In the announcement posted on the ministry's official website, the MOE said it decided to give the consortium, led by Kyuden Mirai Energy Co., a Kyushu Electric Power Co. subsidiary, a budget allocation of up to 3.6 billion yen for the four-year period to cover the consortium's expenditures for the tidal current-propelled electricity generation demonstration project.

The announcement also included details about the MOE's decision to provide the consortium with the budgetary aid "to expand the volume of electricity generated from renewable energy sources" for consumption in Japan.

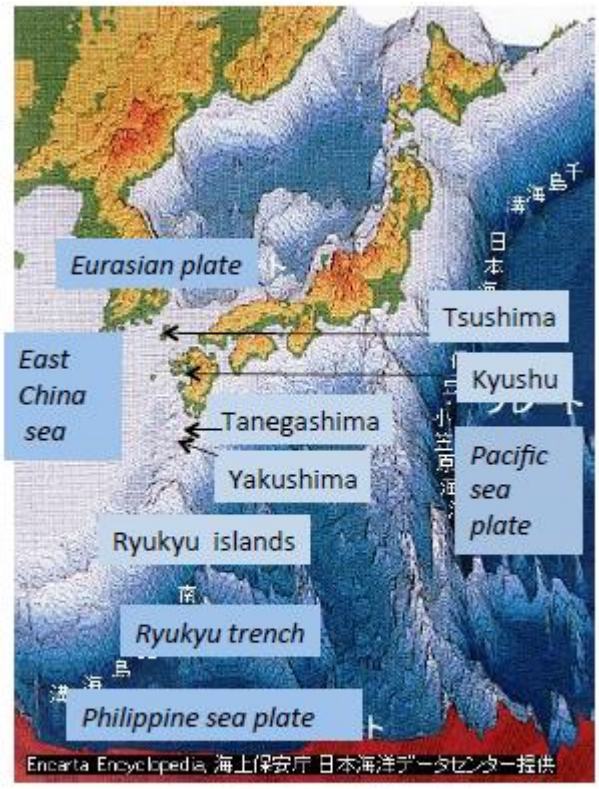


Figure 3- Three dimensional vision of Subsea shelf around Japan

According to the announcement, the government will seek to develop: "the type of tidal current-propelled electricity generation technology suitable for Japan's maritime conditions which would provide the high possibility of being disseminated in Japan and which could limit an impact on the environment through the consortium's demonstration project [in the Nagasaki waters]."

This announcement is consistent with the government's announcement on July 26 2015 that it has decided to adopt a new energy-mix policy goal of bolstering by 2030 the percentage of electricity from renewable energy sources in Japan's annual electricity consumption to "22-24 percent," which is higher than the projected ratio for nuclear power at 20-22 percent for the target year of 2030.

By comparison, the same energy-mix goal calls for limiting the percentage of electricity generated with the combustion of LNG to 27 percent of Japan's annual consumption and that of electricity generated with coal to 26 percent by the same deadline.

Probably, you still remember the vivid newspaper images and television news videos of the Great East Japan Earthquake, and the ensuing devastating tsunamis of March 11 2011, which pounded Japan's northeast, as well as the resultant meltdowns of some nuclear reactors at the Fukushima Daiichi nuclear power plant of Tokyo Electric Power Co. in Fukushima Prefecture, north of Tokyo, and the terrifying consequences.

Japan has since suspended operations of all of its 54 reactors amid voters' wariness of nuclear power. But the government is seeking to restart as many reactors as possible in light of what it perceives as the relatively low generation costs of electricity generated with nuclear reactors. Currently, only two reactors are operating amid lingering voter wariness, despite it being five years since the nuclear disaster.

The horrible post-quake events, voter wariness and annual huge trade deficits stemming from Japan's greater dependency on imported coal and LNG to satisfy its mammoth energy needs have led Japanese policymakers, physicists and journalists to pay keener attention to the appropriateness and necessity of taking advantage of renewable energy resources as far as possible - in lieu of depletable fossil fuels, and nuclear fuels which could trigger a radioactive tragedy if handled carelessly.

In 2014, Japan incurred a trade deficit of 9.1 trillion yen, against a trade surplus of 5.3 trillion yen in 2010, before the nuclear accident. In 2013, Japan's dependency on imported fossil fuels - coal, oil and natural gas - stood at a combined 92 percent of its annual energy consumption, against 81 percent in 2010.

Two years after the nuclear mishap - in April 2013 - the government unveiled a key energy policy announcement entitled, "The Basic Plan on the Use of Oceans," in which it declared that tidal currents are one of the most important renewable energy sources for Japan and that it will

promote the use of ocean renewable energy as a national policy. Voter wariness of nuclear power appears to have encouraged the government to consider the use of ocean renewable energy sources seriously.

Then, on July 15th 2014, after examining data on the hydrographic conditions gathered by the MOE, the national government designated three sea areas off Nagasaki's Goto Archipelago as part of its plan to create six government-endorsed demonstration fields for ocean renewable energy.

I am certain that this archipelago provides the most suitable tidal-current, as well as topographic and other hydrographic conditions, for tidal current-propelled power generation in Japan. It also has suitable social conditions.

This is due to a convergence of multiple favorable factors: its rapid tidal current speed; the idealistic topography of the archipelago, the Kyushu Island and the East China Sea; the archipelago's location in the midst of the open waters of the East China Sea (and the resultant unlikeliness of industrial pollution); its detachment from heavy-traffic shipping lanes; and finally, the understanding of local fisheries cooperatives and the sympathetic attitude of the Goto City Government.

I hope the ITES will give the world's tidal current turbine makers, developers and other industry players a good opportunity to recognise that Nagasaki can provide excellent business opportunities on account of the archipelago being a huge tidal current energy resource, with a vastness that has been verified and validated by voluminous data obtained via four rounds of ADCP investigation campaigns in 2013, 2014, 2015 and 2016, by the Environment Ministry, Kyushu University and by Professor Kyozuka himself.

Generating power with tidal current turbines in the archipelago's straits would give turbine makers and project developers a good reputation, which appears to be an excellent and necessary first step to cash in on the gigantic Asian market, with its vast business potential.

There is the good possibility that turbine makers will be able to profitably generate large quantities of electricity at the archipelago when Japan reaches a stage where large-scale projects are implemented commercially, judging from the results of mathematical integrations stemming from Kyushu University's finite-volume coastal ocean model (FVCOM) outputs on tidal energy resource, which show that the quantity of electricity, once harnessed with a good turbine, would top even 17 megawatt-hours per square meter per year at many Naru Strait locations.

There are many high-energy locations in the archipelago's straits, including Tanoura Strait sandwiched by Fukue and Hisaka Islands, which have so far remained untapped, but which have drawn attention from European tidal energy industry titans like OpenHydro and Atlantis.

3. Why is Nagasaki such a valuable tidal resource?

First of all, let us briefly look at the very basics of oceanography.

The gravitational attraction of the moon's mass is "pulling" on the water in every part of the worldwide ocean, but this pull is strongest on the side of the earth that is closest to the moon. This gravitational pull creates a "tidal bulge of water" on this moon-facing side, whereas the water on the side of the earth that faces AWAY from the Moon bulges outwards as a result of the centrifugal effect.

The earth spins around its axis. As it rotates about its axis, "a point" on the earth's surface passes into and out of these bulges of water, creating the tides.

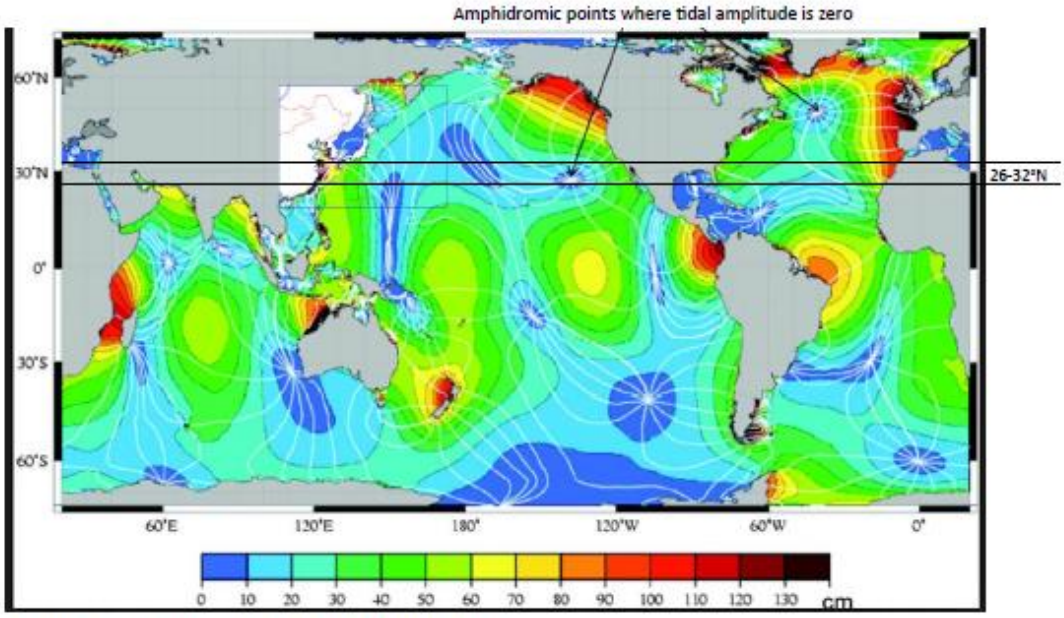


Figure 4- Cotidal chart of North Hemisphere

For example, picture Hawaii in the midst of the Pacific Ocean as an example of such a "point" passing into and out of the tidal bulges. When Hawaii enters a water bulge, the tide rises. When Hawaii leaves a water bulge, the tide falls.

Bearing this in mind, now let me explain WHY the archipelago's straits provide such fast and energetic tidal currents.

In a word, the rapid tidal currents are the consequence of the geometry and topography of the straits and islands of the Goto Archipelago: the bottom topography of sea beds around the Kyushu Island and in the Western Pacific Ocean, and the bottom topography of the East China Sea, as well as the Coriolis force.

Allow me to explain. First of all, let me call your attention to the bottom topography of the undersea shelf stretching from the shorelines of Kyushu Island, on which the Nagasaki prefecture lies: the bathymetric chart of the East China Sea sandwiched between China and Kyushu's west coast, and by the bottom topography of the Western Pacific south of Kyushu.

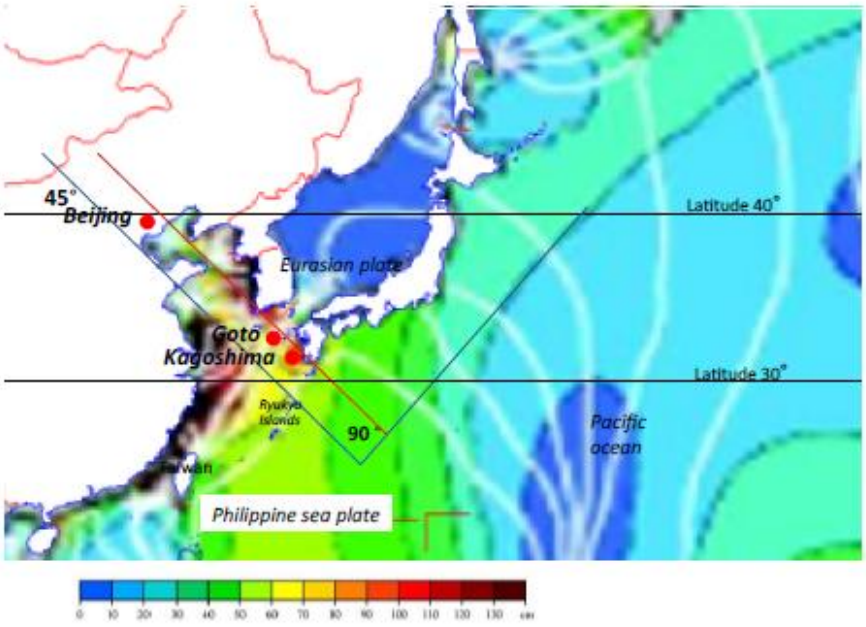


Figure 5- Cotidal chart of Sea around Japan

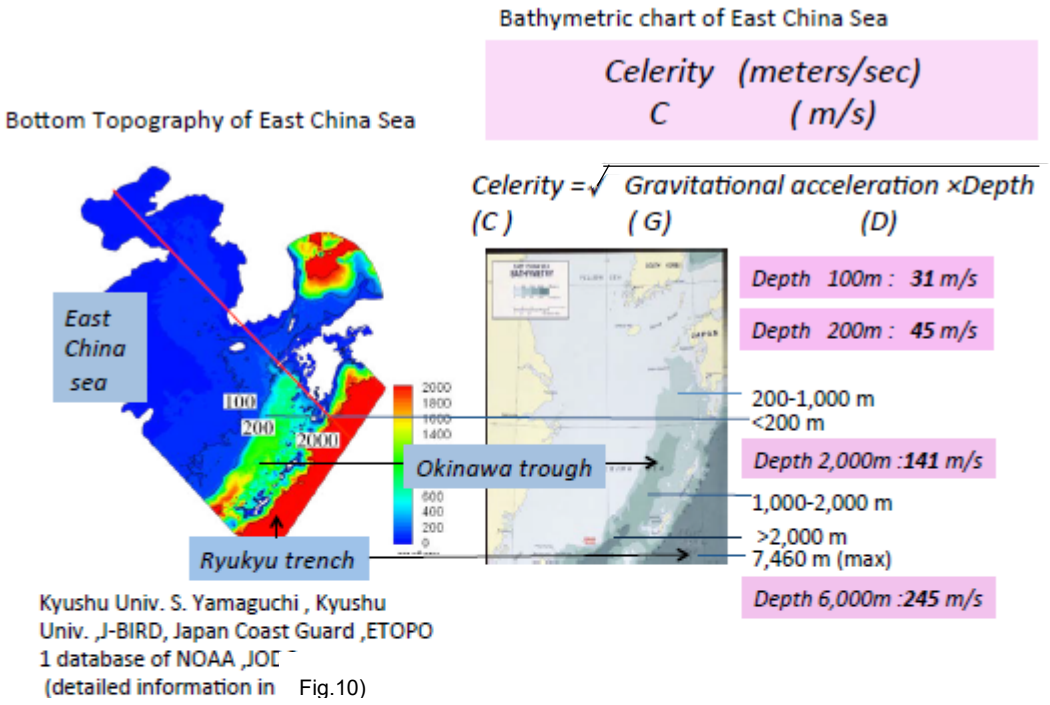


Figure 6- East China Sea

During my PowerPoint presentation for the ITES on November 22nd, I will present a few images that show the geography of relevant landmasses as well as the bottom topography and bathymetric chart of relevant ocean areas.

(For these answers to be posted on the Tidal Today website, please use the bathymetric chart of the East China Sea that can be easily retrieved from the Library of the Congress website - or from the first page of the Wikipedia's description about the "Ryukyu Trench" that carries the beautiful bathymetric chart of the ocean areas sandwiching the Ryukyu Trench and which also shows Kyushu and the eastern coast of China.

You have only to enter three search words - the East China Sea, bathymetry and the Library of Congress - inside a Google window, or enter just one search word, Ryushu Trench, in the case of Wikipedia. Then, you will get the bathymetric charts.)

The size of Kyushu is half that of Scotland's. Nagasaki prefecture occupies roughly the upper half of the west coast of Kyushu, which is the shape of an elongated hexagon. If you focus your attention on the shape of the subsea shelf stretching from Kyushu, you will immediately understand that it looks like a bunch of a grapes, with two large grapes hanging from the bunch's southern tip. These two grapes are the Tanegashima and Yakushima Islands.

In the wide stretch of oceanic areas south of the Japanese Archipelago, the tidal wave generally shifts from east to west, because the earth turns eastward, bringing the archipelago's surrounding waters into the two tidal bulges of water successively. Now, please pay attention to how the tidal wave propagates through the wide swaths (belt) of oceanic area sandwiched between the northern latitudinal lines of 26 and 32 degrees. This strip of the oceanic area is as wide as 670 kilometers.

Kyushu is the point which is firstly washed and reached by this wide swaths of tidal wave when its surrounding waters enter the tidal bulge as a result of the earth's rotation around its axis. As this tidal wave approaches the shorelines of Kyushu and, then, the Ryukyu Islands - which is the long 1,000-kilometer chain of islands separating the Western Pacific and the East China Sea, which look like a long string of stepping stones from Kyushu to Taiwan, lying along the Ryukyu Trench - the local sea bottom starts interfering with the motion of water particles beneath the wave.

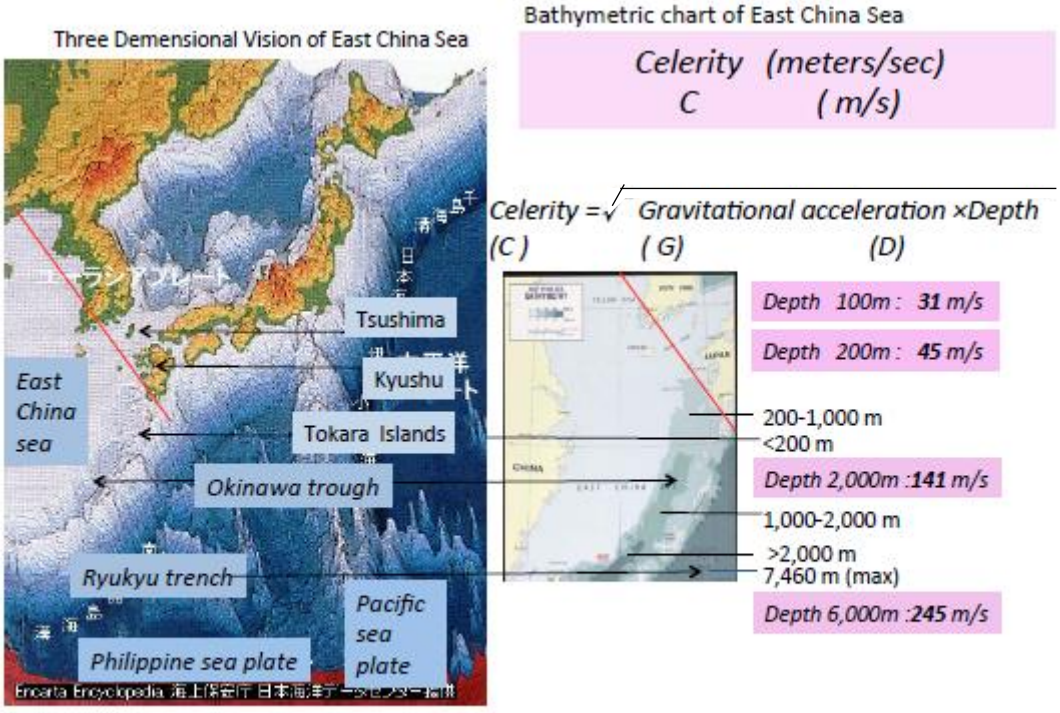


Figure 7- Celerity around Japan

The tidal wave acts as a shallow-water wave due to its long wavelength. The influence of the bottom alters the wave's speed. When the tidal wave begins to interact with the bottom, it slows down and its speed is regulated directly according to the water depth.

The famous formula for calculating the speed of a shallow-water wave is C = √(the square root) of g.d, where C is celerity (i.e., speed), g is gravitational acceleration, and d is water depth in meters. This formula says that, regardless of the height or length of a wave, the celerity of all shallow-water waves is governed entirely by water depth. Note that the shallower the water, the slower is the speed of a shallow-water wave.

Now, take a look, firstly, at the bottom topography of the waters around the eastern, southern and western shores of Kyushu, then that of the ultra-deep Ryukyu Trench (whose maximum depth is 7,460 meters), then that of the wide stretch of the deep-water area south of the trench (roughly 6,000 meters), then that of the waters whose depths range from 200-1,000 meters which lie northwest of the chain's Tokara Islands segment, then that of the waters whose depths are between 1,000 and 2,000 meters northwest of the chain's Amami and Okinawa Islands segment - and, finally, at that of the East China Sea, whose continental shelf extends eastward towards Kyushu for some 300-500 kilometers, limiting the depths of waters above the shelf to up to 200 meters.

You can easily grasp this overall picture if only you take a glance at the Library of Congress's bathymetric chart.

In it, the gray area has a depth of up to 200 meters. The navy (deep-blue) area has a depth of over 2,000 meters. The light-blue area northwest of the chain's Tokara Islands segment has a depth of 200-1,000 meters, while the blue area has a depth ranging from 1000 to 2000 meters.

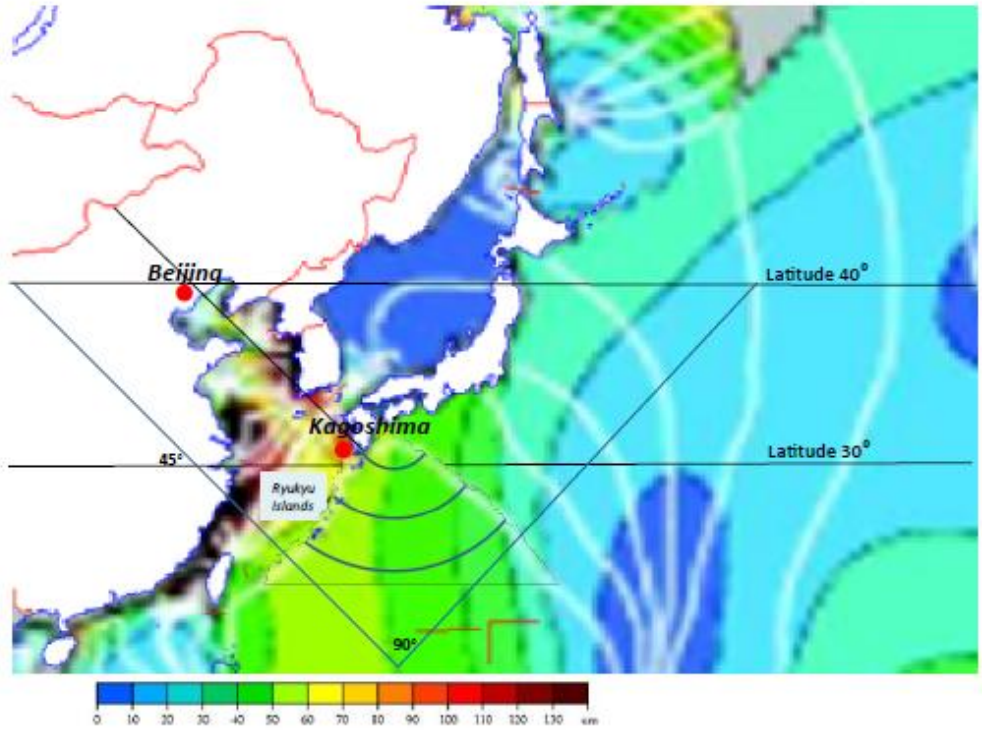


Figure 8- Cotidal Chart of Sea around Japan

At many locations within the wide oceanic area which have a depth of 2,000 meters south of the Ryukyu Trench, the speed of the tidal wave comes to 141 meters/sec. because of the same law. At many locations south of the trench where the depth is 6,000 meters, the speed of the tidal wave comes to 245 meters/sec. At the location where the trench is deepest, the speed stands at 273 meters/ sec.

Summing up, the closer to Kyushu the tidal wave propagates, the slower is the speed of its propagation. In other words, the further away from Kyushu the tidal wave progresses, the faster is the speed of its propagation.

Consequently, the tidal wave is forced to take a gigantic right-hand curve in the wide stretch of waters that lie southeast, south and southwest of Kyushu as if the tidal wave were pushing a huge pendulum whose pivot is at Kyushu's southern tip (Satsuma Peninsula).

As a result, the tidal wave is given a generally fixed direction. Namely, it is forced to propagate northwestward - from the southeast to the northwest (i.e. in the southeast-to-northwest direction) - when it progresses into the East China Sea from the Western Pacific. It propagates, roughly, from the waters off the southern tip of Kyushu in the direction of Beijing (which has the coordinates of 39°55′N, 116°23′E).

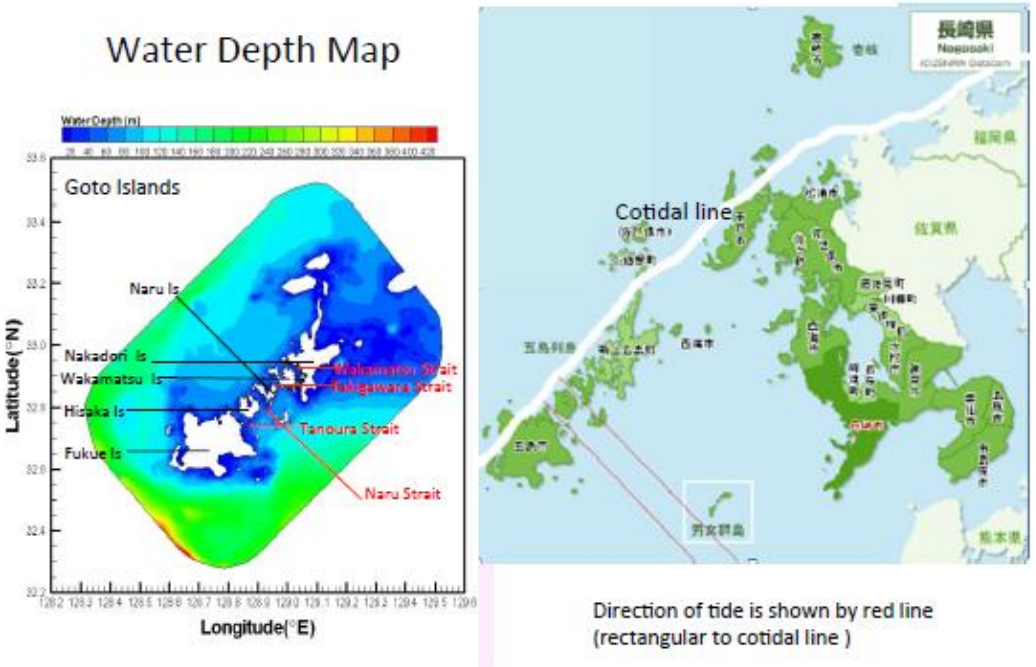


Figure 9- Cotidal line along Goto Archipelago

In other words, the tidal wave progresses with a supplementary angle of roughly 45 degrees in relation to latitudinal lines.

Let me use a metaphor.

Suppose that a 100-kilometer-high Titanic footballer, now standing at the southern tip of Kyushu (the Satsuma Peninsula), kicks a super-long free kick in the direction a goal post set up at Beijing's coordinates. Imagine such a Titan - a sort of gigantic David Beckham - lobbing a ball towards these goal post set up in Beijing. Now imagines that this colossal Beckham scores a goal with one amazing shot, which has the supplementary angle of 45 degrees to Bejing's latitudinal line of 39°55' N.

In actuality, this angle of 45 degrees in relation to latitudinal lines is given to the tidal wave as a result of both the bottom topography of the submarine shelf stretching westward from the landmass of Kyushu and that of the continental shelf stretching westward from the eastern coast of China – and, thanks to the presence of much deeper waters at numerous locations along the Ryukyu Trench, at the Western Pacific as well as above the Ryukyu Trench and the Okinawa Trough.

The straits of the Goto Archipelago stretch from southeast to northwest, because the archipelago stretches in the southwest-northeast direction. In other words, the direction (trend) of the four straits is IDENTICAL to the direction in which the tidal wave propagates. This is a big factor which is responsible for the rapidity of tidal currents at the straits.

The tidal wave has been already given this idealistic angle of roughly 45 degrees - long before it reaches the entrances of the straits. The shape, geometry and the bottom topography of the Goto Archipelago's straits and islands also strongly contribute to speeding up tidal currents at the straits.

Since the tidal wave intrudes into, and weaves through, these narrow straits between the archipelago's major islands - Fukue, Hisaka, Naru, Wakamatsu and Nakadori - resultant tidal currents inevitably speed up, generating large quantities of kinetic energy that can be converted into abundant electric energy with the help of a tidal current turbine.

In addition, once the tidal wave breaks into the archipelago's four straits (Tanoura, Naru, Takigawara and Wakamatsu), water depths available at the straits become even shallower. To cite just two examples, the depths of Naru and Tanoura Straits range from 40 to 60 meters, compared with the depths of 100-200 meters of the waters above the submarine shelves surrounding the archipelago.

While the tidal wave negotiates its way through the archipelago's narrow channels, the speeds of resultant tidal currents surge because the constant volume of seawater must weave through a string of narrowed-down cross sections of the water passages within a fixed duration, regardless of the varying widths of the passages at varying locations along the passages, before the seawater can get out of them and flow into the open sea.

These topological, geometric, geographical, astronomical and oceanographic factors are responsible for the enigma of fast tidal currents at the archipelago's straits. The Coriolis force is also responsible for the gigantic right-hand curve of the tidal wave around the Kyushu Island.

4. What do you see as the main challenges for Project Developers and OEMs working in Japan?

The most important task in encouraging a greater use of marine renewable energy in Japan is to get Japanese society - voters, journalists and politicians - to recognize the usefulness of marine renewable energy.

At present, the national government places priority on satisfying Japan's energy needs by using the cheapest possible energy sources. What matters most for the government's energy policy planners is a comparison of the costs of generating electricity using different energy sources.

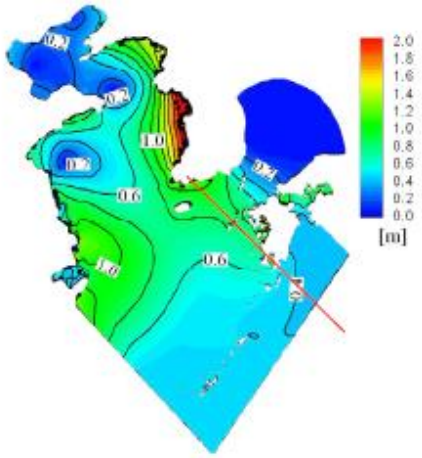
Japan satisfied 92 percent of its energy needs in 2013 on the basis of imported fossil fuel - oil , coal and natural gas. Although this heavy dependency is chronic, the dependency ratio swelled to this level after the Great East Japan Earthquake in 2011 (when oil, coal and natural gas provided only 81 percent), after which Japan suspended the operations of all of its 54 nuclear reactors in the aftermath of the reactor meltdowns at the Fukushima Daiichi Nuclear Power Station.

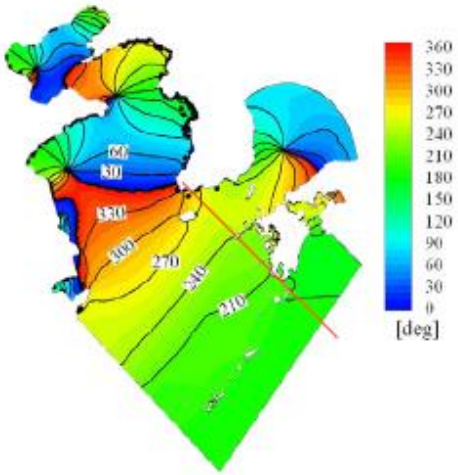
It is high time for Japan to realize and to ponder on the fact that abundant marine renewable energy sources can be obtained domestically. The marine renewable energy industry can become an industry dependent on Japan's own huge domestic demand for electricity.

If Japanese society comes to recognize that the cost of electricity generated with tidal turbines could be driven down to levels that could compete with costs of electricity generated with other energy sources by innovating turbine and relevant technologies, it would be able to make tidal current generation a widely used generation method.

With this social awareness, Japan would be able to legislate a feed-in-tariff system for electricity generated with tidal turbines. Japan's feed-in-tariff system currently pays 36 yen per kilowatt-hour of electricity generated with solar cells. It is now appropriate to establish a feed-in-tariff system for power generated with tidal turbines.

Currently, Japan is on the verge of taking the first step towards accomplishing this goal of making tidal current-based generation a widely used generation method on the basis of the entry of OpenHydro/ DCNS into its energy market and the efforts of engineers, physicists, administrators and other people willing to contribute towards this goal. Japan needs to tackle this issue with a long-term perspective.

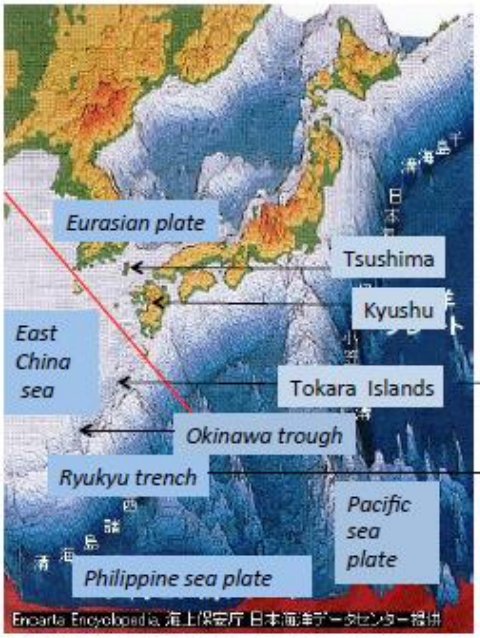




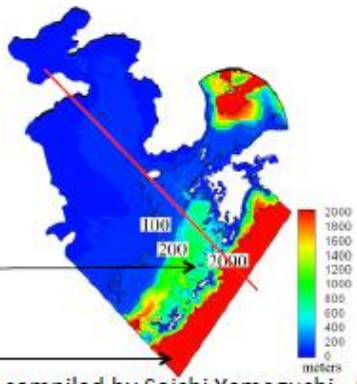
Charts compiled by Soichi Yamaguchi , Associate Professor , Dept.of Earth System Sci. & Tec, Faculty of Engineering Science , Kyushu Univ.
Source of Data analyzed with a Kyushu Univ. supercomputer; J-BIRD, Japan Coast Guard and the ETOPO 1 database of NOAA, JODC

Figure 10(1)- Amplitude of East China Sea

Figure 10(2)- Phase Chart of East China Sea



Bottom topography



Charts compiled by Soichi Yamaguchi , Associate Professor , Dept.of Earth System Sci. & Tec, Faculty of Engineering Science , Kyushu Univ.
Source of Data analyzed with a Kyushu Univ. supercomputer; J-BIRD, Japan Coast Guard and the ETOPO 1 database of NOAA. JODC

Figure 16 - Bottom topography of East China Sea

Figure 11 Amplitude of East China Sea

5. Do you see collaboration with other Asian countries in the near future?

Noble human beings extend a helping hand to others regardless of the nationality of the people they are dealing with. Japanese people, who have good intentions, are ready to help others. Kyushu University Professor Emeritus Yusaku Kyozuka, who currently acts as a Nagasaki University Professor, has said openly that he is consideirng cooperation with people of other Asian countries.

6. Where do you envisage Japan's tidal sector being in the next 5 years?

If we can bring the MOE-funded OpenHydro/DCNS demonstration project that began this year in Nagasaki's Naru Strait to a successful conclusion, it would embolden OpenHydro, other turbine manufacturers and project developers to draw up plans to implement commercial tidal current farms in the waters in and surrounding the Goto Archipelago.

As these moves gain momentum, multiple turbine makers and project developers will come to devise plans to deploy tidal turbine farms in other locations of Kyushu Island and at the long Seto Inland Sea sandwiched between the Shikoku Island and the Honshu main island, the biggest among Japan's four islands making up the Japansese Archipelago.

It is necessary to keep in mind that we must be a bit patient. I think it will take at least 10 years for commercial-scale tidal current generation to become fully-fledged in Japan.