factors are defined as “introduction potential”. Although the so-called targeted value are set within the introduction potential, the introduction potential should be reviewed accordingly since limiting factors such as economical efficiency may change.

1. Photovoltaic (PV) power generation

According to the “Photovoltaic (PV) Roadmap Toward 2030 (PV2030+)” compiled by the New Energy and Industrial Technology Development Organization (NEDO) in June 2009 (hereinafter referred to as the “PV2030+”), the potential of photovoltaic power generation, for which the latent capacity physically feasible for installation in a building or low, unused sites is compiled, is estimated to be 7.98 billion kW in total (of this, 7.29 billion kW is for unused land) (in the PV2030+, it is referred to as “scale feasible to physically introduce”)[1)]. In case of PV power generation, since the factor for locally uneven distribution is small, the potential is often described as the grand total of products from a number of facilities and areas by setting basic unit by facility (for example, 4kW/building). Therefore, in the PV2030+ this is estimated in such a manner.

However, for non-residential buildings, roof types or shape of roofs are complicated and sunlight conditions vary significantly. In addition, equipments such as air conditioning units are installed outdoors in many cases. Hence, in the Potential Study, for non residential buildings, an investigation of basic unit based on sample drawings was carried out. In this investigation, based on the following scenario, the areas where PV cells can be installed was estimated and after assuming the unit output per unit areas as 0.067kW/m^2, the introduction potential was also estimated.

- The installation area over 150m^2/site, over 20m^2/site or over 10m^2/site respectively cannot be secured as area for installation
- the range where each equipment or structure exists;
- the range where power generation cannot be expected due to limited sunlight hours and
- Places without roof.

The result, as illustrated in table 1, was in the range of 2,400 to 56 million kW.

Table 1: Introduction Potential of PV Power Generation on Non-Residential Buildings

Classification	Facility Category	Introduction Potential (10,000 kW)
Public	Governmental buildings	30 to 150
	Schools	740 to 1,100
	Cultural facilities (such as community centers)	100 to 390
	Medical and welfare institutions	10 to 110
	Michi-no-eki (Roadside stations)	10 to 260
	Water supply and sewer systems	60 to 80
	Subtotal	950 to 2,100
Industry	Plants	1,500 to 3,400
	Power stations, etc.	1 to 5
	Subtotal	1,500 to 3,400
Total		2,400 to 5,600

The introduction potential estimated is within the introduction potential of the PV2030+ where the introduction potential of PV power generation for buildings other than residences was estimated to be 8.88 to 91.56 million kW. The result also supported evidence that the ratio of plants, business establishments or schools tended to be high. Accordingly, the importance of policies to promote the installation of PV power generation to such facilities was suggested.

In the Potential Study, suitability of low and unused land suitable for "megawatt solar systems" which are planned or have been constructed was also examined. As indicated in the findings in Table 2, it was estimated to be in the range of 76 to 94 million kW. By combining the potential of non-residential buildings, and low and unused land, the total is estimated to be in the range of 100 million to 150 million kW.

Table 2: Potential for PV Cell Installation at Low and Unused Lots

Lot Classification	Introduction Potential (10,000 kW)
Abandoned cultivated land (*)	6,700
Industrial estates (sold in lots) (*2)	160 to 370
Final disposal sites	310
Others (*3)	390 to 2,000
Total	7,600 to 9,400

(*) It is assumed that for land such as ones being used for forestry or wild land etc that cannot be reclaimed as farm land (because maintaining the physical conditions to reclaim as farm land is very difficult), photovoltaic facilities are installed in parts of land not designated as farm land and land located within designated farm lands but not suitable for farming purposes.

(*2) It is assumed that photovoltaic facilities are installed within a fixed area after subdivision.

(*3) Based on "Research and Development on PV Power Generation Application System and Peripheral Technologies, Research and Development on Diversified Installation Methods" (1995) as compiled by the Central Research Institute of Electricity Power Industry (CRIEPI).

In the Potential Study, a questionnaire survey was conducted for prefectures, ordinance-designed cities, major cities, special cities and special wards (170 municipalities in total) that enquired about conditions for setting goals when introducing to public facilities. From the results, it was learnt that fifteen (15) municipalities set numerical targets for the introduction to public facilities and three (3) municipalities had prepared introduction goals beginning FY2020. However, introduction goals remain under 20% of the introduction potential for public facilities as described earlier and hence further promotion and encouragement of the introduction should be made.

2. Wind power generation

(i) Onshore wind power generation

The resource for onshore wind power generation is often predicted based on the assumption of installing a certain density of wind turbines under favorable wind conditions. Based on the wind conditions map "WinPAS" developed by the Itochu Techno-Solutions Corporation, the Potential Study estimated the resource assuming the installation of wind turbines at sites that are above 80m elevation and have an annual mean wind speed greater than 5.5m/s and the installation is in the range of 10,000 kW/km^2. As a result, the land wind energy resource was estimated to be 1.4 billion kW. The resource for onshore wind power generation within national and quasi-national parks is 17 million kW, which is only 12% of the total.

For the above-mentioned resource map, the resource for onshore wind power generation was projected based on the following scenario by estimating areas feasible for wind turbine installation by overlaying on geographic information system (GIS):

- annual mean wind speed is over 7.5 m/s, over 6.5m/s or over 5.5 m/s;
- altitude less than 1,000m;
- maximum tilt angle of less than 20 degrees;
- distance less than 10km from roads larger than 3m;
- distance from residential area more than 500m;
- prohibited development areas in protection forest areas, special protection zones and Class 1 special zones within national and quasi-national parks, wilderness areas, nature conservation areas, state-designated wildlife protection areas and world natural heritage sites and
- prohibited development areas in fields, building lots, lots used as trunk transportation lines, rivers and wetlands, or golf courses.

As shown in Table 3 and Figure 1, the potential of onshore wind power was estimated to be in the range of 70 million kW to 0.3 billion kW.

The results show that annual mean wind speed has a direct effect on capacity factor and generating cost. For example, the annual mean wind speed of 7.0m/s is equivalent to a capacity factor of 27% [2)]. Based on the findings of the Potential Study, it is possible to estimate the potential in proportion to generating cost.

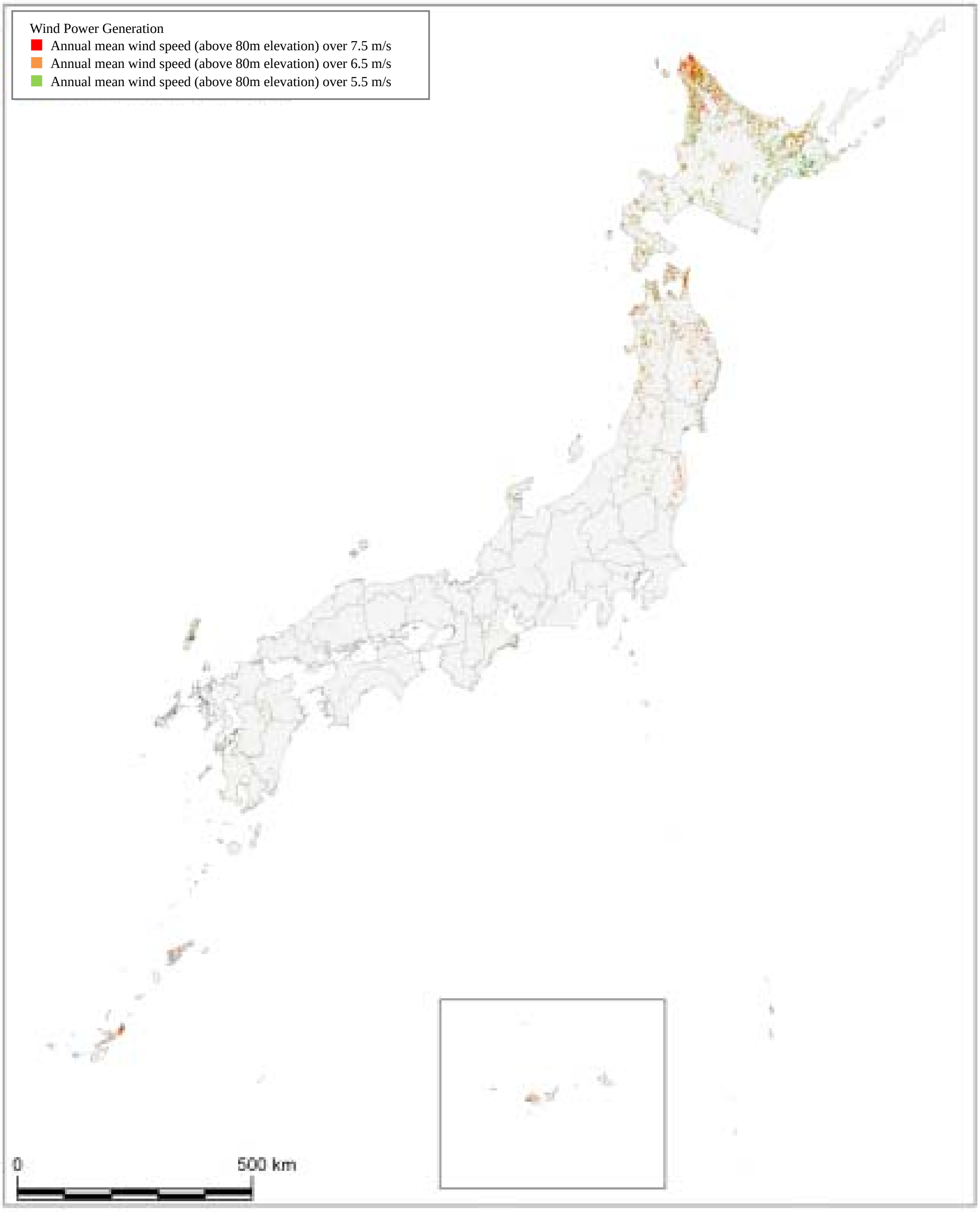


Figure 1: Onshore Wind Power Generation Potential Distribution

(ii) Offshore wind power generation

The resource for offshore wind power generation was also estimated assuming the installation of wind turbines at sites with an elevation above 80m above sea level and with an annual mean wind speed of more than 6.5m/s in a range of 10,000 kW/km^2 based on the WinPAS. From the results, the resource for offshore wind power generation was estimated as 7.7 billion kW.

For the above-mentioned resource map, the potential of offshore wind power was estimated based on the following scenario and by estimating areas feasible for wind turbine installation by overlaying on geographic information system (GIS):

- annual mean wind speed is over 8.5m/s, over 7.5 m/s or over 6.5m/s;
- distance from coast line less than 30km;
- water depth less than 200m (50m for fixed type, between 50m and 200m for floating type) and
- prohibited development area in marine park zones within national and quasi-national parks.

As shown in Figures 2 and 3, the potential for sea-based fixed type and floating type wind power generation were estimated to be in the range of 5.1 million kW to 310 million kW and the range of 56 million kW to 1.3 billion kW respectively.

With respect to offshore wind power generation, promotion of technological development for practical application is very important. In particular, presently the floating type is in research and development stage globally and it is necessary to develop wind turbines that can withstand severe weather conditions such as typhoons prevalent in Japan.

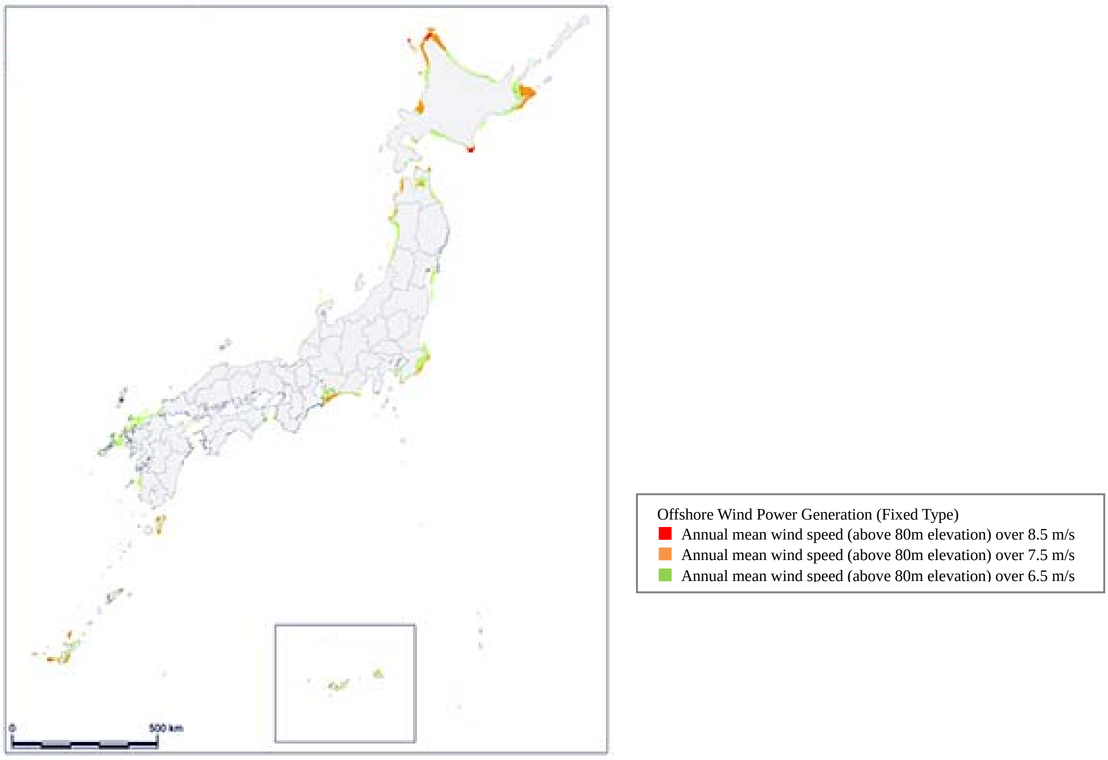


Figure 2: Offshore Wind Power Generation Introduction Potential Distribution (Fixed Type)

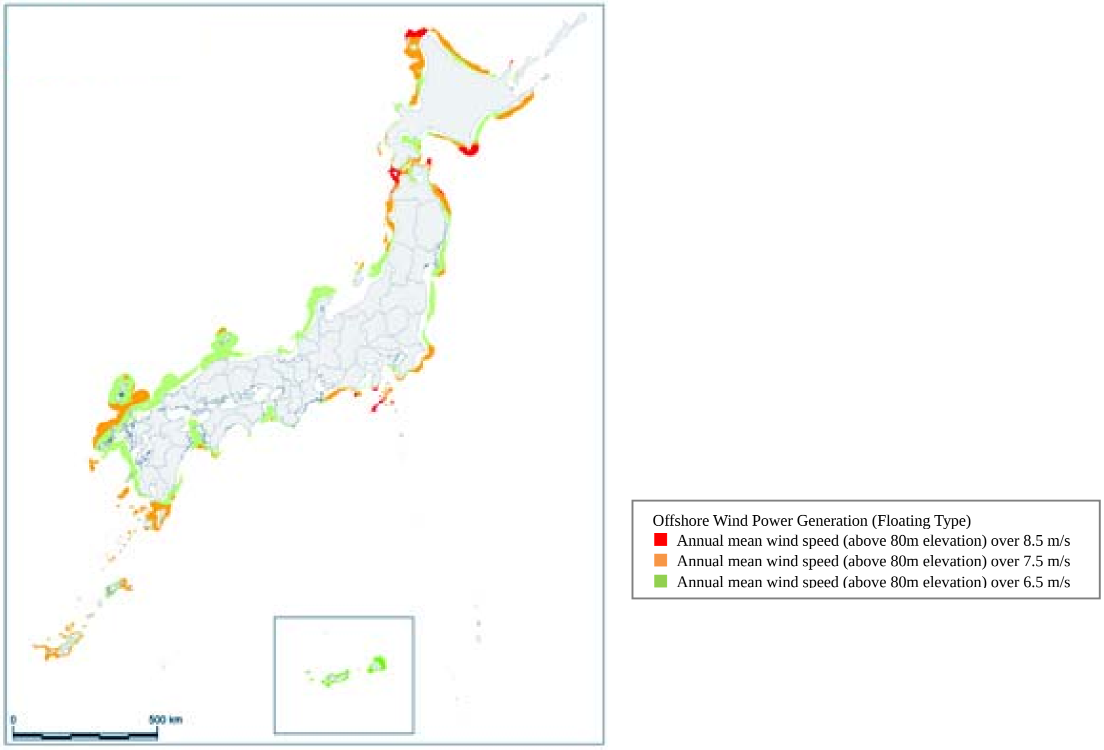


Figure 3: Offshore Wind Power Generation Introduction Potential Distribution(Floating Type)

A characteristic feature of the introduction potential of wind power generation is that the local distribution is extremely uneven. So the simple potential for wind power generation at supply areas of electric power companies in Hokkaido, Tohoku and Okinawa were estimated to exceed the generating system capacity of each electric power company. Change in generated energy from wind power generation to some extent cannot be avoided due to change in weather conditions. Moreover, the interconnection of line capacity between electric power companies is limited. Hence these issues will become limiting factors and hence the capacity that can be assigned to wind power generation is limited to a portion of the local electricity demand. Further, it is also difficult to install windmills in all areas in the range of 10,000 kW/km^2 and hence the realistic potential will be lower than the potential indicated in Table 3. The Japan Wind Power Association prepared an introduction roadmap by setting a long-term introduction goal based on the scenario that wind power generation will provide 10% of the electricity demand nationwide, on the assumption that electric power companies will interconnect to some extent and windmills will be installed in the 1,500 to 1,650kW/km^2 [2)] range.

From the results of the roadmap study, although the distribution of the potential of wind power generation could be obtained from GIS, when establishing project sites, it needs to be stated that local information which cannot be grasped in the GIS level should be accumulated through other means.

3. Medium and small-scale hydro power generation

Although the term “medium and small-scale hydro power generation” has not been strictly defined, the terminology used here will take into consideration the cost of approved projects for medium and small-scale hydro power generation development as conducted by the Ministry of Economy, Trade and Industry, medium and small-scale hydro power generation of less than 30,000kW output.

Although the Study on Potential Hydroelectricity of Unused Fall Head [5)] conducted by the Agency for Natural Resources and Energy is a study on undeveloped hydro power generation potential, with respect to small-scale studies, due to the technical nature of questionnaire surveys, there is a risk that some results may be lower than the actual condition due to the degree of interest of those who responded to the survey. Consequently, in the Potential Study, with respect to water channel alignment data (including altitude data) compiled by the Geographical Survey Institute, catchment flow quantity data and distribution channel water intake data compiled by the Ministry of Land, Infrastructure, Transport and Tourism and prefectures, throughout the entire country was divided into 319 watershed blocks, maintained water volume and water intake flow quantity were taken into account, and the usable water volume was set up. In addition, assuming the installation of hydroelectric power stations at river junctions with catchments within blocks (180,000 locations in total), the usable water volume was established. The annual electric power generation of P (kWh) was estimated assuming 72% generating efficiency as follows:

P (kWh) ＝ 9.8×0.72× assumed annual usable water volume at a generating plant /3,600× effective head at the assumed generating plant.

The construction cost for each assumed electric power station can be estimated by this annual electric power generation, horizontal water conveyance distance and fall head. The potential was estimated assuming the installation of hydroelectric power stations at sites where construction unit cost would be less than ¥2.6 million/kW (installed capacity).

For the above-mentioned potential map, the introduction potential was estimated based on the following scenario and by estimating areas feasible to install windmills by overlaying on the geographic information system (GIS):

- construction unit cost less than ¥500,000/kW, less than ¥1 million/kW, less than ¥1.5 million/kW or less than ¥2.6 million/kW;
- distance less than 10km from roads larger than 3m;
- maximum tilt angle of less than 20 degrees and
- prohibited development in special protection zones and Class 1 special zones within national and quasi-national parks, wilderness areas, nature conservation areas, state-designated wildlife protection areas and world natural heritage sites.

From the results shown in Table 3 and Figure 4, the introduction potential of hydraulic power generation was in the range of 0.8 to 1.5 million kW.

Since the construction unit cost of small-scale hydro power generation is directly related to electricity sales prices for commercialization, based on the findings of the Potential Study, the introduction potential corresponding to the electricity sales prices can be estimated.

Local distribution is also extremely uneven even in the introduction potential of medium and small-scale hydro power generation. Accordingly, the potential was estimated to be concentrated at electricity supply areas in Hokuriku, Tokyo, Chubu and Tohoku.

From the findings of the roadmap, although the potential distribution of medium and small-scale hydro power generation could be obtained from GIS data, it is essential to note that some relevant data, such as fresh-water fisheries rights, have not yet been accumulated. Furthermore, hydro power generation has already been developed at some locations, which is considered to have introduction potential. On the other hand, in cases where water intake for utilization for power generation exists in areas upstream from the flow rate observatory, the flow rate may be underestimated. In addition, although it is assumed that only a single power station will be constructed at a large-scale water channel section of more than 10km, the potential may increase if it is divided allowing for multiple stations. Further, agricultural water channels are not included in the calculation and the standard construction cost is regarded to be a prerequisite for calculating the potential as a threshold value. However, since some locations are actually larger and have been commercialized, the details for these should continue to be examined.

In this Potential Study, the potential and introduction potential of water supply, sewerage and water for industrial use have been examined and the potential and industrial potential were respectively estimated to be approximately 180,000kW and a range of 140,000 to 160,000kW.

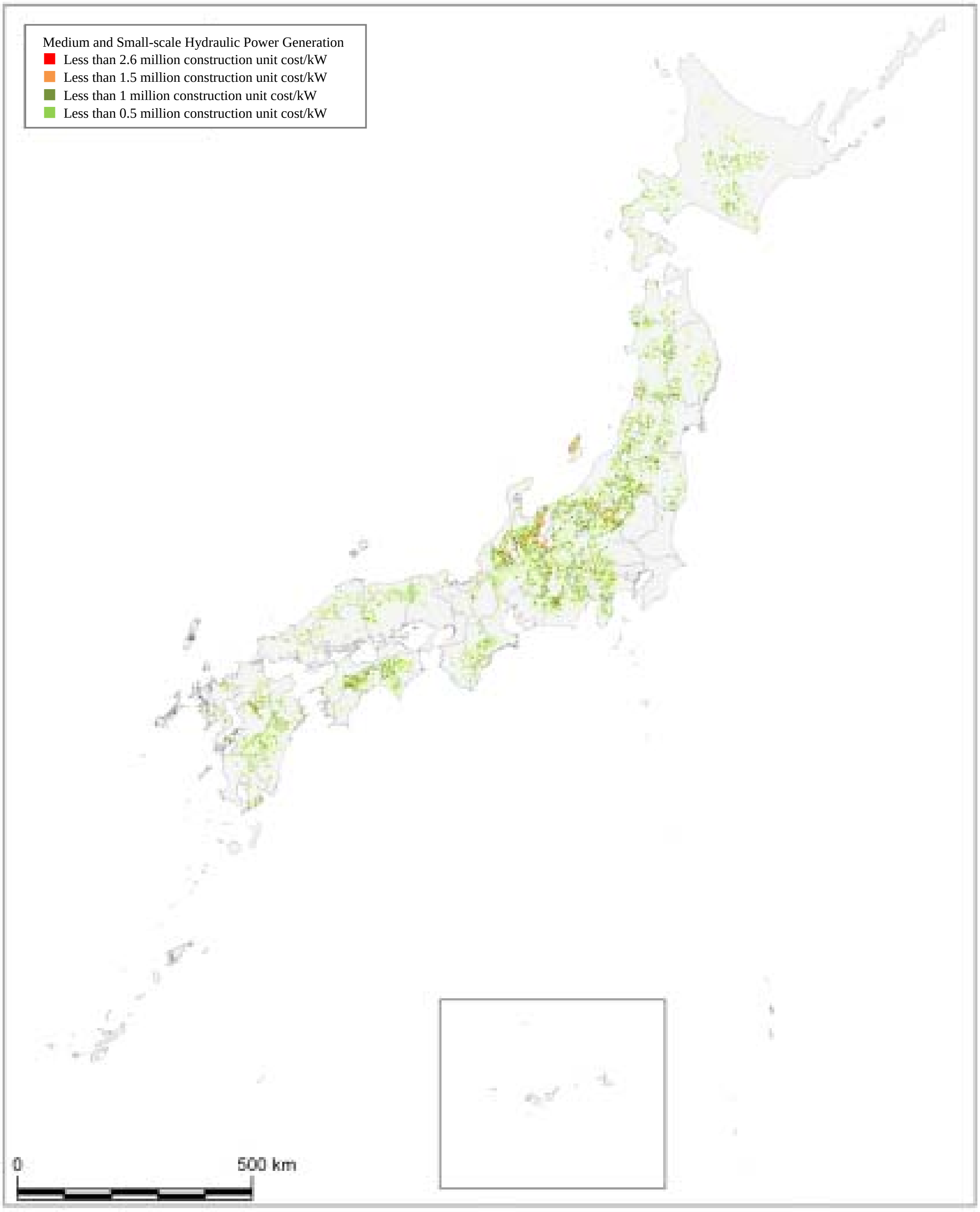


Figure 4: Medium and Small-scale Hydro Power Generation Introduction Potential Distribution

4. Geothermal power generation

In this Potential study, potential was estimated by using information based on geothermal resources density distribution (greater than 150ºC applicable for flash steam generation, 53ºC to 120ºC applicable for Carina cycle generation) prepared by Murakami et al. of the National Institute of Advanced Industrial Science and Technology (AIST) and by newly preparing a geothermal resources density distribution for Rankine cycle generation applicable in 120ºC to 150ºC and by assuming the construction of geothermal power stations at locations with resources density greater than certain level (for example, over 10kW/km^2 at over 150ºC). As a result of the estimation, the potential was estimated to be 24 million kW at over 150 ºC, 1.1 million kW at 120ºC to 150ºC, and 8.5 million at 53 to 120ºC respectively. The potential for national and quasi-national parks with respect to over 150ºC was 19 million kW, which accounted for 83% of the total.

For the above-mentioned potential map and the following scenario, the introduction potential for cases of temperature over 150 ºC and a range of 120ºC to 150 ºC were estimated. Areas feasible for the installation of power stations was estimated through overlaying on the geographic information system (GIS) and a scenario where the power generation cost was designated as a parameter was set.

Introduction potential for over 150 ºC and a range of 120ºC to 150 ºC

- the distance from residential areas is over 100m;
- prohibited development in special protection zones and other special zones (Class 1, Class 2 and Class 3) within national and quasi-national parks, wilderness areas, nature conservation areas, state-designated wildlife protection areas and world natural heritage sites and
- prohibited development on lots used for trunk transportation routes, other lots, rivers and wetlands, and sea waters.

Introduction potential for 53ºC to 120ºC:

- prohibited development in special protection zones and Class 1 special zones within national and quasi-national parks, wilderness areas, nature conservation areas, state-designated wildlife protection areas and world natural heritage sites.
- prohibited development on lots used for trunk transportation routes, other lots, rivers and wetlands, and sea waters.

From the results shown in Table 3 and Figures 5 to 7, the introduction potential of geothermal power generation was 1.1 to 2.2 million kW for over 150ºC, 8,000 to 210,000 kW for 120ºC to 150ºC and less than 7.4 million kW for 53ºC to 120ºC.

Since resources density has a high degree of correlation with generating cost, it is possible to estimate the introduction potential corresponding to generating cost based on the findings of the Potential Study.

With respect to the introduction potential of thermal power generation for over 150ºC, local distribution is extremely uneven and one third (1/3) of the potential exists in Hokkaido and power supply areas of Kansai, Chugoku, Shikoku and Okinawa electricity have very little potential for geothermal power generation. However, as was seen in wind power generation, there are no areas where the estimated value was expected to exceed the generating facility capacity of an electric company. Locally uneven distribution was recognized to be somewhat relaxed in areas with temperature range of 53ºC to 120ºC.

In addition to the points mentioned above, introduction of hot spring power generation at pre existing hot springs and other naturally occurring hot springs was considered. There is a less degree of risk in the development of hot spring power generation to generate power by utilizing existing hot springs, and its potential is estimated to be 720,000kW for locations with capacity of over 30kW/location[3)]. Although generating cost is considered to be less than ¥36/kW, compared with the generating cost of flush steam generation, economic side could be a challenge and hence technologies for lowering the cost need to be developed.

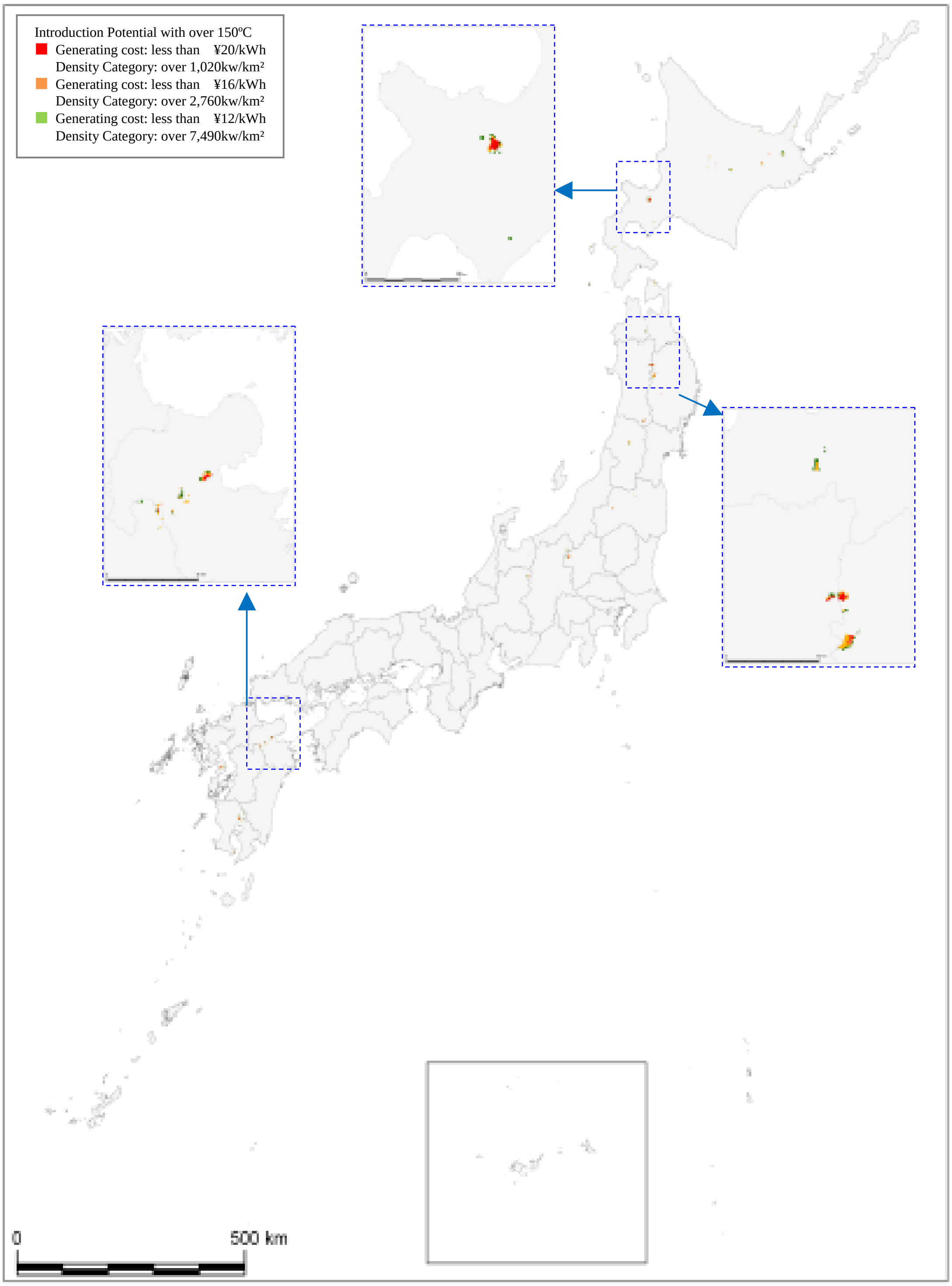
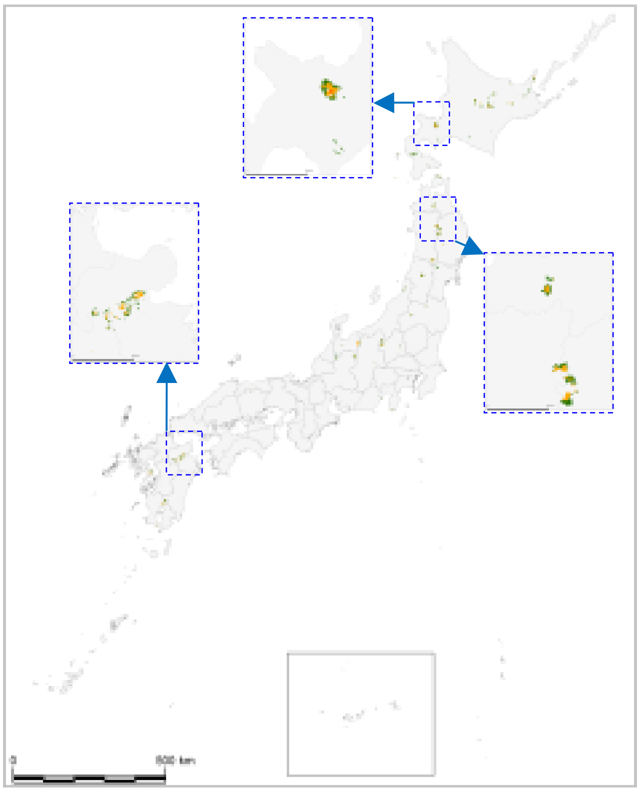


Figure 5: Geothermal Power Generation Introduction Potential Distribution (over 150ºC)



Introduction Potential with over 120 to 150ºC
Generating cost: less than ¥48/kWh
Density Category: over 7kw/km²
Generating cost: less than ¥36/kWh
Density Category: over 88kw/km²
Generating cost: less than ¥24/kWh
Density Category: over 1,050kw/km²

Figure 6: Geothermal Power Generation Introduction Potential Distribution (120ºC to150ºC)

Introduction Potential with over 53 to 120ºC
Generating cost: less than ¥48/kWh
Density Category: over 17kw/km²
Generating cost: less than ¥36/kWh
Density Category: over 164kw/km²
Generating cost: less than ¥24/kWh
Density Category: over 1,590kw/km²

* No area is applicable to less than generating cost of ¥24/kWh and density category of over 1,590kw/km².

Figure 7: Geothermal Power Generation Introduction Potential Distribution (53ºC to120 ºC)

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(3) Masaru NAKAJIMA: Secretary General, Japanese Association for Water Energy Recovery
(4) Hiroki HONDO: Associate Professor, Graduate School of Environment and Information Sciences, Yokohama National University

Sources

(1) New Energy and Industrial Technology Development Organization (NEDO), Photovoltaic (PV) Roadmap Toward 2030 (PV2030+), June 2009, p115 (http://www.nedo.go.jp/library/pv2030/pv2030+.pdf)
(2) Japanese Wind Power Association, Long-term Wind Power Generation Introduction Goal and Roadmap, V1.1, January 2010, p13 (http://log.jwpa.jp/content/0000288882.html)
(3) Yukio ETO and Hirofumi MURAOKA et al., Contribution of Geothermal Energy to 2050 Natural Energy Vision, Journal of the Geothermal Research Society of Japan (GRSJ), 30 (3), 2008

Table 3: Renewable Energy Potential and Introduction Potential

Unit: 10,000kW

		Wind Power Generation			Medium- and Small-scale Hydro Power Generation (*)	Geothermal Power Generation (*2)			(Reference) Generating Capacity of Electric Companies (FY2008)
		Onshore	Offshore (Fixed type)	Offshore (Floating type)		Over 150ºC	120 to 150	53 to120	
Potential		140,000	770,000		1,800	2,400	110	850	
Introduction Potential (by electricity supply region)	Summary Value by Scenario	7,000 to 30,000	510 to 31,000	5,600 to 130,000	80 to 1,500	110 to 220	0.8 to 21	0 to 740	20,218
	Hokkaido	3,000 to 15,000	470 to 12,000	3,800 to 28,000	2 to 130	39 to 71	0.6 to 7	0 to 246	650
	Tohoku	2,100 to 7,400	7 to 4,400	1,000 to 18,000	14 to 410	38 to 76	0 to 5	0 to 194	1,680
	Tokyo	100 to 450	32 to 2,800	640 to 5,200	15 to 220	10 to 18	0 to 1	0 to 112	6,398
	Hokuriku	44 to 520	0 to 420	0 to 5,900	19 to 190	0 to 0.3	0.1 to 3	0 to 26	796
	Chubu	250 to 870	0 to 1,900	110 to 1,900	16 to 270	1.2 to 5.5	0 to 1	0 to 88	3,263
	Kansai	330 to 1,300	0 to 160	0 to 2,400	2 to 38	0 to 0.2	0	0 to 8	3,386
	Chugoku	190 to 1,000	0 to 460	0 to 15,000	4 to 64	0	0	0 to 15	1,183
	Shikoku	110 to 530	0 to 390	0 to 3,800	3 to 73	0	0	0 to 4	666
	Kyushu	630 to 2,200	2 to 5,400	48 to 40,000	3 to 100	25 to 49	0.1 to 3	0 to 52	2,002
	Okinawa	280 to 560	1 to 2,800	1 to 6,300	0 to 0.2	0	0	0	192

(*) Less than 30,000kW of facility capacity: water supply, sewerage and water for industrial use (approximately 180,000kW of the potential) are not included.
(*2) The potential of hot spring power generation is not included.