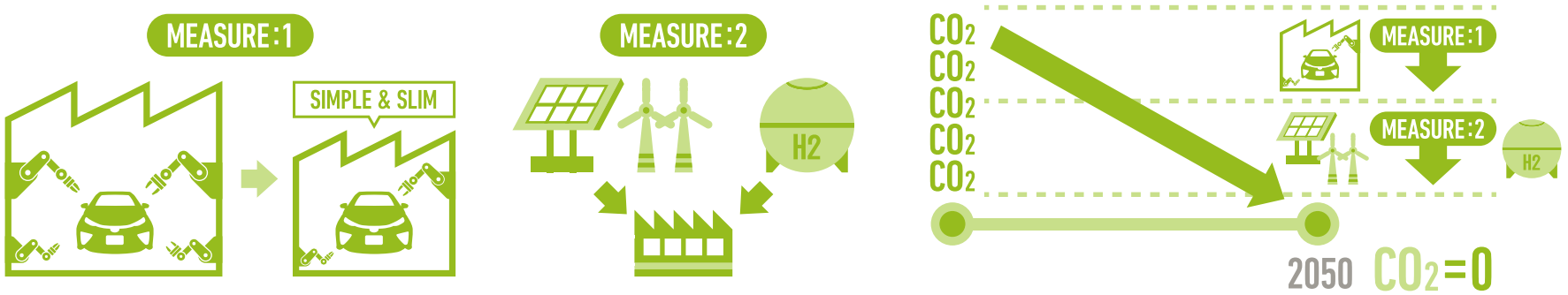
Challenge 3 Plant Zero CO_2 Emissions Challenge

Fundamental Approach The Plant Zero CO_2 Emissions Challenge seeks zero CO_2 emissions in the vehicle manufacturing process. To achieve this, Toyota is introducing innovative technologies, conducting daily *kaizen*, introducing renewable energy, and utilizing hydrogen. First of all, processes and the time required were reduced by simplifying and streamlining manufacturing processes, which made an improvement to energy use efficiency, including equipment optimization and the use of waste heat. Furthermore, we use every possible means to reduce CO_2 emissions including introducing an innovative process called *karakuri* that does not consume any energy source at all.

In addition, we will effectively utilize renewable energies such as solar power and wind power along with hydrogen energy.



Reduce CO_2 Emissions in Production Activities

Introduction of Innovative Technologies and Daily *Kaizen*

In our production activities, we have been developing and introducing low-CO_2 production technologies along with taking daily improvement measures to achieve our reduction targets.

In FY2018, Toyota Motor Corporation (TMC) plant manufacturing divisions worked with production engineering and drive force personnel to conduct energy diagnoses at production sites, propose improvements, implement measures, and undertake energy-saving activities (internal ESCO activities). In addition, TMC continuously undertook *yokoten** of best practices. *Yokoten* places particular emphasis on adoption of steamless and airless processes and shifting to LED lighting, thereby increasing examples that can be expanded from common processes to multiple processes and sharing information on best practices to accelerate daily *kaizen*. As a result, we reduced total CO_2 emissions to 1.14 million tons (down 1.4 percent year on year), and CO_2 emissions per unit produced to 0.394 tons (down 1.1 percent year on year).

Globally, measures for the development of overseas human resources as activity leaders were taken and *genchi genbutsu* training was conducted to make internal ESCO activities more autonomous and accelerate them. *Kaizen* was also achieved by increasing TMC best-practice (from 29 examples to 62 examples) and expanding it to subsidiaries in Japan and to overseas plants.

Affiliated companies in Japan actively implemented internal ESCO activities, but some companies had higher energy consumption as a result of increased aluminum wheel production in conjunction with efforts to make vehicles lighter. Also, CO_2 emissions reduction effects were achieved through the purchase of renewable energy and installation of solar panels and in-house power generation for internal consumption. As a result of these measures, total CO_2 emissions were 7.79 million tons (down 0.2 percent year on year), and CO_2 emissions per unit produced were 0.740 tons (down 0.2 percent year on year).

In order to reduce CO_2 emissions from production activities, we will strive to accelerate our energy saving activities, carrying out internal ESCO activities and other activities.

* *Yokoten* refers to sharing of improvement practices, know-how, non-compliance and other information within the All-Toyota Group

Trends in Total CO_2 Emissions (from Energy Consumption at Stationary Emission Sources) and CO_2 Emissions per Unit Produced at TMC

Third-Party Assurance

FY	2014	2015	2016	2017	**2018**
Total CO_2 emissions (million tons)	1.20	1.18	1.15	1.16	**1.14**
CO_2 emissions per unit produced (tons/unit)	0.414	0.413	0.408	0.398	**0.394**

- Scope: Production and non-production divisions (excluding employee benefit facilities)
- Conversion factors: CO_2 emissions were calculated using the Nippon Keidanren's 1990 conversion factors

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Plant and Work Site Environmental Data
Web https://www.toyota-global.com/sustainability/environment/data/sitedata18_full_en.pdf

Trends in Global Total CO_2 Emissions (from Energy Consumption at Stationary Emission Sources) and CO_2 Emissions per Unit Produced

Third-Party Assurance

FY	2014	2015	2016	2017	**2018**
Total CO_2 emissions (million tons)					
Japan (TMC)	1.26	1.25	1.21	1.20	**1.19**
Japan (consolidated EMS and its subsidiaries)	3.73	3.66	3.55	3.57	**3.61**
North America	1.13	1.17	1.13	1.21	**1.19**
China	0.66	0.65	0.69	0.70	**0.73**
Europe	0.29	0.29	0.27	0.30	**0.30**
Asia (excluding Japan), Australia, Middle East, South Africa, Latin America	0.77	0.77	0.72	0.83	**0.77**
Total	7.84	7.79	7.57	7.81	**7.79**
Direct emissions (Scope 1) (million tons)	2.80	2.72	2.49	2.55	**2.55**
Indirect emissions (Scope 2) (million tons)	5.04	5.07	5.08	5.26	**5.24**
CO_2 emissions per unit produced (tons/unit)	0.757	0.753	0.744	0.741	**0.740**

- Scope of coverage: TMC and consolidated subsidiaries and other companies in Japan and overseas, a total of 121 companies
- Errors in FY2017 data were corrected
- GHG Protocol was used to calculate emissions
- Conversion factors:

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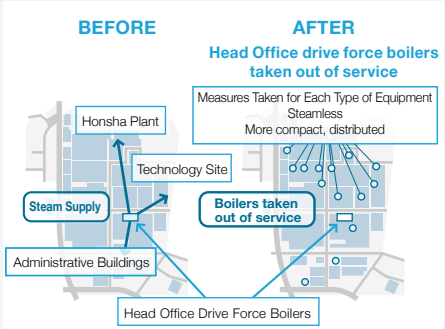
Introducing Renewable Energy and Utilizing Hydrogen

Toyota is promoting the introduction of renewable energy, taking into consideration the characteristics of each country and region. When introducing renewable energy, we place the highest priority on in-house generating facilities (such as solar power generation) and in-house consumption at Toyota plants and other facilities.
In FY2018, we generated 17,578 MWh of renewable energy globally (see pp. 100–102 for information on hydrogen use).

Column Steamless Processes at Head Office (Japan)

Boiler facilities at TMC Head Office supply steam to three locations—the Honsha Plant, administrative office building, and Head Office Technology Site. In FY2015, the total volume of steam supplied reached 120,000 tons. The supply losses with steam are high, and half or less of the energy can be effectively used, so TMC starting planning measures to eliminate the use of steam under the CO_2 zero challenge in FY2016. Specifically, in order to stop steam emissions from the Head Office drive force boiler, energy-saving measures were taken in that facilities used in each process were converted to those that do not use steam, and high-efficiency small-scale boilers were installed for facilities that require steam.
As a result of taking energy-efficient measure, it was possible to cease the use of the Head Office drive force boiler facilities by March 2018, and air conditioning CO_2 emissions fell by 10,000 tons, from 18,000 tons to 8,000 tons, in FY2018.



Column Measures to Reduce Energy Usage Through Temperature and Humidity Control in Painting Booths (India)

TKM, an Indian affiliate, won the Best Kaizen Award in the Kaizen Conference & Competition held by the Confederation of Indian Industry (CII) in June 2017.
Controlling temperature and humidity in painting booths according to the type of paints used is crucial for maintaining painting quality. TKM improved this by installing programmable logic controllers (PLC). Based on daily changes in temperature and humidity over the course of a year, the PLC are programmed to control temperature and humidity at appropriate levels in painting booths.
The result was a decrease in wasteful cooling and reheating and a 390,000 kWh reduction in annual energy consumption (approximately 15 percent).

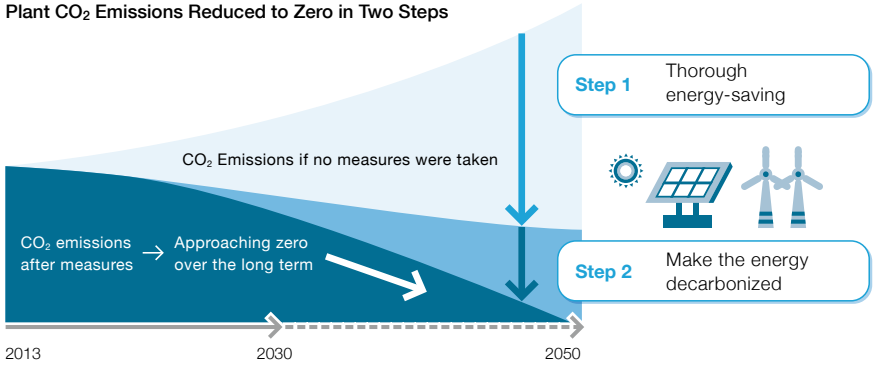
TKM receiving the Best Kaizen Award

Toward Realizing a Decarbonized Society in 2050: Effective Use of Renewable Energy

These days, one means of decarbonization that holds particular promise is renewable energy. Toyota is working to reduce CO_2 through comprehensive energy-saving measures by deploying innovative technologies and daily *kaizen*. However, it is not feasible to reduce the amount of energy used to zero only by introducing these energy-saving activities in manufacturing. To decarbonize the remaining energy, it is necessary to introduce renewable energy and use hydrogen.

The use of renewable energy is an issue that needs to be addressed by all of society, and accordingly, we are collaborating with many parties including the national and local governments as well as local communities and other businesses.

Plant CO_2 Emissions Reduced to Zero in Two Steps



Refer to Challenge 3 (pp. 97–98) for examples of specific measures.

Three Perspectives on the Effective Use of Renewable Energy

The effective use of renewable energy requires comprehensive investigation from the perspectives of environmental, regional, and economic factors. First, we introduce in-house power generation (such as solar power generation) at our own plants and other facilities. Then we consider external purchases. Already, TDB, our affiliate in Brazil, has introduced energy sourced from hydropower generation, and we will proceed with implementation in stages starting with high-suitability areas, taking into regional and environmental characteristics into consideration.

Toyota will strive to introduce systems and mechanisms that will lead to the widespread use of renewable energy. Our objective is to achieve zero CO_2 emissions at plants all over the world by 2050.

* When contracting for and purchasing electric power, we carefully check the type of source and select the one with the lower environmental impact

Main Affiliates That Use Renewable Energy in Each Region of the World

Europe region
TMUK (U.K.)
TMMF (France)

China
TFAP
GTMC
TMCAP

Asia-Pacific region
TMCA (Australia)
Kuozui (Taiwan)
TKM (India)
TKAP (India)
IMC (Pakistan)
ASSB (Malaysia)
TMMIN (Indonesia)

South Africa region
TSAM (South Africa)

Japan
Toyota Motor Corporation*
JTEKT Corporation
Toyota Motor East Japan, Inc.
Denso Corporation
Toyota Boshoku Corporation
Toyota Housing Corporation
Primearth EV Energy Co., Ltd.
Toyota Auto Body Co., Ltd
Admatechs Co., Ltd.

* Honsha Plant, Motomachi Plant, Tsutsumi Plant, Higashi-Fuji Technical Center

North America region
TMMK (U.S.)
TMMBC (Mexico)

South America region
TDB (Brazil)

Renewable Energy Covers All Electric Power at North American Headquarters Campus

Toyota Motor North America, Inc. (TMNA), which marked 60 years of business in the United States, constructed a new headquarters campus in Plano, Texas. The designs feature exterior walls made predominantly from glass to maximize use of natural lighting. Also, southern exposures have generous roof overhangs to control sunlight to appropriate levels. Moreover, the buildings and parking facility have more than 20,000 solar panels installed, providing more than 30 percent of the electric power used in the buildings. Electricity is also purchased from wind power generated in Texas, and as a result, renewable energy covers all electric power usage. These efforts were recognized by the U.S. Green Building Council, and the facility received LEED Platinum, the highest level of LEED environmental certification.

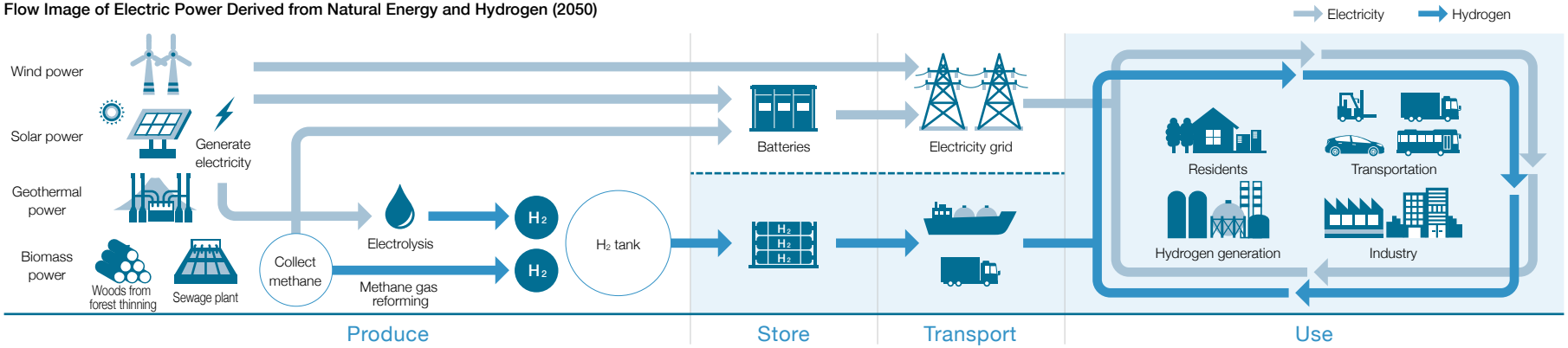
TMNA's new North American Headquarters Campus (solar panels installed on the building)

Toward Realizing a Decarbonized Society in 2050: Use of Hydrogen Energy

In conjunction with the rising use of electricity derived from natural energy in recent years, hydrogen holds great promise as a means of absorbing fluctuations and surpluses in renewable energy and for energy storage and transportation.

Toyota is participating in the creation of mechanisms for the use of hydrogen energy throughout society and is contributing to the realization of a decarbonized society.

Flow Image of Electric Power Derived from Natural Energy and Hydrogen (2050)



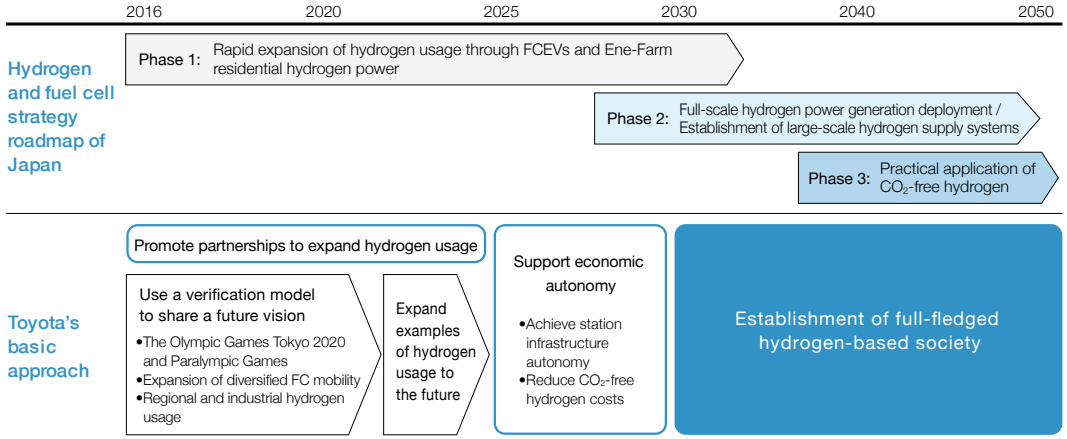
Strategies and Steps

Building infrastructure and making hydrogen widespread as a new energy are major challenges to realizing a hydrogen-based society. Toyota is promoting the widespread use of fuel cell electric vehicles (FCEVs) and actively collaborating national and local governments, local communities, and industries. We will strive to expand the use of hydrogen and make it economically viable.

Toyota's Current Mission

(1)	Achieve a hydrogen-based society through the widespread use of FCEVs
(2)	Collaborate with government, local communities, and the energy industry to build structures and perform verification tests

Aligning Toyota's Strategies and Steps with National Policies of Japan (Examples in Japan)



Main Projects in Japan (Collaboration with Local Communities)

Toyota's FCEV sales target for around 2020 is at least 30,000 units annually on a global basis, including at least 10,000 units in Japan.

Plants

Green hydrogen network for local production and local consumption Fukuoka Prefecture-led initiative to promote collaborative activities among industry-government-academia

(Fukuoka Prefecture, since March 2017)
Use of CO_2-free hydrogen produced from solar power in fuel cell fork lift trucks

Toyota's role
Toyota Motor Kyushu participated in the verification tests for hydrogen use at plants, representing the industry model

Plants

Development of low-carbon hydrogen supply chain in Aichi Prefecture starts

(Aichi Prefecture, since May 2018)
Aichi Prefecture, Chita City, Toyota City, Chubu Electric Power Co., Ltd., Toho Gas Co., Ltd., Toyota Motor Corporation, and Toyota Industries Corporation established an organization to promote collaboration among industry, academia, and government 2030 vision and roadmap formulated

Toyota's role
Certification received for first project to transport biomass gas from the Chita City Purification Center to the Toyota Motomachi Plant and manufacture and use hydrogen

Plants

Expanded and improved fuel cell stack and high-pressure hydrogen tank production facilities in preparation for sales expansion starting in 2020

(Aichi Prefecture, since May 2018)
Fuel cell stacks: Honsha Plant
High-pressure hydrogen tanks: Shimoyama Plant

Toyota's role
Pursuing comprehensive reductions in CO_2 during FCEV production as one measure for achieving the 2050 Plant Zero CO_2 Emissions Challenge

Energy creation

Fukushima Concept for a New Energy Society Conference

(Fukushima Prefecture, since March 2016)

Toyota's role
Provide means of mobility such as fuel cell electric vehicle buses (FCEV buses) and fuel cell forklift trucks

Energy creation

Japan H_2 Mobility, LLC established

(Tokyo, since March 2018)
Established by Toyota Motor Corporation, Nissan Motor Co., Ltd., Honda Motor Co., Ltd., JXTG Nippon Oil & Energy Corporation, Idemitsu Kosan Co., Ltd., Iwatani Corporation, Tokyo Gas Co., Ltd., Toho Gas Co., Ltd., Air Liquide Japan Ltd., Toyota Tsusho Corporation, and Development Bank of Japan Inc.

Toyota's role
Participate in the LLC and operate hydrogen stations through collaboration with parties located throughout Japan

Community

KIX Project, Kansai International Airport Verification of airport model for hydrogen grid (large-scale, centralized model)

(Osaka Prefecture, since May 2014)
Use of CO_2-free hydrogen produced from solar power in fuel cell fork lift trucks

Toyota's role
Toyota Motor Corporation, Toyota Industries Corporation, and Toyota Tsusho Corporation will support the KIX Hydrogen Grid Committee of Kansai International Airport with their knowledge on hydrogen and fuel cell technologies

Energy creation

Keihin Project, Keihin Coastal Area Renewable energy Supply chain verification from hydrogen production to usage (small- to medium-scale dense office model)

(Kanagawa Prefecture, since September 2015)
Use of CO2-free hydrogen produced from solar power in fuel cell fork lift trucks

Toyota's role
Toyota will represent business users of hydrogen

Community

Olympic and Paralympic Games Tokyo Demonstrate models of the next-generation mobility society and a clean, hydrogen-based society to the world

(Tokyo, through 2020)

Toyota's role
Support as a Worldwide partner of the IOC, as well as providing mobility means such as FCEVs and FCEV buses, and initiatives for the next-generation mobility society

SORA production model fuel cell electric vehicle bus launched (March 2018). Toyota plans to deliver more than 100 FCEV buses for the Olympic Games Tokyo 2020 and Paralympic Game.

Major Overseas Projects (Partnerships for the Widespread Use of FCEVs and Hydrogen Usage)

Country	Project Name
Australia	MIRAI test launch (July 2016)
UAE	Participated in joint research for realizing a hydrogen-based society (January 2017)
China	Started driving experiment by launching MIRAI on a test basis (January 2017)
Canada	Started driving experiment by launching MIRAI on a test basis (February 2017)
U.S.	Shell and Toyota collaborate on building a hydrogen station network in California (February 2017)
U.S.	Started verification tests for large-scale FC trucks at the Port of Los Angeles (April 2017)
U.S.	TMNA, an American affiliate, establishes Tri-Gen to produce hydrogen, electricity, and water from biomass (December 2017)

Expansion of the Hydrogen Council

In January 2017, the Hydrogen Council was established in Davos, Switzerland as the first global hydrogen initiative. The council is represented by leaders from global companies including Toyota striving to promote hydrogen usage as a means to achieve climate change goals.

In November 2017, the Council announced the world's first concrete vision for the use of hydrogen. Due to advances in hydrogen-related technologies, hydrogen is expected to account for 18 percent of final energy demand by the middle of the 21st century, reducing CO_2 emissions by 6.0 billion tons, generating 2.5 trillion dollars in business annually, and creating jobs to 30 million people. Eleven leading companies in the petroleum, gas, energy, chemicals, technology, and automotive fields in Asia, North America, and Europe joined the Council as new members in March 2018. The number of members reached 39 companies in one year since the Council's establishment, which is sure to spur innovation in hydrogen-related technologies.

Forecast of the Effects of Hydrogen-related Technologies

Percentage of final energy accounted for: **18%**

Converted amount of annual business: **$2.5 trillion**

CO_2 emissions: **6.0 billion tons**

Projected employment creation effects: **30 million jobs**

TMNA Builds Tri-Gen to Produce Hydrogen, Electricity, and Water from Biomass

TMNA, a U.S.-based affiliate, will build Tri-Gen, a fuel cell power generation plant (2.35 MW) and hydrogen station, at the Port of Long Beach in California in collaboration with Fuel Cell Energy, Inc. Tri-Gen will extract hydrogen from biogas derived from livestock waste and sewage and generate electricity from molten carbonate fuel cells*, producing electricity, heat and water entirely. Construction will begin in 2018, and operations are scheduled to commence around 2020.

The daily generating capacity will be enough to power approximately 2,350 average-sized homes, and the 1.2 tons of hydrogen produced will meet the daily driving needs of approximately 1,500 fuel cell electric vehicles. A portion of the electricity generated and the water produced will be supplied to the Long Beach site of Toyota Logistics Service, meeting all of the site's electric power needs with renewable energy. The hydrogen will be supplied via the adjacent hydrogen station to fuel pre-delivery new deliveries of Mirai FCEVs and the heavy-duty commercial fuel cell trucks that have been in trial operation since 2017.

* Molten carbonate fuel cell:
A fuel cell that uses molten carbonate as the electrolyte and operates at 600°C to 700°C. Households and automobiles use polymer electrolyte fuel cells, which operate at temperatures of approximately 80°C.

Heavy-duty commercial fuel cell truck

Conceptual Diagram of Tri-Gen