Toray Group’s Hydrogen-related Businesses

September 5, 2023
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Ⅰ. Toray Group’s Sustainability Initiatives

Ⅱ. Hydrogen that Contributes to Realizing Carbon Neutrality

Ⅲ. Toray Group’s Hydrogen Strategy
Toray Group’s Sustainability Initiatives
Achieving Sustainable Growth

- Expansion of Sustainability Innovation (SI) and Digital Innovation (DI) businesses
- Target: Expanding revenues from businesses related to these areas to about 60% of total by 2025

**Growth Business Fields under AP-G 2025**

### SI Business
**Sustainability Innovation Business** (*1)

1. Products that accelerate measures to counter climate change
2. Products that facilitate sustainable, recycling-based use of resources and production
3. Products that help provide clean water and air and reduce environmental impact
4. Products that help deliver better medical care and hygiene for people worldwide

### DI Business
**Digital Innovation Business**

- Materials, equipment, technologies, and services that help improve convenience and productivity by supporting the widespread adoption of digital technology

- **SI&DI Projects**
  - Carbon fibers for aircrafts
  - Electrolyte membranes for production of H2
  - Bioprocess using membranes
  - Chemical recycling using subcritical water
  - RO membranes for seawater desalination
  - Environmentally friendly offset plate
  - Cancer Antibody Drug TRK-950
  - Protective clothing
  - Polyimides
  - Semiconductor manufacturing and inspection equipment

- **GR Business**
  - Products that accelerate measures to counter climate change
  - Products that facilitate sustainable, recycling-based use of resources and production
  - Products that help provide clean water and air and reduce environmental impact
  - Products that help deliver better medical care and hygiene for people worldwide

- **LI Business**
  - Materials, equipment, technologies, and services that help improve convenience and productivity by supporting the widespread adoption of digital technology
As a Part of Commitment to Growth Fields, Sustainable Innovation (SI) Business has been Expanded
Carbon Neutrality Initiatives

Helping the broader society to reduce overall greenhouse gas emissions through the Sustainability Innovation (SI) Business. Also reducing Toray Group greenhouse gas emissions* by maximizing the use of renewable electricity, hydrogen, and low carbon-footprint raw materials, based on expansion of the SI Business. (*Scope 1, 2, 3)

Contributing to building a carbon-neutral world

Increasing the Volume of Greenhouse Gas Emissions Avoided through the Sustainability Innovation (SI) Business

Achieving carbon neutrality for the Toray Group by 2050

Adopting greenhouse gas emissions reduction technology in business activities

Returns from the SI Business

- Maximizing the use of zero-emission electricity and fuels
- Increasing the efficiency of existing production processes
- Developing innovative low-greenhouse gas emission production technologies
- Developing and maximizing the use of recycling technology and biotechnology
- Taking on the challenge of CO₂ recycling and carbon capture

(Corresponding KPIs)

FY2030 Target [Compared to FY2013]

- GHG emissions in production activities: 4.5-fold
- CO₂ emissions avoided in value chain: 25-fold

FY2030 Target [Compared to FY2013]

- GHG emissions per unit of revenue for the entire Toray Group: Over 50% reduction
- GHG emissions of Toray Group in Japan: Over 40% reduction
Hydrogen that Contributes to Realizing Carbon Neutrality
Hydrogen’s Contribution to Realizing Carbon Neutrality

Hydrogen is the Key to Fulfilling Carbon Neutrality

Created by Toray based on Bloomberg NEF’s "New Energy Outlook 2021" Green Scenario

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Global Movement toward Hydrogen

Europe
- Green hydrogen in/outside the region: 10 million ton/year for each in 2030
- Water electrolysis system installed in the region: ~100 GW

Global Hydrogen-related Projects (until 2030)

Europe
- Green hydrogen in/outside the region: 10 million ton/year for each in 2030
- Water electrolysis system installed in the region: ~100 GW

USA
- Clean hydrogen production in 2030: ~10 million ton/year
- Target hydrogen cost in 2031: 1 USD/kg
- Legislated tax incentives and Clean Hydrogen Hubs

China
- Hydrogen from renewable energy resources in 2025: ~250 thousand ton/year

Japan
- Clean hydrogen supply in 2030: ~3 million ton/year
- Water electrolysis system deployed in/outside Japan in 2030: ~15 GW
- Target hydrogen price in 2030: 30 JPY/Nm³ (2.4 USD/kg)

Other Countries and Regions
- Countries and regions of abundant renewable energy such as Chile, Australia, India, Middle East, and Africa will transition to export of hydrogen after fulfilling the demand within its own country/region.

Hydrogen to be Integrated Concurrently into Global Systems Led by National Policy, Further Driving Rapid growth. The Key to Future Success is Demand Creation.
Emerging Hydrogen Markets

[Created by Toray based on Bloomberg NEF’s “New Energy Outlook 2022”]

Hydrogen Long-term Demand Forecast (upper) and Transition to Clean Hydrogen (lower)

Unit: Million tons
Assumption: Bloomberg NEF’s Net-zero scenario

Demand expected to grow to 500 million tons in 2050 (5 times the current size)

Transition to hydrogen from other energy
- "Hydrogen Integration"
  - Industry (steel, etc.), Power generation
  - Buildings (residential, commercial)
  - Transport (commercial vehicles, etc.)

Replacement to clean hydrogen
- Ammonia, methanol, refinery

Green Hydrogen to be more than 80%

- Hydrogen to Enter in Expansion Period after 2030 thanks to the Positive Cycle of Scale-up and Cost Reduction
- New Demand to Grow along with the Expansion of Hydrogen Integration

Green: derived from renewable energy
Blue: gray hydrogen with CO₂ capture
Gray: derived from fossil fuel

Existing Demand
New Demand

2020 2030 2040 2050
0% 25% 50% 75% 100%
0 100 200 300 400 500

Gray Hydrogen
Blue Hydrogen
Green Hydrogen

Shift
Expansion

Replacement to clean hydrogen
Ammonia, methanol, refinery

Green Hydrogen to be more than 80%

- Hydrogen to Enter in Expansion Period after 2030 thanks to the Positive Cycle of Scale-up and Cost Reduction
- New Demand to Grow along with the Expansion of Hydrogen Integration

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Toray Group’s Hydrogen Strategy
Toray Group’s Strategies for the Expansion of Hydrogen Business

Production

Renewable Energy Resources
- Solar
- Wind
- Water

Clean Electricity
- Water
- PEM Electrolyzer Cell
  - H₂O
  - Anode catalyst
  - Cathode catalyst
  - Polymer Electrolyte Membrane
  - Subgasket
  - CCM
  - Porous Transport Layer (PTL)
  - Separator

Hydrogen
- Water Electrolyzers
  - Alkaline
  - Proton Exchange Membrane (PEM)
  - Diaphragm

Transportation & Storage

Transport & Storage Facilities
- Storage Tanks
- Hydrogen Electrochemical Compressor
- Hydrogen Refueling station
- Hydrogen Tube Trailer

Hydrogen Consumers
- Industry
  - Chemicals, Refinery, Steel, Cement, etc.
- Power
  - Single/Multi Fuel Combustion
- Building
  - Stationary Fuel Cells
- Transport
  - Forklift
  - Car
  - Residential Commercial
- Use
  - Water Resources
    - Water Treatment Membranes
  - Hydrogen
    - Electrolyte Membrane
    - CP, GDL
    - CCM

Providing Toray Group’s Proprietary Advanced materials throughout the Hydrogen Supply Chain as Solutions to Realize Hydrogen Society

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Overview of Hydrogen-related Materials and Technologies

Key Elemental Technologies

- Polymer Technology
- Spinning Technology
- Carbonizing & Sintering Technology
- Film Manufacturing & Coating Technology
- Catalyst Formulation Technology

Evaluation and Analysis Technologies

Toray Group’s Products

- Carbon Fiber
  - Top share in the industry
- Carbon Paper / Gas Diffusion Layer
  - Top share in the industry
- Polymer Electrolyte Membranes
  - Start of production planned in 2025
- Catalyst Coated Membrane/ Membrane Electrode Assembly
  - Top share in water electrolysis

End Products

- High-pressure H₂ Gas Tanks
- Fuel Cell Systems (stationary, mobility)
- Water Electrolyzer Systems

Leveraging on Toray Group’s Proprietary Technologies to Develop and Propose Core Materials that Support Hydrogen Society

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## Toray Group’s History of Hydrogen-related Materials Development

### Products

<table>
<thead>
<tr>
<th>Products</th>
<th>1990-</th>
<th>2000-</th>
<th>2010-</th>
<th>2020-</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon Fiber for High-pressure H₂ Gas Tanks</strong></td>
<td>1961-Began R&amp;D</td>
<td>Development and mass production of T700S</td>
<td>Started sales and expanded varieties of T720S</td>
<td></td>
</tr>
<tr>
<td>Application to natural gas tanks</td>
<td>Application to hydrogen tanks</td>
<td>Full-scale mass production</td>
<td></td>
<td></td>
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<tr>
<td><strong>Carbon Paper (CP) &amp; Gas Diffusion Layer (GDL) for Electrode</strong></td>
<td>1982-Began development of CP</td>
<td>Development of rolled-type CP / GDL</td>
<td>Enhance business expansion in automobiles</td>
<td></td>
</tr>
<tr>
<td>Application to fuel cell vehicles, expansion of models</td>
<td>Introduction of mass production facilities at Ehime Plant (CP, GDL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydrocarbon (HC) Electrolyte Membranes</strong></td>
<td></td>
<td>Development for fuel cells</td>
<td></td>
<td>Start of sales planned in 2025</td>
</tr>
<tr>
<td>Began full-scale R&amp;D</td>
<td>Development for water electrolysis</td>
<td></td>
<td>Start of production planned in 2025</td>
<td></td>
</tr>
<tr>
<td><strong>Catalyst Coated Membranes (CCM) &amp; Membrane Electrode Assembly (MEA)</strong></td>
<td>Early 90s- Began development at each former company (Degussa, Umicore, etc.)</td>
<td>Development in Toray Group</td>
<td>Expansion of business</td>
<td></td>
</tr>
<tr>
<td>Acquisition by Toray, establishment of Greenerity</td>
<td>Began mass production</td>
<td>Established 3rd plant</td>
<td></td>
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</tbody>
</table>

**Promoting Development and Commercialization of Unique Advanced Materials from a Long-term Perspective**
Toray Group’s Strengths

Products

- Carbon Fiber
- Carbon Paper/Gas Diffusion Layer
- Hydrocarbon Electrolyte Membrane
- Catalyst Coated Membrane/Membrane Electrode Assembly

Converting Toray’s Unique Technologies and Strengths into Customer Value

- High performance and reliable quality based on proven track record
- Global production and technical support system
- Design of excellent strength, conductivity, gas permeability
- Free of impurities, excellent surface quality
- Design and control of polymer and membrane structure
- Excellent gas barrier and proton conductivity
- Design and control of catalyst layer
- Ultimate pursuit of catalyst loading reduction

Value to the Customer

High-pressure Hydrogen Gas Tanks
- Lightweight
- Reliability
- Higher pressure applicability

Fuel Cell Systems
(Stationary, mobility)
- Improved fuel efficiency
- High power
- Safety
- High durability

Water Electrolyzer Systems
- Energy conservation
- High H₂ production rate
- Precious metal conservation
- High durability

Aim for Sustainable Growth by Creating and Sharing Value from Customers’ Perspective

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Toray Group’s Hydrogen-related Products (1): Film Products

PPS Films for Subgaskets

Polymerization
- World’s largest capacity with plants in Japan and Korea
- Integrated to resins, films and fibers

Biaxial Orientation
- Structural control by orientation and crystallization
- A wide variety of thickness

Converting & Final Use
- Attachment of seal layer and cut out
- Used for water electrolysis and fuel cells

PPS: Polyphenylene sulfide  
CCM: Catalyst Coated Membrane  
MEA: Membrane Electrode Assembly  
BPP: Bipolar plate

Subgasket

PPS Film  
Torelina™

Heat resistance, Electrical Insulation  
Flame retardancy, Low ionic elution  
Chemical stability

Durability Test

PPS Film

Breaking elongation retention rate (%)

0 20 40 60 80 100

Processing time (hours)

0 1000 2000 3000

Current Material

(water 95 °C)

Toray’s Unique Value Chain and Characteristics such as Durability and Low Ionic Elution are Highly Evaluated and Adopted for Water Electrolysis and Fuel Cell Applications
Toray Group’s Hydrogen-related Products (2): Resin and Fiber & Textile Products

**Molded Resin Products (PPS)**

- **PPS Polymer**
- **Resin Compound**
- Molding Process Final Product

**Examples of Use**

- Manifold
- Piping
- Gas-liquid separator
- Stack end plates

- End Plates for fuel cell stack (PPS resin)

**Low Ionic Elution Features Allow for Application in Balance-of-plant Components**

**Diaphragm for Alkaline Electrolyzer**

- **Alkaline Water Electrolyzer**
- **Cell Structure**

- BPP: Bipolar plate

- **Fine Fiber Structure Allows for both Low Resistance and High Gas Barrier**
Toray Group’s Hydrogen-related Products (3): Carbon Recycling-related Products (R&D stage)

**Sources of Hydrogen and Mixed Gases**
- Water: Artificial Photosynthesis
- Biomass: Microorganisms Gasification
- Waste Plastics: Gasification
- Natural Gas: Steam Reformation
- Exhaust Gas: CO₂ Recovery
- Biogas

**Sources of Carbon Dioxide**
- Exhaust Gas
- Biogas

**Raw Material Gases**
- Hydrogen
- Carbon Monoxide
- Carbon Dioxide

**Valuables**
- Ammonia
- Methane
- Methanol
- Synthetic Fuel
- Polymer etc.

**Promoting R&D of Innovative Technologies that Contribute to Carbon Recycling**

- High-Efficient Hydrogen Separation Membrane
  - Utilize Toray’s RO membrane technologies to demonstrate world’s highest level of high-purity hydrogen

- All-Carbon CO₂ Separation Membrane
  - Hollow, porous carbon fiber with proprietary dual all-carbon structure demonstrates excellent heat resistance, separation efficiency, high durability, and miniaturization

- Hydrogen-oxidizing bacterium to create raw materials for polymers
  - Selected for NEDO’s Green Innovation Fund Project (joint project of six organizations)

**Selected for NEDO’s Green Innovation Fund Project (joint project of six organizations)**
Examples of Adoption and Value Demonstration

1. Carbon Fiber and Electrode Materials used for Fuel Cell Vehicles

- Adopted in over 30 million cars (cumulative) including Toyota’s MIRAI, Honda’s CLARITY and other FCEVs

2. CCM, MEA used for Fuel Cells and Water Electrolysis Systems

   Greenerity®

   - Have participated in many demonstration projects mainly in Europe
   - Leading company in fuel cell battery and water electrolysis markets

3. Large-scale Hydrogen Production Demonstrations (Hydrocarbon electrolyte membranes)

(1) Green Innovation (GI) Fund (Sep. 2021)
   • Adopted by the green hydrogen project “Development of a Large-Scale Polymer Electrolyte Membrane (PEM) Water Electrolyzer, and Demonstration of Decarbonization of Heat Demand” under the GI funding program (5 years, up to 14 billion yen, 2/3 funding)

(2) Partnership with Siemens Energy (same as above)
   • The two companies will cooperate to promote industrial scale PEM water electrolyzers equipped with Toray’s hydrocarbon electrolyte membranes

(3) Yamanashi Hydrogen Company (YHC) (Feb. 2022)
   • Establishment of YHC, the first company to specialize solely in Power-to-Gas (P2G) in Japan
   • Started the Yamanashi Model P2G System, utilizing hydrogen as heat source
   • Started feasibility study in India (Apr. 2022) and Scotland (Nov. 2022)
Challenge for Expansion of Hydrogen-related Businesses

Revenue

2022

20 Billion Yen

2025

60 Billion Yen

2030

300 Billion Yen

- Provide Toray Group’s Proprietary Advanced Materials throughout the Hydrogen Supply Chain
- Collaborate with Customers to Demonstrate values, while Aiming for Sustainable Growth

Toray Group’s Advanced Materials Contribute to Bringing about Hydrogen Society

**Production**
- Alkaline Water Electrolyzer
- PEM Water Electrolyzer
- Clean Fuel (Ammonia, Synthetic Methane, etc)

**Use**
- Material Handling
- Passenger Car
  - Bus
  - Truck
  - Train
  - Ship
  - Aviation
- Special Purpose Vehicle
- Stationary Fuel Cell

**Transportation & Storage**
- High Pressure Hydrogen Tank
- Electrochemical Compressor
- Hydrogen Tube Trailer
- Hydrogen Refueling Station

**Engineering**
- Plastic Liner
- Subgasket
- Engineering Plastic & Molded Products
- Powder for 3D Printing & Modelling Service

**Analytical Service**
- Carbon Fiber for Tanks
- Carbon Paper (CP)
- Gas Diffusion Layer (GDL)
- Diaphragms
- Hydrocarbon (HC) Electrolyte Membranes
- Catalyst Coated Membrane (CCM)
- Membrane Electrode Assembly (MEA)
- Hydrogen Separation Membrane
- CO₂ Separation Membranes
- Hydrogen-oxidizing Bacteria
- Equipment Engineering
- Analytical Service

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