

HYDROGEN ENGINE

Impact Valuation Report



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Interactive Guide

The Hydrogen Engine Impact Valuation Report is available as an interactive PDF that includes features such as navigation to related pages and links to related webpages.



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CEO Message

THE ENGINE.

Best Reliability, Availability, and Maintainability

HD Hyundai Infracore Engine, a technology that creates a better life for society and people, is moving toward becoming a Global Top Engine Maker by providing a Total Solution with a Full Line-up of high-quality, high-specification engines that meet increasingly stringent environmental regulations.

HD Hyundai Infracore has been leading the development and production of the first engine technology, both domestically and internationally, since 1975.

In recent years, the engine market has been facing increasingly stringent emission regulations around the world, especially in developed markets in North America and Europe, and HD Hyundai Infracore's Engine Division has been advancing eco-friendly and high-efficiency engine technology and preemptively developing various electrification technologies as a Total Power Solution Provider leading advanced technological innovation in powertrains. In particular, we decided to develop a hydrogen combustion engine from 2021 and proposed a national project to the Industrial Technology Assessment Institute under the Ministry of Trade, Industry and Energy, and have been working on the project 'Development of 300kw-class Zero-CO₂ hydrogen combustion engine system and storage supply system for construction machinery and commercial vehicles' since May 2022.

HD Hyundai Infracore conducted an impact valuation of the hydrogen combustion engine to determine the potential value of the hydrogen combustion engine, which is expected to be a pillar of the future powertrain. The analysis was conducted using EY's 'Long-term Value' methodology, which measures the tangible and intangible value delivered to stakeholders over the long term through the production and use of hydrogen combustion engines.

Based on these efforts, HD Hyundai Infracore will lead innovation in the engine and construction machinery industries and grow into a company that creates not only economic growth but also sustainable value for its stakeholders. We look forward to your continued interest in the changes and innovations that HD Hyundai Infracore will make.

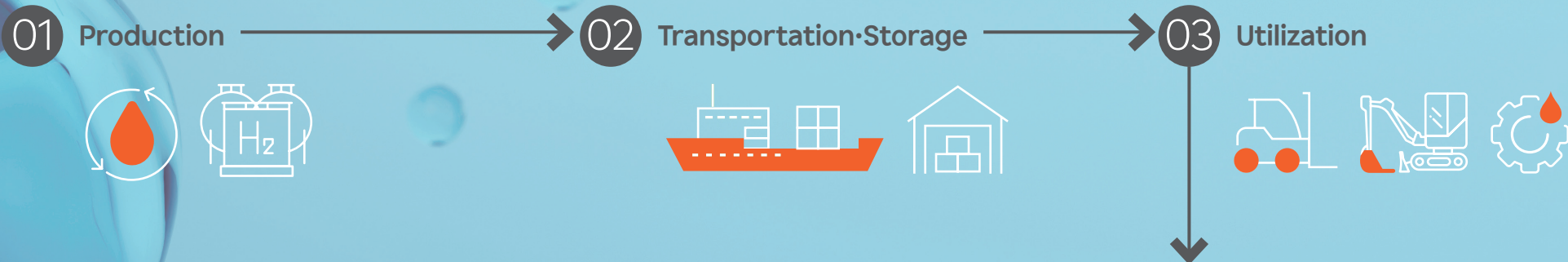
CEO Young Cheul Cho 

CEO Seung Hyun Oh 

Vision for Hydrogen Economy

“In the coming 50 years, we will create new growth momentum different from what we have seen.” - HD Hyundai-

Finding new energy sources to mitigate the speed of climate change has become a common challenge for humanity. Among various new energy sources, hydrogen is gaining global attention as a future clean energy source. HD Hyundai, in March 2021, declared its commitment to leading the hydrogen market by leveraging the capabilities of its group affiliates across the entire hydrogen value chain, from production to transportation/storage and utilization, through the 'Hydrogen Dream 2030 Roadmap'. HD Hyundai Construction Machinery Sector, we will take on the role of utilizing the hydrogen value chain by developing and commercializing fuel cell-based construction machinery such as hydrogen excavators and hydrogen forklifts, as well as hydrogen combustion engines.



HD Hyundai Construction Machinery sector, Hydrogen Products

HD HYUNDAI XITESOLUTION

- Hydrogen forklift



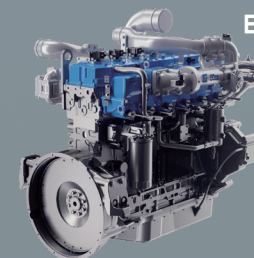
HD HYUNDAI CONSTRUCTION EQUIPMENT

- Hydrogen Excavator



HD HYUNDAI INFRACORE

- Hydrogen Engine



Impact Valuation Overview

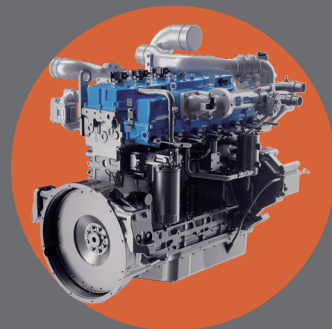
Features of Hydrogen Engine

HD Hyundai Infracore has been leading the development and production of the first engine technology, both domestically and internationally, since 1975. As efforts to solve the climate change crisis accelerate in all industries, there is a need to advance engine technology to reduce emissions and CO₂. Meanwhile, the need for carbon-free and pollution-free power sources has led to the development of battery-based power sources and fuel cell-based power sources. However, they are difficult to apply to large-scale mobility such as trucks and buses due to charging time, battery weight, and high price. HD Hyundai Infracore is developing a hydrogen engine, a future carbon-neutral powertrain technology that emits no CO₂ and little other air pollutants, based on its high level of diesel and CNG engine technology.

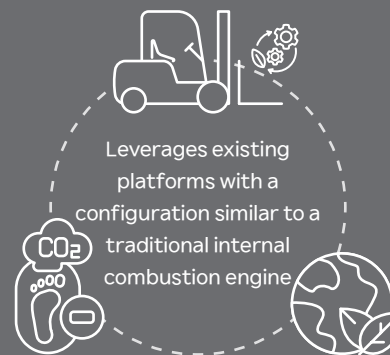
A hydrogen engine is a device that generates mechanical power by burning hydrogen as a fuel, just as a diesel engine uses diesel oil and a CNG engine uses natural gas. Hydrogen as a fuel is characterized by zero carbon dioxide emissions during combustion because it does not contain carbon due to its chemical nature. In addition, hydrogen engines are similar in components to existing internal combustion engines, so existing platforms can be utilized, and retrofitting of aging equipment or vehicles is easy. In terms of price, hydrogen engine vehicles will initially have an increased component cost compared to conventional internal combustion engine vehicles due to the addition of hydrogen storage tanks, but it is expected to be lower than the cost of vehicles equipped with batteries or fuel cells.

Product for Impact Valuation

Hydrogen Engine



Development Background



Key Features

- 01 Hydrogen-fueled engine, which is a zero-emission technology
- 02 Leverages existing platforms with a configuration similar to a traditional internal combustion engine
- 03 Low cost compared to rechargeable batteries and fuel cells

Impact Valuation Process for Hydrogen Engine

01
Understanding
the product to be
measured



Interviews with hydrogen engine development departments and personnel, review of internal data and relevant literature to understand the characteristics of the product to be measured and develop ideas for value measurement.

02
Recognize
product value



Identify the value a product creates, directly or indirectly, for stakeholders throughout its lifecycle. In this process, we establish the product or service that serves as the criterion for assessing the value of each product.

03
Setting a
reference price



Establishing the criteria and rationale for converting an accrual of product value into a monetized price. This process utilizes a variety of prior research and reasonable hypotheses to establish a fair price per unit of value.

04
Calculate the
Long-term Value
of a product



Multiply the accrual of product value by the reference price to get the value per category and stakeholder in the Long-term Value framework. The final Long-term Value of the product is then calculated by assuming the expected lifetime of the product.

Impact Valuation Result

HD Hyundai Infracore conducted an impact valuation to identify the potential value of a hydrogen engine. The value delivered to stakeholders by the hydrogen engine was measured according to the EY Long-term Value Framework methodology, distinguishing it into 1) Customer value, 2) People value, 3) Societal value, and 4) Financial value. This assessment assumed that the hydrogen engine would be utilized for 10 years¹⁾ after being sold. Customer value, People value, and societal value were measured in comparison to a reference point, which was a similar product, a diesel engine. The LTV per hydrogen engine was found to be approximately KRW 396 million. This can be estimated as the value provided to stakeholders by one hydrogen engine sold and operated by HD Hyundai Infracore over a period of 10 years.

1) Based on average uptime of construction machinery (1,702 hours/year), cargo vehicles (47,085 km/year), and motorcoaches (64,605 km/year).

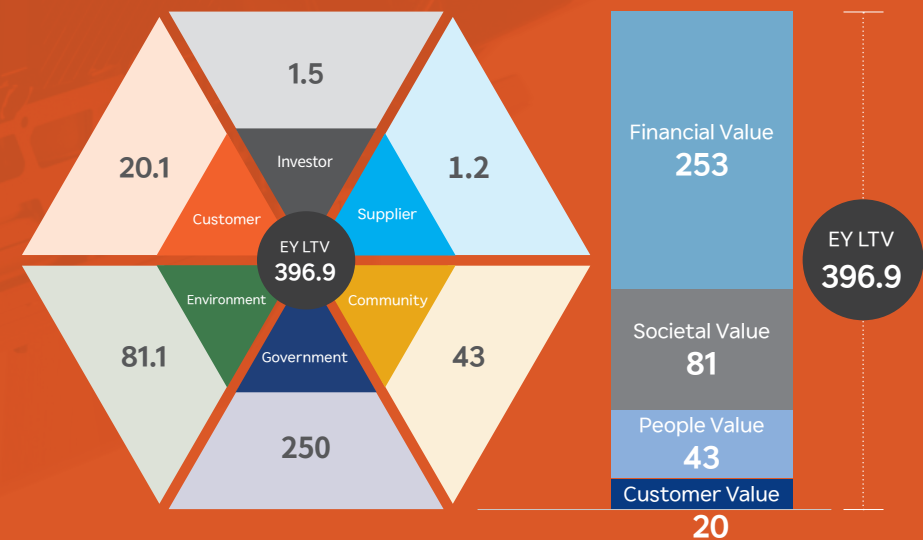
Valuation Result

(Unit: KRW in millions)

Categories	Value Recognition	Customer	Community	Government	Environment	Investor	Supplier	Total
Customer value	Fuel cost savings	10.8	-	-	-	-	-	10.8
	Construction company Scope3 emissions reduction	9.3	-	-	-	-	-	9.3
People value	Health benefits from Reduction in fine dust emissions	-	43.0	-	-	-	-	43.0
Societal value	GHG emission reduction	-	-	-	32.4	-	-	32.4
	Air pollutant emission reduction	-	-	-	48.8	-	-	48.8
Financial value	Government subsidy savings	-	-	250.0	-	-	-	250.0
	Increasing supplier profits	-	-	-	-	-	1.2	1.2
	Increasing company profits	-	-	-	-	1.5	-	1.5
Total		20.1	43.0	250.0	81.1	1.5	1.2	396.9

(Unit: KRW in millions)

Each hydrogen engine delivers approximately **396 million KRW** in Long-term Value to stakeholders



This measurement was conducted based on data managed by the company, utilizing national statistics, research findings, and other relevant sources. The monetary values used in the measurement may be subject to change based on new research results, and the completeness of the measurement results cannot be verified, so it cannot be considered as part of financial disclosure.

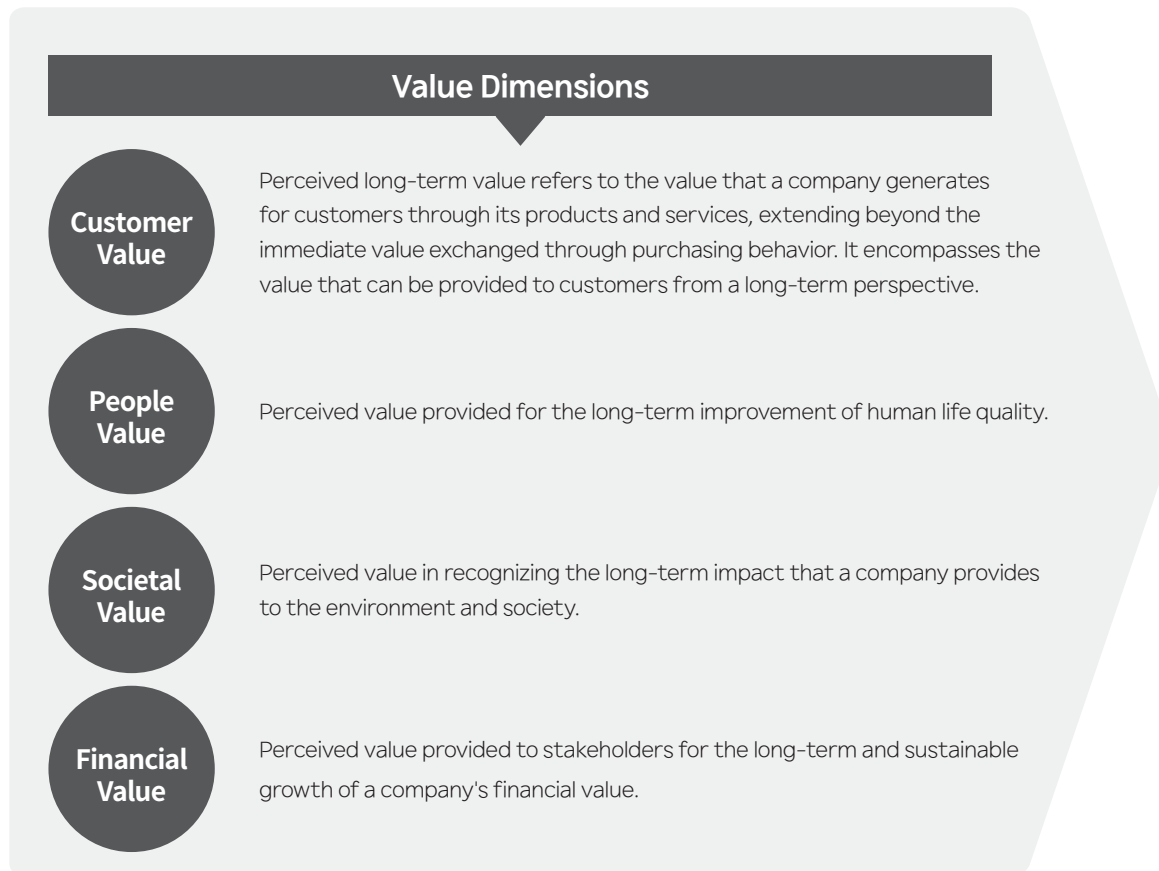
Impact Valuation Calculations and Rationale

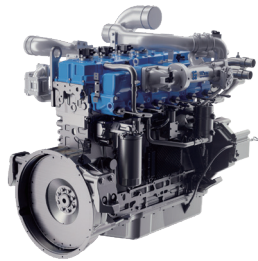


Value Recognition	Measurement Methods	Monetization base price	Monetization reference price sources
Fuel cost savings	Estimated fuel economy of hydrogen-powered products (9.26 km/kg) compared to diesel engine fuel economy (4 km/L) for heavy-duty trucks.	<ul style="list-style-type: none"> Diesel price: KRW 1,783/L Hydrogen price: KRW 4,000/kg 	<ul style="list-style-type: none"> Diesel prices: December 2022 average Hydrogen price: 2030 projected price from the Ministry of Trade, Industry and Energy's Hydrogen Economy Revitalization Roadmap
Construction company Scope3 emissions reduction	Average CO ₂ eq emissions of diesel-powered products x carbon credit trading price	<ul style="list-style-type: none"> Carbon credit trading price: KRW 13,100/ton 	<ul style="list-style-type: none"> KAU22, as of Mar/09/23
Health benefits from Reduction in fine dust emissions	Average PM2.5 emissions from diesel-powered products x Health benefits of reducing PM2.5 emissions	<ul style="list-style-type: none"> Health benefits of reducing PM2.5 emissions: KRW 0.214 billion/ton 	<ul style="list-style-type: none"> Particulate Matter(PM2.5) Emissions on Respiratory Disease, Last updated, Youngsoo Lee, 2015
GHG emission reduction	Average CO ₂ eq emissions of diesel-powered products x Social Cost of Carbon	<ul style="list-style-type: none"> Social Cost of Carbon : 51USD/ton 	<ul style="list-style-type: none"> Social Cost of Carbon, EPA, USA
Air pollutant emission reduction	Average air pollutant emissions for products with diesel engines x Eco-cost per air pollutant	<ul style="list-style-type: none"> CO Eco-cost : 0.24396Euro/kg NOx Eco-cost : 6.3638Euro/kg PM10 Eco-cost : 7.98Euro/kg PM2.5 Eco-cost : 35Euro/kg 	<ul style="list-style-type: none"> Eco-costs emissions 2022 V1.1, TU Delft (2022)
Government subsidy savings	Estimated subsidy difference for hydrogen-powered products compared to government and municipal subsidies for similar products (hydrogen electric trucks)	<ul style="list-style-type: none"> Subsidies for hydrogen electric trucks: KRW 450 million 	<ul style="list-style-type: none"> KRW 250 million in national subsidies and KRW 200 million in local subsidies
Increasing supplier profits	Engine Raw Material Price x Sales Operating Margin	<ul style="list-style-type: none"> Operating margin on sales: 7.4% 	<ul style="list-style-type: none"> Standards for Special Purpose Machines, Industrial Research Institute (2021)
Increasing company profits	Engine revenue x revenue operating margin	<ul style="list-style-type: none"> Operating margin on sales: 7.4% 	<ul style="list-style-type: none"> Standards for Special Purpose Machines, Industrial Research Institute (2021)

Long-term Value Method

The value of a company, product, or service is not just the value described in its financial statements. Value comes in many different forms and perspectives, and both tangible and intangible values need to be measured and managed in line with a company's strategic priorities. EY Long-term Value recognizes the limitations of current market approaches to value measurement and aims to explain the long-term value of companies, products and services through the measurement of intangible and non-financial values. The EY Long-term Value methodology can be applied to the measurement of value creation across a company's operations and to the measurement of specific products and services. The Long-term Value measurements in this report are for a specific product (hydrogen engine), and the results are illustrative of the product being measured and do not affect the calculation of corporate value or the value of other products and services.





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