PRESS RELEASE

October 19th, 2018

World's First Successful Ammonia Synthesis Using Renewable Energy-Based Hydrogen and Power Generation

Progress Toward Realization of Hydrogen Energy Carriers

JGC Corporation

Yokohama Japan – JGC Corporation and the National Institute of Advanced Industrial Science and Technology (AIST; hereinafter referred to together as the JGC Group), under the auspices of the Cross Ministerial Strategic Innovation Promotion Program[*1] (SIP) "Energy Carriers" (Management Entity: JST), led by the Cabinet Office Council for Science, Technology and Innovation[*2], announced today that its joint study has resulted in the world's first success in the synthesis of ammonia with hydrogen produced through the electrolysis of water by renewable energy, and generation of electricity through gas turbines fueled by synthesized ammonia.

<Outline of Current Research and Development>

Since 2014, JGC, based on its evaluation of the use of ammonia as an energy carrier has participated in the SIP "Energy Carriers"[*3] research title "New Catalysts for producing Ammonia and the Use of Hydrogen Produced Through the Electolysis of Water by Renewable Energy for the Production of Ammonia".

In May this year, JGC, together with the AIST and the National Institute of Technology, Numazu College, as well as our subsidiary, JGC Catalysts & Chemicals Ltd., achieved success in development of a new ruthenium catalyst[*4] capable of efficiently synthesizing ammonia at a low temperature and low pressure through improvement of carrier and catalyst production methods using catalysts. The JGC began operation of a demonstration plant (capable of producing ammonia at the rate of 20 kg per day) that synthesized ammonia using a high purity hydrogen gas cylinder installed on the premises of the Fukushima Renewable Energy Institute, AIST in Koriyama City, Fukushima Prefecture for this catalyst and temporary hydrogen provision.

Through this demonstration plant, together with confirming the high activity at a low temperature and pressure of the newly developed catalyst, the JGC Group verified the enabling of a change in ammonia production volume through rapid operational condition changes when using renewable energy, which was an issue. At this time, instead of the high purity hydrogen gas cylinder used for the demonstration plant, the JGC Group tested synthesis of ammonia using hydrogen produced through electrolysis of water through power generated by solar power equipment installed on the same premises, and realized a demonstration plant (power generation: 47 kW) through gas turbines fueled by synthesized ammonia.

Furthermore, cooperation was received from the Fukushima Renewable Energy Institute, AIST for the test of hydrogen production, and cooperation was received from the SIP Energy Carriers (Ammonia Direct Combustion) Team for the test of ammonia gas turbine

power generation.

This is the first case in the world of hydrogen that utilizes renewable energy from the JGC Group, as well as power generation fueled by ammonia production and this, and advances the establishment of an energy chain that utilizes ammonia that does not emit CO_2 (CO_2-free) from production to power generation.

Going forward, the JGC Group will continue to carry out the ammonia synthesis test and research and development toward cost reduction of ammonia production utilizing renewable energy, together with actively working toward energy diversification and realizing a low-carbon society by achieving the vision promoted by SIP Energy Carriers research of “Japan creating an innovative low-carbon, hydrogen-fueled economy and taking the lead in hydrogen related industries on the world market” by the year 2030.

<Ammonia Synthesis Demonstration Plant>

(The red cylinder at the front of the photograph is a high purity hydrogen cylinder storing hydrogen produced from renewable energy.)

※1 Energy Carriers
A method by which hydrogen, which is difficult to store or transport over long distances, can be made easier to handle by changing it to liquid form.

※2 Cross Ministerial Strategic Innovation Promotion Program
The Overall technical research and development Innovation Council is not bound by the traditional sectionalism of individual ministries and seeks new paths toward achieving innovation and technical progress.

※3 Council for Science, Technology and Innovation
Under the leadership of the Prime Minister and the Minister responsible for technology, this is one of the “important policy making bodies” which leads the work of various ministries with regard to the development of basic and and innovative technical advances.

※4 Ruthenium Catalyst
Although we sought a reaction at a high temperature and pressure of about 400-500℃ and 14-30 MPa for an iron-type catalyst using the “Haber-Bosch Process,” the ruthenium catalyst newly developed this time is able to synthesize ammonia at a low

temperature and pressure of below about 400℃ and 5 MPa. The catalyst developed this time is able use rare earth oxides as carriers, and has excellent stability compared to the ruthenium catalyst that utilizes carbon-type carriers that is already being produced.

【Reference】

<Research and Development Framework>

Currently, amid a world-wide drive toward preserving the environment and creating a sustainable society and where new forms of energy are being sought in the bid to realize a low-carbon world, the use of hydrogen, which produces no carbon dioxide(CO_2) when burnt is receiving increased attention. Since 2014, the Cabinet Office, in its “Cross Ministerial Strategic Innovation Promotion Program(SIP)”, has expressed Japan’s intention to create an innovative low-carbon, hydrogen-fueled economy by the year 2030 and to take the lead in hydrogen related industries on the world market through its “Energy Carriers” research.

<Advantages of Ammonia as an Energy Carrier>

In order to make real use of hydrogen as an energy source, questions of cost and safety arise together with the topics of efficiency of transport and storage, meaning that the use of an energy carrier method for hydrogen such as ammonia is required. Not only does ammonia contain a large amount of hydrogen, is easily liquefied and emits no CO_2 when burned, it is already widely used as a fertilizer meaning that a supply chain is in place. These factors make it an ideal energy carrier for hydrogen.

<Problems Related to the Method of Manufacturing Ammonia>

At present, natural gas is used as the fuel for producing ammonia; the hydrogen and nitrogen obtained through reforming steam and air at high temperature and pressure in the presence of a catalyst produces ammonia in what is called the “Haber-Bosch Process”. As this process results in the emission of large quantities of CO_2, this has been seen as a barrier to the use of ammonia as a hydrogen energy carrier.

As a means of reducing the amount of CO_2 emitted, a method involving the development of the use of renewable energy to produce hydrogen from water through electrolysis has received attention. However, the hydrogen produced by this method is at low pressure. For the use of the “Haber-Bosch Process” , high temperature/high pressure condition is necessary to produce ammonia, meaning that the energy efficiency of the process is reduced.

<Attachments>

Attachment 1: Development Outline
Attachment 2: Ammonia Production Process
Attachment 3: The Energy Chain Utilizing CO_2-Free Ammonia Tested this Time

【Contact】
<Main Article>
Akihiro Yamagami / Haruki Fujiwara
PR & IR Department
JGC Corporation
TEL：81-45-682-8026
E-mail：yamagami.akihiro@jgc.com
fujiwara.haruki@jgc.com

<SIP Function>
TEL：81-36-257-1337
Council of Science, Technology and Innovation, Cabinet Office
6th floor, Central Common Government Offices No.8,
1-6-1 Nagatacho, Chiyoda-ku, Tokyo 100-8914
http://www8.cao.go.jp/cstp/gaiyo/sip/

Attachment 1

Development Outline

Hydrogen Energy Carrier

Liquid Hydrogen

Organic Hydride

Ammonia

Methane

Composition of Ammonia
(Hydrogen + Nitrogen = Ammonia)

<Features of the Traditional Method>
- Steam is created by burning natural gas or similar fuel
- Synthesis Process Under High Temperature/High Pressure Condition
- The raw material, hydrogen, is under high pressure
- Large quantities of CO_2 are emitted in the production of hydrogen
- Cost effectiveness varies with the price of natural gas

As a solution

Ammonia production process using renewable energy to produce the raw hydrogen through electrolysis

(Features)
- No CO_2 is emitted in the production of the hydrogen
- The hydrogen produced is at low pressure
- The catalysts used previously were not efficient
- Easy to vary the quantity of hydrogen produced when renewable energy is used

Background of the development

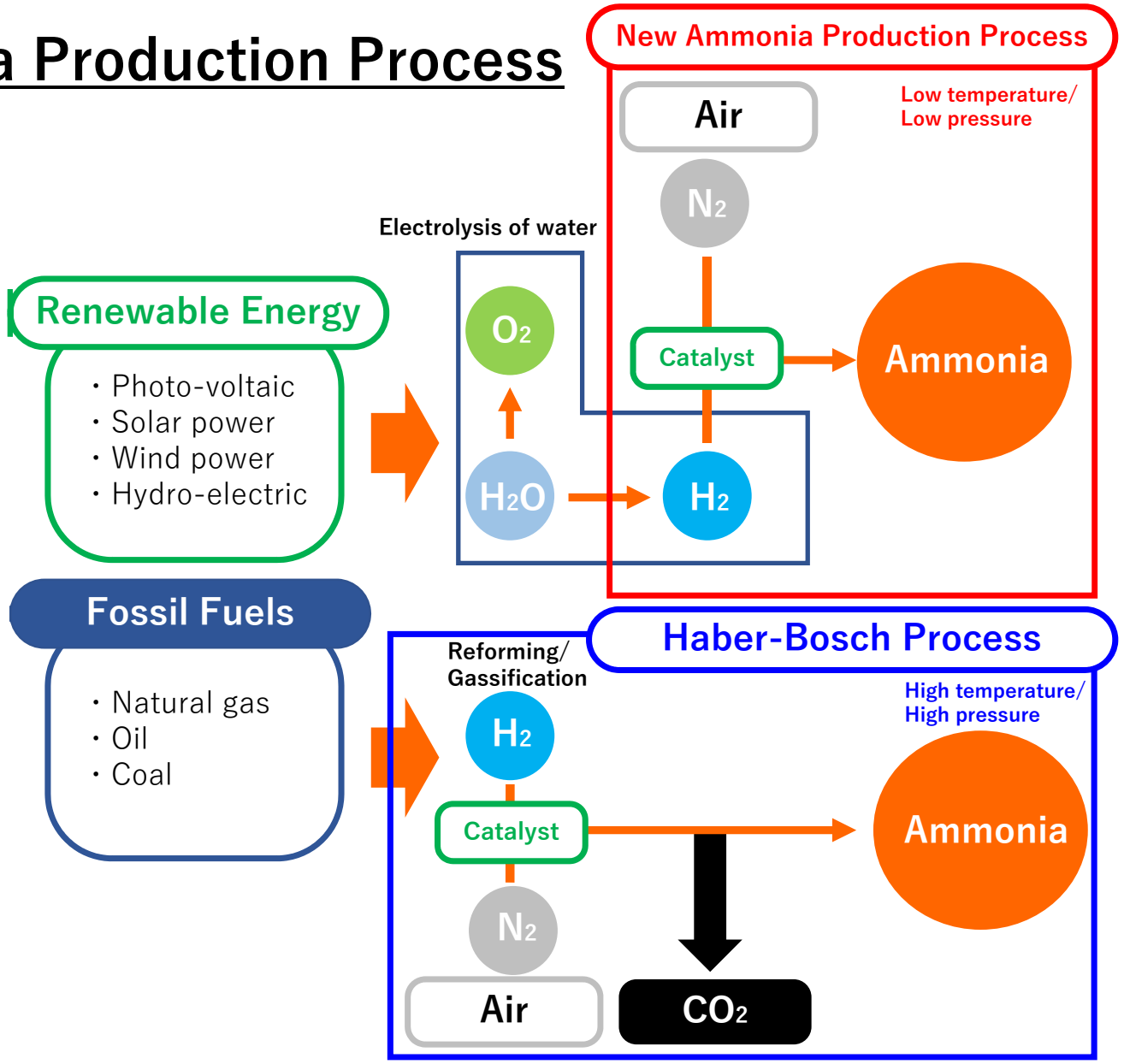
Developments by JGC

Demonstration test of the catalysts for the new ammonia production process
- Development and testing of new catalysts that will function under low temperature/low pressure conditions
- Construction and operation of the demonstration plant for the new catalysts

Production of Ammonia Using Renewable Energy
- Ammonia production tests employing hydrogen produced by electrolysis using renewable energy

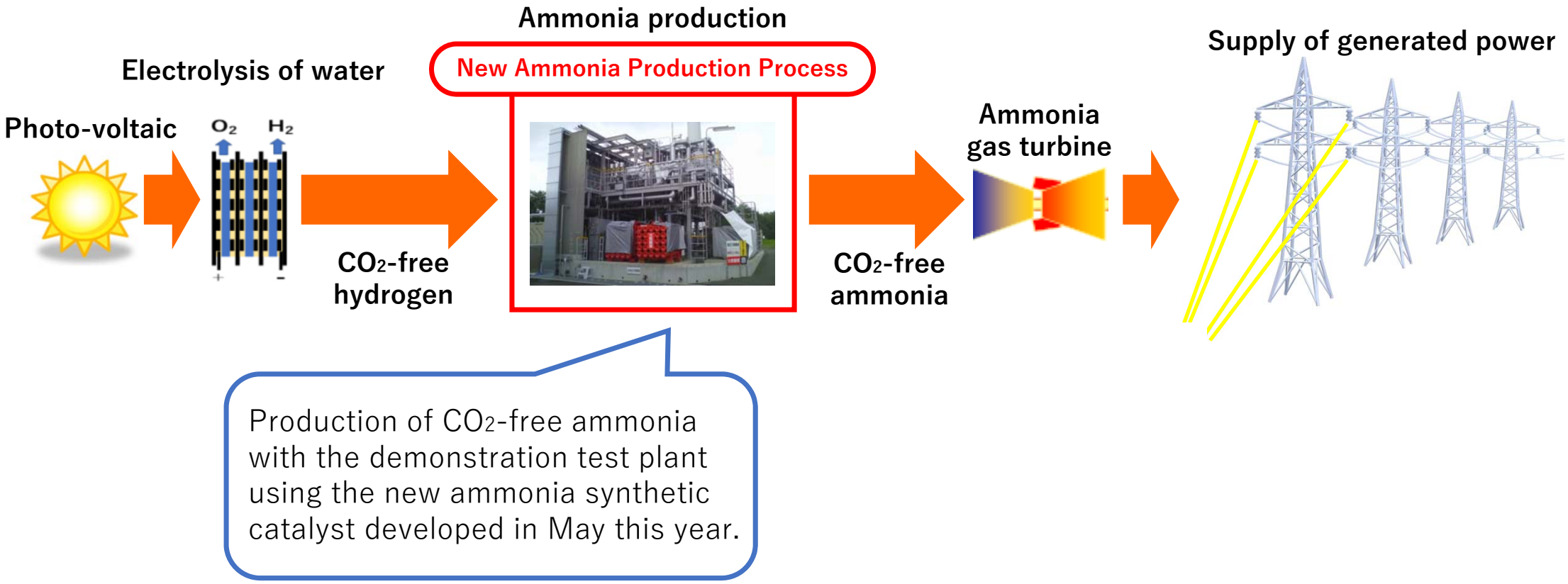
Attachment 2

Ammonia Production Process



Attachment 3

The Energy Chain Utilizing CO_2-Free Ammonia Tested this Time (Utilization of the New Ammonia Synthesis Process)



Production of CO_2-free ammonia with the demonstration test plant using the new ammonia synthetic catalyst developed in May this year.