IHI is Striving to Make Renewable Energy Widely Available

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It is urgent that renewable energy be promoted in order to prevent global warming and secure sufficient quantities of fossil fuel for the next generation. IHI is committed to the development of renewable energy, especially marine and biomass energy, (which uses wood and algae), to contribute to Japan's domestic energy self-sufficiency, with an eye to further global expansion. Furthermore, we are able to offer a lithium ion battery system to supplement inconsistent sources of energy such as solar and wind power. IHI is always striving to realize the dream of sustainable global development based on renewable energy.

1. Introduction

Awareness of the risk of global warming and the nuclear power plant accident triggered by the 2011 off the Pacific coast of Tohoku Earthquake (the Great East Japan Earthquake) in March 11, 2011, has meant increased interest in the promotion of renewable energies.

Renewable energies are defined as "those recognized as permanently usable energy sources" by law, indicating that the energies concerned are "renewable" without depletion.

These energies include well-known examples such as "sunlight," "wind," etc. **Table 1** shows various categories of renewable energies.

Table 1 Types of renewable energy

Item	Marine energy	Materials and events
1	Ocean energy	- Waves - Rise and fall of the tide - Ocean current *1 - Temperature difference between surface and bottom sea water *1
2	Energy from biomass (biological resources)	- Wood biomass *1 - Glass and plant biomass (including algae) *1 - Organic waste biomass *1
3	Solar energy	- Solar heat - Sunshine *1
4	Wind energy	- On land wind force - Offshore wind force
5	Water energy	- Large-scale hydraulic power generation - Medium-to small-scale hydraulic power generation
6	Geothermal energy	
7	Snow and ice cold energy	
8	Energy from unused temperature difference *1	

(Note) *1 : Energies currently challenged by IHI

2. Introduction of the IHI approach to renewable energies

This approach to renewable energies covers wide-ranging fields. Rather than solely encompassing the generator set directly involved and similar technologies and products, it also includes materials related to their utilization, development and promotion as well as the renewable energy supply industries.

Among IHI's multitude of approaches related to renewable energies, this paper introduces the following approaches:

(1) Utilization of boundless marine energy
 ① Ocean current power generator
 ② Ocean thermal energy conversion

(2) Utilization of blessings of forests
 ① Development of high-performance forestry machines that help boost the efficiency of wood biomass harvesting
 ② "IHI's forestry package" targeting local production for local consumption
 ③ Gasification of wood biomass
  - Cogeneration (supply of electricity and heat)
  - Methane production
 ④ Mixed combustion with a high ratio of wood biomass in coal-fired power plants
 ⑤ Wood biomass power generation industry of USA

(3) Extracting energy from mainly food-related plant effluent
 - Generation of methane gas using the IHI-IC reactor and gas-engine co-generation

(4) Photovoltaic power generation
 ① EPC project of photovoltaic power generation plants
 ② Mega-solar power project

(5) Storage of renewable energy
 ① Lithium-ion battery system
 ② Production of biofuel from oil-producing microalgae
 ③ Production of bioethanol from non-edible plants

(6) Power generation at low-grade heat below 100°C
 - 20 kW micro binary power generation system

3. Utilizing energy from the vast ocean

Japan is surrounded by the sixth-largest Exclusive Economic Zone (EEZ) in the world, and producing energy from the ocean with due consideration to the environmental impact is quite rational for this resource-poor country in an effort to enhance its self-sufficiency ratio in terms of the energy supply. When comparing a case of constructing a plant on land, however, many challenges in terms of cost-effectiveness and technologies remain, and patient efforts are needed.

IHI is addressing the following two technologies from three perspectives of ① relatively large-scale power generation with a single system, ② stable power generation, and ③ optimally exploiting the merits of the IHI Group.

3.1 Ocean current power generation

One of the methods of utilizing marine energy involves driving turbines by ocean currents, similar to the wind force generation process. "Tidal power generation" involves using the rapid flow caused by the rise and fall of the tide in narrow straits. Conversely, while ocean current power generation involves a slightly slower current flow, it remains stable in terms of flow direction and power generation provided all year round (**Fig. 1**).

In a consortium with other outside organizations, in 2011, IHI commenced R&D into this "ocean current generation" officially commissioned by New Energy and Industrial Technology Development Organization (NEDO). The strong "Kuroshio" ("Black current") ocean current runs close to Japan's coastline, and the related technology is anticipated to be applicable in regions favorable for power transmission, namely the sea area around Yakushima, Kagoshima Prefecture: off Kochi Prefecture: off Kii Peninsula and the Ogasawara Islands, etc. There are plans to have a single twin-turbine 2 MW generator set, with a turbine diameter of about 40 m. The initial target is to undertake a demonstration test with a scale model in the actual sea area within three years (**Fig. 2**).

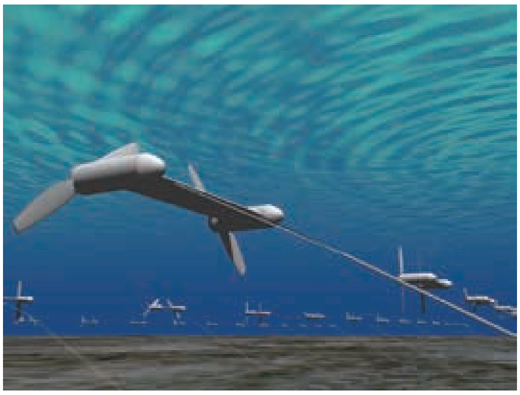


Fig. 2 Farm of ocean current power generation

3.2 Ocean thermal energy conversion

With this technology, power generation takes place exploiting the temperature difference (about 20°C or more) between the surface temperature (about 25°C) and bottom temperature (about 5°C) at a depth of 600 to 1 000 m. Stable power generation is ensured year-round in low latitudes, such as to assume part of the base load. This is the critical advantage of this technology, which other renewable energies cannot provide.

Low-boiling medium (ammonium, etc.) is vaporized in the vaporizer using the temperature of the warm surface and driving the turbine for generation. Vapor discharged from the turbine is condensed at the low temperature of the bottom water and then pumped back to the vaporizer, whereupon this cycle is repeated (**Fig. 3**). The piping housing the flow of the low-boiling medium is also sealed, meaning it will never leak to the outside.

In conjunction with other companies, IHI accepted a consignment in 2012 officially concerning the verification test of this type of power generation for the area from Okinawa Prefecture to Kumejima, and commenced construction work the same year. This will be a verification project involving long-term continuous operation using real seawater as a world first. The ocean thermal energy conversion plant can be roughly classified into two categories: the land type which, although small-scale, will utilize the deep seawater for multiple purposes and the ocean floating type: mainly for

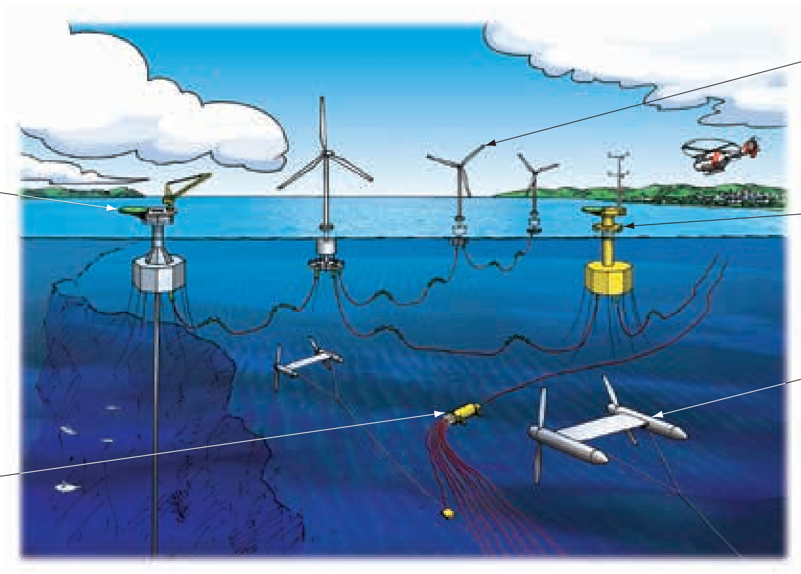


Fig. 1 Marine energy

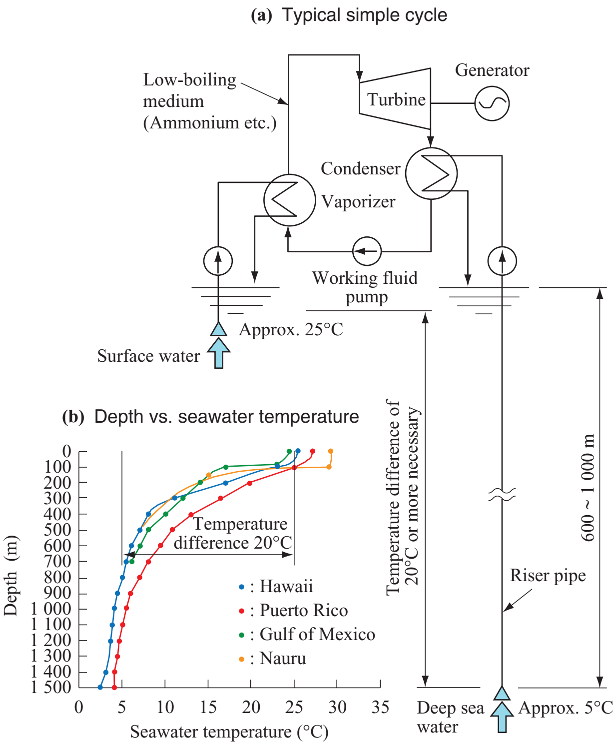


Fig. 3 Ocean thermal energy conversion[1]

large-scale power generation (refer to **Fig. 1**).

IHI will fully exploit the experiences obtained from the land type verification project on Kumejima and the longtime cultivated plant engineering capacities of the IHI Group in positive engagement with the project, targeting the commercial operation of floating-type plants.

4. Utilization of the blessings of the forest

As 70% of the land area of Japan is covered in forest, it is crucial, as a resource-poor country, that it optimally and sustainably exploits these resources in terms of both materials and energy.

Certain people may have negative feelings about tree cutting. Actually, however, the artificial forest of Japan is becoming increasingly devastated due to a lack of thinning. Advanced countries in forestry, such as Finland, Germany and Austria, etc., undertake cutting and use 60 to 90% of the forest growth, achieving sustainable forestry involving so-called "cutting and use of the amount of growth." In contrast, in Japan, only about 25% of the growth is cut, while unattended forests have dense spindly trees and are dark inside, which renders any tree cutting impossible, regardless of intention.[2] It is thus crucial to establish sustainable forestry as in the case of advanced forestry countries. Namely, there is a continuous need for adequate cutting proportional to growth, while any clear-cut space is to be planted without fail.

Needless to say, timber should first be used as a material and an energy source after expiration of its service life as a material. Presently, however, the demand for domestic timber is insufficient to keep pace with growth. Under current circumstances, IHI considers it essential to proceed with the utilization of timber for energy in parallel.

The IHI Group is currently active on both sides: the "supply" side of timber, involving the development of high-performance forestry machinery, and the "demand" side of using them as an energy source (**Fig. 4**). Accordingly, IHI benefits from reviewing and proposing the project based on due consideration of the supply-demand balance, without adopting a one-sided view of either the supply or demand side.

4.1 High-performance forestry machinery helping boost the efficiency of wood biomass harvesting

Forwarder F801, the high-performance forestry machinery of IHI Construction Machinery Limited (IK) (refer to **Fig. 4**), ensures substantially increased efficiency in timber transport operation in forests, reducing costs and ultimately significantly boosting the income of forestry workers.

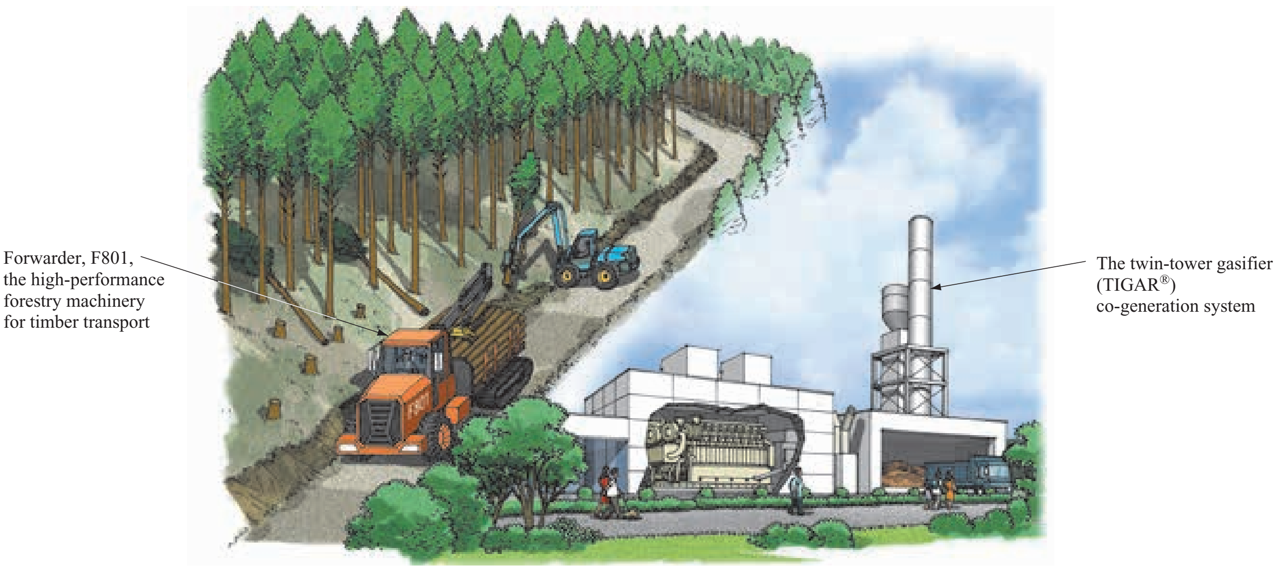


Fig. 4 Wood biomass

The combination of forwarder with the harvester (a single high-performance forestry machine that can handle trimming, pruning, peeling, and cutting) established by an advanced forestry country overseas can nearly double productivity from conventional levels.

4.2 "IHI's Forestry Package" targeting local production for local energy consumption

The IHI Group is also engaged in cost reduction of lumbers and wood fuels (chips, pellets) and regional vitalization using these resources ("IHI's forestry package"). IHI has assembled not only its own products, but also the best suited products of other companies while planning, in conjunction with forestry workers, local authorities, and local enterprises, the vertically-integrated operation of business entities. As of present, proposition is made on the review of feasibility of business while considering individually different circumstances of various local authorities. IHI expects that these activities contribute to renovation of domestic forestry and the job security and vitalization of the forest areas.

4.3 Gasification of wood biomass

To exploit wood biomass for high-level energy, IHI has been engaged in the development of a system centering around the twin-tower type gasification furnace (TIGAR® : Twin IHI GAsifieR).

TIGAR was originally developed to utilize low-grade (brown) coal with high water content, but can also be applied to wood biomass. Gas enriched with hydrogen produced from gasification can be used as engine fuel for power generation and for wide-ranging applications, including as a raw material for various chemical materials (**Fig. 5**).

4.3.1 Cogeneration (of electricity and heat)

When a practical scale allowing the accumulation of unused timber (from thinning, etc.) in Japan is considered from the perspective of local production for local energy consumption, gasification of wood biomass and the use of

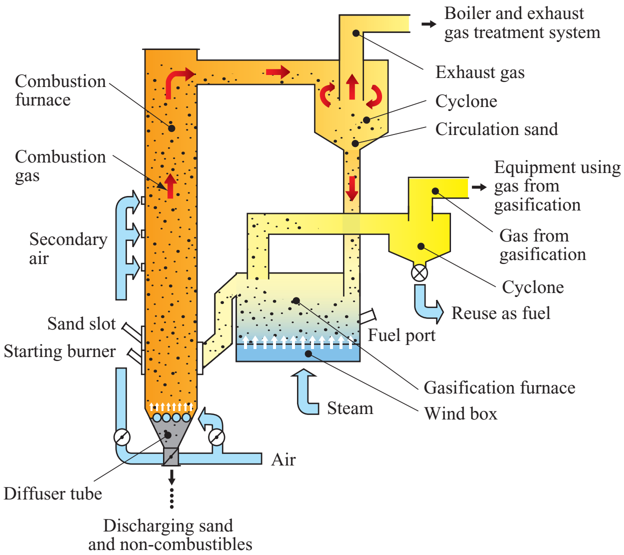


Fig. 5 TIGAR : Twin IHI gasifier

the resulting gas to fuel gas engines for power generation would prove effective. Namely, such process would require less water and offer higher generation efficiency than conventional generation systems featuring a combined boiler and steam turbine. In other words, the power obtained from an equivalent amount of wood may exceed conventional levels. Moreover, with this system, heat not used for power generation can be recovered as steam or hot water, which, in turn, boosts the overall energy efficiency.

4.3.2 Production of methane

Gas from gasification can be used to produce methane gas using a catalyst. The type of gasification furnace employed by IHI enables the content of nitrogen mixed into gas to be minimized, so that it is appropriate for methane production. Methane gas thus produced can be mixed into existing city gas pipelines and transported over long distances after control of the calorific power, which will boost the low carbonization of city gas (fossil fuel).

In 2010, IHI proposed this process, jointly with other companies, for NEDO's strategic next-generation biomass energy utilization technology development project (development of implementation technology), which was accepted. IHI and other companies target its early implementation by optimizing gasification conditions and confirming the durability of the catalyst in two years.

4.4 Mixed burning with a high ratio of wood biomass for coal-fired power generation

An increasing number of cases involve mixed burning with wooden biomass inside and outside Japan, which targets lower carbonization of coal-fired power generation. Presently in Japan, mixed burning in coal-fired boiler systems remains at about 5% on a calorie base. Commissioned by the Ministry of the Environment, however, IHI is undertaking R&D in an effort to substantially improve the mixed burning ratio. Ultimately, the intention is to achieve a 50% mixed burning ratio on a calorie basis and mainly rely on combustion technology in proceeding to develop a process with high overall energy efficiency, covering biomass harvest to processing and emission treatment.

4.5 Wood biomass power generation business in the USA

IHI is involved in the operation of a wood biomass power plant in California, USA. In the USA, there is active new construction and renovation of biomass power plants due to tax benefits for power plants with renewable energy. IHI has delivered boilers and other equipment to US power plants and will also obtain know-how on O&M (Operation and Maintenance) services by participating in their operation.

5. Extracting energy from mainly food-related plant effluent

5.1 Methane gas generation by an IHI-IC reactor for gas-engine cogeneration

Based on organic industrial wastewater discharged from plants of beer, beverages, and other food industries and the paper-making industry, methane is produced and used to fuel gas-engine power generation, while waste heat is also used effectively. Accordingly, a wastewater treatment system with optimal yields can be established.

Although such organic industrial wastewater has mainly been treated via the activated sludge process conventionally, this has proved problematic due to the cost of treating the bulk sludge generated. Compared to the conventional activated sludge process, the IHI-IC reactor (**Fig. 6**) of IHI Kankyo Engineering Co., Ltd. (IKE) has the following merits: ① excess sludge generation reduced to about 1/10, ② running costs reduced to about 1/20, ③ site area reduced to about 1/100, and ④ treatment rate increased by 20 to 35 times. Though the introduction of this reactor to large wastewater treatment facilities has progressed considerably, its introduction for medium to small facilities has been limited, mainly due to the costs involved. However, income from the sale of electrical power generated by the FIT renewable energy system, will accelerate payback of the investment cost for introduction. With this in mind, we will concentrate our efforts on disseminating this reactor to medium- and small-scale facilities in the future.

6. Photovoltaic power generation

6.1 EPC photovoltaic power plant project

Since enforcement of the renewable energy FIT system in July, 2012, the successive construction of large photovoltaic power plants in the megawatt class (1 000 kW) has got underway in Japan.

Photovoltaic power generation requirements are expected to intensify in the future as a means of effectively utilizing unused land or large and flat spaces such as the roof of the plant. In the IHI Group, IHI Plant Construction Co., Ltd. (IPC) is developing the EPC project (lump-sum contract including design up to plant construction) for photovoltaic power generation. Apparently, the photovoltaic power generation system may resemble a simple system of assembled units. However, to maintain business feasibility by securing high generation output over a long period of 20 years or more, high-level engineering is required in terms of installing equipment which is highly resistant to storm and salt damage, identification of equipment quality, and equipment combination. IHI will meet customer requests by leveraging its abundant long-term experience in the power plant sector.

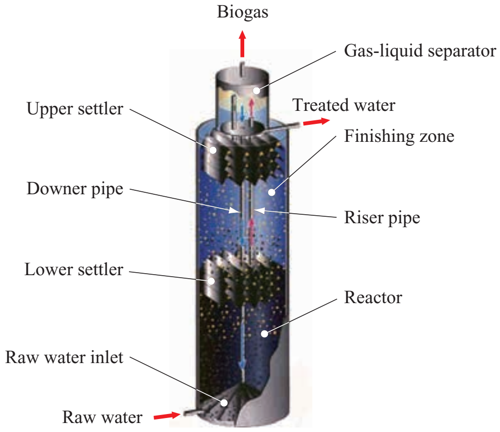


Fig. 6 IHI-IC reactor

6.2 Mega-solar generation project

Together with several other companies, IHI has founded the SPC (Special Purpose Company) and constructed a 70 000 kW solar power plant (**Fig. 7**) in its own area of Kagoshima Prefecture. This SPC is engaged in a project involving selling all the electricity it generates.

7. Storage of renewable energy

7.1 Issues concerning "Weather-Dependent" power generation

Only 60% of heat energy can be converted to electricity, despite best efforts. Conversely, the electricity is of extremely high quality and a convenient form of energy that can be almost totally converted to heat and power and easily transmitted to remote locations via electric wires. However, since it is difficult to store large amounts of electricity, the present principle is based on a so-called "balancing rule," whereby electricity is namely generated in an amount appropriate to demand at the time.

This poses a problem when renewable energies, such as weather-dependent sunlight, wind force, or sunlight unusable for power generation overnight, are to be introduced. Though demand exists, it may be impossible to generate sufficient power due to cloudiness, a lack of wind or the loss of solar radiation, and a generator set with adjustable output must be provided separately to compensate for the above. Unfortunately, at present, we must depend on the generator set using fossil energies of coals and gases.

7.1.1 Lithium-ion battery system

To overcome the above problem, various approaches are taken to store power generated with renewable energy in a battery for free use as required. IHI has cooperated with the American manufacturer in a project involving the provision of systematized lithium-ion battery cells. This battery uses highly heat-resistant electrode material developed by MIT (the Massachusetts Institute of Technology). Thanks to its highly-evaluated safety and long service life, 83 units were accepted by and delivered to the Tokyo Fire Department

Fig. 7 70 MW solar power generation plant in Kagoshima prefecture (rendering)

in 2011. We intend to develop this system, combined with increasingly popular photovoltaic power generation, to ensure a continued power supply in emergencies. We will strive our utmost to meet customers' needs as part of the BCP (Business Continuity Plan) and for large-scale electricity storage systems (**Fig. 8**), supplementing any generation instabilities by solar and wind power in the future.

7.2 Value as "Liquid Fuel"

7.2.1 Production of biofuel from oil-producing microalgae

7.2.2 Production of bioethanol from non-edible plants

IHI is also cooperating with other authorities to produce biofuel from algae efficiently and generate oil (**Fig. 9**) and bioethanol from non-edible plants. Liquid fuel is considered key for mobile vehicles, such as cars and airplanes, in the long-term, due to its high energy density per unit volume. In addition, liquid fuel can be easily stored in a tank, which makes it appropriate for "large-scale energy storage." This is an advantage electricity cannot match.

Producing liquid fuel using algae or plants means converting sunshine into a "storable" form: a special value which photovoltaic power generation lacks.

8. Power generation at low-grade heat below 100°C

8.1 20 kW binary power generation system

IHI has developed a package-type compact binary generator set based on turbo machine technology cultivated through development of turbochargers for automotive, ships' and industrial compressors. This generator set has sending-end output peaking at 20 kW with hot water input at 70 to 95°C, and also includes a grid connection function as standard, connectable to supply mains at AC 200 or 400 V. Marketing of the product is scheduled for 2013 (**Fig. 10**).

Similarly to the case of ocean thermal energy conversion previously described, this system uses low-boiling medium (high-safety fluorine medium with zero ozone-depleting potential and low global warming potential for this system) and employs a closed-loop Rankine cycle. The turbine generator (**Fig. 11**) has a direct drive construction, in which the radial turbine is directly coupled to the high-speed generator, with reduced noise and vibration. Since it comes in a compact type of 20 W, unlike similar conventional binary generation systems, and produces the small amount of hot water necessary for generation, this machine will meet small-scale power generation needs in hot springs. Conventionally, the introduction of generators for such small-scale generation has been abandoned.

9. The way ahead

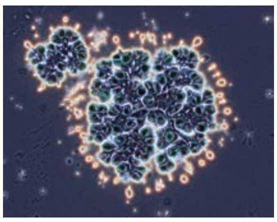
9.1 Our target, "Benefits of the Next Generation"

Energy-related issues are often tackled in terms of global warming caused by the increase in CO_2 along with the consumption of fossil energies, although certain people doubt the link between increased CO_2 and global warming. Regardless, we, as human beings living in the present world, must limit our consumption of finite fossil energy when the issue is viewed from the perspective of "securing available energy for the next generation."

Fig. 8 Lithium ion battery system to supplement inconsistent sources of energy such as solar and wind power

(a) Cultivation of oil-producing microalgae

(b) Microscopic photo of oil-producing microalgae*1



(Note) *1 : The yellow particulates around algae are oil drops.

Fig. 9 Oil-producing microalgae

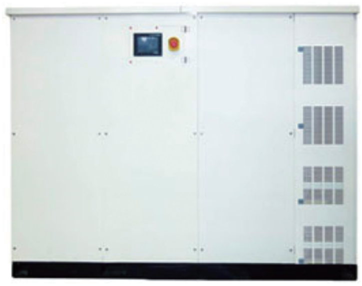


Fig. 10 20kW micro binary generator (Prototype)

Fig. 11 Micro turbine generator

9.2 Focusing "Energy Conservation" after all is considered

Consequently, IHI believes we must proceed with "energy conservation": involving suppressing the aggregate amount of energy consumed on the one hand and "increasing the ratio of renewable energies" to replace fossil energies on the other. IHI is ceaselessly striving to conserve energy via ultra-supercritical pressure boilers achieving highly-efficient power generation, turbochargers improving vehicle fuel economy, and the energy conservation of compressors.

On a global level, it is considered inevitable that developing countries will see an increase in aggregate energy consumption, linked to population growth and improved living standards. IHI can best contribute to energy conservation by refining long-cultivated energy conservation technologies and thus optimizing specifications and costs for the global acceptance of the same.

In Japan, since the population is already in decline, the further promotion of energy conservation will surely reduce the aggregate consumption below the present level. If the introduction of renewable energies could be promoted positively in this case, a reduction in aggregate consumption and a substantial increase in the ratio of renewable energies could be achieved simultaneously.

Japan will give an example by establishing an ideal energy system as a world first.

10. Conclusions

As has been described to date, IHI will actively strive to expand the utilization of renewable energies as well as promote energy conservation. IHI will also get actively involved in the supply of products and the business of "supplying" renewable energies continuously in a manner appropriate to the customer needs. IHI believes our activities will contribute to the enhanced energy independence of Japan and to global efforts to "secure energy for the next generation."

At IHI, we are certain customers will support our activities in the future.

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