(English Translation of the original Japanese version)

Report of the Initiatives for Next-generation Aviation Fuels

Roadmap for Establishing Supply Chain for Next-Generation Aviation Fuels

~ Aiming to Commence Utilization by the 2020 Tokyo Olympics and Paralympics ~

July 2015

Initiatives for Next-generation Aviation Fuels
INAF, JAPAN

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Contents

Explanatory Notes

○ Aviation fuel

A general term referring to the fuel used for aircraft. This term is used to refer to a concept comprising the terms of “conventional aviation fuels,” “next-generation aviation fuels” and “alternative aviation fuels.”

○ Conventional aviation fuel

Jet fuel which is derived from crude oil and currently used as fuel for aircraft. Kerosene, etc.

○ Next-generation aviation fuel

Unlike conventional aviation fuel, fuel that is not derived from crude oil but derived from biomass. A diverse range of raw materials is possible, including that produced from municipal waste, waste timber, non-food plants, sugar, alcohol or microalgae.

○ Alternative aviation fuel

Drop-in aviation fuel certified under the ASTM D7566 standard as an alternative to conventional aviation fuel. Currently, this fuel as used for aircraft is a mixture of conventional aviation fuel and next-generation aviation fuel.

Disclaimer

Executive Summary

1. Significance of Formulating a Roadmap for Japan

(1) From the standpoint of energy security and reduction of greenhouse gas emissions in the aviation sector as well, industry, government and academia need to collaborate to promote the introduction of next-generation aviation fuels. So that a broad range of variety of interested parties cooperate, it is important that a broad overview be provided of next-generation aviation fuels.

(2) In other countries, activities have been furthered which promote the introduction of next-generation aviation fuels and alternative aviation fuels. Such efforts include the sales agreement for alternative aviation fuels concluded between British Airways and Solena Fuels under the GreenSky London project, the sales agreement for alternative aviation fuels concluded between United Airlines and AltAir Fuels, as well as the use and preparation of alternative aviation fuels for commercial flights and team travel during the 2014 FIFA World Cup in Brazil and the 2016 Rio de Janeiro Olympics and Paralympics.

(3) It is within this context that the Initiatives for Next Generation Aviation Fuels (INAF) were established in May 2014 to formulate a roadmap with the aim of establishing a supply chain for next-generation aviation fuels in Japan. The INAF is comprised of 46 organizations from industry, government and academia.

(4) The roadmap compiled after INAF deliberations offers a rough sketch of a path leading to the introduction of next-generation aviation fuels, and brings together the entire supply chain from the procurement of raw materials, production of next-generation aviation fuels, their mixture with conventional aviation fuels to produce alternative aviation fuels, and refueling of aircraft after the fuel has been transported to the airport.

(5) For business development, more substantive discussions are needed which are based on this sketch. It is hoped that, in the future, a broad range of parties, not only those who are members of the INAF, will work together to accelerate the establishment of a supply chain for next-generation aviation fuels, and show the world Japan's advanced commitment to next-generation aviation fuels when the Tokyo Olympics and Paralympics open in 2020.

2. Summary of the Roadmap

(1) In order to establish a supply chain for next-generation aviation fuels by 2020, fuel production was reviewed by adopting six raw materials: municipal waste, microalgae, natural oils, waste food oil, non-edible biomass and woody biomass, for the formulation of a roadmap.

(2) The development of a supply chain for next-generation aviation fuels from these raw materials will enable the production of next-generation aviation fuels and supply of alternative aviation fuels to begin by FY 2020, and thereafter, the quantity supplied will be expandable.

(3) The principal path to be followed in the future is formulation of a business plan during FY 2015 ~ 2016, the design and construction of a plant from FY 2016 ~ 2018, trial operation

in FY 2019, and commencement of fuel supplies in FY 2020. Also, by FY 2018, handling methods, which take into account international guidelines, will need to be developed for the way in which these fuels are to be handled during transport and mixture as well as at airports and aircraft, just as has been done for conventional aviation fuels. Moreover, mixing methods need to be considered, which take into account fuel quality management, cost and other factors.

(4) Policy incentives promoting the introduction of next-generation aviation fuels are a prerequisite to this roadmap. In addition, to realize this roadmap, it is necessary to reduce costs so that next-generation aviation fuels are price competitive with conventional aviation fuels, establish markets for by-products, as well as develop additional technologies, and it would be desirable that a detailed review be immediately launched with the goal of business development.

(5) The specific details concerning mixing ratios for next-generation aviation fuels, business expenses, estimated price of alternative aviation fuels, quantity demanded, quantity able to be supplied and other such particulars will be reviewed during formulation of a detailed business plan.

(6) The characteristics of each raw material are as follows:

① Municipal waste: Municipal waste is a fuel production business undertaken in major cities in Japan, and a path along which the early commencement of production and future expansion of supply can be anticipated based on the quantity of municipal waste available, presence of collection systems, gasification, cleanup, FT synthesis, and the degree to which applicable technologies for upgrade have advanced.

② Microalgae: Microalgae is a fuel production business undertaken in other countries, and because of the high oil productivity rate per unit area and the fact that competition with foods can be mitigated, this is a path whose supply can be expected to be expanded over the long term through the establishment of technology for stable and large quantity cultivation of microalgae.

③ Natural oils: Natural oils are a fuel production business undertaken in Japan. Honeywell Company UOP has established a track record with this technology. In addition to the progress being made in commercialization in the United States, natural oil raw materials are available in regions around Japan, and because natural oils are able to be physically collected, this path can be expected to commence early.

④ Waste food oil: Waste food oil is a fuel production business undertaken in Japan. Most of such production is already put to other uses. However, the fact that there is a collection system and highly developed production technology which takes into account advances made in other countries, this is a path where the production of next-generation aviation fuels can be expected to commence early.

⑤ Non-edible biomass: Non-edible biomass is a business in which fuel production can also be anticipated in other countries. Growth-arrested bioprocess, which is at the core of this business, is an isobutanol production method having high raw material efficiency, so this is a path where supply can be expected to be increased over the long-term.

⑥ Woody biomass: Woody biomass is a fuel production business undertaken in regions throughout Japan. Because this raw material is an untapped resource available in large volume in Japan, this path can be expected to increase supply over the long term through construction of an economically efficient raw material collection system.

3. Future Considerations

(1) When operating the business, a business promotion framework, which is able to be construct the ideal system for ensuring each enterprise's profit, will be determined by those enterprises participating in the project in line with a concrete business model, while keeping in mind that the framework is an important factor affecting financing.

(2) It is unavoidable that the price of alternative aviation fuel, which is calculated based on the necessary costs for such a business, will significantly exceed the price of conventional aviation fuels over recent years. In order to establish a supply chain for alternative aviation fuels, it is important that such consideration proceed from the standpoint that businesses such as fuel producers and air carriers which comprise the supply chain, users of airline services which are growing and expanding, and the broad-based public which enjoys the benefits of greenhouse gas countermeasures and energy security bear costs in keeping with the degree to which such benefits are enjoyed.

(3) The means which have been considered for making up the aforementioned price differential include lowering costs through improvements at each stage of the supply chain, system optimization, technological innovation, user fees, area charges, and public support, and further debate on such means is awaited. Furthermore, it is necessary that technological and development systems be refined through operation of a demonstration project, that by-products be used and applied, advances made in the schedule for upgrading to accommodate a diverse range of raw materials, and, moreover, advances be made through the promotion of sales and purchases.

(4) In 2020 when the Tokyo Olympics and Paralympics are scheduled to open, the MRJ, which is currently being developed and will be Japan's first domestically manufactured passenger aircraft in 50 years, is also scheduled to be flying through the skies of Japan and the world, so the manufacture of next-generation aviation fuels in Japan as well as the commencement and promotion of an alternative aviation fuel supply is a good opportunity for Japan, which advocates a national commitment to tourism, the environment and technology, to establish a new presence, and it is desirable that the promotion of this business be accelerated now.

I. Initiatives for Next Generation Aviation Fuels

1. Background Behind Establishment of the INAF

The demand for commercial air services is projected to increase steadily in the future, and increases in the number of passengers as well as the volume of cargo have continued at an annual rate of 5% such that, in 20 years, demand will be approximately 2.6 times higher than its current level[1]. Therefore, for air transport to grow, it is essential that sustainable development be based on the promotion of measures to counter global warming and ensure energy security for a stable supply of fuel.

As for aviation sector, measures to address global warming, carbon neutral growth has become an international pledge, backed by such moves as the resolution (CNG2020[2]) passed at the General Assembly of the International Civil Aviation Organization (ICAO[3]), stating that carbon dioxide emissions[4] from the international aviation sector would not be allowed to increase beginning in 2020[5]. In every country, along with the introduction of highly fuel-efficient equipment and the realization of efficient transport through advances in air traffic control technology, activities have intensified in the move toward introduction of next-generation aviation fuels. From the standpoint of energy security as well, the United States is promoting the development and introduction of next-generation aviation fuels from the standpoint of reducing dependence on foreign oil, and momentum is gaining in industry as such activities are advanced in each country.

As for the situation in other countries at the beginning of 2014 in regard to the introduction of next-generation aviation fuels, in 2012, as part of the GreenSky London project, British Airways and Solena Fuels reached an agreement for the sale of alternative aviation fuels, and the site for construction of a refining plant on the outskirts of London was announced in 2014. In addition, United Airlines concluded a sales agreement for alternative aviation fuels in 2013 with AltAir Fuels. Under this project, next-generation aviation fuel and conventional aviation fuel will be mixed at a plant, which will be an improved existing facility, and the supply of alternative aviation fuel is scheduled to commence at Los Angeles Airport in 2014[6]. Furthermore, in Brazil, preparations are underway to use[7] next-generation aviation fuels for commercial flights and transporting teams during the 2014 FIFA World Cup as well as the 2016 Rio de Janeiro Olympics and Paralympics.

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1 Based on estimates prepared by the Boeing Company (see reference 3).

2 CNG is an acronym of Carbon Neutral Growth.

3 ICAO is an acronym of International Civil Aviation Organization, a specialized institution under the auspices of the United Nations, concerned with international civil aviation and headquartered in Montréal.

4 Carbon dioxide emissions from the international aviation field are approximately 1.5% of total global emissions (based on IEA data in reference 4).

5 Paragraph 6 of the 2010 ICAO General Assembly resolution (see reference 1)

6 As of March 2015 commencement of supply has not been confirmed, but an application for subsidies presented by AltAir Fuels regarding investment for increasing production capacity was accepted in 2014 and it seems the project is progressing. (See September 10, 2014 news release by the California Energy Commission)
http://www.energy.ca.gov/releases/2014_releases/2014-09-10_naturalgas_biofuels_grants.html

7 During the 2014 World Cup, Brazil's GOL Airlines used alternative aviation fuel, which was a 50% mixture of next-generation aviation fuel using non-edible corn oil and had cooking oil as the raw material (IATA data (reference 2) p. 11). Preparations are also underway for the Olympics and Paralympics.

The 2020 Tokyo Olympics and Paralympics offers the perfect opportunity for Japan to show the world its progressive commitment, and such a response is also sought in the aviation sector. The establishment of a supply system for next-generation aviation fuels, an issue that is already urgent, needs to be accelerated so as to realize supply of alternative aviation fuels at airports in Japan in FY 2020. There is no single raw material or production method for next-generation aviation fuels. Because the burden placed on the global environment as viewed through production costs and lifecycles differs depending on the quantity of raw material which can be procured, location where such fuel is produced and supplied as well as other conditions, these factors need to be integrated and optimized from many different perspectives. To that end, it is essential that a roadmap be based on consideration from a comprehensive point of view looking across the entire supply chain including raw material procurement, production technology and distribution routes, as well as the legal framework.

Taking into account the period of time required to establish such a supply system and based on an awareness that domestic companies possessing such technology and business know-how need to collaborate to immediately address this issue, the University of Tokyo, Boeing Company, Japan Airlines Co., Ltd., Nippon Cargo Airlines Co., Ltd., All Nippon Airways Co., Ltd., Narita International Airport Corporation and the Japan Petroleum Exploration Co., Ltd. designed a plan to launch a collaborative structure of organizations involved with next-generation aviation fuels, prepared the founding purpose shown in Chart 1, and called on interested parties to join together.

After this course of action was taken, the Initiatives for Next Generation Aviation Fuels was established in May 2014.

Chart 1: Founding Purpose of the Initiatives for Next Generation Aviation Fuels

In aviation, carbon neutral growth has become an international pledge, which has been backed by the General Meeting of the International Civil Aviation Organization (ICAO) resolving not to allow carbon dioxide emissions to increase beginning in 2020 (CNG2020) in the international aviation sector. In the aviation sector which is expected to grow globally in the future, the reduction of carbon dioxide emissions is an urgent issue to be addressed in fulfilling this pledge. All countries are actively working to make next-generation aviation fuels more widespread as they serve as an important measure for achieving the goal of reducing carbon dioxide emissions worldwide.

In such context, a roadmap is essential which is based on consideration from a comprehensive point of view looking across the entire supply chain including raw material procurement, production technology and distribution routes, as well as the legal framework for establishment of a supply structure for next-generation fuels in Japan.

Based on the aforementioned awareness of the issue, the Initiatives for Next Generation Aviation Fuels shall be established to promote the establishment of a supply structure and make if become more universal in regard to next-generation aviation fuels.

April 2014

The University of Tokyo, Boeing Company, Japan Airlines Co., Ltd., Nippon Cargo Airlines Co., Ltd., All Nippon Airways Co., Ltd., Narita International Airport Corporation and the Japan Petroleum Exploration Co., Ltd.

2. Review Structure and Overview of Activities

For the Initiatives for Next Generation Aviation Fuels (INAF[8]), the seven organizations that drafted the aforementioned founding purpose serve as the steering committee members, and the companies and other organizations associated with the supply chain for aviation fuels, including the steering committee members, are the INAF's members (Chart 2). Also, the INAF has set up four subcommittees, which will organize and deliberate issues and solutions pertaining to ① supply chains using municipal waste for the raw material (First Subcommittee), ② supply chains using oils produced by microalgae for the raw material (Second Subcommittee), ③ supply chains using other materials for the raw material (Third Working), and ④ legal system (Fourth Subcommittee).

As the subcommittees developed an understanding of salient issues and the plenary sessions shared such information and compiled questions to be addressed, the INAF prepared a roadmap for establishing a supply chain for next-generation aviation fuels in Japan over the period of approximately one year.

Chart 2: Members of the Initiatives for Next-generation Aviation Fuels

[Members]

IHI Corporation
ITOCHU ENEX Co., Ltd
ITOCHU Corporation
Japan Aerospace Exploration Agency
ORIX Environmental Resources Management Corporation
Kawasaki Heavy Industries, Ltd.
Green Earth Institute Co., Ltd.
K-laboratory Co., Ltd.
National Institute of Advanced Industrial Science and Technology
JFE Engineering Corporation
Shell Japan Ltd.
Sumitomo Corporation
Japan Petroleum Exploration Co., Ltd.
All Nippon Airways Co., Ltd.
Sojitz Corporation
Chitose Laboratory (formerly Neo-Morgan Laboratory Incorporated)
Chiyoda Corporation
The University of Tokyo
Toyo Engineering Corporation
TOYOTA CENTRAL R&D LABS., Inc.
Narita International Airport Corporation
JGC Corporation
Nikki-Universal Co., Ltd.
Japan Asia Investment Company, Limited
The Institute of Energy Economics, Japan
Nippon Cargo Airlines Co., Ltd.
Japan Airlines Co., Ltd.
Nomura Research & Advisory Co., Ltd.
Hitachi Zosen Corporation
PHOENIX BUSINESS CO., LTD.
The Boeing Company
Microwave Chemical Co., Ltd.
Mitsui Engineering & Shipbuilding Co., Ltd.
Mitsui Global Strategic Studies Institute
Mitsubishi Research Institute, Inc.
Mitsubishi Heavy Industries, Ltd. /Mitsubishi Hitachi Power System, Ltd.
euglena Co., Ltd.
REVO International, Inc.

INAF Observers:
Ministry of Agriculture, Forestry and Fisheries
Ministry of Economy, Trade and Industry
Ministry of Land, Infrastructure, Transport and Tourism
Ministry of the Environment
Ministry of Defense
New Energy and Industrial Technology Development Organization
National Agriculture and Food Research Organization
International Air Transportation Association (IATA)

[46 member organizations]

While information and awareness of the issues was shared among members and scenarios anticipated for establishing supply chains for each raw material in the aim of introducing next-generation aviation fuels, issues particular to each type of raw material as well as common issues, including development of a legal framework, were identified and solutions compiled, and a framework leading to concrete operations were studied and reviewed in the subcommittees and plenary sessions. Furthermore, the website has been utilized to communicate such information externally[9].

8 INAF is an acronym of the Initiatives for Next Generation Aviation Fuels
9 Public announcement given regarding establishment of the Initiatives on July 9, 2014. The website URL is http://inaf-japan.tumblr.com/.

II. Details of Each Review Structure's Activities

1. Plenary Sessions

(1) General Overview of Activities

At the plenary sessions, an awareness of the issues related to next-generation aviation fuels were shared among the members, and reports prepared and given on the progress made by the subcommittees and information shared about global trends by inviting experts from other countries.

(2) Membership Roster: See Chart 2 (P11)

(3) Meetings Held and Summary of Proceedings

①First Plenary Session: Friday, May 30, 2014, 13:30~16:00

(Venue: Sanjo Conference Hall, The University of Tokyo)

Item 1: Founding Purpose of the Initiatives for Next Generation Aviation Fuels and the Manner in which Work will Proceed	(The University of Tokyo)
Item 2: Trends in Bio-Jet Fuel: Accelerating Global Developments and Japan's Future	(Nippon Cargo Airlines Co., Ltd., Japan Airlines Co., Ltd., and All Nippon Airways Co., Ltd.)
Item 3: Sustainable Aviation Fuels: Global Challenges, Regional Opportunities	(Boeing Company)

The first plenary session was the first meeting of the INAF, so the steering committee provided information about the background behind establishment of the INAF and its purpose. The session discussed the direction future activities would take. More specifically, after the University of Tokyo provided on overview of the INAF as well as information pertaining to the global context in relation to the INAF's activities, Nippon Cargo Airlines Co., Ltd., Japan Airlines Co., Ltd., and All Nippon Airways Co., Ltd. furnished information about their respective efforts to reduce environmental load in the aviation sector, trends pertaining to the development and use of next-generation aviation fuels around the world, and issues to be addressed in having next-generation aviation fuels more widely used. The Boeing Company presented information about the company's global activities regarding next-generation aviation fuels. During the question-and-answer portion, a question was posed to confirm whether the municipal waste to be used as a raw material was the raw waste treated at waste disposal sites or whether it was the ashes after incineration at a waste treatment site. The reply was that the former is the raw material to be reviewed and, at the current point in time, consideration is being given to general municipal waste collected in the Tokyo metropolitan area. Also, a question was posed about the provisional calculations produced by air carriers, and confirmation indicated that air carriers would like to begin using next-generation fuels to the extent possible no later than 2020 when the Tokyo Olympics and Paralympics are held.

②Second Plenary Session: Tuesday, June 10, 2014, 10:00~12:00 (venue: Boeing Japan)

Item: The Status of Bio-derived Fuels for Aviation (The Boeing Company)

At the second plenary session, a technical fellow of the Boeing Company and also chairman of an ASTM standards[10] technical subcommittee concerned with next-generation aviation fuels

[10] Standards established and issued by ASTM International, the world's largest international standard organization, regarding performance and test methods for materials associated with a wide range of industrial products including aviation fuel. The organization has approximately 160 technical committees, and sets standards for a variety of materials and other items under each committee's purview, and there are over 12,000 standards. (Source: ASTM International's website)

came to Japan and provided information about technical matters related to next-generation aviation fuels as well as the status of establishment of international standards, and this information was shared with the entire INAF membership. The main items were as follows.

- Air transport differs from land transport, and for the extended future, aircraft have no choice but to depend on liquid fuels with high energy density.
- For that reason, the diversification of fuels is an issue of vital importance to air carriers, and from the standpoint of reducing that burden, the Boeing Company is working to develop and make next-generation aviation fuels more widespread.
- For fuels proposed as next-generation aviation fuels to be certified for use as drop-in fuels[11] on aircraft which have been designed on the basis of the properties of conventional aviation fuels refined from fossil fuels, it is essential that an original equipment manufacturer (OEM), such as the Boeing Company, which has full knowledge of aircraft systems participate.
- The ASTM standards, which are the international standard for aviation fuels, are stipulated in D7566 Annex for next-generation aviation fuels, and in D7566 for alternative aviation fuels, including the ratios[12] for mixture with next-generation aviation fuels.
- At the time the meeting was held (June 10, 2014), the standards for next-generation aviation fuels were FT SPK[13] (D7566 Annex A1) and HEFA SPK[14] (D7566 Annex A2), and SIP[15] was also soon to be enacted (on June 15, 2014, a standard was set in D7566 Annex A3).
- The Boeing Company has hopes for a fuel known as Green Diesel, which is produced from biomass derived oils, to be a next-generation aviation fuel in the future, and is working to have standards enacted in the ASTM D7566 Annex. Currently, Green Diesel and next-generation aviation fuel (HEFA SPK) are fractionated, but both are chemically similar with the exception of freezing points[16], so consideration is being given to incorporating a freezing point that Green Diesel will be able to satisfy into the D7566 standard. If an alternative aviation fuel, which is a mixture of Green Diesel and conventional aviation fuel, can be used for aircraft, the ratio of aircraft fuel that is able to be produced from raw material will increase, so it is expected that there will be a tremendous increase in the quantity of next-generation aviation fuels produced. (The name Green Diesel is often misunderstood to be the same as biodiesel, and beginning in 2015, it has been called High Freeze Point HEFA.)

③ Third Plenary Session: Monday, September 1, 2014, 13:30~16:30
(Venue: Narita International Airport)

[11] Drop-in fuel has the same properties as conventional aviation fuel, and no changes are required to the existing infrastructure such as aircraft, airports, fuel supply facilities and so on for use in aircraft.
[12] Percentage that next-generation aviation fuels account for of alternative aviation fuels
[13] FT SPK: Fischer-Tropsch Hydroprocessed Synthesized Paraffinic Kerosine.
FT synthesis is hydrocarbon synthesis developed by German researchers F. Fischer and H. Tropsch. It is a method that uses a gas mixture of carbon monoxide and hydrogen at a specific ratio for the raw material to produce naphtha and kerosene-gas oil by using iron, ruthenium, cobalt or another metal catalyst. Products show a wide-ranging distribution from methane to wax in accordance with the Schulz-Flory distribution (see data from the JX Nippon Oil & Energy Corporation (reference 18).
[14] HEFA SPK: Synthesized Paraffinic Kerosine from Hydroprocessed Esters and Fatty Acids, also known as Bio SPK (Bio Derived Synthesized Paraffinic Kerosine).
[15] SIP: Synthesized Iso-Paraffines from Hydroprocessed Fermented Sugars, also known as DSHC (Direct Sugar to Hydrocarbon).
[16] Temperature at which a substance begins to freeze, also known as the congealing point or freezing point.

Item 1: Subcommittee Reports
- Subcommittee 1
  (Japan Airlines Co., Ltd., National Institute of Advanced Industrial Science and Technology, Toyo Engineering Corporation)
- Subcommittee 2 (IHI Corporation)
- Subcommittee 3 (Nippon Cargo Airlines Co., Ltd.)
- Subcommittee 4 (The Boeing Company)

Item 2: Overview of Narita International Airport and Aircraft Fueling Facilities (Narita International Airport Corporation)

After the second plenary session, the INAF's activities moved into full swing in July. On July 9th, the INAF's establishment was publicly announced, and the subcommittees began their investigations. At the third plenary session in September, these circumstances was taken into account and the status of reviews conducted by each subcommittee over previous two months since July was confirmed at a full session of the INAF's members, and information was provided about the aircraft fueling facilities at Narita International Airport and a tour was also taken of the facilities.

With regard to the First Subcommittee which was reviewing a supply chain using municipal waste as the raw material, Japan Airlines Co., Ltd., National Institute of Advanced Industrial Science and Technology, and Toyo Engineering Corporation provided on overview of technical options for gas production from municipal waste. The deliberations were premised on a fuel price of 100 JPY per liter, and not all raw materials would be converted to next-generation aviation fuel, but when used in combinations with electricity and other products, economic competitiveness in the production would be pursued. IHI Corporation provided an explanation about the Second Subcommittee, which was investigating a supply chain in which oils produced by microalgae would be used as the raw material, and an explanation was given to the effect that attention will be focused on the issue of quantitative matching of fuel supply and demand with the aim of formulating a roadmap. Nippon Cargo Airlines Co., Ltd. provided an explanation about the Third Subcommittee which was investigating a supply chain where materials other than municipal waste and microalgae would be used as the raw material, and a presentation was given of the raw materials narrowed down for review, stating that the manufacture, refinement and supply of these will be examined according to their location as the investigation proceeds further. The Boeing Company provided an explanation regarding the Fourth Subcommittee which was studying the legal system and talked about the status of review concerning waste treatment and inspections for fuel quality as well as wishes presented by each subcommittee for revisions in the legal system.

With regard to Item 2, the Narita International Airport Corporation provided an explanation of the routes and structure used for aircraft fuel as well as an overview of the facilities, stating that because Narita International Airport is an inland airport, aviation fuel is unloaded at Chiba Port in Tokyo Bay and transported to the airport by pipeline. At the airport, aircraft are fueled from hydrants, and information was shared about issues pertaining to cases where next-generation aviation fuels are introduced.

④Fourth Plenary Session: Thursday, November 6, 2014, 10:00~12:30
(Venue: Faculty of Engineering, The University of Tokyo)

Item: Activities in the United States for Commercializing the Supply of Next-Generation Aviation Fuels (Federal Aviation Administration, Department of Energy, LanzaTech)

The fourth plenary session in November welcomed US government officials and a next-generation aviation fuel enterprise, which were invited by the Boeing Company to speak at a seminar sponsored by the University of Tokyo and Boeing Company[17], and the parties concerned from the United States shared information with the entire INAF membership about the business development of production and supply of next-generation aviation fuels as well as examples of efforts to introduce next-generation aviation fuels in the United States.

Mr. Hileman of the Federal Aviation Administration (FAA) gave an overview of the FAA's efforts aimed at having next-generation aviation fuels more widely used as well as policies promoting the introduction of next-generation aviation fuels with attention directed to the quantification of environmental, economical and social issues. Mr. Holladay from the Department of Energy (DOE) gave an overview of the DOE's efforts in the context of overall US government's efforts related to next-generation aviation fuels as well as the importance of collaboration among government departments and agencies. Mr. Fleming from LanzaTech[18] gave a summary of the demonstration testing and development projects, which the company is undertaking, as well as the company's processes for consideration of the environment and such advantages.

During the exchange of opinions after the three gave their presentations, discussions focused on points such as, although the use of next-generation aviation fuels has advantages for environmental improvement in the sense of reducing greenhouse gases, such fuels need to be competitive at the current point in time in terms of pricing with conventional aviation fuels; that if a structure is able to be constructed so that raw material may be procured at a low price, such a structure would give next-generation aviation fuels price competitiveness, and this issue is considered to be a challenge but not impossible; and that one method of lowering the overall manufacturing cost cited was the production of comparatively high priced biochemical products as a by-product, but it would be necessary to have demand for and quantity of the by-product produced to match the anticipated scale of production of next-generation aviation fuels. Furthermore, it was confirmed that sustainability, which should be discussed in the background of next-generation aviation fuels, is a broad concept that not only includes greenhouse gases, but also hydrological cycle systems, atmospheric environment as well as biodiversity.

⑤Fifth Plenary Session: Wednesday, January 28, 2015, 13:30~16:30
(venue: Sanjo Conference Hall, The University of Tokyo)

[17] "Aviation and Environment Workshop" held on November 5, 2014. Data is available at the following URL: http://aviation.u-tokyo.ac.jp/event.html (viewed May 4, 2015)
[18] LanzaTech developed a unique processing method that uses microorganism based fermentation to convert gases, including carbon monoxide and carbon dioxide, into fuel and chemical products such as ethanol and butadiene, and has worked to create a business of licensing the technology (see March 26, 2014 news release by Mitsui & Co., Ltd.).

Item 1: Organization of the Summary (draft) Item 2: Roadmap of Each Path (draft) • Subcommittee 1 (Japan Airlines Co., Ltd.) • Subcommittee 2 (All Nippon Airways Co., Ltd.) • Subcommittee 3 (Nippon Cargo Airlines Co., Ltd., Nikki-Universal Co., Ltd., Green Earth Institute Co., Ltd., Mitsui Engineering & Shipbuilding Co., Ltd.)

At the fifth plenary session, the Secretariat provided suggestions on the main points for the INAF's report in preparation for the summary due in several months while taking into account previously held discussions, and the INAF confirmed that the work should proceed in the direction proposed. Also, reports were given about the progress of each subcommittee's investigations and these reports were shared with the entire INAF membership.

During the plenary session discussions regarding consideration given to the summary, questions were raised about the necessity of nationwide efforts in regard to promoting the introduction of next-generation aviation fuels, the points regarding which detailed review should proceed in dividing up roles between the government and private sector, as well as the necessity for a debate about how Japan should undertake future allocation, including with the automobile sector, of hydrogen, a large quantity of which is needed in the process considered for refining next-generation aviation fuels.

⑥ Sixth Plenary Session: Friday, April 3, 2015, 13:00~15:00

(Venue: Sanjo Conference Hall, The University of Tokyo)

Item: Report of the Initiatives for Next Generation Aviation Fuels

At the sixth plenary session in April which was also the last general meeting, the basic points to be included in the draft report, which had been coordinated within the INAF since mid-March, were confirmed. In the subsequent exchange of opinions, there was debate about numerical transactions such as investment scale. In regard to this, it was pointed out that such figures are necessary for illustrating to a wide variety of audiences the fuel production business, that there is a risk information pertaining only to numerical figures might take on a life of its own, that numerical figures are forecast based on hypotheses and there is a method of noting to the effect that future results may differ from forecasts. It was decided that this issue would be settled in the final reconciliation process of the report.

Also, this would be the final plenary session held, and reconciliation of the report would be done by email and it was confirmed that the plan was to have the report released publicly at a general public symposium in July after the translation into English.

2. Steering Committee

(1) General Overview of Activities

The Steering Committee certified newly participating members in the INAF, planned the plenary sessions and reviewed the summary.

(2) Membership Roster:

A total of seven organizations form the membership of the steering committee: The University of Tokyo, Boeing Company, Japan Airlines Co., Ltd., Nippon Cargo Airlines Co., Ltd., All Nippon Airways Co., Ltd., Narita International Airport Corporation and the Japan Petroleum Exploration Co., Ltd.

(3) Meetings Held

In addition to holding a total of eight meetings as described below, information was shared and discussions conducted by email.

- 1st: Wednesday, May 14, 2014 15:30~17:30 (Venue: Boeing Japan)
- 2nd: Tuesday, June 10, 2014 12:00~13:00 (Venue: Boeing Japan)
- 3rd: Monday, June 30, 2014 13:00~15:00 (Venue: Boeing Japan)
- 4th: Monday, September 1, 2014 10:00~11:00 (Venue: Narita Int'l Airport)
- 5th: Wednesday, November 12, 2014 13:00~15:00 (Venue: Boeing Japan)
- 6th: Wednesday, November 18, 2014 15:00~17:00 (Venue: Boeing Japan)
- 7th: Wednesday, January 21, 2015 15:00~17:00 (Venue: Boeing Japan)
- 8th: Monday, March 16, 2015 10:00~12:00 (Venue: Boeing Japan)
- 9th: Friday, April 24, 2015 15:00~17:00 (Venue: Boeing Japan)

(4) Summary of Proceedings of Each Session

At each session of the steering committee, discussions were held on the INAF's operations, which included deliberating plans for plenary sessions, verifying the meeting material, establishing and checking on the progress of subcommittees, preparing press releases, coordinating each subcommittee's investigations, managing the overall schedule, and planning the symposium.

3. Subcommittee 1

(1) General Overview of Activities

A roadmap was considered from the standpoint of early realization of a supply chain for which municipal waste serves as the raw material, while taking into account possibilities for future growth of such business. In order to clarify issues pertaining to the three methods for producing next-generation aviation fuels, which are 1) the conversion of synthesis gas, which is produced by gasification of municipal waste, to liquid fuel by means of FT synthesis and then upgrading the liquid fuel, 2) the use of bacterial cells for ethanol fermentation of synthesis gas, which is produced by gasification of municipal waste and made into aviation fuel by increasing the carbon chain count (ATJ[19]), and 3) the use of yeast for ethanol fermentation of dehydrated pulp obtained from separating, pulverizing and pulping municipal waste and then ATJ processing after distillation, the subcommittee investigated the development of business employing these methods on the premise that domestically produced fuel would be supplied at a price of 100 JPY per liter, which is the same as the price of conventional aviation fuels in recent years. The initial review was conducted to verify the consistency of small scale systems based on purely domestic production, as well as formulate a roadmap.

(2) Membership Roster:

A total of 21 organizations are members of the First Subcommittee: ITOCHU ENEX Co., Ltd,

[19] Acronym of Alcohol to Jet. ATJ is a method of producing next-generation aviation fuel using alcohol as the raw material, and there are two types of production from isobutanol and from ethanol, and consideration is being given to establishing provisions for both under ASTM D7566 Annex.

ITOCHU Corporation, Japan Aerospace Exploration Agency, ORIX Environmental Resources Management Corporation, National Institute of Advanced Industrial Science and Technology (Chair), JFE Engineering Corporation, Shell Japan Ltd., Japan Petroleum Exploration Co., Ltd. (preparation of business development scenarios), The University of Tokyo, Toyo Engineering Corporation (technical summaries), Japan Asia Investment Co., Ltd., Japan Airlines Co., Ltd. (Secretariat), Nomura Research & Advisory Co., Ltd., Hitachi Zosen Corporation, Mitsui Engineering & Shipbuilding Co., Ltd., Mitsui Global Strategic Studies Institute, Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment, New Energy and Industrial Technology Development Organization and IATA[20] Japan (International Air Transport Association).

(3) Meetings Held and Summary of Proceedings

In addition to holding a total of eight meetings as described below, information was shared and discussions conducted by email.

① First meeting: Friday, July 4, 2014, 14:00~17:00 (Venue: Boeing Japan)

National Institute of Advanced Industrial Science and Technology, Hitachi Zosen Corporation and JFE Engineering Corporation gave presentations to share information about the current state of technology for gasification of municipal waste, and the subcommittee's objectives were shared, which was to investigate a supply chain for production using municipal waste as a raw material on the assumption of domestically produced next-generation aviation fuel being priced at 100 JPY per liter.

② Second meeting: Friday, July 25, 2014, 14:00~17:00 (Venue: Boeing Japan)

Mitsui Global Strategic Studies Institute, Toyo Engineering Corporation and ITOCHU Corporation each gave presentations to share information about LanzaTech's bacterial cells, FT synthesis and the GreenSky London Project. Items to be reviewed concerning production technology and processes, demonstration plants and commercial plans, and economic competitiveness were discussed and consolidated.

③ Third meeting: Friday, August 22, 2014, 11:30~16:00 (Venue: Biomass Refinery Research Center, National Institute of Advanced Industrial Science and Technology)

At the Biomass Refinery Research Center of the National Institute of Advanced Industrial Science and Technology, a tour was conducted of a bench-scale plant[21] for producing aviation fuel in an integrated manner from raw material with a BTL (biomass to liquid) process employing the FT synthesis, and discussions were held on commercialization ideas, energy calculations, and the consolidation of review items.

④ Fourth meeting: Friday, September 5, 2014, 14:00~17:00 (Venue: Boeing Japan)

Discussions were held with the aim of developing this business on the condition that the gasification and reforming furnace by the Japan Recycling Corporation, which is a wholly owned subsidiary of JFE Engineering Corporation, is utilized, and consideration was divided into demonstration plants and commercial plants, and the current circumstances surrounding

[20] An international industrial group comprised of air carriers, etc., which is headquartered in Geneva and Montréal.
[21] A bench scale plant is larger than a lab scale plant fabricated in a research laboratory, and smaller than a demonstration or commercial plant.

facilities for aviation fuel production were consolidated.

⑤ Fifth meeting: Friday, October 3, 2014, 14:30~17:00 (Venue: Boeing Japan)

Discussions were held concerning provisional calculations pertaining to the profitability of production of next-generation aviation fuels by means of gasification of municipal waste and the FT synthesis.

⑥ Sixth meeting: Friday, October 17, 2014, 14:30~17:00 (Venue: Boeing Japan)

Discussions were held on Hitachi Zosen Corporation's technology for producing next-generation aviation fuel with the use of yeast for ethanol fermentation of dehydrated pulp obtained from separating, pulverizing and pulping municipal waste and then undergoing ATJ processing after distillation, as well as on business schemes and the supply chain all the way through to aircraft fueling.

⑦ Seventh meeting: Thursday, November 27, 2014, 13:30~17:00 (Venue: East Japan Works, JFE Steel Corporation (Chiba region))

Based on an explanation by Japan Petroleum Exploration Co., Ltd. concerning case studies of investment evaluations for next-generation aviation fuel production businesses using municipal waste as the raw material, information was shared about assessing investments for business development, referencing a technique known as framing which is conducted in the first step of the investment of violation process.

⑥ Eighth meeting: Friday, January 16, 2015, 15:00~17:00 (Venue: Boeing Japan)

Based on an explanation by IATA on worldwide trends pertaining to next-generation aviation fuel supply chains and quality inspection systems, discussions were held on fuel standards and quality inspections, and the future schedule for putting together a summary was confirmed.

4. Subcommittee 2

(1) General Overview of Activities

In regard to a supply chain for next-generation aviation fuel which uses the raw material oil content known as algae oil produced from microalgae, because such a process is undertaken from production of raw material which differs from other paths, and it is assumed that the raw material will be produced overseas in view of the climate and required area suitable for such growth, and that production may be repeated because microalgae which exist in nature are used, and that there are differences in oil content depending on the type of microalgae used, a roadmap was drafted while seeking collaboration and cooperation for such business and taking into account that there are different elements in development related to production process and production technology.

The current situation is one in which previous reviews have been accomplished through the demonstrative stage and efforts are being made to create a larger scale. Accordingly, the examination considered the manner in which support is to be provided for business implementation as well as issues after upgrading, and the possibilities for collaboration and cooperation not just among producers but also refiners and others. Production will take place overseas for large-scale demonstrations and full-scale business development, so the issues to be addressed are: in what state may fuel be brought into Japan and under what terms.

(2) Membership roster:

A total of 28 organizations are members of the Second Subcommittee: IHI Corporation (Chair), ITOCHU Corporation, ORIX Environmental Resources Management Corporation, K-laboratory Co., Ltd., National Institute of Advanced Industrial Science and Technology, Sumitomo Corporation, Japan Petroleum Exploration Co., Ltd., All Nippon Airways Co., Ltd. (Secretariat), Chitose Laboratory, Chiyoda Corporation, The University of Tokyo, Toyota Central R&D Labs, JGC Corporation (Deputy Chair), Japan Asia Investment., Ltd., Nomura Research & Advisory Co., Ltd., PHOENIX BUSINESS CO., LTD., Microwave Chemical Co., Ltd., Mitsui Global Strategic Studies Institute, Mitsubishi Research Institute, Inc., euglena Co., Ltd., Ministry of Agriculture, Forestry and Fisheries, Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment, Ministry of Defense, New Energy and Industrial Technology Development Organization, National Agriculture and Food Research Organization, and International Air Transportation Association (IATA).

(3) Meetings Held and Summary of Proceedings

In addition to holding a total of five meetings as described below, the review proceeded in working groups (WG) from the fourth meeting on (see ④Fourth meeting), and after information was shared by email among the subcommittee's members, the roadmap prepared by the working group was examined at the fifth meeting. Also, the working group conducted an exchange of opinions with experts on alternative aviation fuels at the IATA head office.

① First meeting: Wednesday, July 9, 2014, 14:45~17:00 (Venue: Boeing Japan)

After the objectives of the Second Subcommittee were shared, discussions were held on the issues, and requests presented concerning systematic reforms and the future schedule. The Subcommittee commenced discussions on the premise the provision of one percent of the aviation fuel consumed by Japan's air carriers by FY 2020. Furthermore, for the cultivation of microalgae, a vast land area with good growing conditions is needed, and it is anticipated that such cultivation will take place overseas. It was indicated that public support would be necessary if discussions are premised on the aim of supplies at a price of 100 JPY per liter which is the same as the price of conventional aviation fuels in recent years.

② Second meeting: Monday, August 4, 2014, 15:30~18:00 (Venue: Boeing Japan)

New Energy and Industrial Technology Development Organization (NEDO) gave a presentation on the current state of the development of production technology to derive fuel from microalgae in Japan, and BioFuel Systems, a Swiss company invited by PHOENIX BUSINESS CO., LTD., gave a presentation on technology and activities for producing oil from microalgae in the ocean, and this information was shared.

③ Third meeting: Wednesday, August 27, 2014, 15:30~17:30
(Venue: All Nippon Airways Co., Ltd)

Discussions were held on issues related to technology development, the quantity of next-generation aviation fuels demanded, and the utilization of public funds.

④ Fourth meeting: Friday, September 19, 2014, 9:00~11:30 (Venue: Boeing Japan)

Euglena Co., Ltd. gave a presentation and shared information about the company's research and business plans. Also, in order to prepare a draft of the roadmap, a working group was established which was comprised of IHI Corporation, Japan Petroleum Exploration Co., Ltd., Chitose Laboratory, JGC Corporation, euglena Co., Ltd. and the Secretariat.

⑤ Fifth meeting: Monday, January 19, 2015, 15:30~17:30 (Venue: Boeing Japan)

Taking into account the formulation of a roadmap for supplying next-generation aviation fuel which uses algae oil produced from microalgae as the raw material, discussions were held based on the working group’s proposal. While continuing to give consideration to achieving the milestones and targets for the quantity of fuel produced in FY 2020 and FY 2030, review was conducted of the significance of a roadmap starting with microalgae, measures for realization of production of next-generation fuels that are price competitive, and the necessity of public support.

5. Subcommittee 3

(1) General Overview of Activities

Examination was conducted of the possibilities for realizing next-generation fuels which use for the raw material elements other than municipal waste and algae oil produced from microalgae, while also bearing in mind overseas production for large-scale demonstration projects and full-scale business development. Also, with regard to product importation, bio crude oil importation and technology upgrades, reviews were conducted about addressing the diversification of raw materials, ensuring sources of hydrogen, and technical issues. After discussions which included possibilities for collaboration and cooperation, principally investigating the processes and technologies for refining raw material to produce fuel which was of interest to the members of the subcommittee, a roadmap was ultimately formulated in which the raw materials covered would be natural oils (with the exception of waste food oils), waste food oil, non-edible biomass (cellulosic sugar; hereinafter the same) and woody biomass.

(2) Membership roster:

A total of 24 organizations are members of the Third Subcommittee: ITOCHU ENEX Corporation, ITOCHU Corporation, Japan Aerospace Exploration Agency, Kawasaki Heavy Industries, Ltd., Green Earth Institute Co., Ltd., K-laboratory Co., Ltd., National Institute of Advanced Industrial Science and Technology, Japan Petroleum Exploration Co., Ltd., Chiyoda Corporation, The University of Tokyo, Toyota Central R&D Labs, JGC Corporation, Nikki-Universal Co., Ltd., Japan Asia Investment Co., Ltd., Nippon Cargo Airlines Co., Ltd. (Secretariat), Nomura Research & Advisory Co., Ltd., Mitsui Engineering & Shipbuilding Co., Ltd., Mitsubishi Heavy Industries, Ltd./Mitsubishi Hitachi Power System, Ltd., euglena Co., Ltd., Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment, New Energy and Industrial Technology Development Organization and National Agriculture and Food Research Organization.

(3) Meetings Held and Summary of Proceedings

In addition to holding a total of six meetings as described below, from November on, information was shared and discussions conducted within the subcommittee while separate discussions were conducted between the Secretariat and the relevant members, in addition to email correspondence.

① First meeting: Thursday, July 3, 2014, 14:00~16:00 (Venue: Boeing Japan)

After confirming the purpose of the INAF and this subcommittee, a presentation was given and questions asked about Mitsubishi Hitachi Power System, Ltd.'s woody biomass gasification and FT synthesis technology. Later discussions were held on current issues to be addressed as well as the content to be considered during the following subcommittee meetings.

② Second meeting: Wednesday, July 30, 2014, 14:00~16:00 (Venue: Boeing Japan)

Along with examining importation of raw material and products for fuel, the Green Earth Institute gave a presentation about growth-arrested bioprocess technology and an overview of the business, and Nikki-Universal Co., Ltd. gave a presentation providing an overview and the achievements made with technology from Honeywell UOP (hereinafter, "UOP"), and this information was shared.

③ Third meeting: Wednesday, August 20, 2014, 14:00~16:00 (Venue: Boeing Japan)

Taking into account previous discussions, the focus of the expected review of a supply chain not dependent on municipal waste or microalgae was organized into four categories: 1) importation of fuel produced overseas, 2) Japanese corporations producing fuel overseas and then the importation of such fuel, 3) importation of raw material and then the production of fuel in Japan, and 4) production of raw material and fuel production in Japan, and the current status of each category was confirmed.

④ Fourth meeting: Friday, September 26, 2014, 13:30~15:00 (Venue: Boeing Japan)

Taking into account discussions at the third meeting, there are options with regard to importation which can be envisioned no matter what raw material is used, and because it would be more efficient to conduct a detailed review during the process of business development, such a review by the subcommittee was shelved, and raw materials and technologies were selected that would be available for producing next-generation aviation fuels by FY 2020, and discussions proceeded toward the formulation of a roadmap for fuel production.

⑤ Fifth meeting: Friday, October 10, 2014, 14:00~16:00 (Venue: Boeing Japan)

After presentations, which were given by the Green Earth Institute, Mitsubishi Hitachi Power System and ITOCHU Corporation, on business scenarios conducive to examination of a roadmap, discussions were held.

⑥ Sixth meeting: Monday, October 20, 2014, 14:00~16:00 (Venue: Boeing Japan)

The Green Earth Institute and Mitsui Engineering & Shipbuilding Co., Ltd. each gave presentations on a roadmap for next-generation aviation fuel using, respectively, non-edible biomass and waste food oil as the raw material. In order to commence production of next-generation aviation fuel by FY 2020, roadmaps were compiled and drafted for the four raw materials including natural oils, about which a presentation had been given by Nikki-Universal Co., Ltd., and for woody biomass, about which a presentation have been given by Mitsubishi Hitachi Power System, so as to pursue the feasibility of multiple raw materials.

6. Subcommittee 4

(1) General Overview of Activities

Information was shared regarding the current state of inquiries presented by each subcommittee about the legal system and procedures. And, the subcommittee members shared those matters that are feasible under the current legal system with regard to the business of producing next-generation aviation fuels as currently anticipated. It is essential that any examination be based on concrete business models including whether or not it is possible to simplify procedures, and discussions were held about the legal system concerning next-generation aviation fuels at each stage of the supply chain, quality management of fuel, and standards.

(2) Membership roster:

A total of 19 organizations are members of the Fourth Subcommittee: IHI Corporation, Japan Aerospace Exploration Agency, Green Earth Institute Co., Ltd., National Institute of Advanced Industrial Science and Technology, Japan Petroleum Exploration Co., Ltd., Chitose Laboratory, The University of Tokyo, Narita International Airport Corporation, Japan Asia Investment Co., Ltd., The Institute of Energy Economics, Japan, Nomura Research & Advisory Co., Ltd., The Boeing Company (Secretariat), Mitsubishi Heavy Industries, Ltd./Mitsubishi Hitachi Power System, Ltd., euglena Co., Ltd., Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment, New Energy and Industrial Technology Development Organization and International Air Transportation Association (IATA).

(3) Meetings Held and Summary of Proceedings

A total of five meetings were held as described below and information was shared as well as deliberations conducted by the subcommittee.

① First meeting: Tuesday, July 8, 2014, 14:00~16:00 (Venue: Boeing Japan)

After confirming the purpose of the Fourth Subcommittee, the members exchanged ideas about the direction of future discussions, and conducted hearings to inquire about requests for legal system revisions from the First, Second and Third Subcommittees. Also, the Narita International Airport Corporation gave a presentation about aircraft fueling facilities at the airport, and information was shared about standards pertaining to aviation fuel as well as the actual state of fuel transport and fueling at the airport.

② Second meeting: Tuesday, July 15, 2014, 14:00~16:00 (Venue: Boeing Japan)

In a hearing with the First Subcommittee, views were expressed requesting flexible treatment under the Waste Disposal Law for the transportation of waste material across administrative districts, and, because such transportation is possible under the current system, it was confirmed that such verification for compliance is needed based on a specific business plan. Also, an overview was presented of the Cartagena Act[22], which is the system used for

[22] Act on the Conservation and Sustainable Use of Biological Diversity through Regulations on the Use of Living Modified Organisms (Act No. 97 of June 18, 2003). It is known as the “Cartagena Act” because it was enacted as a domestic law for ratifying the Cartagena Protocol (named after Cartagena, Columbia where the meeting was held to debate the protocol).

genetically modified microalgae.

③ Third meeting: Tuesday, July 22, 2014, 14:00~16:00 (Venue: Boeing Japan)

During hearings with the Second and Third Subcommittees, it was pointed out that fuel production facilities are in the demonstration stage and that the amount of investment for plant construction is large, so requests were made for public support, and discussion held which took into account trends in other countries.

④ Fourth meeting: Thursday, December 4, 2014, 13:30~15:30 (Venue: Boeing Japan)

The requests for systematic reforms presented by the First, Second and Third Subcommittees were compiled, and information was shared about systems and standards pertaining to aviation fuel.

⑤ Fifth meeting: Thursday, January 15, 2015, 13:30~15:30 (Venue: Boeing Japan)

IATA gave a presentation about global trends concerning supply chains for next-generation aviation fuels and quality inspection systems, and a question and answer session was held. Information pertaining to aviation fuel systems and standards was compiled.

III. Review Results

1. Basic Understanding

(1) Significance of Review

① Positioning of Aviation Sector Measures in the Context of Worldwide Measures to Counter Global Warming

In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) which was released in November 2014, the extreme likelihood was once again pointed out that anthropogenic emissions of greenhouse gases are the dominant factor in global warming and that sustained reductions are needed over a wide range of greenhouse gas emissions to limit warming and other climate change. In December 2014, at the 20th Climate Change Conference (COP20) under the United Nations Framework Convention on Climate Change, debate is moving forward on an international framework to take effect in 2020 in regard to mitigation and adaptive strategies to address global warming[23].

The IPCC, COP and other international organizations have indicated in great detail the risks arising from climate change, including sea level rise, abnormal weather, natural disasters and so on, and the International Energy Agency (IEA) has pointed out that postponing the strengthening of measures to address global warming will avert 1.5 trillion USD in low carbon investment (approx. 180 trillion JPY [24]) before the year 2020, but an additional investment in the sum of 5 trillion USD (600 trillion JPY) will be required to subsequently return to the course of change to the proper direction[25]. In view of these circumstances, there is no question that, in the aviation sector as well, industry, countries and the ICAO[26] need to collaborate to

[23] Global warming mitigation measures are measures for reducing emissions of greenhouse gases, and global warming adaptive measures are measures to alleviate the adverse effects of warming by reconciling the way in which nature and society interact.

[24] Converted at a rate of 120 JPY to 1 USD; hereinafter the same.

[25] IEA: World Energy Outlook Special Report "Redrawing the energy-climate map", 10 June 2013, P11.

[26] The reduction of greenhouse gases from international airports is addressed through the ICAO in accordance

strengthen measures to counter global warming.

② Utilization of Next-Generation Aviation Fuels for Reduction of Greenhouse Gases and Energy Security in the Aviation Sector

The use of next-generation aviation fuels is one of the aviation sectors four principal measures for reducing greenhouse gases along with the development and introduction of aircraft having high fuel efficiency, improvement of flight systems, and the introduction of economically competitive methods. Particularly, at the current point in time when practical implementation of electric propulsion aircraft is not anticipated, even looking ahead into the medium and long-term future extending to the year 2050, next-generation aviation fuels and alternative aviation fuels, which are drop-in fuels that may be utilized with current aircraft and related infrastructure, are regarded as an important means supporting a reduction in greenhouse gases. With demand for aviation transport and aviation fuel expected to increase in the future, assuming a mixture ratio of 10%, the quantity of next-generation aviation fuel to be demanded in 2050 is estimated to be around 36.8 million to 57.5 million tons (oil equivalent conversion) [27].

The ICAO and IATA have also pointed out the importance of such next-generation aviation fuels and are working to promote their introduction. After the 2013 ICAO General Assembly passed a resolution requesting that the ICAO and member countries work to promote the introduction of next-generation aviation fuels, the Alternative Fuels Task Force (AFTF), which was established by General Assembly resolution, has been assessing the lifecycle of next-generation aviation fuels and forecasting production levels. Those results will be reported to be General Assembly in 2016.

Also, countries are proceeding with consideration of next-generation aviation fuels from the standpoint of energy security. Japan's Basic Energy Plan[28] also indicates that the country’s energy security environment is becoming increasingly severe, and, in order to address such a situation, it is important that industry, government and academia collaborate and work together to promote the introduction of next-generation aviation fuels.

③Sustainability of Next Generation Aviation Fuels

In the consideration of next-generation aviation fuels, it is necessary to attend to reductions in greenhouse gases throughout the entire supply chain, competition with foodstuffs, and diversity. Next-generation aviation fuels emit almost the same level of greenhouse gases when burned as conventional aviation fuels do, but, if next-generation aviation fuels are derived from biomass, then carbon is absorbed in the raw material growth process, so in terms of the carbon cycle, it is possible to have zero emissions in terms of the carbon cycle. However, when viewing the entire supply chain, a review is required which takes into account greenhouse gas emissions during conversion of the land use associated with raw material cultivation as well as production and transport. On this point, there are high expectations for

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with the Kyoto Protocol adopted in 1997, and just as with international maritime transport, it does not cover reduction targets for each country.

[27] IEA Bioenergy: “The Potential Role of Biofuels in Commercial Air Transport – Biojetfuel”, September 2012, P8

[28] Cabinet decision dated April 11, 2014 (see reference 8)

cellulosic materials and microalgae from the standpoint of sustainability on account of a reduction in greenhouse gases and avoidance of competition with foodstuffs, and the development of such technology are being advanced worldwide.

④ Business Development for Next-Generation Aviation Fuels

For business development, it is essential that a specific quantity of fuel be ensured which will be committed to upgraded facilities, that there be collaboration and joint ventures of several companies to that end, and that a supply system will be established for diesel and other by-products. Also, the construction of a more general-purpose business system, rather than a system requiring rigorous business terms, is necessary for developing the business of next-generation aviation fuel production in Japan as well as its subsequent expansion. Business growth is achieved through technological innovation derived from accumulated knowledge as well as significant cost reductions achieved in system optimization. It is important that a demonstration project be instituted, and that such results lead to technological innovation and cost reductions so as to generate momentum for specific business development.

Furthermore, in developing the supply chain business for next-generation aviation fuels, the quantity of demand is an important factor. Also, at one time, fuel costs accounted for approximately one third of total expenses for aircraft transportation operations, and fuel prices also are an important factor in the efforts, made for business development. Alternative aviation fuels are a substitute for conventional aviation fuels, so demand over the short and medium term will be influenced by changes in the price of conventional aviation fuel. However, in view of the aforementioned importance of alternative aviation fuels and next-generation aviation fuels, the key to business development is for issues of demand and price to be overcome through industry, government and academia collaborating to construct and implement measures to promote the introduction of next-generation aviation fuels.

(2) Positioning of Review Results

Forty-six organizations with an interest in next-generation aviation fuels have participated in the INAF's planning, and the results of reviews during discussions which take into account the knowledge held by these organizations have been compiled in this report. This report is presented as a roadmap that organizes, along with the period up to when production is commenced, matters to be achieved as well as issues to be overcome in the future for each process in the production of next-generation aviation fuels and supply of alternative aviation fuels, for which there is a high likelihood of being produced by businesses in Japan.

This report presents an overall picture of the entire supply chain from procurement of raw materials to production of next-generation aviation fuel, its mixture with conventional aviation fuel to produce alternative aviation fuel and then its transport and supply to aircraft, and this report offers a sketch with the aim of having next-generation aviation fuels introduced, and it includes not only the results of reviews, but also the material used in the process of deliberation. In heading for business development in the future, the final round of discussions necessary for specific business development are needed in the fields of government policy, products, raw materials, technology, sustainability, distribution, cost calculations, financing, equipment, and business administration based on this sketch.

In the future, it is hoped that business development will be advanced through the collaboration of a wide range of interested parties not limited to the organizations participating in the INAF.

(3) Consideration of the Implementing Enterprise

①Advantages for the Implementing Enterprise

The implementing enterprise supporting the supply chain for next-generation aviation fuel will be able to enjoy a variety of benefits by, above all, being involved in the aviation business, which is expected to see dramatic growth. Also, it can be expected to respond appropriately to energy trends. Moreover, over the short term, it will present an image of being an excellent company with the capability to contribute to measures to counter global warming, which appeal to clients, and over the medium and long term, the implementing enterprise will construct a bridgehead obtaining a variety of operating profits including those from derivative operations by occupying a front-runner position in the growing field of supplying next-generation aviation fuels.

②Relationship with Stakeholders

For instance, as it can be understood from the fact that United Airlines concluded a sales contract for alternative aviation fuel with AltAir Fuels in 2013 and that the airline is advancing efforts related to the introduction of alternative aviation fuels combining next-generation aviation fuel, the relationship between air carriers and fuel producers is the crux of the supply chain for next-generation aviation fuel.

Also, looking at the example of KLM, the KLM Corporate Biofuel Programme was started in 2012. In cooperation also with the companies participating in the programme (initially started with eight companies in 2012, six more were added in 2013, two more along with one government ministry in 2014 so that, as of October 2014, 17 organizations are participating), one commercial flight per week is operated between New York and Amsterdam, using alternative aviation fuel derived from biomass. Through such programs, participating companies are able to appeal to society about the extent of their awareness of environmental issues, and air carriers are able to acquire preparations for full scale use of alternative aviation fuel through the use of aviation fuels in this programme.

(4) Consideration of the System Encompassing Aviation Fuel Supply

①Aviation Fuel Supply Chains and Systems

(a) Conventional Aviation Fuels

The principle system applicable to the supply chain for conventional aviation fuels are largely considered to be those shown in Chart 3. Conventional aviation fuel comes under hazardous materials classified as “Category IV Class II petroleum” (flashpoint at one atmospheric pressure is 21°C or higher but lower than 70°C) as prescribed by the Fire Service Act. So, in each process along the supply chain, the fuel is basically required to be safely handled under the auspices of the Fire Service Act.

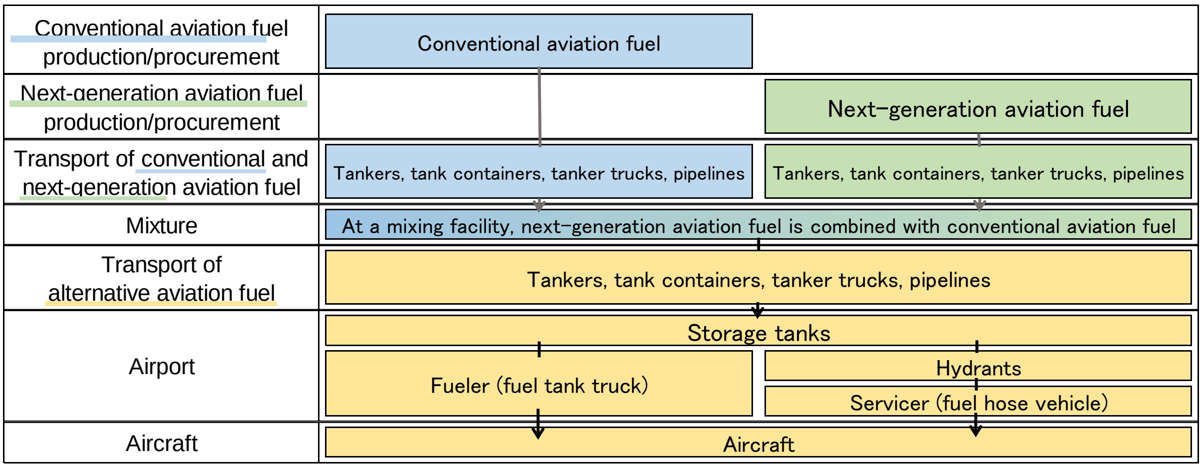
Chart 3: Principal Systems Applicable to Supply Chain for Conventional Aviation Fuel

1. Fuel production facilities	・Fire Service Act
	・High Pressure Gas Safety Act
	・Relevant ordinances of local governments Etc.
2. Transport	・Fire Service Act (tankers, tank containers, tank trucks)
	・Petroleum Pipeline Business Act (pipelines)
3. Airports	・Fire Service Act (oil storage tanks, high-end facilities and other aircraft fueling facilities in general)
4. Aircraft	・Civil Aeronautics Act (airworthiness, examination of operating provisions)

(b) Next-Generation Aviation Fuels

A general overview of the supply chain for next-generation aviation fuel is shown in Chart 4.

Chart 4: Supply Chain for Next-Generation Aviation Fuel



In terms of standards, alternative aviation fuels are certified and utilized as having the same properties as conventional aviation fuels, and just as with conventional aviation fuels, they are applicable under the system shown in Chart 3 above as pertains to the Fire Service Act and other laws and regulations. As for any impact that next-generation aviation fuels and alternative aviation fuels have on transportation facilities and aircraft fueling facilities at airports, it is important to steadily compile actual examples in consideration of safety while also taking into account that alternative aviation fuels have the same properties as conventional aviation fuels.

Also, at major airports within Japan, tanks, hydrants and other fueling facilities are used jointly by multiple petroleum wholesalers, who are the fuel vendors, and multiple air carriers, who are the fuel purchasers, and, even if a certain air carrier would like to procure alternative aviation fuel, the consent of all parties associated with the joint use fueling facility is necessary and the setting of a new user fee will be necessary, so, when alternative aviation fuels are handled at an airport, preparations are necessary for establishing such a system (see pp. 36~38 of the attached documentation). The development of such a structure at airports will be necessary even at those airports where there is a fueler fueling system, hydrant fueling system or a combination of the two.

②Standards for Aviation Fuel

(a) International Standards for Aviation Fuel: ASTM Standards

With regard to aviation fuels, the performance necessary for safe operation of aircraft is prescribed and standards have been set to ensure such performance. With regard to standards for aviation fuel, the de facto international standard is the ASTM standard, and a standard, which is known as D1655, has been prescribed for conventional aviation fuels[29]. Also, a standard, which known as D7566, has been prescribed for alternative aviation fuels which combine next-generation aviation fuels with conventional aviation fuel.

(b) Procedure for Enacting ASTM Standards for Aviation Fuel

The procedure when establishing new ASTM standards pertaining to aviation fuel or when amending the specifications of current standards is prescribed in ASTM D4054[30], and there are three procedural stages. The test program in Stage I comprises procedures for certifying that candidate fuels do have an adverse effect on engine safety, durability or performance. The tests, which aircraft manufacturers and aircraft engine manufacturers conduct internally, in Stage II comprise procedures for certifying in-house that, when the candidate fuel is used, the company's products will function safely and there are no problems with airworthiness. During this stage, the parties continue to coordinate their activities with aviation authorities. The establishment or amendment of standards in Stage III comprise procedures through which the draft investigation report prepared based on the test and verification results in the aforementioned Stages I and II is examined by the technical committee responsible for aircraft fuels at ASTM International to determine the advisability of enacting a standard[31].

(c) Standards for Alternative Aviation Fuels

The ASTM standard for alternative aviation fuels is D7566. This standard covers fuels combining next-generation aviation fuels with conventional aviation fuel, and next-generation aviation fuels are prescribed in annexes to D7566. Currently, there are three specified in annexes, FT SPK (Annex A1, established in 2009), HEFA SPK (Annex A2, established in 2011) and SIP (Annex 3, established in 2014), and the mixture ratios are up to 50% for FT SPK and HEFA SPK, and up to 10% for SIP. Also, in 2015 or 2016, the enactment of standards for three new fuels is expected, including High Freeze Point HEFA (Green Diesel).

D7566 prescribes the standards and test methods required when producing or shipping alternative aviation fuels, but there are no stipulated procedures or quality control methods for verifying compliance with the standard during the distribution process after shipment from the production plant. Quality control in the distribution process is prescribed in other documents[32].This point is the same also for the aforementioned (②(a)) D1655.

③Quality Control of Aviation Fuel

(a) Overview

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29 Jet A-1, which accounts for the bulk of the aviation fuel used in Japan, is one fuel that complies with D1655.

30 Available for purchase on the ASTM International website (http://www.astm.org/Standards/D4054.htm) (62 USD as of February 26, 2015). A user's guide is also available free of charge on the CAAFI website, a group concerned with next-generation aviation fuel (http://www.caafi.org/information/pdf/D4054_Users_Guide_V6_2.pdf).

31 According to the Midwest Aviation Sustainable Biofuels Initiative (MASBI), the amount of time and money required when enacting a completely new ASTM standard for aviation fuel from scratch is at least three years and 30 million USD (approximately 3.6 billion JPY). See reference 14.

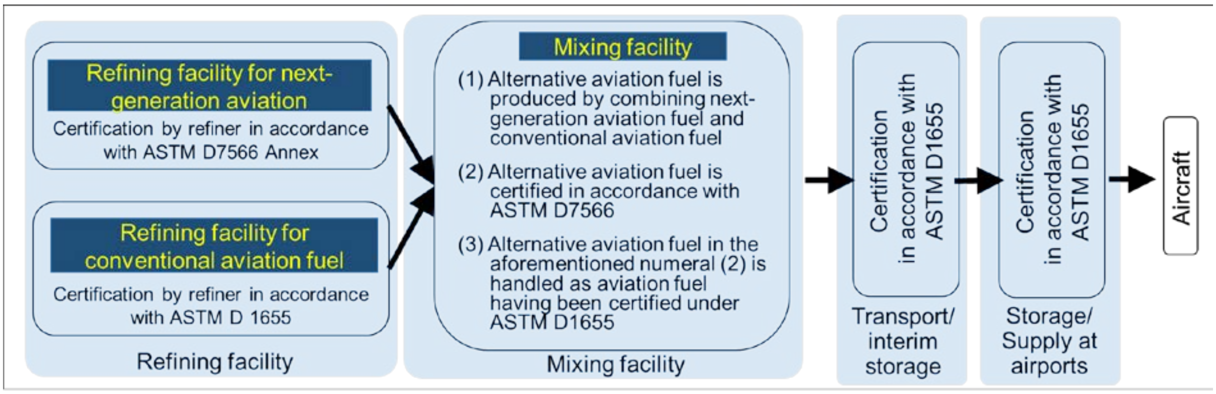
32 For example, ICAO 9977, EI/JIG Standard 1530, JIG 1, JIG 2, API 1543, API 1595, ATA-103, etc.

In contracts for sale of aviation fuel, the time at which ownership is transferred is generally at the point when the fuel is feed into an aircraft at an airport, and the fuel vendor is required to provide fuel, which has been ordered by the purchasing air carrier, that complies with the quality for said fuel at the time of fueling when ownership is actually transferred. As described above with regard to aviation fuels, conventional aviation fuels, next-generation aviation fuels and alternative aviation fuels are certified under the respective standards D1655, D7566 Annex and D7566 at the time of production. Also, the aviation fuel fed to aircraft is supplied after a process in which it is handled in transportation and at the airport, but the vendor, who has ownership of the fuel during transportation to and storage at the airport, is required to deliver fuel, which meets the standard at the time of production, to air carriers in a state where the quality is controlled, maintained and complies with the standard under an established transportation and quality control method.

(b) International Handling of Aviation Fuel along the Supply Chain

Quality controls along the supply chain after certification under D1655 or D7566 at the time of fuel production and shipment have been standardized in accordance with established commercial practices, and such practices are shown in general in Chart 5, which is based on ICAO documentation[33].

Chart 5: Quality Control of Aviation Fuel along the Supply Chain



Note: Chart has been prepared based on IATA documentation from the Fourth Subcommittee (Attachment p. 150), and p. 35 of the FAA documentation diagraming a synopsis of the ICAO documentation.

For certification at the time of fuel production and shipment, testing for compliance with all quality standards prescribed in D1655 and D7566 is performed for each batch, and, when certifying to the effect that compatibility with quality standards continues in each process of the supply chain, it is customary to conduct inspections of each batch according to 10 items[34], which have been simplified down from the inspection conducted at time of production and shipment. According to a survey conducted by the FAA, the former costs between 1000 and 2000 USD, and the latter between 100 and 200 USD. Also, for testing under D7566, there are some portions where modifications to D1655 testing devices need to be made, but such modifications are not considered that difficult of an obstacle for the introduction of alternative aviation fuel[35].

[33] ICAO 9977, Manual on Civil Aviation Jet Fuel Supply, First Edition - 2012

[34] Density, distillation characteristics, flashpoint, freezing point, dissolved gum, copper corrosion, missed separation index based on the micro-separometer method, color, thermal conductivity, and thermal stability

[35] Reference 13, pp. 45 and 50.

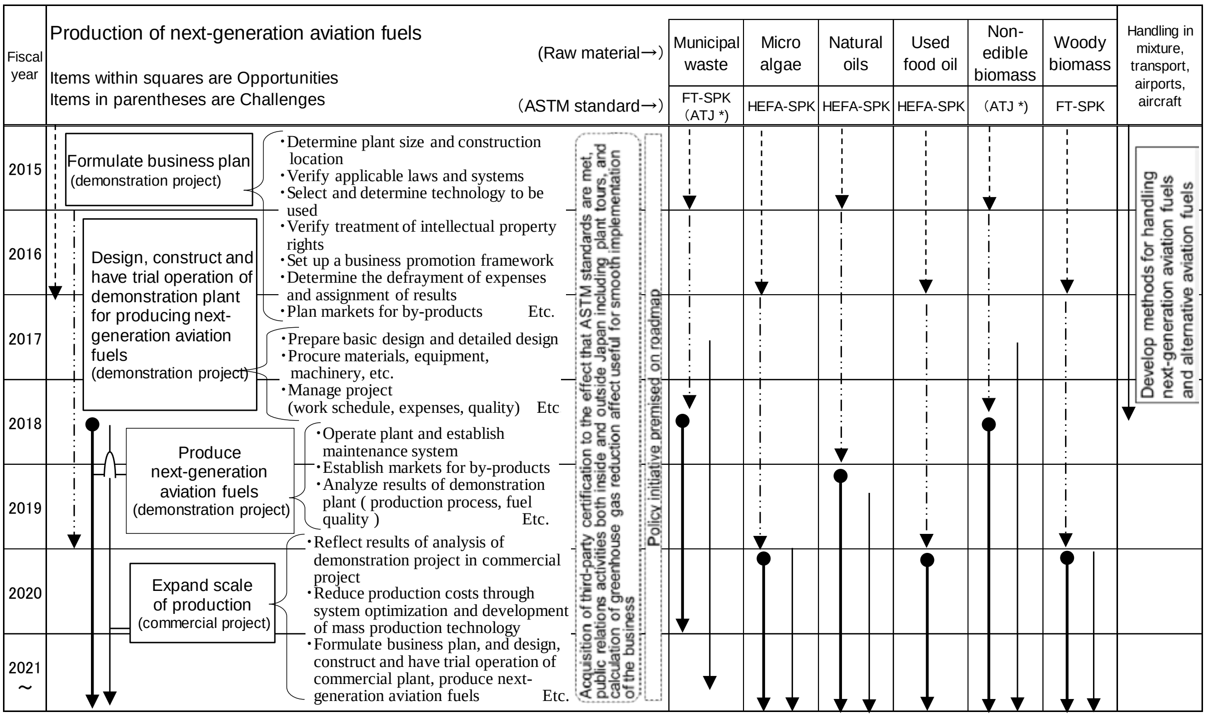
2. Roadmap

(1) Roadmap for Establishing a Supply Chain for Next-Generation Aviation Fuels

(See Chart 6)

As shown in Chart 6, a roadmap has been formulated for utilizing technology that companies in Japan possess or have available to use to produce next-generation aviation fuels and establish a post-production supply chain to begin making use of alternative aviation fuel.

Chart 6: Roadmap for Establishing a Supply Chain for Next-Generation Aviation Fuels



Notes:

- The size of the plant project increases in order from small to large beginning with lab, bench, demonstration and commercial. Here, an assumption that the size will increase beginning in FY 2021 has been taken into account, and the projects have been arranged so that a demonstration project is implemented by FY 2020 and a commercial project in FY 2021 or thereafter.
- The roadmap for each raw material is based on the results of reviews conducted by each subcommittee (see appendix (only Japanese version) pp. 76, 105, 135 and 136).
- Provisions for the ASTM standard ATJ have not been prescribed in D7566 Annex as of May 2015, but enactment of such provisions is anticipated in 2015 or 2016.

① Raw Materials

Of those raw materials, the technology for which Japanese companies possess or able to utilize for producing next-generation aviation fuels, fuel production was reviewed and consolidated into six raw materials, municipal waste, microalgae, natural oils (excluding waste food oils; hereinafter the same), waste animal oil, non-edible biomass (cellulosic sugar; hereinafter the same), and woody biomass, while giving overall consideration to the feasibility of production from the standpoint of raw material procurement and the capability to address increased demand in the future over the approximately five years remaining until FY 2020. After realizing the production of next-generation aviation fuels and commencement of supply of alternative aviation fuel by FY 2020 through an expansion of operations producing next-generation aviation fuels from each of these raw materials which have the features described below, supplies will be able to be increased thereafter.

With regard to municipal waste, Japan has a collection system in place, and the production technology for this raw material has also been used in the GreenSky London Project, plus there are ASTM standards as well. Research on microalgae has advanced as part of the strategic next-generation biomass energy utilization and development project of the New Energy and Industrial Technology Development Organization (NEDO), and there are ASTM standards for production technology. The production technology for using natural oils as the raw material is being used already in projects in the United States and there are ASTM standards enacted. Japan has a collection system for waste animal oil, this production technology is being used in projects overseas, and there are also ASTM standards. The enactment of ASTM standards for production technology employing non-edible biomass are under review, and when the standards are established, the high yields from this raw material will make it possible to produce fuel. Within the NEDO project, research on woody biomass is being advanced, and construction of an economically competitive collection system would allow the untapped raw material in Japan to be utilized effectively. In the future, if demand exceeds the supply of these raw materials, there is also the option of importing any of these raw materials.

②Path for Establishing Supply Chain

In the limited time period of approximately five years, the business entity needs to be set up for the fuel production project, a feasibility study conducted as well as other research done to formulate a business plan and then construct a plant (basic design, detailed design, procurement, construction, trial operation), which will need to be completed by FY 2019 in order to establish a supply chain for next-generation aviation fuels by FY 2020. Considering that plant design, construction and trial operation will require a period of two to three years, a roadmap is needed so that a business plan is formulated in FY 2015 or 2016, the plant designed and constructed in FY 2016 to 2018, trial operation conducted in FY 2019, and the supply of fuel begun in FY 2020. Depending on the raw material, commencement of fuel supply may also be anticipated in FY 2018 to 2019.

After next-generation aviation fuels are produced, they will be combined with conventional aviation fuel to produce alternative aviation fuel, and then transported to airports where, after being fed into aircraft, they will be used to fly the aircraft. For each process in this supply chain, it is necessary to develop handling methods in accordance with international guidelines, just as with conventional aviation fuels, no later than FY 2018 when production of next-generation aviation fuels is anticipated to begin.

This roadmap is premised on there also being a policy initiative aimed at promoting the introduction of next-generation aviation fuels. Also, to realize the roadmap, it is necessary to further improve, develop and optimize technology, establish markets for by-products, and continue to reduce costs with the aim of being competitive in terms of price with conventional aviation fuels, and it is desirable that a detailed review be initiated immediately with the aim of business development.

③Facilitating Establishment of a Supply Chain

A supply chain for next-generation aviation fuels is established through the cooperation and collaboration of interested parties in a diverse range of sectors. So, in order to set up the business entity for the fuel project, public relations activities are needed to gain the understanding of businesses, investors and other related parties. Providing tours for VIPs, who come to Japan for the Tokyo Olympics and Paralympics, of the supply chain from the production of next-generation aviation fuels all the way through to fueling aircraft with alternative aviation fuels as well as offering test flights in aircraft using alternative aviation fuels are considered useful for expanding the business to other countries and attracting investment from overseas.

In addition, the distribution of aviation fuel is premised on the fuels compliance with standards, and what is needed for compliance with such standards is for the produced next-generation fuel to satisfy the properties prescribed in D7566 Annex, and the alternative aviation fuel which has been mixed with conventional aviation fuel to satisfy the properties prescribed in D7566. There are also methods through which the fuels are certified by a third-party organization. There are also cases where it may be considered useful in practical terms for the fuel sold to comply with standards verified by a third-party organization for the benefit of Japanese businesses that newly produce next-generation aviation fuels and alternative aviation fuels and for the broader distribution of such fuels in the future. From the same standpoint, it is also useful to build up a track record of fuel use by having flights of aircraft using alternative aviation fuel, which has been mixed with samples of next-generation aviation fuels produced during trial operation of the plants. Furthermore, it is also important to calculate the reduction effect on greenhouse gas emissions throughout the entire supply chain.

When formulating a detailed business plan, the particulars will be studied for the mixture ratio of next-generation aviation fuels, business expenses, estimated price of alternative aviation fuel, quantity demanded, quantity capable of being supplied, and other items.

(2) Raw Material Procurement and Production

①Municipal Waste

(a) Business Overview

The existing collection system will be used to secure municipal waste for the raw material to produce next-generation aviation fuel. It is anticipated that a large quantity of municipal waste will be able to be secured in large urban areas, and locations for plant siting will be considered while also taking into account the timing for renovation of a large incinerator facility. For fuel production, of the three available methods which are the method by which municipal waste is gasified, the synthesis gas cleaned up and then undergoing FT synthesizing and hydrocracking, the method using ATJ from ethanol produced directly from municipal waste, and the other method using ATJ from ethanol produced through synthesis gas from municipal waste, Japanese companies possess technology for the method which uses FT synthesis and there are already ASTM standards for this production method (FT SPK). This method is technically advanced, while it is estimated that it will take several years until ASTM standards are enacted for the two fuel production methods employing ATJ from ethanol, therefore, business development of fuel production using FT synthesis will move forward. The review of business development will proceed with an eye toward the establishment of ASTM standards for fuel production by means of ATJ from ethanol.

(b) Path Leading to Commencement of Supply by FY 2020 (See Chart 7)

Technical advancements will be made at the level of the demonstration plant in gasification, cleanup, FT synthesis and upgrading technologies. When the implementing entity is determined, then business planning, demonstration plant design and construction can be undertaken from FY 2015 to 2017, and, after trial operation is conducted in FY 2017 and 2018, the production of next-generation fuel can be expected to begin in FY 2018. The results from the demonstration plant will be taken into account, and, after studying whether or not elemental technology may be applied to a commercial plant as well as the most appropriate conditions and disincentives for each process, confirmation will additionally be made with a demonstration plant as to whether or not capability can be demonstrated if these are combined, and efforts aimed at developing a commercial project will begin in FY 2019. The same path will be taken for production using ATJ, if ASTM standards are prescribed.

Chart 7: Roadmap for Supply of Next-Generation Aviation Fuel Using Municipal Waste as the Raw Material

Fiscal Year	Opportunities	Challenges
2015	< Formulation of business plan > ● Set up business entity for demonstration project, review plant concept, formulate business plan	■ Ascertaining the specific properties of the mystical waste serving as a raw material, and selecting cleanup technology
2016	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Estimate cost of constructing demonstration plant, and construct the plant	■ Appropriately managing project
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Construct demonstration plant and prepare for trial operation < Increase in production scale (1) > ● Launch organization to study commercial plant project	■ Appropriately managing project ■ Establishing trial operation framework
2018	〈 Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) 〉 ● Trial operation of demonstration plant < Production of next-generation aviation fuel (1) > ● Produce next-generation aviation fuel at demonstration plant < Increase in production scale (2) > ● Determine scale and site for construction of commercial project, and review systems for collecting municipal waste over a wide area	■ Appropriately managing project ■ Analyzing results of demonstration plant operation
2019	< Production of next-generation aviation fuel (2) > ● Supply alternative aviation fuel which combines the fuel produced at the demonstration plant < Increase in production scale (3) > ● Prepare basic design of commercial plant	■ Appropriately managing project ■ Analyzing results of demonstration plant operation ■ Reflecting the results of analysis of demonstration plant in the basic design for a commercial plant ■ Conducting feasibility study for commercial project
2020	< Production of next-generation aviation fuel (3) > ● Operate demonstration plant, conclude operations, and reassess them 〈 Increase in production scale (4) 〉 ● Make a determination on investment in commercial project	■ Reflecting the results of analysis of demonstration plant in the commercial project ■ Soliciting and securing operators, investors and other parties to be involved in commercial project
2021 ~	〈 Increase in production scale (5) 〉 ● Design, construct, operate and maintain commercial plant	■ Establishing the business entity to produce next-generation aviation fuel using municipal waste as the raw material ■ Advancing the commercial project to be undertaken by the business entity

Notes: This is a roadmap organizing the path and issues to be addressed which are anticipated for producing next-generation aviation fuel and commencing the supply of alternative aviation fuel by FY 2020 on the basis of the review results produced by the First Subcommittee.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

Japan has a system for collecting municipal waste and it is easy to procure this raw material.

FT synthesis-based fuel production technology has been adopted in the GreenSky London Project and the reliability of the technology is high at the current point in time, so this is considered to be one fuel production path effective for establishing a supply chain for next-generation aviation fuel by FY 2020. ATJ-based production from ethanol is also similarly considered to be an effective path because the enactment of the relevant ASTM standards is anticipated in the near future. Also, because a large quantity of municipal waste is discharged in Japan, this path can be expected to allow for an increase in the quantity of fuel produced in keeping with increases in demand in the future, if a municipal waste collection system over a broad area can be operated in an economically competitive manner.

(d) Characteristics of the Business

This business utilizes the existing collection system to procure municipal waste within Japan, and using this as the raw material, produces next-generation aviation fuel domestically. It contributes to a recycling-oriented society in terms of the use of waste as a resource. Also, the quantity of municipal waste and the amount of air transportation, which is proportional to the quantity of fuel that needs to be produced, will tend to increase along with the increase in population, so procurement of this raw material accompanying an expansion in production is considered to be relatively easy.

(e) Evaluation

Most municipal waste is already being recycled, but taking into account the quantity of municipal waste available as a raw material, the presence of a collection system, and the degree to which utilization technology has advanced, municipal waste can be expected to serve as a path providing the capability for an early start to production as well as allow for future increases in supply to produce next-generation aviation fuel in Japan.

In preparation for business development, it is important that improvements be made which are tailored to the business of next-generation aviation fuel in terms of the collection of large quantities of raw material, the gasification and reforming facilities when producing synthesis gas from municipal waste, and the cleanup technology used in the process prior to FT synthesizing of synthesis gas.

One criterion concerning the quantity of raw material to be collected for business development is that securing 2000 tons per day of municipal waste permits 1000bpsd[36] (oil equivalent conversion of approximately 159L each day) of next-generation aviation fuel to be produced. This is equivalent to the amount of municipal waste discharged by 2 million people, and, depending on the site of the production plant, municipal waste will need to be collected from multiple local governments. If an integrated processing is sought for collecting general waste and industrial waste as well as transportation of the waste across prefectural and municipal boundaries in order to secure such a large quantity of municipal waste, then it needs to be kept in mind that procedures will be required under the Waste Disposal Law. Existing gasification

[36] bpsd is an abbreviation of barrel per stream day, referring to the quantity processed per day when the facility is operating at full capacity. One barrel of crude oil is approximately 159 L.

reforming facilities are based on the concept of averting any generation of dioxin and having zero landfill disposal, so the gasification and reforming process is not necessarily suited to the production of synthesis gas conducive for aviation fuel production. Also, cleanup technology needs to be improved so as to increase the precision with which materials that are anti-catalysts in the FT synthesis and contained in synthesis gas are removed by a combination of the present technologies that have already been developed.

②Microalgae

(a) Business Overview

Next-generation aviation fuel is produced by hydrorefining oil content known as algae oil, which is produced by microalgae. One continuous process from the growth of microalgae to production of next-generation fuel is the focus of this operation. Taking into account that photosynthesis causes microalgae to propagate, the microalgae is cultivated in warm locations where there is ample sunlight and in outdoor cultivation facilities such as pools, so locations for siting such a facility were reviewed with an eye toward cultivation and fuel production overseas. A business operation is envisioned through collaboration with parties mainly associated with the enterprise pursuing research as part of the NEDO project. There are already ASTM standards for the production technology (HEFA-SPK).

(b) Path Leading to Achievement of Goal (See Chart 8)

In FY 2015 and 2016, tests will be conducted on large-scale cultivation of microalgae, and an integrated process developed extending from raw material production to fuel production. In FY 2016 and 2017, a demonstration cultivation facility will be constructed at a location suitable for the cultivation of microalgae, and along with expanding the scale of production and considering cost-cutting measures, the properties of algae oil, which differ depending on the type of microalgae, will be taken into account and consideration given to sharing the refinement process. In FY 2018 and 2019, stable large volume cultivation of microalgae will be verified, and issues to be addressed in moving toward the commercial project identified as well as points studied for improvement. In FY 2020, the production and supply of next-generation aviation fuel will commence, but it is envisioned that efforts will continue to be advanced for increasing the scale of cultivation and improving efficiency of the production process, as well as increasing the quantity of next-generation aviation fuel produced.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

Technology will need to be established for large-scale stable cultivation and cost reductions, and the quantity of next-generation aviation fuel that will be able to be produced in FY 2020 will be limited. After FY 2020, when technology has been established for large-scale stable cultivation of microalgae at a reduced cost, this path is expected to allow for an increase in the production of next-generation fuel in keeping with future rising demand through the procurement of large volumes of the raw material microalgae due to the high reliability of hydrorefining technology for producing next-generation aviation fuel from algae oil.

(d) Characteristics of the Business

Because it is anticipated that locations having a climate suitable for the cultivation of microalgae are overseas, supply chains are possible for both the production of next-generation aviation fuel overseas and then its importation into Japan as well as production overseas and its application to air carriers at local airports. Because microalgae absorb carbon during the growing process, it can be regarded as having zero emissions in the carbon cycle, and is sustainable in that sense. It also contributes to the formation of a recycling-oriented society. In addition, raw material production for next-generation aviation fuel is incorporated into the operation, so the procurement of raw material accompanying an increase in production is considered to be relatively easy.

Chart 8: Roadmap for Supply of Next-Generation Aviation Fuel Using Oil Produced from Microalgae as the Raw Material

Fiscal Year	Opportunities	Challenges
2015	<Formulation of business plan (1)> ● Increase productivity of microalgae cultivation ● Develop a process integrating the extraction of algae oil from cultivation and the production of next-generation aviation fuel from algae oil ● Determine locations suitable for cultivation	■ Establishing technology for large volume and stable cultivation of microalgae ■ Taking into account that the properties of algae oil produced differ depending on the type of microalgae, and conducting review on sharing processes when producing fuel from each of these algae oils ■ Consolidating the issues to be addressed accompanying importation of algae oil into Japan
2016	< Formulation of business plan (2) > ● Increase productivity and formulate business plan which takes into account the integrated process ● Construct a demonstration level large volume cultivation facility at a site suited for cultivation	■ Consolidating a process for sharing and a process for not sharing the processes for producing fuel from algae oils having different properties
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Review technology for low-cost, large volume and stable cultivation of microalgae ● Design and construct demonstration plant for production of next-generation aviation fuel	■ Appropriately managing project
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Conduct trial application of technology for low-cost, large volume and stable cultivation at a demonstration cultivation facility ● Design and construct demonstration plant for production of next-generation aviation fuel	■ Appropriately managing project
2019	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) > ● demonstration project Construct and have trial operation of demonstration plant for production of next- ● generation aviation fuel	■ Appropriately managing project ■ Analyzing results of demonstration plant operation
2020	< Production of next-generation aviation fuel > ● Cultivate microalgae and demonstration facility, and produce next-generation aviation < Increase in production scale (1) > ● Increase scale of microalgae cultivation taking into account the scale of the commercial project	■ Reflecting the results of analysis of demonstration plant in the commercial project ■ Securing site for large volume cultivation
2021 ～	< Increase in production scale (2) > ● Advance commercial project which takes into account the scale of microalgae able to be cultivated ● Increase scale of next-generation fuel production by increasing scale of cultivation	■ Reducing cultivation costs in stages, and improving cultivation productivity by increasing cultivation scale ■ Improving refining efficiency when producing next-generation aviation fuel from algae oil

Notes: This is a roadmap organizing the path and issues to be addressed which are anticipated for producing next-generation aviation fuel and commencing the supply of alternative aviation fuel by FY 2020 on the basis of the review results produced by the Second Subcommittee.

(e) Evaluation

Although there are issues to be addressed concerning microalgae in reaching a mass production level, oil productivity per unit area is high and competition with foodstuffs can be mitigated, so the previous understanding held in 2012[37] when there was great expectation for its use as a raw material in fuel production still holds today, and, from a long-term perspective, it is a segment enabling preparation for the production of next-generation aviation fuel that is both feasible and sustainable.

[37] Council on Competitiveness-Nippon (reference 17), p. 1.

In preparation for business development, a large-volume stable cultivation technology needs to be established and productivity increased of the microalgae cultivation, and taking into account the production process for algae oil and the properties of algae oil which differ depending on the type of microalgae, an economically competitive process for production of fuel from algae oil needs to be established. It is important that enterprises engaged in the cultivation of microalgae and production of algae oil work together to set production targets and milestones and then achieve them so as to resolve these issues to realize business development.

In promoting this business in the future, attention also needs to be given to procedures under the legal system. When expanding this business on a commercial scale, it is anticipated that microalgae will be cultivated in an open system. But, if the cultivated microalgae is genetically recombined, then procedures will be required in accordance with the Cartagena Act (see note 22), which prescribes restrictions on the use of genetically modified organisms. In cases where non-native species of microalgae are used as well, the Quarantine Act, Invasive Alien Species Act and other laws will need to be kept in mind based on the specific operational configuration. Also, if the next-generation aviation fuel produced from microalgae (HEFA SPK) consists of saturated hydrocarbons, such production may fall within the purview of chemical substances[38] requiring notification in accordance with the Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, so such matters need to be addressed early, including the confirmation of any procedures.

③ Natural Oils (Excluding Waste food oil)

(a) Business Overview

Utilizing UOP's next-generation aviation fuel production technology, several types of natural oils are used as raw material and put through a preprocess hydroprocess and fractionation process to produce the next-generation aviation fuel, Honeywell Green Jet Fuel™. It is envisioned that the implementing enterprise will operate the business based on a licensing agreement with UOP. There is already an ASTM standard for the production technology (HEFA-SPK).

(b) Path Leading to Commencement of Supply by FY 2020 (See Chart 9)

In FY 2015, several types of raw materials will be selected for use, and simulations of the production of next-generation aviation fuel performed. In FY 2016, the basic design will be formulated for a demonstration plant with the detailed design, construction and trial operation of the plant taking place from FY 2017 to 2018. Production of next-generation aviation fuel will begin at the plant in FY 2019. From FY 2020 on, it is anticipated that the results of the production process for next-generation aviation fuel at the demonstration plant and products will be taken into account to design and construct a commercial plant increasing the quantity processed by three to five times so as to augment the quantity of next-generation fuel produced.

[38] MITI2-10 "Alkane (C=10~29)," MITI2-9 "Nonane," MITI2-8 "octane," etc.

Chart 9: Roadmap for Supply of Next-Generation Aviation Fuel Using Natural Oils as the Raw Material

Fiscal Year	Opportunities	Challenges
2015	< Formulation of business plan > ● Select multiple candidate raw materials ● Conduct simulation of next-generation aviation fuel production process using UOP technology	■ Selecting raw materials that can be stably procured ■ Determining implementing enterprise
2016	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Conduct trials for producing fuel from selected candidate raw materials (oversees implementation anticipated) ● Prepare basic design for demonstration plant	■ Concluding licensing and engineering agreement with UOP
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Prepare detailed design for demonstration plant	■ Appropriately managing project
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) > ● Construct and have trial operation of demonstration plant	■ Appropriately managing project
2019	< Production of next-generation aviation fuel (ongoing from 2019) > ● Operate demonstration plant, and produce next-generation aviation fuel < Increase in production scale (1) > ● Commence basic design for commercial plant	■ Narrowing down raw materials to ensure operational stability of plant ■ Commencing plant operation, appropriately managing and maintaining operations ■ Reflecting results of demonstration plant operation
2020 ～	< Increase in production scale (2) > ● Prepare basic design, detailed design for commercial plant, construct and operate	■ Increasing scale of demonstration plant production capacity by 3~5

Notes: This is a roadmap formulated from the standpoint of back casting on the assumption that production of next-generation aviation fuel and supply of alternative aviation fuel will commence by FY 2020 on the basis of the review results produced by the Third Subcommittee which take into account knowledge possessed by Nikki-Universal Co., Ltd.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

Because the fuel production technology used in this path has been developed by some companies in the United States for commercialization[39] and natural oils for the raw material can be physically gathered in areas within Japan, this is considered to be a fuel production path that will be effective for establishing a supply chain for next-generation fuel by FY 2020. Also, if natural oils can be collected in large volume in an economically efficient manner, this path can be expected to increase the quantity of fuel produced in keeping with future increases in demand.

(d) Characteristics of the Business

This business collects natural oils available in regions within Japan and uses them as the raw material to produce next-generation aviation fuel in Japan. Next-generation aviation fuel can be produced at one plant using tallow, non-edible oil and many other types of natural oils for the raw material. Also, in the production process, Honeywell Green Diesel™ is also produced as a by-product, so, if as anticipated High Freeze Point HEFA is prescribed in ASTM D7566 Annex in 2015 or 2016, it is expected that next-generation aviation fuel will be able to be produced in large volume at a low cost by FY 2020.

(e) Evaluation

Next-generation aviation fuel using natural oils as the raw material is widely produced around the world. UOP utilizes tallow, inedible oil and other natural oils as the raw material at its demonstration plant in the United States to produce 250 barrels per day (approx. 40kL) of

[39] The technology to be used for the United Airlines project at Los Angeles Airport in the United States is UOP's Renewable Jet Process. (See note 6 for information about this project)

next-generation aviation fuel (Honeywell Green Jet Fuel™), and supplies alternative aviation fuel for demonstration flights to the US military as well as private air carriers. There is also spinoff technology[40], which UOP developed jointly with other companies and has a business track record on a commercial scale of over 10,000bpsd of raw material processed, and the technology has been evaluated as highly reliable.

Although a characteristic of this business is that several types of natural oils can be used as the raw material to produce fuel at one plant, in order to ensure operational stability of the plant in preparation for business development, it is useful to limit the natural oils for raw material. For that reason, when the operation is initially begun, several types of natural oils will be used as the raw material in order to ensure quantity, but, thereafter, as operations are continued, it will be important to select appropriate raw materials and ensure their procurement so that this business may develop. Also, expanding outlets for High Freeze Point HEFA (Green Diesel) by strengthening collaboration with the automobile industry is also useful for increasing production of next-generation aviation fuel. Just as with microalgae, the relationship between HEFA SPK and regulations concerning chemical substances needs to be kept in mind.

④Waste food oil

(a) Business Overview

Existing collection systems are utilized to secure waste food oil for raw material to produce next-generation aviation fuel through refining and upgrading. There are already ASTM standards for the production technology (HEFA-SPK). Focusing on Chiba, southern Ibaraki, southern Saitama and eastern Tokyo where large quantities of waste animal oil are collected, and an implementing enterprise is envisioned which will comprise three processes: raw material supply, preparation of crude fuel, and separation/refinement. The technology for producing next-generation aviation fuel by using waste animal oil as the raw material and then preparing crude fuel and separating and refining it makes use of the same technology as production from algae oil and natural oils.

(b) Path Leading to Commencement of Supply by FY 2020 (See Chart 10)

In FY 2015, the properties of waste animal oil capable of being collected will be ascertained to select the refining technology applicable to such properties, and the optimum site for the fuel production plant will be reviewed based on routes along which waste food oil is collected. In FY 2016 to 2018, the basic design and detailed design for the fuel production plant will be prepared and the plant constructed. In FY 2018 and 2019, the plant will undergo trial operation and improvement by taking into account the results of tests and analyses of product samples. The production of next-generation aviation fuel and the supply of alternative aviation fuel will begin in FY 2020. From FY 2020 on, candidate sites for second and third operations will be

[40] The derived technology is the Ecofining™ Process, which was jointly developed by UOP together with Italy's ENI SpA. Using this technology, a plant, which has the capability to produce more than 130 million gallons per year of green diesel (approximately 20 million kL), has been operating since 2014 (in Louisiana, United States) (according to a UOP press release dated March 15, 2014(*)).The plant does not produce aviation fuel, but the Ecofining™ Process is a technology that is also capable of producing next-generation aviation fuel.
(*) http://www.uop.com/?press_release=honeywell-uop-renewable-fuel-technology-powering-largest-commercial-advanced-biofuel-facility-in-u-s

selected and reviews will be conducted on expanding the operation after feasibility studies are performed while taking into account the quantity of waste animal oil that is able to be secured.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

Japan has a commercial system for collecting waste food oil and procurement of the raw material is easy. By adopting technology from UOP in the United States, Neste Oil Oyj in Finland or some other source that is highly applicable to the waste food oil whose collection is anticipated, this is considered to be one path for fuel production where the reliability of the technology is high at the current point in time and will be effective for establishing a supply chain for next-generation aviation fuel by FY 2020. On the other hand, the theoretical level[41] of next-generation aviation fuel supply which is able to be produced from the procurable waste food oil is not sufficient to meet estimated future demand[42] and the likelihood of increasing the scale of production is low[43], so it is positioned as a supplement until large-scale fuel production can be realized.

(d) Characteristics of the Business

This business utilizes the existing collection system to procure waste food oil within Japan, and produce next-generation aviation fuel domestically using this oil as the raw material. It contributes to the formation of a recycling-oriented society in terms of utilizing waste as a resource. However, it needs to be kept in mind that, presently, most of the waste food oil in Japan is added to compound feed, or is put to use as a raw material for soap and other industrial applications.

(e) Evaluation

Although most of the waste food oil in Japan is currently being put to other uses, because a collection system is in place and the Boeing company's activities in China[44] have moved forward to develop the production technology to a high degree of proficiency, it is expected to be a strong path which will allow for the early production of next-generation aviation fuel.

In preparation for business development, the number one issue to be addressed is maximizing the quantity of waste animal oil collected, and, the optimum technology needs to be adopted for producing the greatest quantity of fuel possible in accordance with the physical properties of the waste food oil raw material, for which the quantity collected is able to be maximized.

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[41] The current quantity of commercial waste food oil collected is 300,000 tons per year (estimate), and, even assuming that all of this is able to be used as raw material, the quantity of next-generation fuel produced is estimated to be around hundred and 120,000 kL.

[42] The quantity of conventional aviation fuel consumed by Japan's air carriers is approximately 8.5 million kL (2013 Annual Report on Air Transport Statistical Surveys, Ministry of Land, Infrastructure, Transport and Tourism), and, even if alternative aviation fuel (50% mixture ratio) was used for 10% of that, the quantity of next-generation aviation fuel demanded would be approximately 430,000 kL.

[43] In Japan with its decreasing population, because an increase in the quantity collected cannot be anticipated and most of the commercial waste animal oil is already used for livestock feed (added to component feed), for industry (soap, paint, ink, etc.), there are limits on the quantity of waste food oil which can be used as raw material for next-generation aviation fuel.

[44] On March 21, 2015, the Boeing Company used alternative aviation fuel on a Hainan Airlines commercial flight (B737-800) from Shanghai to Beijing. It was a 50% mixture of next-generation aviation fuel produced by Sinopec (China Petrochemical Corporation) using waste food oil collected from restaurants in China as the raw material.

Just as with microalgae, the relationship between HEFA SPK and regulations concerning chemical substances needs to be kept in mind.

Chart 10: Roadmap for Supply of Next-Generation Aviation Fuel Using Waste food oil as the Raw Material

Fiscal Year	Opportunities	Challenges
2015	< Formulation of business plan (1) > ● Survey the storage quantities and unit prices of waste animal oil in the areas targeted for this business ● Ascertain the physical properties of the waste food oil which can be collected, and the refining technology applicable to such physical properties ● Select the most appropriate candidate sites for the plant along the collection route	■ Acquiring license for selected refining technology ■ Finding location for production facility
2016	< Formulation of business plan (2) > ● Determine the fuel production capacity of the plant in keeping with the quantity of waste food oil which can be collected and used ● Determine the implementing enterprise, and review operational profitability	■ Determining production capacity of plant, taking into account operational profitability ■ Reviewing production process, and calculating greenhouse gas emissions effect
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Prepare basic design and detailed design for plant, and initiate construction work	■ Appropriately managing project
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Construct, complete and have trial operation of the plant ● Conduct tests and analyses of the quality of fuel samples	■ Appropriately managing project ■ Assessing quality of first fuel samples
2019	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) > ● Perform plant improvement work based on the results of fuel sample tests and analyses ● Conduct trial operation after plan improvements, produce fuel samples, and test and analyze them	■ Improving apparatus to enhance fuel quality ■ Assessing quality of second fuel samples
2020 ～	< Production of next-generation aviation fuel > ● Operate fuel production plant, and produce next-generation aviation fuel	■ Commencing operation of plant, and appropriately managing and maintaining operation

Notes: This is a roadmap formulated from the standpoint of back casting on the assumption that production of next-generation aviation fuel and supply of alternative aviation fuel will commence by FY 2020 on the basis of the review results produced by the Third Subcommittee which take into account knowledge possessed by Mitsui Engineering and Shipbuilding Co., Ltd.

⑤Non-edible biomass (Cellulosic Sugar)

(a) Business Overview

Sugar solution is produced through scarification of non-edible biomass, which then undergoes bioconversion to produce isobutanol and then ATJ to produce next-generation aviation fuel. The Green Earth Institute supports the production of isobutanol from sugar solution, and it is anticipated that an operation in collaboration with other enterprises will manage the upstream portion from securing raw materials to the production of sugar solution as well as the downstream portion of the production of next-generation aviation fuel from isobutanol. Large volume production in the future is conditioned on the procurement of the raw material non-edible biomass from the United States or other countries outside Japan. Production of isobutanol from sugar solution uses a growth-arrested bioprocess. Because the microorganisms used in the production process do not propagate, this fuel production is expected to have high raw material yield without energy loss from propagation and thus be highly productive. ASTM is currently reviewing standards for ATJ from isobutanol.

(b) Path Leading to Achievement of Goal (See Chart 11)

In FY 2015 and 2016, samples of isobutanol will be produced for next-generation aviation fuel production, and a fuel production plant will be designed, constructed and undergo trial operation in FY 2016 and 2017. Also when ASTM standards are enacted for ATJ from isobutanol, from the standpoint of promoting fuel sales, it is anticipated that certification, stating that the production method for this operation complies with ASTM standards, will be acquired from a third-party organization. In FY 2018, next-generation aviation fuel will begin to be produced at the initially constructed plant, and the results obtained from this plant will be taken into account in proceeding to design, construct and conduct trial operation of a plant on an even bigger scale. Thereafter as well, it is anticipated that the operation will be expanded by further increasing plant scale and licensing the growth-arrested bioprocess so as to further increase production.

Chart 11: Roadmap for Supply of Next-Generation Aviation Fuel Using Non-edible biomass (Cellulosic Sugar) as the Raw Material

Fiscal Year	Opportunities	Challenges
2015	< Formulation of business plan > ● Verify the expanded scale of isobutanol production for next-generation aviation fuel ● Produce sugar solution from non-edible biomass, collaborate with partner companies on the production of next-generation aviation fuel from isobutanol, and formulate a	■ Verifying the expanded scale of isobutanol production employing growth-arrested bioprocess ■ Forming the next-generation aviation fuel production enterprise with partner companies
2016	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (1) > ● Have outside contractor produce samples of next-generation aviation fuel from ● isobutanol	■ Contracting to commission production of next-generation aviation fuel samples from isobutanol ■ Enacting ASTM standards for ATJ
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (2) > ● Construct and have trial operation of demonstration plant for fuel production ● After ASTM standard enacted for ATJ, certify that the fuel produced in this operation 〈 Increase in production scale (1) 〉 ● Site for construction of commercial fuel production plant	■ Appropriately managing project ■ Assessing profitability of entire process from raw material procurement to fuel production
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel (3) > ● Conduct trial operation of demonstration plant for fuel production < Production of next-generation aviation fuel (ongoing from 2018) > ● Produce next-generation aviation fuel at demonstration plant < Increase in production scale (2) > ● Formulate business plan for commercial project ● Procure financing for commercial project, and design and construct commercial plant	■ Appropriately managing project ■ Establishing production structure for demonstration plant ■ Analyzing operational results of demonstration plant ■ Reflecting results of demonstration plant analysis in commercial project
2019	< Increase in production scale (3) > ● Construct and conduct trial operation of commercial plant	■ Appropriately managing project
2020	< Increase in production scale (4) > ● Produce next-generation aviation fuel at commercial plant	■ Appropriately managing project
2021 ~	< Increase in production scale (5) > ● Increase size and expand commercial production plant for next-generation aviation fuel	■ Innovating technology for mass production

Notes: This is a roadmap organizing the path and issues to be addressed which are anticipated for producing next-generation aviation fuel and commencing the supply of alternative aviation fuel by FY 2020 on the basis of the review results produced by the Third Subcommittee which take into account knowledge possessed by the Green Earth Institute.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

By using growth-arrested bioprocess which has high raw material yield without the energy loss accompanying propagation of micro-organisms, which was inevitable with conventional fermentation methods, highly productive fuel production has been made possible. So, if non-edible biomass can be collected in large volume and in an economically efficient manner, then this path can be expected to increase the quantity of fuel produced in keeping with future increases in demand.

(d) Characteristics of the Business

Fuel production overseas is also anticipated to enable collaboration with other enterprises in the upstream and downstream portions aside from the production of isobutanol from sugar solution as well as to enable stable and inexpensive procurement of the raw material non-edible biomass. In such a case, supply chains are conceivable for both importing into Japan as well as supplying air carriers at local airports overseas. Also, because the raw material non-edible biomass absorbs carbon during the growing process, it can be regarded as having zero emissions in terms of the carbon cycle, and, in that sense, this business is sustainable.

(e) Evaluation

Growth-arrested bioprocess, which is at the core of this operation, has properties that differ from conventional fermentation methods. While, conventionally, only C6 sugars could be used for biomass and microorganisms would propagate during fermentation generating fermentation inhibitors and decreasing productivity, the growth-arrested bioprocess is not dependent on propagation, so productivity does not decline even if fermentation inhibitors are present. In addition, non-edible biomass C5 and C6 sugars can be used. This is expected to be a highly efficient method for producing isobutanol from raw material.

In preparation for business development, it is necessary to increase the overall scale of the process integrating the downstream portion from securing raw material to sugar solution production as well as the upstream portion covering growth-arrested bioprocess and the production of next-generation aviation fuel from isobutanol. Besides isobutanol, growth-arrested bioprocess also enables conversion to amino acids, and achievements have been made in increasing the scale of the conversion process to amino acids. Because there are examples of such implementation on a scale approaching commercialization in the United States, it is important that such cases be taken into account when realizing an increase in scale.

⑥Woody Biomass

(a) Business Overview

Using woody biomass as the raw material, next-generation aviation fuel is produced by upgrading, after FT synthesis, the source gas produced with biomass gasification technology. It is anticipated that FT synthesis, which uses untapped biomass in Japan, will be performed at locations near the raw material and the upgrading from FT synthesized crude fuel will be implemented intensively at a large scale facility. There is an ASTM standard for the production method (FT-SPK). Biomass gasification technology uses oxygen and water vapor as the gas supplying agents to burn some of the raw material to form a high temperature field of 800 to 1200°C, and this heat converts the biomass into source gas whose principal components are hydrogen and carbon monoxide (thermal decomposition gasification).

(b) Path Leading to Achievement of Goal (See Chart 12)

In FY 2015, construction will move forward on an integrated production system for next-generation aviation fuel. In FY 2016, a system will be structured for collecting untapped woody biomass as well as a system for returning project benefits, including greenhouse gas emissions effects, to the parties comprising the supply chain so as to form an enterprise for the demonstration plant project for fuel production. From FY 2017 to 2019, the demonstration plant will be designed, constructed and undergo trial operation, and the production of next-generation aviation fuel will begin in FY 2020. From FY 2020 on, it is anticipated that issues to be addressed will be identified based on results obtained from the demonstration plant and a commercial plant will be reviewed that reflects the acquired knowledge in an effort to advance the launch of a commercial project.

Chart 12: Roadmap for Supply of Next-Generation Aviation Fuel Using Woody Biomass as the Raw Material

Fiscal Year	Opporturnities	Challenges
2015	< Formulation of business plan (1) > ● Configure business model from raw material collection to fuel production ● Develop catalyst for next-generation aviation fuel production, and review system optimization	■ Establishing an economically competitive collection system for woody biomass ■ Improving technology, including raising the quality of the gas in the gasification process from raw material
2016	< Formulation of business plan (2) > ● Launch demonstration project ● Formulate business plan for demonstration plant	■ Forming the enterprise comprising the supply chain from raw material collection to fuel production
2017	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel(1) > ● Design and construct demonstration plant	■ Appropriately managing the project
2018	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel(2) > ● Construct demonstration plant	■ Appropriately managing the project
2019	< Design, construction and trial operation of demonstration plant for production of next-generation aviation fuel(3) > ● Construct and conduct trial operation of demonstration plant	■ Appropriately managing the project ■ Improving demonstration plant to take into account results of trial operation
2020	< Production of next-generation aviation fuel > ● Operate demonstration plant and produce next-generation aviation fuel ● Analyze results of demonstration plant operation	■ Establishing operational and maintenance structure of the plant
2021 ～	< Increase in production scale > ● Formulate business plan for commercial project ● Design, construct and conduct trial operation of commercial plant ● Operate commercial plant, and produce next-generation aviation fuel	■ Identifying and verifying issues to be addressed concerning the commercial plant based on the results of the demonstration plant ■ Establishing an economically competitive raw material collection system that corresponds to the scale of the commercial plant ■ Establishing fuel production technology that corresponds to the scale of the commercial plant

Notes: This is a roadmap formulated from the standpoint of back casting on the assumption that production of next-generation aviation fuel and supply of alternative aviation fuel will commence by FY 2020 on the basis of the review results produced by the Third Subcommittee which take into account knowledge possessed by Mitsubishi Hitachi Power System, Ltd.

(c) Position of this Path in the Context of the Overall Supply of Alternative Aviation Fuel

In accordance with the Japanese government’s Basic Plan for the Promotion of Biomass Utilization[45], 8 million tons (dry weight) of forest off-cuts were generated in 2010 and most of that went unused at the time. So, if the woody biomass, which is scattered about regions as well as not being used, is able to be collected in large volume in an economically efficient manner, then this path can be expected to increase the quantity of fuel produced in keeping with future increases in demand.

(d) Characteristics of the Business

This is an operation to be undertaken in areas throughout Japan by using the untapped woody biomass in these areas as the raw material. It contributes to the launch of regional biomass fuel businesses. Also, the raw material woody biomass absorbs carbon during the growth process, so it can be regarded as having zero emissions in terms of the carbon cycle and is sustainable in that sense, contributing into the formation of a recycling-oriented society.

(e) Evaluation

This is an operation which uses for the raw material not only ligneous biomass, such as forest

[45] Cabinet decision dated December 17, 2010 (see reference 8)

cut-offs, wood waste and so on, but also herbaceous biomass including rice straw, wheat straw, rice husks and other agricultural non-foods When consideration is given to the abundance of raw material, its sustainability, formation of a recycling-oriented society, and its contribution to launching fuel businesses in regional areas, business development is expected to be realized from a long-term standpoint.

In preparation for business development, economically efficient raw material collection system needs to be constructed through fuel production on a demonstration scale, and, subsequently, the scale of the fuel production technology increased as well as the entire supply chain optimized. It is also necessary to increase the reduction effect on CO2 emissions.

(3) Handling during Transport, Mixture as Well as at Airports and Aircraft

In Japan, the quality of conventional aviation fuels is controlled in accordance with international practices. More specifically, based on guidelines[46] established by JIG[47], an international organization which prepares and administers quality standards and handling policies for conventional aviation fuels, industry standards have been established in Japan[48], and conventional aviation fuels are handled along the supply chain processes in accordance with these standards. Also at airports in Japan, it is mainly JIS standard conventional aviation fuel, which has been refined domestically, that is utilized at shared use storage facilities, and JIG has prepared AFQRJOS[49] regarding quality standards that conventional aviation fuels should maintain at such shared use facilities. With regard to handling in Japan, the Uniform Standard for Shared Use Storage Facilities, which conforms to AFQRJOS, has been formulated by the Petroleum Association of Japan[50]. In order to address usage by the many parties concerned, standards for conventional aviation fuels meeting this standard have been established so that they not only comply with ASTM D1655 but also with another international standard DEF STAN 91-91, and these operations are implemented in accordance with these standards.

In the handling of next-generation aviation fuels during transport and at the airport after they have been produced, standards for handling fuel along the supply chain described above as well as unified standards for shared use storage facilities have also been enacted for conventional aviation fuels. So, in the future, it would be desirable to take into account the international practices specified by JIG to appropriately enact a policy for Japan after consideration by the relevant parties.

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[46] The Joint Guidelines for Aviation Fuel Quality Control and Operating Procedures

[47] JIG is an acronym of Joint Inspection Group, an organization headquartered in London whose members are international petroleum wholesalers and other companies.

[48] Guidelines concerning standards for handling jet fuel. These guidelines have been prepared and revised to take into account the joint guidelines prescribed by JIG. (See September 22, 2005 press release (*) by the Petroleum Association of Japan.)

(*) http://www.paj.gr.jp/paj_info/press/2005/09/22-000320.html (viewed May 9, 2015)

[49] AFQRJOS is an acronym of Aviation Fuel Quality Requirements for Jointly Operated Systems. In addition to satisfying the quality standards required under ASTM D1655, AFQRJOS differs significantly from the ASTM D1655 standard in that it requires traceability from the supplying facility until it is loaded on an aircraft.

[50] "Production Method and Specifications of Jet Fuel in Oil Refineries" (Journal of the Japan Institute of Energy, January 2014) (Reference 19).

Also, mixing occurs in tank internal blend in which next-generation aviation fuel and conventional aviation fuel are mixed in a storage tank, line blind in which they are mixed inside a pipeline at the time of shipping, and tanker truck blend in which they are mixed inside a tanker truck during shipping. Such mixing needs to be reviewed by taking into account fuel quality management, cost and other factors.

With regard to handling in terms of aircraft which ultimately use the alternative aviation fuel which is a combination of the produced next-generation aviation fuel, the alternative aviation fuel certified under ASTM D7566 is an aviation fuel that has been certified based on tests and data to verify that there are no issues in terms of the safe flight of the aircraft, just the same as for conventional aviation fuels certified under D1655. So, there are no issues in terms of airworthiness as long as the fuel has the properties prescribed in D7566.

3. Future Issues for Review

(1) Consideration of the Business Promotion Framework

① Issue Awareness

In order to establish a supply chain for next-generation aviation fuel, it is necessary that there be a functioning integrated structure which extends from raw material production and procurement to product supply. With regard to the business promotion framework for an integrated system, in consideration of the current situation in which there is no such enterprise administering the entire system, the enterprises responsible for each process will be called upon to collaborate to construct the overall framework. As to what sort of business promotion framework will be selected is closely related to the issue of how to balance securing efficiency of the entire system and ensuring the sustainable management of enterprises responsible for the system. For operational implementation, a business promotion framework will be selected enabling the construction of an optimal business framework that ensures the interests of each enterprise in line with a well-defined business model.

②Business Promotion Framework and Financing

A business promotion framework will be agreed upon among the enterprises deciding to participate in the business, whose development will be based upon, among other things, a business plan (① particular circumstances, ② superiority of the principal technology, ③ background besides technology, which includes business related trends, environmental and social nature as concerns industry, government and other institutions, ④future outlook and possibilities and issues to be addressed, ⑤ specific description of the operation, ⑥ scheduling, ⑦ revenue forecasts and financing plans, and ⑧ business promotion framework (including personnel plans), and that structure will be an important factor affecting financing.

③Consideration of Individual Business Promotion Structures

There are legal forms such as specific purpose companies (SPC) as well as joint ventures (JV) which do not have any legal personality. In contrast to the former where the company, which is the entity promoting the business, has greater independence than the individual participating companies, the latter tends to have stronger individual intent expressed by the participating companies, which is ultimately reflected in operation of the business.

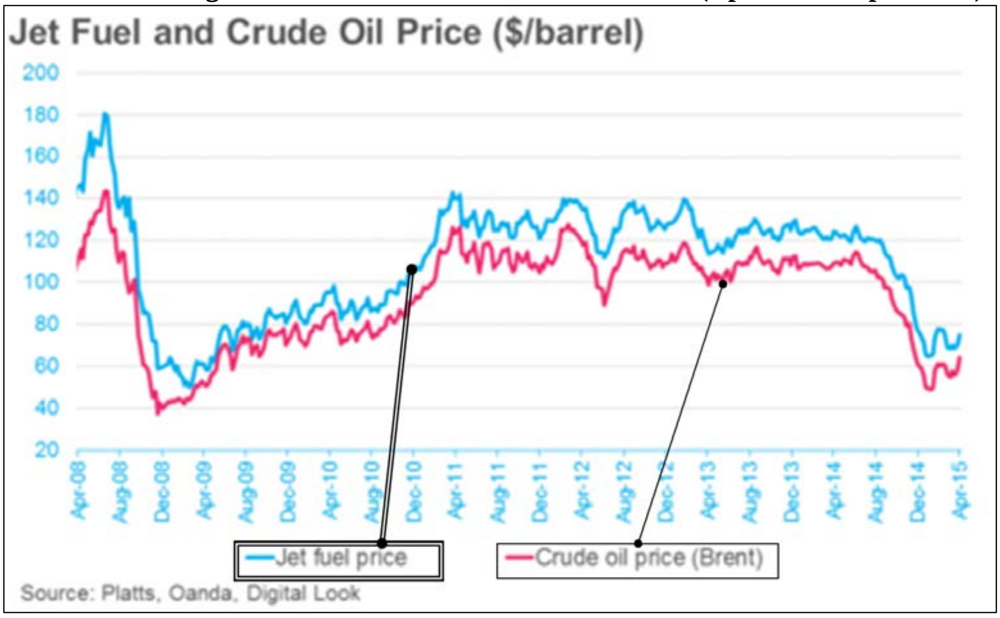
Moreover, in the case of corporate management, there are stock companies, limited liability companies (LLC) or limited liability partnerships (LLP), and research partnerships. The framework to be selected differs depending on what will be done with regard to investors, asset holders and profit distribution.

(2) Consideration of Costs

① Expenses Necessary for the Business and Provisional Calculation of Estimated Profit

It is unavoidable that the price of alternative aviation fuel calculated based on the necessary business costs will significantly exceed the price of conventional aviation fuel in recent years (approximately 100 JPY/L). With the current situation the way it is, it does not follow that the business will be economically competitive for some time on account of this price difference. In particular, the rapid fall in the price of crude oil since the summer of 2014 has also halved the price of conventional aviation fuel (Chart 13). Given the fuel price at the current point in time (as of April 2015), it is extremely difficult to produce alternative aviation fuel.

Chart 13: Change in Price of Conventional Aviation Fuel (April 2008~April 2015)



(Source: IATA website (viewed on April 30, 2015))

② Options for Covering the Difference between Income and Expenditures

The significance of introducing next-generation aviation fuels is that it provides for a stable supply of aviation fuel and by extension sustainable growth in the aviation sector by ensuring energy security and promoting measures to counter global warming. Therefore, in order to establish a supply chain for next-generation aviation fuels, it is important that consideration proceed from the standpoint of having the fuel producers, air carriers and other businesses comprising the supply chain, the growing and expanding users of aviation services, and, moreover, the public at large which benefits from ensured energy security and measures to counter global warming all bear the cost in keeping with the extent of the benefit received. Based on this point, means for offsetting the aforementioned difference in prices include reducing costs through improvements at each stage of the supply chain, system optimization, technological innovation, user charges, area charges, and public support, discussion about which is anticipated in the future.

Requests have been received from businesses, which will assume responsibility for production of next-generation aviation fuels, for subsidies and specially recognized depreciation of capital investment in order to alleviate the burden on the business during the initial stage when such burden arising from investment in production equipment has a significant effect, and from air carriers requesting a reduction in aircraft fuel taxes as well as petroleum and coal taxes when using next-generation aviation fuels. In any case, when designing the specifics of an efficient business system, it is hoped that serious discussion will proceed on the appropriate allocation of cost burdens among a broad range of interested parties, while continuing to take into consideration the profits gained from business implementation, the importance of establishing a supply chain for next-generation aviation fuels, and the fiscal situation in which Japan finds itself as well as other factors.

(3) Issues to be Addressed in Business Implementation

① Toward Establishment of a Supply Chain for Next-Generation Aviation Fuels

With regard to next-generation aviation fuels, against a backdrop of such necessity as related to global warming countermeasures and energy security as well as future general needs anticipated based on such necessity, there are businesses interested in such a supply chain, and the INAF is also comprised of such businesses and other organizations. On the other hand, in order to actually realize this business development, planning of the production scale and price for a stable supply is able to be done once a specific demand can be estimated.

In other words, there is a gap between the bird's-eye view of a supply chain along with the roadmaps for individual technology paths compiled by the INAF and the implementation of an operation which will realize these ideas, and it is necessary for interested parties in industry, government and academia in Japan to collaborate to create the market described above, and to promote the general enhancement of the entire supply chain including those portions which purchase and use fuel by refining technological and development systems through implementation of demonstration projects, by making upgrading processes more advanced to be compatible with different raw materials, and moreover by promoting sales and purchases.

In addition, many of the processes for producing next-generation aviation fuels use hydrogen. As it is forecast that fuel-cell electric vehicles, which use hydrogen as the fuel, will become more widespread in the future, it is necessary to secure hydrogen needed for the production of next-generation aviation fuels while at the same time giving consideration to trends in the automobile and other sectors, because the quantity of hydrogen produced is also limited.

②Overseas Partners

The INAF proceeded to consider issues in Japan while taking into account global trends including those in the United States, about which information was provided by the United States Federal Aviation Administration, Department of Energy, LanzaTech, The Boeing

Company, IATA and other organizations. Furthermore, the ICAO and other countries are moving forward with efforts promoting the introduction of next-generation aviation fuels. To establish a supply chain for next-generation aviation fuels in Japan without falling behind advanced being made around the world, partnerships with such relevant organizations in other countries are useful. Also, because the current situation is one in which ASTM standards, the de facto international standard for next-generation aviation fuels, are being enacted and amended by interested parties in other countries, it is clearly evident that overseas partnerships are essential for promoting the production of next-generation aviation fuels and the use of alternative aviation fuels.

(4) Direction for Resolving Issues

The price of crude oil fell by more than 50% between the summer of 2014 and January 2015, breaking the 50 USD per barrel mark, and the price of conventional aviation fuel has similarly gone down. Nevertheless, the current decline in the price of conventional aviation fuel does not in any way decrease the necessity for developing next-generation aviation fuel. Moreover, the fuel development operations have a long lead time until stable supply can be achieved, and it is not uncommon for periods of 10 years or more to be required. Therefore, the broad range of parties interested in next-generation aviation fuels needs to be aware that development of this business in accordance with long-term forecasts is the pressing issue, and to undertake a demonstration project at an early stage irrespective of recent supply and demand levels.

In addition, the business of producing and supplying aviation fuel is long-term. Fuel prices fluctuate significantly. So, in order to sustainably promote this business, it is necessary to facilitate continuing technological development and secure a margin of investment. As the development of next-generation aviation fuels continues to move from the demonstration stage to the commercial stage around the world, interested parties need to collaborate to prevail in the international competition.

In 2020, when the Tokyo Olympics and Paralympics are scheduled to be held, it is not difficult to imagine that much more of the world's attention will be focused on Japan than it is now. The MRJ, which is currently under development as Japan's first domestically manufactured passenger aircraft in 50 years, is scheduled to be flying across the skies of Japan and the world in 2020. Commencing and promoting the production of next-generation aviation fuels and the supply of alternative aviation fuels in Japan is a golden opportunity for the nation, which advocates a national commitment to tourism, the environment and technology, to establish a new presence, and it is desirable that the promotion of this business be accelerated now.

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Principal Acronyms

AFQRJOS	Aviation Fuel Quality Requirements for Jointly Operated Systems
AFTF	Alternative Fuels Task Force
ATJ	Alcohol to Jet
BTL	Biomass to Liquid
CNG	Carbon Neutral Growth
COP	Conference of the Parties
DEF STAN	UK Defense Standards
DOE	Department of Energy, USA
FAA	Federal Aviation Administration, USA
FT SPK	Fisher-Tropsch Hydroprocessed Synthesized Paraffinic Kerosine
HEFA SPK	Synthesized Paraffinic Kerosine from Hydroprocessed Esters and Fatty Acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEA	International Energy Association
INAF	Initiatives for Next Generation Aviation Fuels
IPCC	Intergovernmental Panel on Climate Change
JIG	Joint Inspection Group
JV	Joint Venture
LLC	Limited Liability Company
LLP	Limited Liability Partnership
MRJ	Mitsubishi Regional Jet
NEDO	New Energy and Industrial Technology Development Organization
OEM	Original Equipment Manufacturer
SIP	Synthesized Iso-Paraffins from Hydroprocessed Fermented Sugars
SPC	Specific Purpose Company
SPK	Synthesized Paraffinic Kerosine