Gauging Opportunities from the Hydrogen Economy

Contributor

Jason Ye, CFA
Director
Strategy Indices
jason.ye@spglobal.com

EXECUTIVE SUMMARY

The Fourth Industrial Revolution will be driven by renewable energy,[1] and in the context of energy transition, hydrogen could play a vital role. According to the International Energy Agency (IEA), to achieve net zero emissions by 2050, an investment of USD 1.2 trillion in low-carbon hydrogen supply and use would be required.[2] The hydrogen council projected a USD 2.5 trillion global hydrogen market by 2050.[3] The U.S. Department of Energy projected an estimated USD 750 billion annual revenue and a cumulative 3.4 million jobs created by 2050 under the hydrogen economy.[4] Leveraging advanced machine learning and natural language processing technology, S&P Dow Jones Indices launched the S&P Kensho Hydrogen Economy Index, which is designed to track companies involved in the hydrogen economy, including companies focused on the production, transportation, and storage of hydrogen. In this paper, we will introduce the hydrogen economy, and how we measure the opportunity from it through an indexing approach.

INTRODUCTION

Hydrogen is the simplest and smallest element in the periodic table. It is also the most abundant chemical substance in the universe, constituting roughly 75% of all normal matter.[5] On Earth, hydrogen is mostly found in molecular forms such as water and organic compounds. Like electricity, hydrogen is also secondary energy. Hydrogen can be produced from water; when molecular hydrogen and oxygen are combined and react, the process generates energy, and either water or hydrogen peroxide is produced. The heating value of the process is 141.80 MJ/kg, which is 3 times the heat value of diesel (44.80 MJ/kg), and 4.3 times the heat value

[1] Mathuros, Fon, "The Fourth Industrial Revolution Will Be Driven by Renewable Energy," World Economic Forum, January 2016. https://www.weforum.org/press/2016/01/the-fourth-industrial-revolution-will-be-driven-by-renewable-energy/

[2] IEA (2021), *Global Hydrogen Review 2021*, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2021.

[3] Hydrogen Council. November 2017. "Hydrogen Scaling Up. A Sustainable Pathway for the Global Energy Transition." https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf.

[4] UShydrogenstudy.org. 2019. "Roadmap to a US Hydrogen Economy." www.ushydrogenstudy.org.

[5] Bhagwat, Swetha Ravikumar and Maria Olczak (October 2020). "Green Hydrogen Bridging the Energy Transition in Africa and Europe." Africa-EU Energy Partnership. https://cadmus.eui.eu/bitstream/handle/1814/68677/QM-02-20-822-EN-N.pdf

Hydrogen is a clean, efficient, and sustainable energy source that will likely play an essential role in the decarbonization movement of the next few decades.

of coal (32.50 MJ/kg).[6] Unlike burning diesel or coal, the combustion process of hydrogen generates zero carbon emissions. If we can reduce or eliminate the carbon emission in the hydrogen production process, it could be a clean, efficient, and sustainable energy source that would likely play an essential role in the decarbonization movement of the next few decades.

Professor John Bockris came up with the term “hydrogen economy” in his speech at the General Motors Technical Center in 1970.[7] However, the process of establishing a hydrogen economy has historically been slow and challenging, primarily due to the large scale of infrastructural investment required and high hydrogen production costs. As of 2020, the global demand for hydrogen was about 70 million tons (see Exhibit 1). Almost all this demand was for refining and industrial use, such as decreasing sulfur content in diesel fuel and production of ammonia and methane. In the future, hydrogen can replace natural gas to provide heat for buildings, and be used for oil refinement, cement production, and steelmaking in the industrial sector. It can serve as an alternative to fossil fuel for vehicles such as buses, trains, ships, and even airplanes. In addition, hydrogen can be used as a storage of low-cost, excess renewable electricity, which could support the integration of renewable electricity systems. Under the net zero by 2050 scenario, global hydrogen demand could almost triple by 2030, reaching over 200 million tons (see Exhibit 1).

Under the net zero scenario, the growth of hydrogen demand would be supplied by the production of blue hydrogen and green hydrogen.

On the production side, currently, hydrogen is produced mainly from fossil fuels (gray hydrogen), resulting in close to 900 million tons of CO_2 emissions per year.[8] Under the net zero scenario, the growth of hydrogen demand would be supplied by the production of blue hydrogen and green hydrogen (see Exhibit 1).

[6] Linstrom, Peter (2021). NIST Chemistry WebBook. NIST Standard Reference Database Number 69. NIST Office of Data and Informatics. doi:10.18434/T4D303.

[7] Dr. John O’M. Bockris 1923 - 2013. *Infinite Energy Magazine*, Issue 111, September/October 2013, pp. 26-30. http://www.infinite-energy.com/images/pdfs/BockrisObit.pdf.

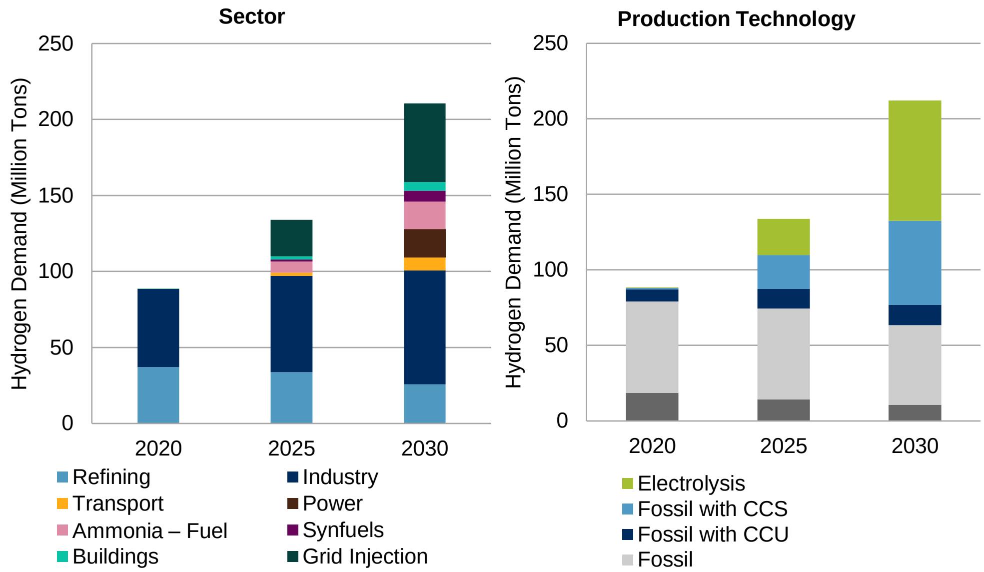
[8] International Energy Agency (IEA) (2021), *Hydrogen*, IEA, Paris. https://www.iea.org/reports/hydrogen.

Gray hydrogen is sometimes referred to as the "dirty" method of producing hydrogen.

Blue hydrogen follows the same production process as gray hydrogen, but it adds technology called carbon capture and storage.

Green hydrogen is considered the clean way of producing hydrogen and is the only 100% renewable hydrogen production method.

Exhibit 1: Projected Global Hydrogen Demand in the Net Zero Scenario



Source: IEA (2021), Hydrogen, https://www.iea.org/reports/hydrogen. Data as of Oct. 26, 2021. CCU refers to carbon capture utilization and CCS refers to carbon capture storage. Chart is provided for illustrative purposes.

HYDROGEN PRODUCTION

What do these different colors of hydrogen mean? Hydrogen is an invisible gas with no color; the hydrogen color spectrum reflects different pathways to produce hydrogen. The most common colors are gray, blue, and green. Different production methods result in different levels of greenhouse gas (GHG) emissions.

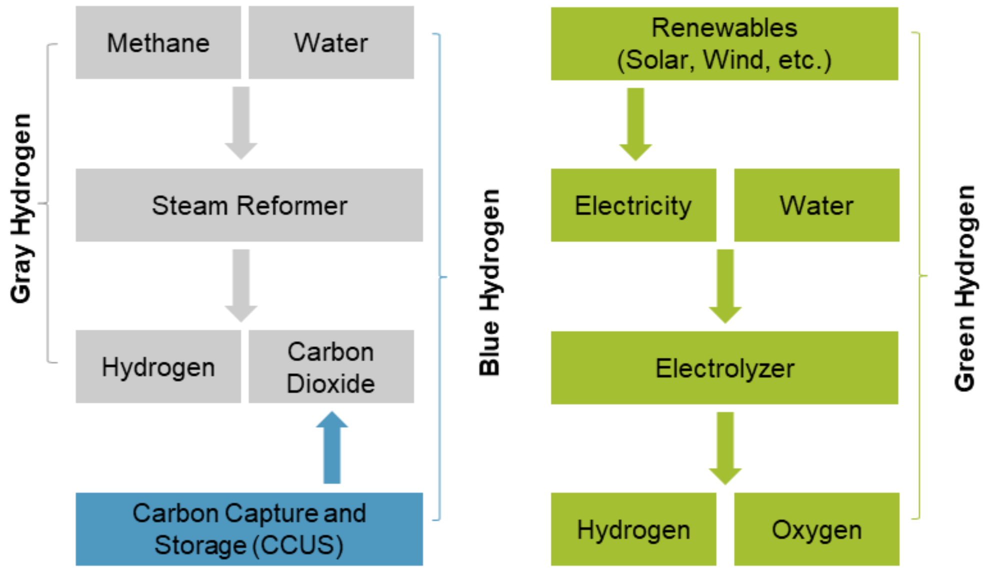
Gray hydrogen is generally produced through natural gas reforming, or steam methane reforming (SMR). It splits the methane (CH_4) and water (H_2O) steam into carbon dioxide (CO_2) and hydrogen (H_2). This is the most used technology in hydrogen production today and is widely adopted at an industrial scale. However, gray hydrogen production generates CO_2, which affects the environment. Gray hydrogen is sometimes referred to as the "dirty" method of producing hydrogen.

Blue hydrogen follows the same production process as gray hydrogen, but it adds a technology called carbon capture utilization and storage (CCUS) to capture the carbon dioxide produced and store or utilize it in other ways. Since a large part of the carbon dioxide is captured, the environmental impact can be reduced.

Green hydrogen is produced by splitting water (H_2O) into hydrogen (H_2) and oxygen (O_2) through electrolysis. Since the production process does not generate any carbon dioxide, it is considered the "clean" way of producing hydrogen and is the only 100% renewable hydrogen production method. Exhibit 2 shows the three main ways of producing hydrogen.

In the short term, blue hydrogen can be used to replace gray hydrogen as an intermediate, low-emission solution.

Exhibit 2: Hydrogen Production Methods

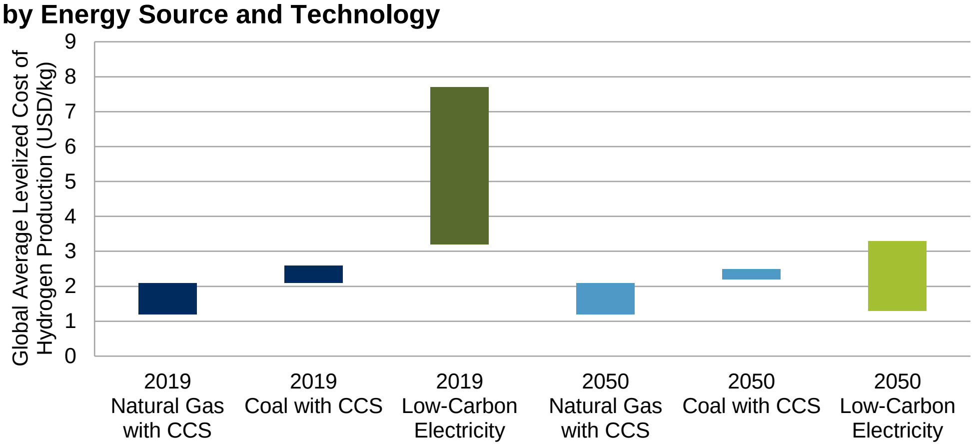


Source: S&P Dow Jones Indices LLC. Chart is provided for illustrative purposes.

There are other hydrogen colors. For example, black and brown hydrogen refer to producing hydrogen from fossil fuels through gasification, but these are the most environmentally damaging approaches. Turquoise hydrogen is produced through methane pyrolysis, which could be low-emission hydrogen if the thermal process is powered by renewable energy and the carbon produced is stored.

In the long term, the cost of green hydrogen could decrease dramatically, which could lead to a wide adoption of green hydrogen in the next few decades

Exhibit 3: Potential Global Average Levelized Cost of Hydrogen Production by Energy Source and Technology

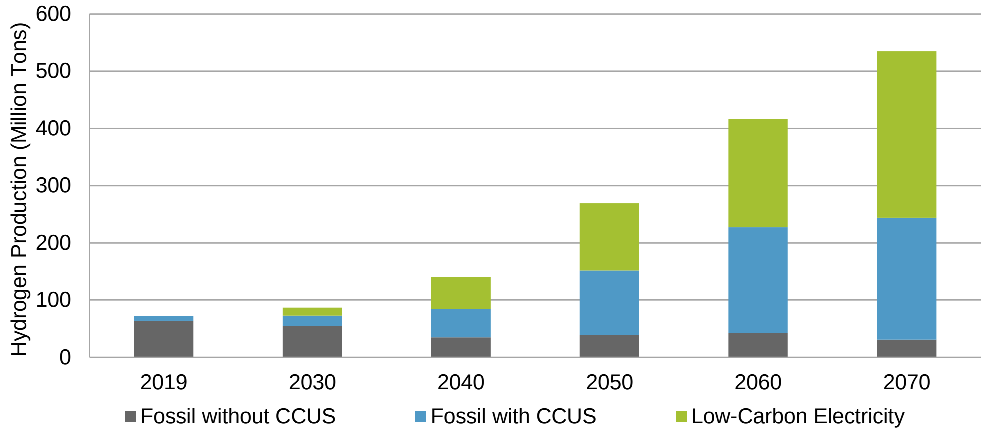


Source: IEA (2020), CCUS in Clean Energy Transitions, https://iea.blob.core.windows.net/assets/181b48b4-323f-454d-96fb-0bb1889d96a9/CCUS_in_clean_energy_transitions.pdf. All rights reserved. Data as of September 2020. Chart is provided for illustrative purposes.

Exhibit 3 shows the cost of producing hydrogen using different approaches. In 2019, producing green hydrogen was significantly more expensive than producing gray or blue hydrogen. In the short term, blue hydrogen can be used to replace gray hydrogen as an intermediate, low-emission solution. In the long term, with the growing supply of renewable electricity such as solar and wind, along with the electrolyzer's cost decrease with the economies of scale, the cost of green hydrogen could decrease dramatically, which could lead to a wide adoption of green hydrogen in the next few decades (see Exhibit 4).

Gaseous state storage is currently the most common approach due to its reasonable cost.

Exhibit 4: Projected Global Hydrogen Production in the Sustainable Development Scenario



Source: IEA (2020), CCUS in Clean Energy Transitions, https://iea.blob.core.windows.net/assets/181b48b4-323f-454d-96fb-0bb1889d96a9/CCUS_in_clean_energy_transitions.pdf. All rights reserved. Data as of September 2020. Chart is provided for illustrative purposes.

Different transportation forms require different technologies and channels.

Storage and Transportation

While combustion is the traditional way of converting hydrogen into power, fuel cells are a new, more efficient method.

Hydrogen is commonly stored in a gaseous or liquid state. Gaseous state storage is currently the most common approach due to its reasonable cost. In a gaseous state with small volumes, hydrogen is usually stored in pressurized tanks that are either all metal or composite overwrapped pressure vessels. Salt caverns, depleted gas fields, or oil reservoirs are typically used for large-volume, long-term gaseous state hydrogen storage. In a liquid state, hydrogen is stored at low-temperature, highly insulated tanks. But those tanks can only be used for small-to-medium volumes. For large volumes in a liquid state, hydrogen can be stored in material compounds such as ammonia and methanol. However, once hydrogen is under common compound state, thermal or catalytic chemical reactions are needed to release the hydrogen, which could lead to energy loss.

Hydrogen can also be transported in a gaseous or liquid state, or via chemical carriers such as ammonia. Different transportation forms require different technologies and channels. Tube trailers can be used for either gaseous or liquid state hydrogen; the technology is relatively mature, but it can only carry a small amount and is usually requested on demand. Large volumes of hydrogen can be transported through either pipelines or liquid tanks. A hydrogen pipeline is an efficient approach to carrying hydrogen across regions, but it requires intensive capital investment. Liquid tanks can store a large amount of liquid hydrogen and be put on marine vessels or railways for long-distance shipping. However, it is not easy to convert hydrogen from a gaseous to a liquid state, and the tank materials also require bearing ultra-low temperature and high pressure.

Fuel Cells

The S&P Kensho Hydrogen Economy Index is designed to track potential opportunities from the hydrogen economy.

To use hydrogen in various applications, it must be converted into heat or electricity. While combustion is the traditional way of converting hydrogen into power, fuel cells are a new, more efficient method.

Like traditional batteries, fuel cells have positive and negative electrodes separated by an electrolyte. Hydrogen, together with oxygen, can be converted into water through fuel cells without generating any GHGs. Compared to internal combustion engines, fuel cells are more efficient and quieter. However, wide adoption of fuel cells is impeded by high costs and low durability.

S&P KENSHO HYDROGEN ECONOMY INDEX

The S&P Kensho Hydrogen Economy Index is designed to track companies involved in the hydrogen economy, it covers the full spectrum of the hydrogen economy value chain above, including:

1. All methods of hydrogen production;
2. Services and technology that enable the liquefaction of hydrogen and movement of liquefied hydrogen from point of production to end consumer;
3. Hydrogen storage technologies; and
4. The manufacturing and distribution of fuel cells.

The back-tested index data shows an outperformance to its benchmark and the S&P 500 but with higher volatility.

As of Jan. 31, 2022, approximately 70% of index constituents by weight have business exposure to hydrogen production, 30% have business exposure to hydrogen storage, 30% have business exposure to hydrogen distribution, and 45% have business exposure to fuel cells. The sum adds up to greater than 100% because companies can have business exposure to multiple value chains across the hydrogen economy.

Back Tested Performance

Since May 31, 2017, the S&P Kensho Hydrogen Economy Index outperformed the S&P Kensho New Economies Composite Index and the S&P 500® by 3.10% and 3.12% per year, respectively.[9] However, this outperformance came with higher volatility, given that the S&P Kensho New Economies Composite Index and the S&P 500 are more diversified indices with higher numbers of constituents, while the S&P Kensho Hydrogen Economy Index has only 19 constituents as of January 2022. The index is heavily tilted toward small- and micro-cap companies (see Exhibit 5).

[9] Based on hypothetical historical performance. The S&P Kensho Hydrogen Economy Index was launched June 1, 2021. All data for the period prior to that data is back-tested hypothetical data. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Exhibit 5: Back-Tested Risk/Return Profiles

PERIOD	S&P KENSHO HYDROGEN ECONOMY INDEX	S&P KENSHO NEW ECONOMIES COMPOSITE INDEX	S&P 500
BACK-TESTED ANNUALIZED RETURN (%)			
1-Year	-32.62	-18.51	23.29
3-Year	29.93	21.60	20.71
Since May 15, 2017	18.38	16.49	16.43
BACK-TESTED ANNUALIZED VOLATILITY (%)			
1-Year	38.24	28.41	13.36
3-Year	32.45	32.45	22.46
Since May 15, 2017	36.26	25.45	19.88
BACK-TESTED RISK-ADJUSTED RETURN			
1-Year	-0.85	-0.65	1.74
3-Year	0.92	0.67	0.92
Since May 15, 2017	0.51	0.65	0.83
BACK-TESTED MAXIMUM DRAWDOWN (%)			
Since May 15, 2017	-46.71	-37.69	-33.79

Source: S&P Dow Jones Indices LLC. Data from May 2017 to January 2022. The S&P Kensho Hydrogen Index was launched on June 1, 2021. The S&P Kensho New Economies Composite Index was launched on Feb. 6, 2017. All data prior to index launch date is back-tested hypothetical data. Index performance based on total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Hydrogen is likely to be a critical clean energy source for the global net zero initiative in the next several decades.

CONCLUSION

Although the concept of the hydrogen economy was first proposed over 50 years ago, the technology and innovation behind enabling wide adoption of hydrogen applications have only recently taken off. Hydrogen is likely to be a critical clean energy source for the global net zero initiative in the next several decades. The S&P Kensho Hydrogen Economy Index is designed to measure companies involved in this area. The index outperformed the S&P 500 historically.

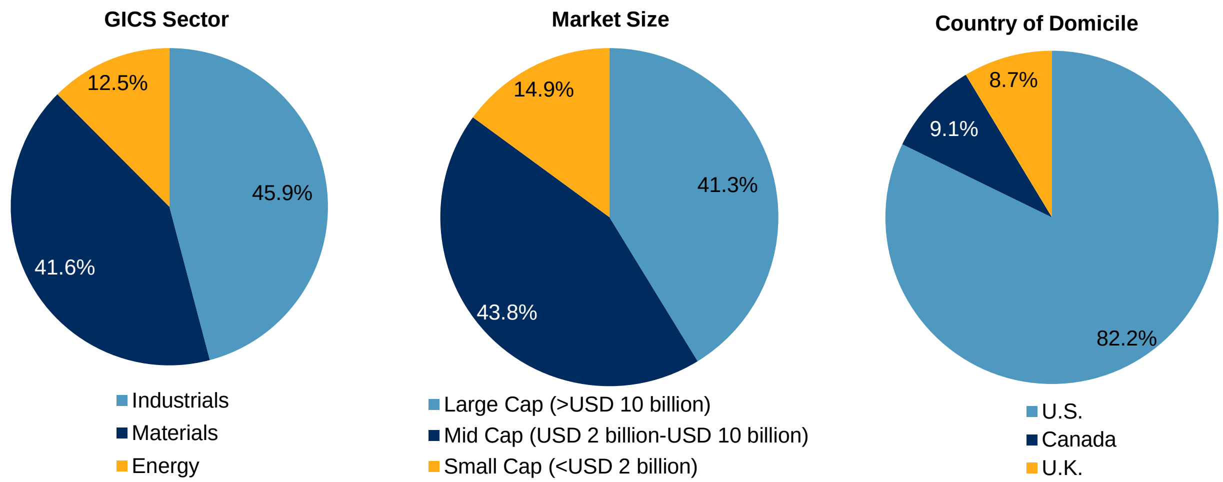
APPENDIX

Exhibit 6: Index Constituents

COMPANY	TICKER	COUNTRY OF DOMICILE
Shell plc ADR	RDS/A	U.K.
Linde plc	LIN	U.S.
Air Products & Chemicals Inc	APD	U.S.
Cummins Inc	CMI	U.S.
Westlake Chemical Corp	WLK	U.S.
Plug Power Inc	PLUG	U.S.
Olin Corp	OLN	U.S.
The Chemours Company	CC	U.S.
Chart Industries	GTLS	U.S.
Nikola Corporation	NKLA	U.S.
Ballard Power Systems Inc	BLDP	Canada
TechnipFMC plc	FTI	U.S.
Worthington Industries Inc	WOR	U.S.
Bloom Energy Corp	BE	U.S.
Fuelcell Energy Inc	FCEL	U.S.
Hyster-Yale Materials Handling Inc. A	HY	U.S.
Luxfer Holdings PLC	LXFR	U.K.
Westport Fuel Systems Inc	WPRT	Canada
Advent Technologies Holdings, Inc	ADN	U.S.

Source: S&P Dow Jones Indices LLC. Data as of Jan. 31, 2022. Table is provided for illustrative purposes.

Exhibit 7: Index Breakdowns



Source: S&P Dow Jones Indices LLC. Data as of Jan. 31, 2022. Chart is provided for illustrative purposes.

PERFORMANCE DISCLOSURE/BACK-TESTED DATA

The S&P Kensho Hydrogen Economy Index was launched June 1, 2021. The S&P Kensho New Economies Composite Index was launched on February 6, 2017. All information presented prior to an index's Launch Date is hypothetical (back-tested), not actual performance. The back-test calculations are based on the same methodology that was in effect on the index Launch Date. However, when creating back-tested history for periods of market anomalies or other periods that do not reflect the general current market environment, index methodology rules may be relaxed to capture a large enough universe of securities to simulate the target market the index is designed to measure or strategy the index is designed to capture. For example, market capitalization and liquidity thresholds may be reduced. Complete index methodology details are available at www.spglobal.com/spdji. Past performance of the Index is not an indication of future results. Back-tested performance reflects application of an index methodology and selection of index constituents with the benefit of hindsight and knowledge of factors that may have positively affected its performance, cannot account for all financial risk that may affect results and may be considered to reflect survivor/look ahead bias. Actual returns may differ significantly from, and be lower than, back-tested returns. Past performance is not an indication or guarantee of future results. Please refer to the methodology for the Index for more details about the index, including the manner in which it is rebalanced, the timing of such rebalancing, criteria for additions and deletions, as well as all index calculations. Back-tested performance is for use with institutions only; not for use with retail investors.

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