Building a Community-Integrated Low-carbon Hydrogen Supply Chain

Kanagawa Prefecture, City of Yokohama,
Kawasaki City, Iwatani Corporation, Toshiba Corporation, Toyota Motor Corporation,
TOYOTA INDUSTRIES CORPORATION,
Toyota Turbine and Systems Inc.,
JAPAN ENVIRONMENT SYSTEMS CO., LTD

Project Overview

Project name

Ministry of the Environment: Regional Cooperation and Low-carbon Hydrogen Technology Demonstration Project
Introduction of fuel-cell forklifts in the Keihin Waterfront Area and demonstration of feasibility of building a low-carbon hydrogen utilization model

Planned project duration

FY2015-FY2018 (4-year project)

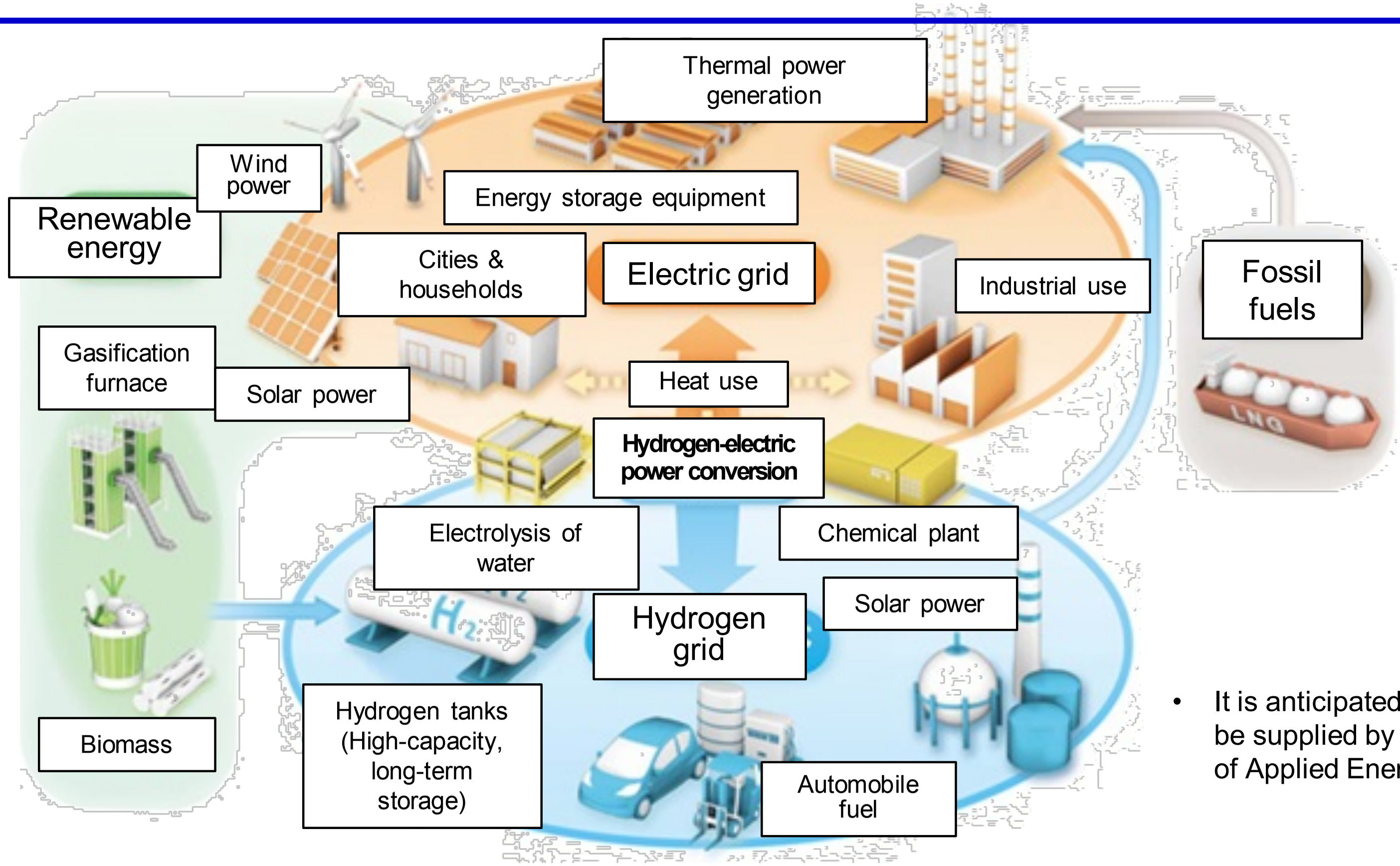
Project Overview

▼Trial of building a hydrogen supply chain, from the production of CO2-free hydrogen produced using renewable energy to its storage, transport, and utilization; investigation of the commercial feasibility of the supply chain.

▼Realization of a simple integrated system for utilizing hydrogen, with the goal of contributing to future regional development and helping mitigate global warming.

An Ideal Low-Carbon Society

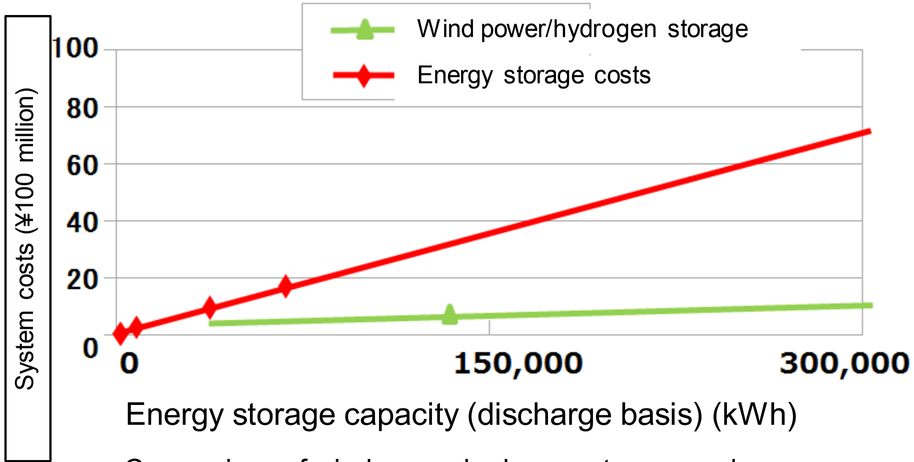
▼ We aim to expand the use of renewable energy and use electricity and hydrogen in order to create a society that employs various forms of energy.



- It is anticipated that 13% to 20% of total energy will be supplied by hydrogen (estimate by the Institute of Applied Energy; source: HyGrid Study Group)

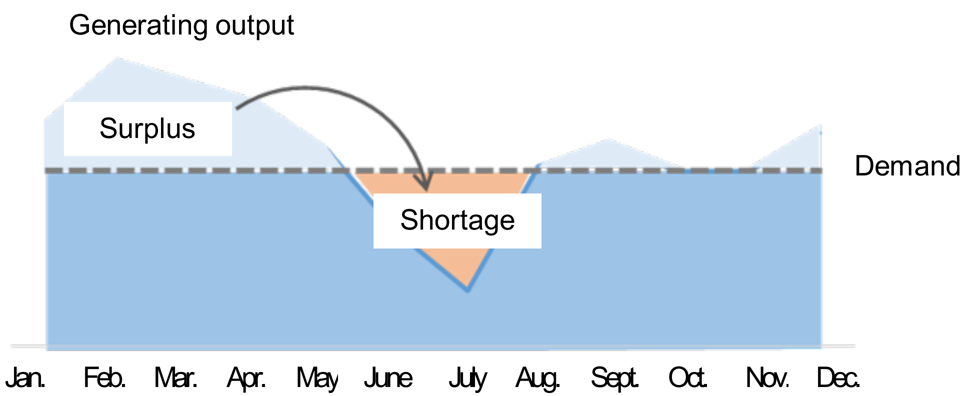
The Potential of Hydrogen

- ▼ Can be produced from various sources of primary energy; can be stored and transported
- ▼ Can compensate for fluctuations in renewable energy production
- ▼ Hydrogen may be more cost-effective for large-scale and regular energy storage
- ▼ Hydrogen storage on a seasonal basis appears promising/possible



Comparison of wind power hydrogen storage and energy storage costs (example)

Source: Possibilities of Developing a Hybrid Grid Using Hydrogen, HyGrid Study Group (April 23, 2014)



Responses to Seasonal Fluctuations in Wind Power Production

Organizational Structure of the Project

Ministry of the Environment
Global Environment Bureau,
Climate Change Policy Division

Committee

Chairperson
Prof. Emer. Kenichiro Ota,
Yokohama National
University

Vice Chairperson
Prof. Emer. Yoji Uchiyama,
University of Tsukuba

Secretariat

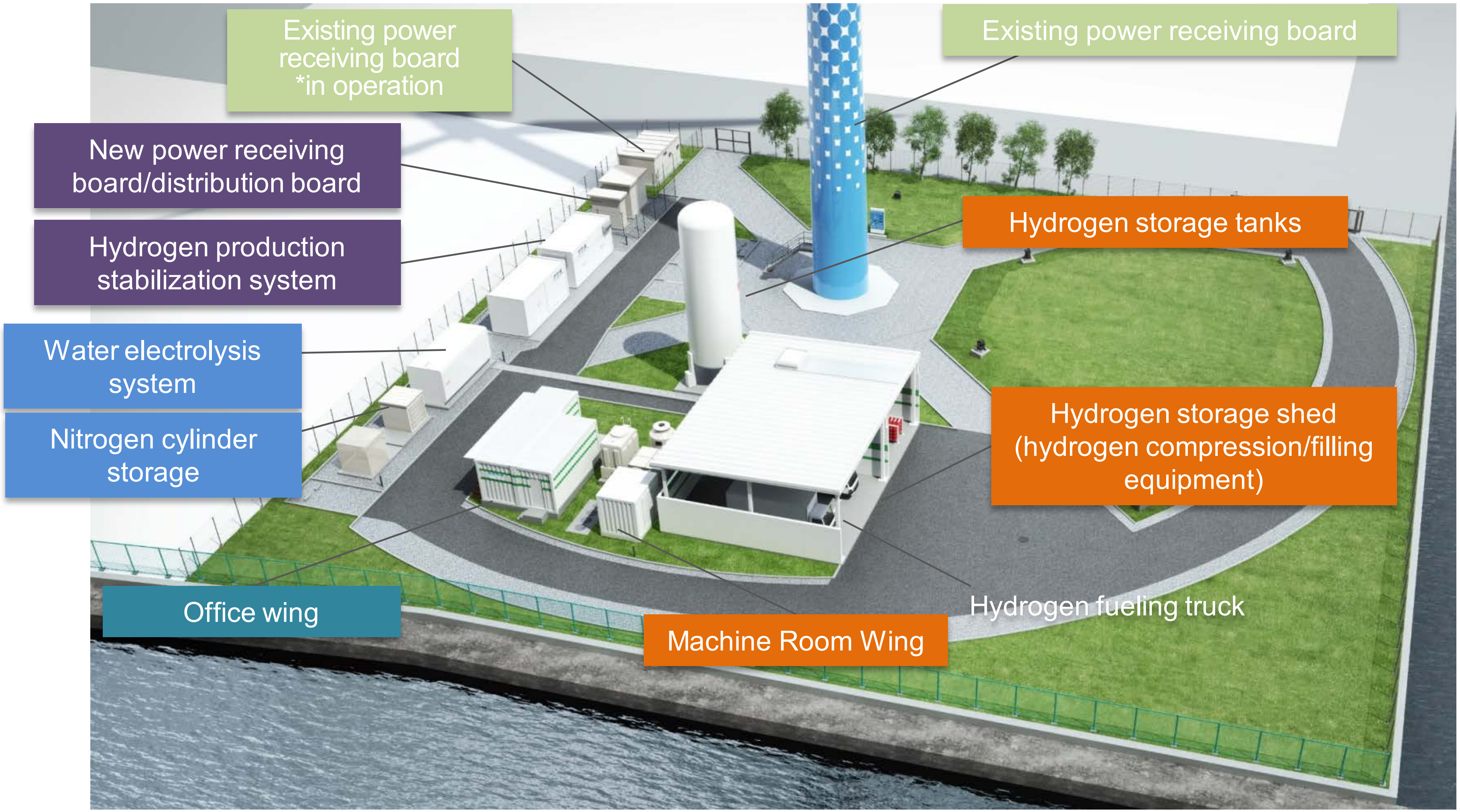
Kanagawa Prefecture	Toyota Motor Corporation	Japan Environment Systems

Manufacturing	Storage/Transport	Utilization	FS/Future Development
Toshiba Corporation	Iwatani Corporation	Yokohama City	Japan Environment Systems
Toyota Turbine and Systems Inc.		Kawasaki City	Toyota Motor Corporation
		Toyota Industries Corp.	

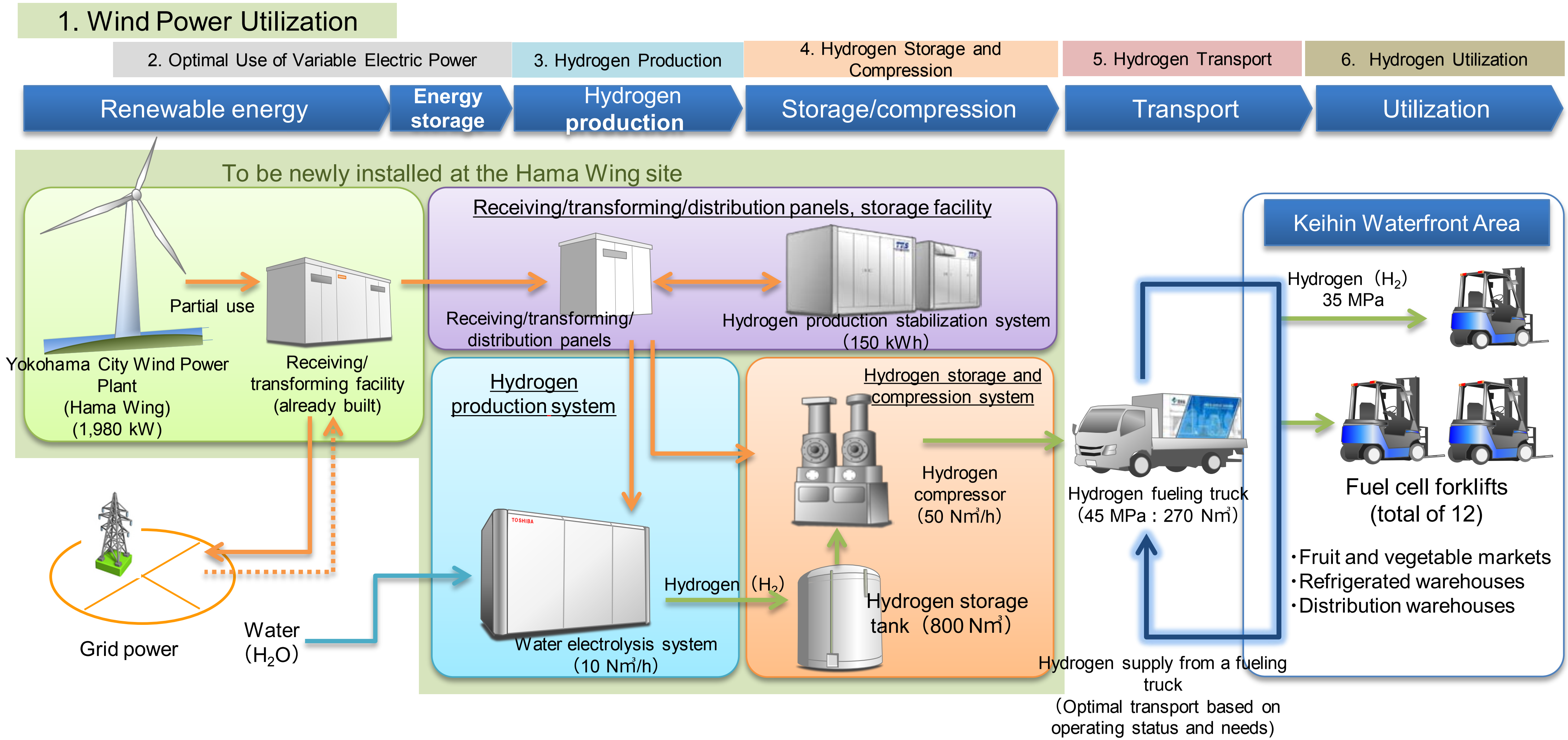
Trial Area

首都高速神奈川7号横浜北線
東海道新幹線
菊名
新横浜
Kirin Brewery Co., Ltd.
(Kirin Yokohama Brewery)
鶴見
Kawasaki City
Nichirei Logistics Group
(Higashi-Ogishima
Distribution Center)
首都高速神奈川1号横羽線
Yokohama City
Nakamura Logistics Inc.
（Kawasaki FAZ Distribution Center）
首都高速湾岸線
首都高速神奈川5号大黒線
Yokohama Central Wholesale
Market
(Vegetable and Fruit Section)
横浜
Hama Wing
(Yokohama Wind Power Plant)
桜木町

Hydrogen Supply Point



Project System Flow



Wind Power Utilization

Utilization of CO_2-free Electricity Generated at the Yokohama City Wind Power Plant (Hama Wing)

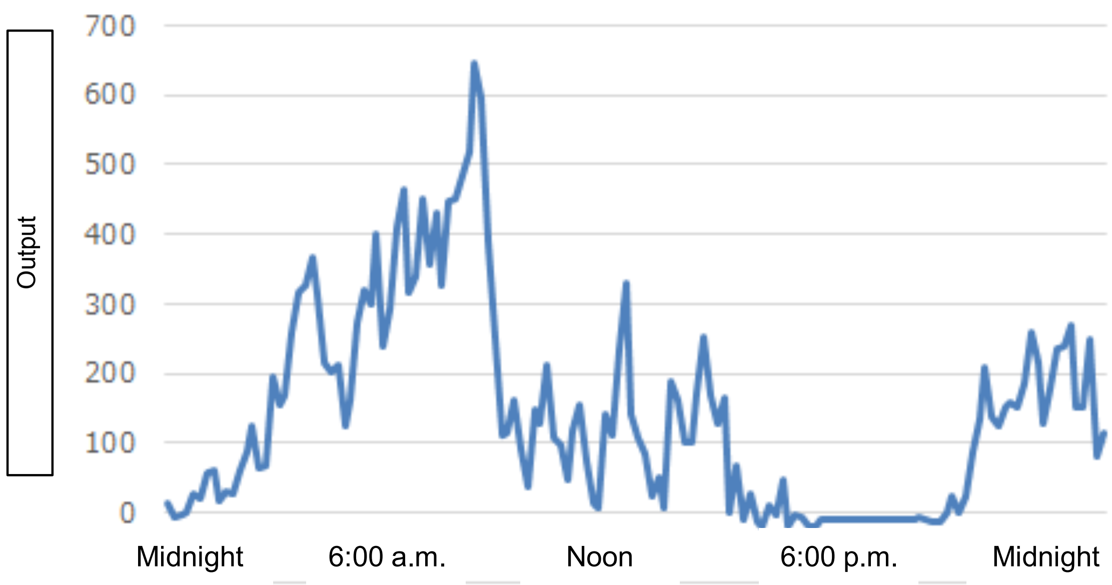
Hama Wing and the Yokohama Bay Area

Specifications	
Manufacturer	Vestas (Denmark)
Rated output	1,980 kW
Hub height	78 m
Blade diameter	80 m
Peak height	118 m

1. Wind Power Utilization

Establish priority for the limited amount of wind-generated power, which fluctuates widely, and build a system that uses it optimally.

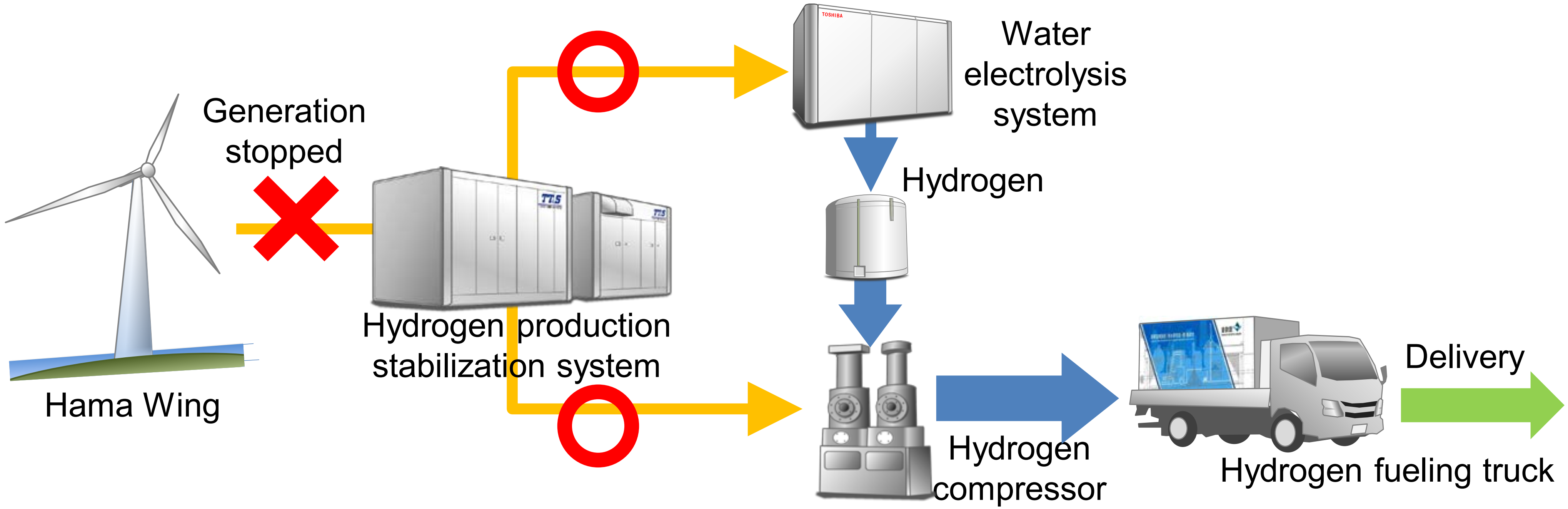
Generated output on July 3, 2014



Item	Value
Power generated per year	Approx. 2.20 million kWh
Facility operation rate	12.4 %

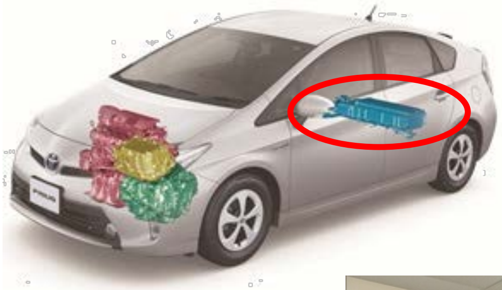
2. Optimal Utilization of Variable Electric Power

- ▼ By using an energy storage system, electric power can be supplied to facilities even when Hama Wing is not generating power. This enables the stable production and supply of hydrogen.
- ▼ The system will store electricity when Hama Wing output is high, and the stored electricity will be supplied to the water electrolysis system and hydrogen compressor when output is low or operation stops altogether.



2. Optimal Utilization of Variable Electric Power

Reusing end-of-life batteries from hybrid vehicles as secondary batteries makes sense environmentally.

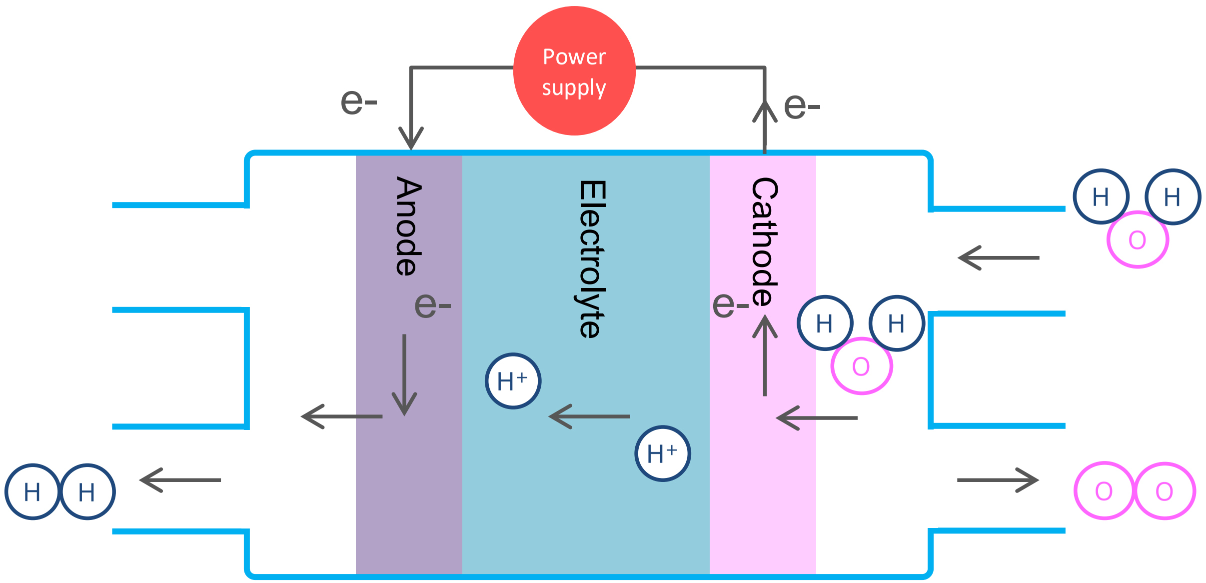


Hydrogen production stabilization system (power storage system): Toyota Turbine and Systems Inc.

Specifications (planned)	
Battery type	Nickel metal hydride
No. of cells	180
Output	150 kWh

3. Hydrogen Production

Electricity generated at Hama Wing will be used for water electrolysis to produce hydrogen.
Electricity generated at Hama Wing will also be used to power equipment, achieving CO2-free hydrogen production.

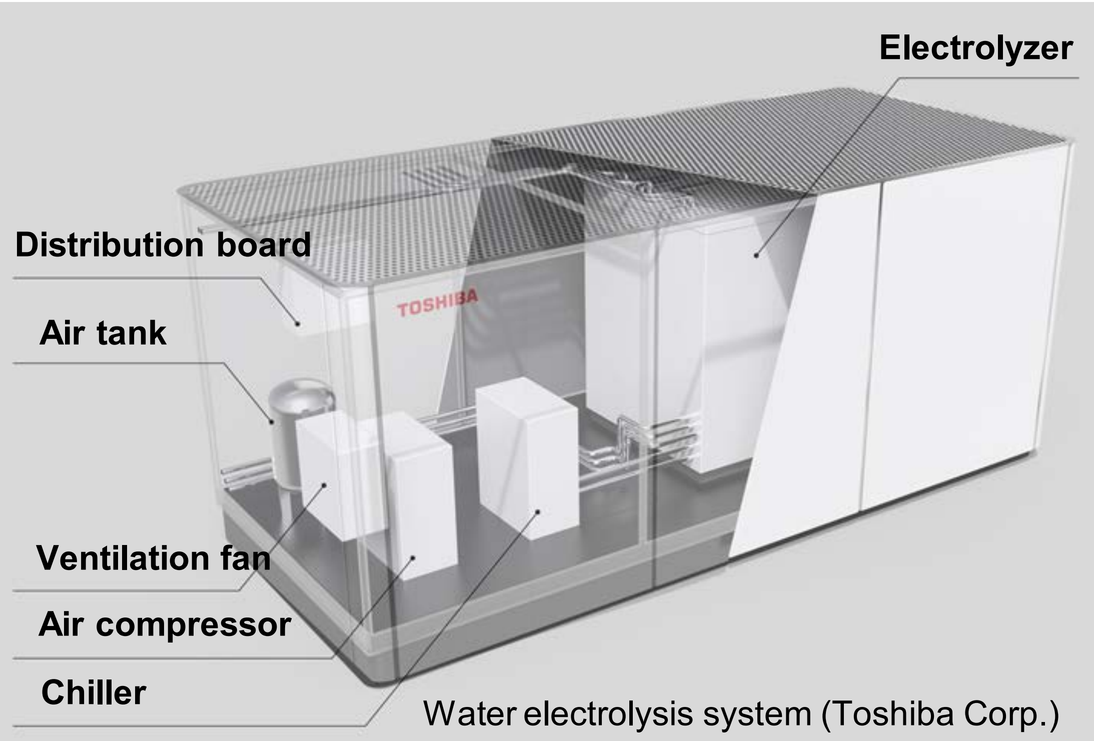


Anode: $2H^+ + 2e^- \rightarrow 2H_2$

Cathode: $H_2O \rightarrow 1/2O_2 + 2H^+ + 2e^-$

3. Hydrogen Production

Hydrogen can be produced flexibly according to the fluctuating amount of wind-generated power.



Water electrolysis system (Toshiba Corp.)

Specifications (planned)	
Size (m)	D6×W2.5×H2.3
Type	Solid polymer type
Production capacity	10 Nm^3/h

4. Hydrogen Storage and Compression

- ▼ Hydrogen storage tanks suitable for demonstration will be installed during the trial so that hydrogen can be supplied efficiently to fuel cell forklift users.
- ▼ A fueling truck will fill the tanks on demand.

Hydrogen storage tank


Compressor

Specifications		
Hydrogen storage tank	Pressure	0.8 Mpa
	Storage Capacity	800 Nm^3
Compressor	Filling pressure	45 Mpa max.
	Capacity	50 Nm^3/h

5. Hydrogen Transport

▼ Japan's first hydrogen fueling truck will be introduced to service the fuel cell forklifts.

(1) A small fueling truck is necessary to meet forklift usage conditions, including proximity between usage areas and fueling trucks, suitability for indoor usage.

(2) The truck is an environmentally (no hyphen) friendly hybrid vehicle.

Hydrogen shed and hydrogen fueling truck

Specifications		
Vehicle used		Hybrid Truck 4t
Capacity		270 Nm^3
Fueling equipment	Dimensions (m)	D3.5×W1.8×H1.35
	Tanks	2 (300 L, 45 MPa)

6. Hydrogen Utilization

▼ Fuel cell forklifts, which went on sale in November 2016, will be used. They emit zero CO_2 during operation.

Fuel Cell Forklift (Toyota Industries Corp.)

Specifications	
Maximum load	2,500 kg
Refueling time	3 minutes
Hydrogen fuel capacity	13.4 Nm^3
Duration of operation	Approx. 8 hours*

* Calculated based on a 55% use rate

6. Hydrogen Utilization

- ▼ Domestic forklift users tend to possess low to medium numbers of units and use them for various purposes.
- ▼ Fuel cell forklifts will be operated at four sites under different conditions.

Site	Yokohama Central Wholesale Market	Kirin Brewery Co., Ltd. (Kirin Yokohama Brewery)	Nakamura Logistics Inc.	Nichirei Logistics Group
Aim	• Short-distance transport • High-frequency use	• Transport of heavy objects	• Use in refrigerated warehouse & indoor fueling	• Use in refrigerated distribution
Use				

Results of Previous Trial of Full-scale Use

▼ Trial period: November 2016 – June 2017

▼ Hydrogen procurement: Iwatani Industrial Gases Corp. (Chiba Plant)

▼ Details: 2 fuel cell forklifts
(one each operated by the Yokohama City Central Wholesale Market and Nakamura Logistics)
1 hydrogen fueling truck

▼ Objectives: (1) To develop expertise in hydrogen supply and fueling
(2) To gain further knowledge of hydrogen and fuel cells
(3) To be an early adopter of fuel cell forklifts

Results of Previous Trial of Full-scale Use

▼ Atrial operation was conducted to prepare for full-scale operations, to confirm operation of the fueling truck, and to ensure user convenience.

Fueling test

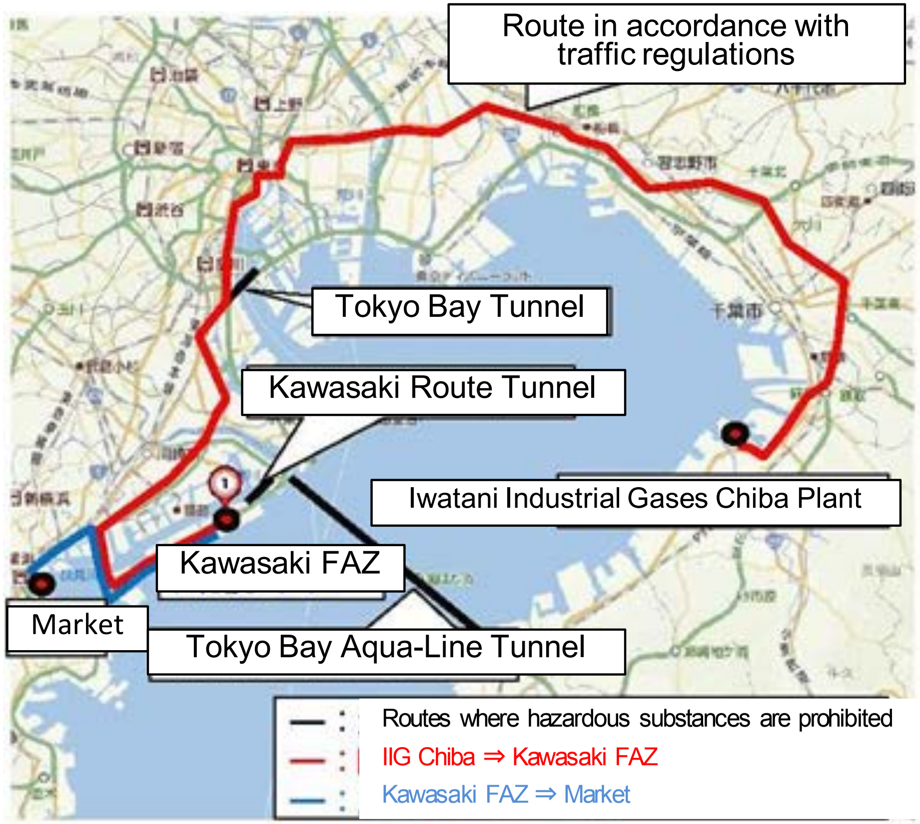
Hydrogen fueling takes about 3 minutes for each forklift

General comments regarding use of fuel cell forklifts

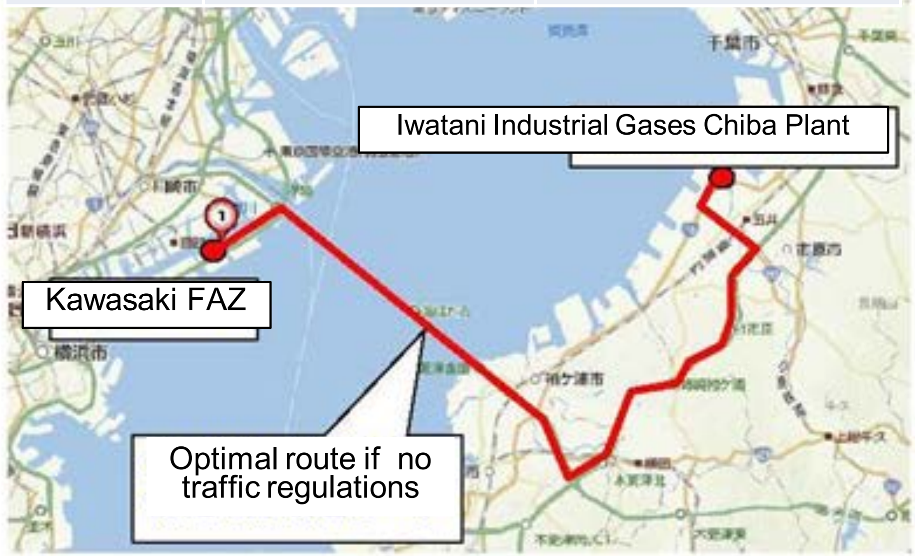
Evaluation	Comments
Good	It is beneficial that the fueling time for fuel cell forklifts is shorter than for electric forklifts.
Good	We were able to use the forklift in normal operations without any particular problems.
Good	We thought handling would be difficult, but that wasn’t the case. It can be handled in the same manner as an electric forklift.
Fair	We’re not well-acquainted with hydrogen technology, so there are concerns about safety.
Fair	We would like you to consider increasing the hydrogen delivery frequency.

Results of Previous Trial of Full-scale Use

During trial operations, hydrogen was supplied from the Iwatani Industrial Gases Chiba Plant.
⇒ There were restrictions on delivery routes, and this will be an issue for future business development.



	Restricted routes	Optimal route
Distance	110 km	60km
Travel time	Approx. 3 hours	Approx. 1 hour 30 minutes



Details of Future Trial

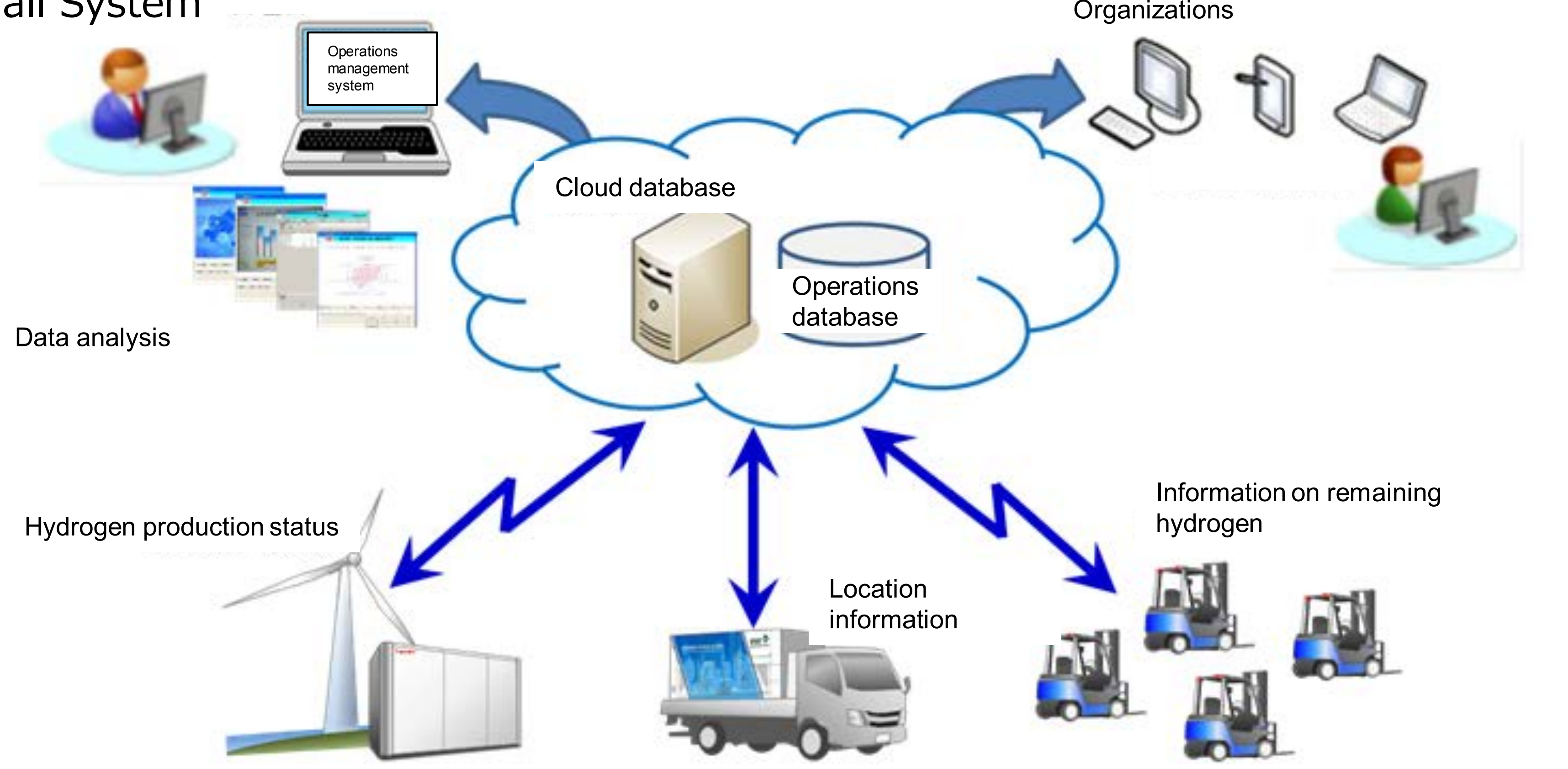
- ▼ Production of CO_2-free hydrogen using electric power from Hama Wing will commence.
- ▼ The trial will be conducted with 12 fuel cell forklifts and two hydrogen fueling trucks to supply hydrogen.
- ▼ Cloud computing will be used to manage and operate processes from hydrogen production to utilization.

	Supply method	Production	Transport	Utilization
Step 1	Periodic	Hydrogen for 12 fuel cell forklifts will be produced	Periodic deliveries once per day using two hydrogen fueling trucks	Hydrogen consumption: 13.4 Nm^3/unit (8 hours of operation) Maximum consumption: 13.4 × 12 units = 161 Nm^3
Step 2	On demand (Limited sites/number of units)	Hydrogen consumption by fuel cell forklifts will be estimated and appropriate amounts will be produced	Hydrogen remaining in fuel cell forklifts will be calculated and hydrogen will be delivered (maximum of 3 times daily) (forecast demand and conduct trial of just-in-time delivery)	Hydrogen consumption volume: 40.2 Nm^3/unit max. (24-hour continuous operation anticipated)

Details of Future Trial (Management System)

An operations management system will be used to determine operating data for each vehicle and facility.

Overall System

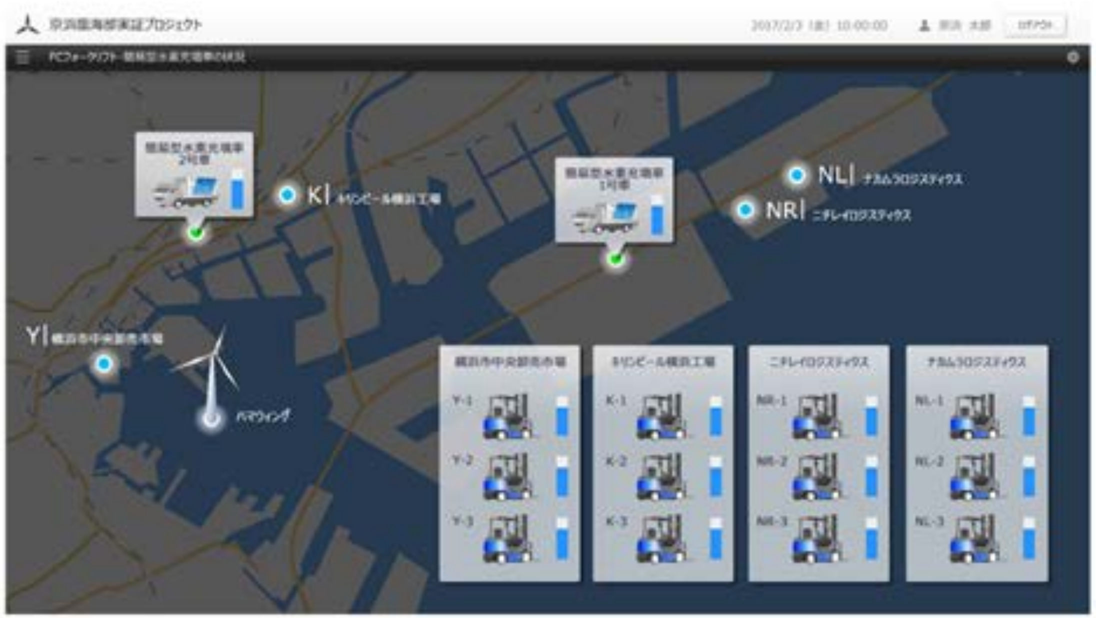


Details of Future Trial (Management System)

The operating status of Hama Wing trial facilities and fuel cell forklift hydrogen usage volumes will be continuously monitored to meet user needs through optimal transport.

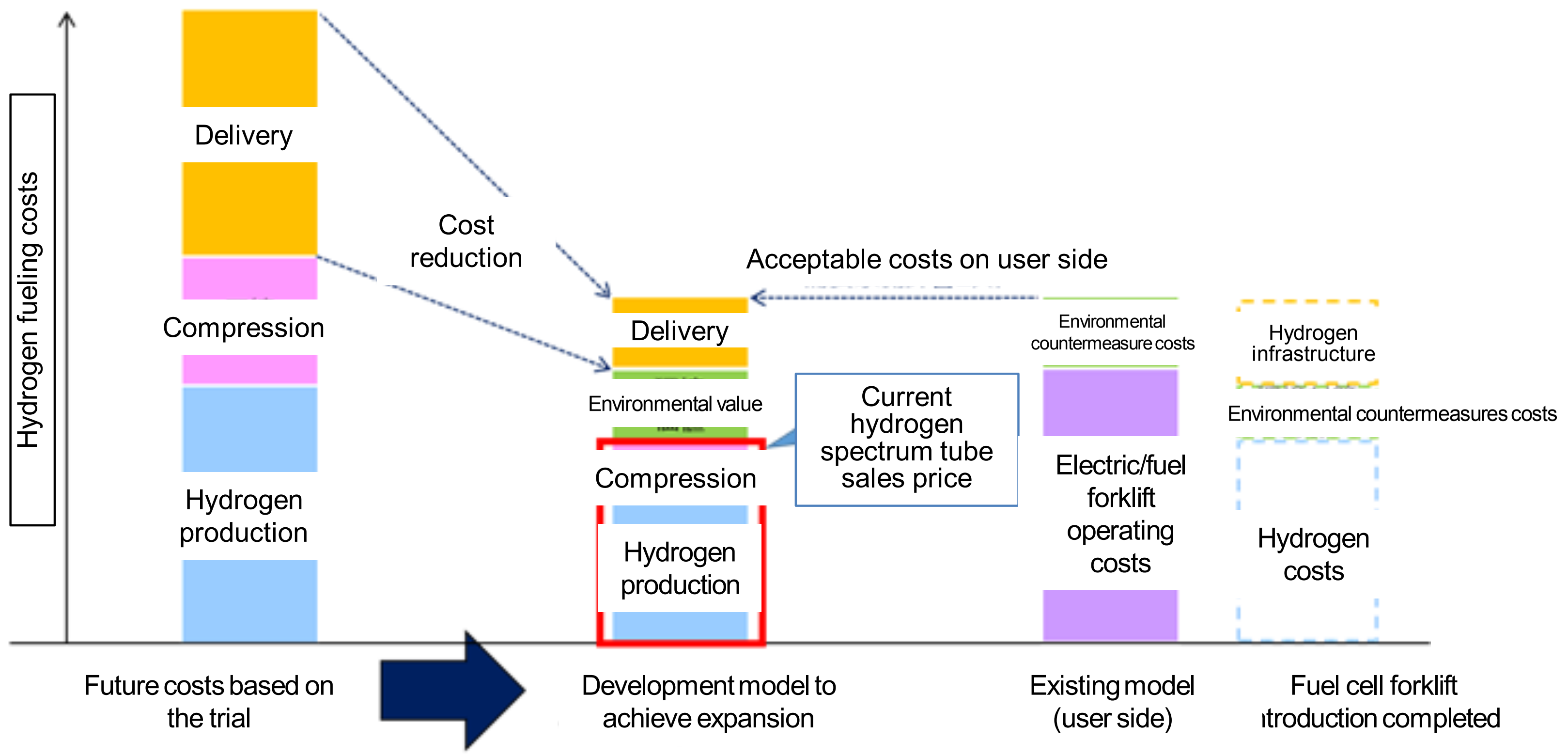
Hydrogen Production Operating Status

Fuel Cell Forklift Operating Status



Cost Verification

The optimal hydrogen cost will be estimated, taking into consideration the operating costs of existing forklift operation at sites where fuel cell forklifts are introduced as well as environmental considerations.
⇒Issues will be carefully examined to achieve the optimal cost.



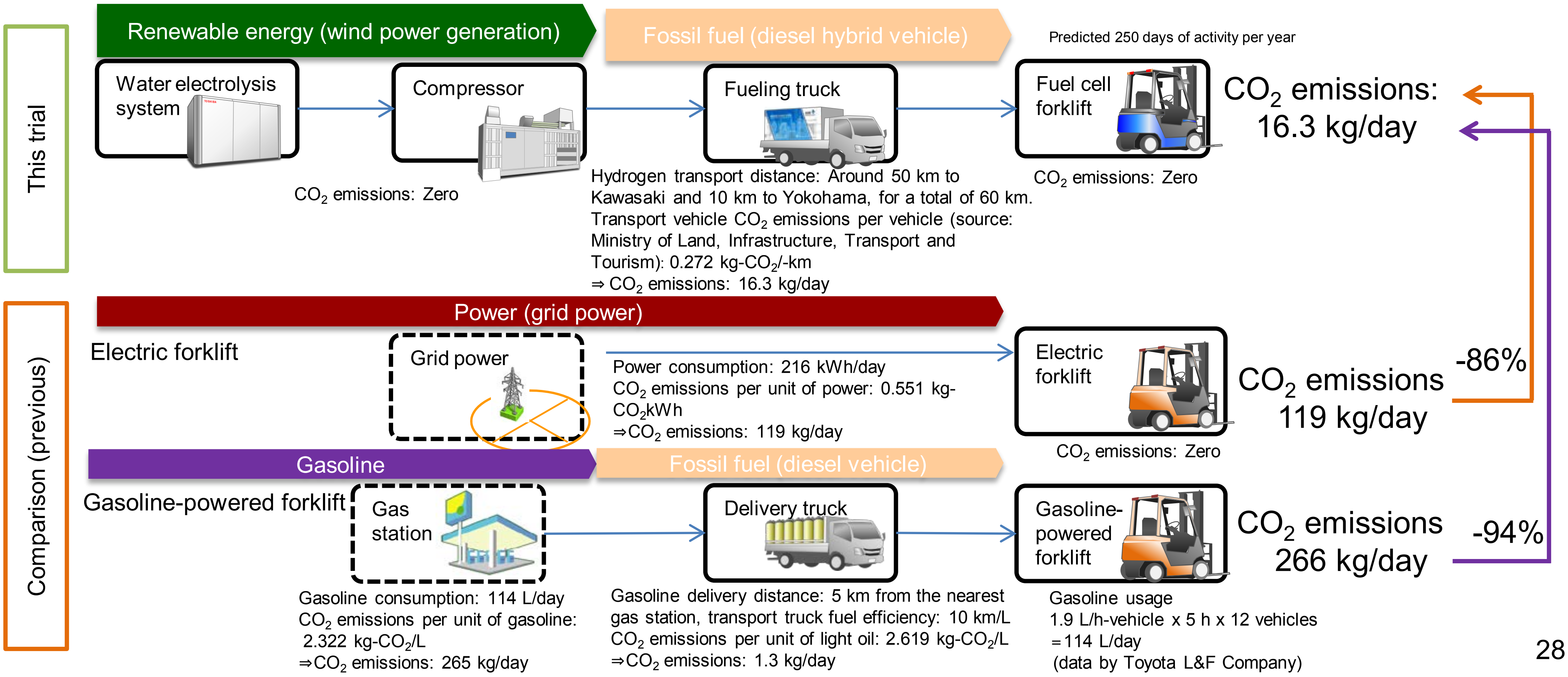
Cost Verification

We will verify the extent to which current (high) costs can be reduced through economies of scale, deregulation, etc.

	Main factors behind high cost
Facility cost Maintenance cost	Effects on cost from small-scale trials (hydrogen production capacity, hydrogen supply volume, etc.)
Operation cost	The High Pressure Gas Safety Act requires the constant presence of three qualified persons to oversee hydrogen compression.
Electricity cost, fuel cost	Electric power costs for water electrolysis, compression, etc.
Other	Cost of delivery from hydrogen production and supply sites

Survey of Future Project Feasibility (CO_2 Reduction)

Building a supply chain of hydrogen produced with CO_2-free methods can <u>reduce overall CO_2 emissions by at least 80%</u> compared to a conventional approach.



Future Trial Schedule

	FY2015	FY2016	FY2017	FY2018
Project overview	Basic design, prototype, feasibility study	System building Test run	System building (cont.) Demonstration system introduction, operation start	Operation Evaluation and impact study
■ Hydrogen production	Design/manufacturing preparation	Receiving/transforming equipment modification, distribution panel construction Water electrolysis construction	Demonstration operation	
■ Hydrogen storage	Design/manufacturing preparation	Tank/compressor construction	Demonstration operation	
■ Hydrogen transport	Manufacturing of system No.1	Manufacturing of system No.2 Demonstration operation (one system)	Demonstration operation (two systems)	
■ Secondary batteries	Design/manufacturing preparation	Hydrogen production stabilization system construction	Demonstration operation	
■ Hydrogen utilization		Test operation: Two systems Demonstration operation (two facilities)	Full-scale operation: 12 systems Demonstration operation (four facilities)	
■ Construction at Hama Wing site	Plan/design	Ordering Foundation, infrastructure, and office construction ★Start of water supply	Demonstration operation ★Electricity supply from Hama Wing	Recovery
□ Demonstration operation phase		Trial	Full-scale verification	

Note: Factors such as future discussions with the Ministry of the Environment may cause changes to the demonstration details and implementation plan.

Toward the realization of a low-carbon hydrogen society