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Incorporating Environmental Considerations into Commodity Indices

Contributors

Fiona Boal
Managing Director, Head of Commodities and Real Assets
S&P Dow Jones Indices
fiona.boal@spglobal.com

Stephane Audran
Managing Director – Co-Head, Global Strategic Indices
J.P. Morgan
stephane.r.audran@jpmorgan.com

Steven Bullock
Managing Director, Global Head of Research and Methodology
S&P Global Sustainable1
steven.bullock@spglobal.com

Kimberly Gallant
Executive Director – Co-Head, Investable Index Solutions, Americas Lead,
Global Markets Sustainability Center
J.P. Morgan
kimberly.n.gallant@jpmorgan.com

Adam Denny
Senior Analyst,
Global Research & Design
S&P Dow Jones Indices
adam.denny@spglobal.com

Gwen Yu
Executive Director – Global Markets Sustainability Center
J.P. Morgan
gwendolyn.yu@jpmorgan.com

Executive Summary

The focus of the paper is on the environmental footprint of commodities and the incorporation of environmental metrics into transparent, rules-based commodity indices.

In the first section, we identify and discuss the various challenges associated with investing in commodities from a sustainability standpoint. The focus is on environmental impacts, and while we do not specifically address social and governance considerations, we acknowledge that they are important and a key area of future research.

We then present a new dataset that measures the environmental footprint of the S&P GSCI constituents. The dataset provides robust and comprehensive physical and financial impact data on GHG emissions, water consumption and land use at the commodity level, based on life cycle impact assessment factors and natural capital valuation metrics. We then introduce the concept of commodity valuation intensity, which ascribes an economic value to environmental impacts on a per unit of commodity production or per dollar invested (or dollar per contract value). This allows for comparison across commodities and types of environmental impacts.

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We begin the process of building our index frameworks by redefining new commodity "sectors" to reflect the changing dynamics of the global economy. We divide the components into three economic sectors: energy systems, food supply and other, based on their impact on the environmental transition and potential substitutions within each category.

The paper describes two index framework approaches to adjusting the S&P GSCI to incorporate environmental data. The first is the Optimization Approach, which seeks to reduce the environmental footprint of the index while minimizing weight and sector deviations from the S&P GSCI. The optimized constituent weights are constrained to help maintain diversification, investability and liquidity for the index. There is also an embedded transition mechanism that seeks to decarbonize the index year-on-year. The second approach (Substitution Approach) incorporates both negative and positive environmental externalities. Specifically, we introduce the concept of the environmental displacement ratio to measure the overall impact of those commodities that have a net positive role to play in the transition. This approach also incorporates a glidepath to changing allocations over time and considers an allocation to carbon emission allowances.

We conclude that it is possible to build commodities indices that incorporate environmental footprint data while maintaining the similar inflation sensitivity and diversification benefits as the benchmark. In the final section of the paper, we consider the need for additional research and discussion on the topic.

S&P DJI and J.P. Morgan contributed equally to this paper.

Introduction

Commodities are the building blocks of the economy. They are essential for the provision of shelter, sustenance, warmth and light. They are real, investable assets, and they can be highly relevant to multi-asset portfolios in relation to diversification and inflation protection.

Since the beginning of 2020, commodities markets have been trading through a period of heightened volatility, grappling with multiple sources of uncertainty, including the conflict in Ukraine, the return of high inflation, tightening monetary policy, U.S. dollar strength and the economic repercussions from COVID-19, as well as a series of supply shocks across individual commodity markets.

This volatility is based on a plethora of geopolitical issues in the short term, but longer term there are additional constraints that affect supply and demand imposed by the energy transition and the incorporation of sustainability considerations. These market dynamics present both opportunities and challenges to those involved in the broad commodity investment ecosystem.

Sustainability considerations have become a major focus for many institutional investors. Some asset classes such as equities and fixed income have led the way, as granular information is already available to incorporate them in to a portfolio composition. Commodities, which play a key role in current environmental impacts and in the transition to come, have paradoxically lagged this evolution.

In this context, market participants have expressed their desire for a framework to begin to incorporate sustainability considerations into their commodity portfolios. To date, the investing community has not grappled with this issue in regard to commodities, as much as it has with other asset classes.

The commodities market currently lacks some of the tools necessary to address this demand completely. This paper seeks to outline potential solutions for incorporating environmental considerations in commodity indices and identifying some of the remaining gaps. In doing so, we hope to not only provide market participants with considerations for their own analysis, but also help the industry identify those tools needed for further progress.

The Role of Commodities in a Diversified Portfolio

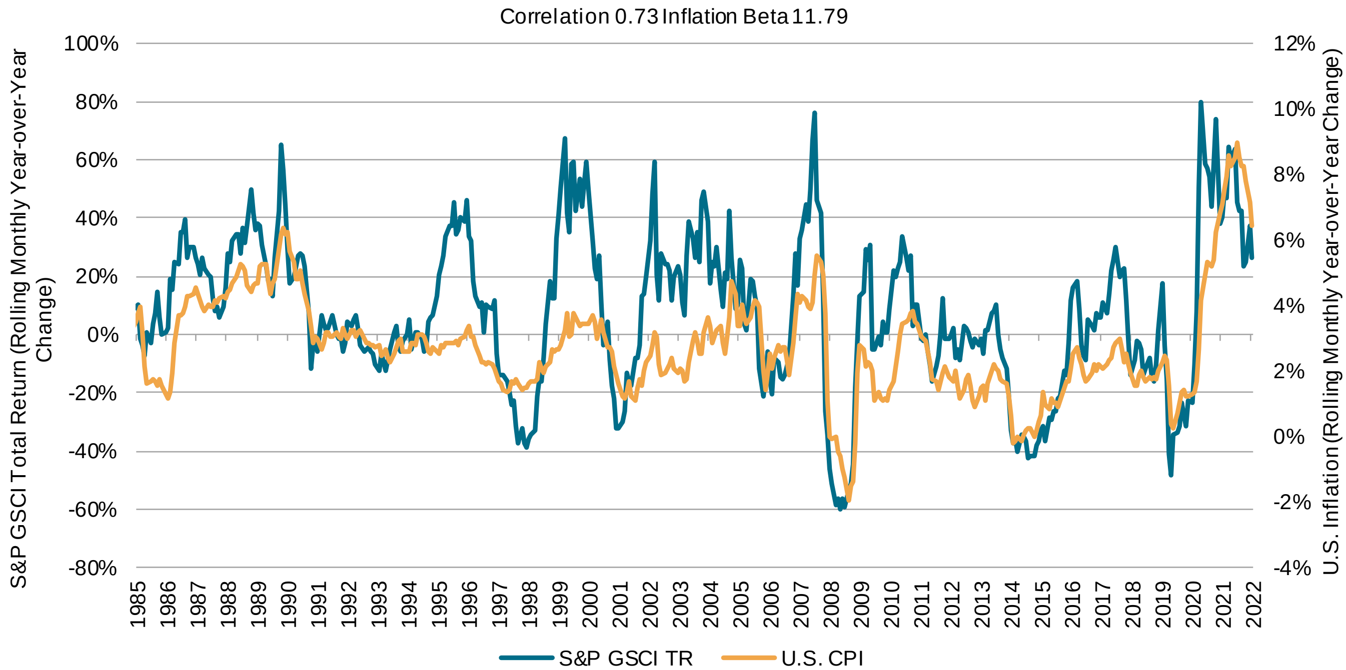
Market participant interest and demand for commodities as an asset class have been spurred by diversification needs and inflation protection. Both roles were brought back to the forefront in the 2021-2022 period, when a focus on the climate transition began to accelerate. Market participants' motivations for incorporating environmental considerations vary. Many are looking to understand the financial risks and opportunities associated with holding an asset or are looking to incorporate changing demand dynamics into their portfolio design. Some may build on their desire to measure and mitigate their environmental footprint, leading to the creation of defined sustainability commitments across their investment strategies, while maintaining desired portfolio diversification.

Commodities as a Hedge Against Inflation

Commodities have historically proven to be a hedge against inflation. They are often touted as being particularly effective when it comes to unexpected inflation, because it is often a commodity supply shock that causes unexpected inflation.

To better understand the relationship between returns and inflation, we need to analyze the "inflation beta" of an asset class. Inflation beta measures the sensitivity of asset returns to changes in inflation. For example, an inflation beta of 5 indicates that the asset return would go up by 5% for every 1% rise in inflation. Inflation beta helps quantify the inflation hedging ability of a given asset class, since it captures both the direction and magnitude of the change in return against the change in inflation. Inflation beta can be an important determinant of inflation protection: for example, a relatively high inflation beta means that even a small allocation to such assets may offer inflation protection for the whole portfolio. We compare the historical monthly year-over-year percentage changes in inflation against the S&P GSCI and calculate an inflation beta measure for commodities (see Exhibit 1).

Exhibit 1: S&P GSCI Inflation Protection



Source: S&P Dow Jones Indices LLC, Federal Reserve Bank of St. Louis. Data from December 1985 to December 2022. The S&P GSCI Index was launched April 11, 1991. All data prior to index launch date is back-tested hypothetical data. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Inflation is defined as the year-over-year percentage change in the monthly U.S. CPI. S&P GSCI returns are monthly rolling year-over-year total returns. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with ba ck-tested performance.

Commodities as a Diversifying Asset in a Multi-Asset Portfolio

Diversification is one of the fundamental tools used by investors to improve risk adjusted returns. For multi-asset investors, commodities have historically offered much needed diversification in particular parts of the economic cycle, namely inflationary periods where both equity and bond returns may be structurally challenged (see Exhibit 2).

Exhibit 2: Correlation of Monthly Asset Returns

Asset	S&P GSCI	Gold	S&P 500	Real Assets	Bonds
S&P GSCI	1.00				
Gold	0.07	1.00			
S&P 500	0.42	0.05	1.00		
Real Assets	0.58	0.24	0.80	1.00	
Bonds	-0.17	0.37	0.27	0.42	1.00

Source: S&P Dow Jones Indices LLC. Data from June 2012 to October 2022. Index performance based on total return in USD, with the exception of bonds. Gold is represented by the S&P GSCI Gold. Real assets are represented by the S&P Real Assets Index. Bonds are represented by the S&P U.S. Aggregate Bond Index. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Sustainability Considerations in Commodities

Investors are also increasingly considering sustainability as a key criterion when designing portfolios. This is true across asset classes, but commodities present a specific challenge in that respect: the production of commodities generates negative environmental externalities, such as air and water pollution. However, society's reliance on commodities is irrefutable and, in many cases, projected to increase. The transition to a low-carbon economy, for example, is projected to require 4 times as many critical minerals by 2040 for clean energy technologies as it does today.[1] Incorporation of sustainability principles into a commodity index is a conundrum not easy to solve. We present a number of environmentally aware commodity benchmark solutions in this paper, that we hope will encourage debate on the subject and represent the first step toward including environmental metrics in the commodity investment landscape.

In this paper we will do the following.

1. Identify some, though certainly not all, of the challenges related to sustainably investing in commodities.
2. Present a unique dataset measuring the environmental footprint of physical commodities defined as greenhouse gas (GHG), water consumption and land use intensities.[2]
3. Explore various approaches to adjusting the S&P GSCI to incorporate environmental footprint data.
    a. The first method (Optimization Approach) borrows the application of ESG metrics to index construction from other asset classes. We target an initial fixed reduction in environmental intensity compared to the benchmark index while

[1] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

[2] GHG = kgCO2e per unit of production

Water consumption intensity = m3 per unit of production

Land use intensity = m2 per unit of production seeking to minimize tracking error, and then implement a transition glidepath intended to reduce the GHG intensity at subsequent rebalances. This framework incorporates the concept of transition, recognizing the expectation that there will be changes to how energy is generated and how food is consumed. The initial focus of this approach is negative externalities as represented by the dataset described later in this paper.

b. The second method (Substitution Approach) introduces the concept of environmental displacement ratios by incorporating science-based positive externalities, enabling the index to tilt allocations toward commodities necessary to the transition, and adding relevant and diversifying assets to the index constituent set.

4. Consider the next steps in the development of investable commodities benchmarks that incorporate ESG metrics.

The Commodity-Sustainability Conundrum: Specific Challenges of Investing in Commodities Sustainably

To be clear, the focus of this paper is on the environmental footprint of commodities, the E in ESG, which is not to diminish the social and governance (the S and G) considerations, which are plentiful in commodities supply chains. We briefly consider these, but essentially view incorporating them as a future evolution of this framework.

1. Sourcing Environmental Data

The overarching challenge of defining and measuring the environmental footprint of commodities underpins the commodity-sustainability conundrum. In this case, the scope of measurement is limited to GHG emissions, water consumption and land use. Other important environmental impacts such as non-GHG pollution and other nature-related risks and dependencies are not included in this stage. A top-down approach to measurement is taken with a focus on cradle-to-gate life cycle analysis (LCA), with the exception of fossil fuels where in-use (downstream) impacts are included. Considering a broader number of environmental metrics, extending measurement across the entire value chain and incorporating bottom-up data are worthy goals for future iterations of this framework.

Top-down commodities' LCA is complex, in part because it can fluctuate from one region or producer to another. Much of the extraction and refining takes place in countries where accessing data may be more demanding. While rising GHG emissions may be thought of as inflicting a universally applicable cost to society, the impact of water consumption and land use varies substantially across and within countries. Historically, few sources have been able to successfully measure those effects consistently and thoroughly.

We leverage a new S&P Global Sustainable1 dataset that evaluates negative environmental externalities across the entire S&P GSCI investable universe.

2. Considering Nature-Related Impacts

Multiple nature-related dependencies, including deforestation and biodiversity loss, are affected by the commodities value chain. Much of this footprint is location and business specific, such as the contribution of cattle to country-specific deforestation or biodiversity loss related to mining of certain metals. It is important to note that some corporations have integrated sustainable practices in an effort to alleviate their negative impacts and transition toward more nature-positive business operations. Even though it is possible to extrapolate geographic location data for commodities from what is traded in commodity futures exchanges, matching data on sourcing from individual businesses is not readily consumable nor standardized.

The assessment of nature-related impacts is heavily integrated and its LEAP framework[3] is still being streamlined and formalized through market convened organizations such as the Taskforce on Nature-related Financial Disclosures (TNFD). Advancements are still required to improve standardization and the availability of implementable data. As a result, the analyses presented herein only consider some nature-related impacts, for example, ecosystem losses related to the conversion of pastureland for cattle farming.

A more holistic inclusion of nature-related impacts will be an important framework evolution in the future.

3. Measuring Social and Governance Impacts

Commodities have long been a major source of economic activity for developing countries, providing employment opportunities and a degree of wealth transfer from more advanced economies. However, the sector has also attracted scrutiny regarding employment conditions, effects on local communities and society at large. Issues of labor and human rights, competition with indigenous peoples' land and institutions, and improper oversight across the value chain continue to raise concerns across the world. Growing commodities demand may in fact amplify some of these and further complicate the necessary "just transition" regarding

[3] LEAP: Locate interface with Nature; Evaluate dependencies and impacts; Assess risk and opportunities; Prepare to respond to nature related risks and opportunities and report https://framework.tnfd.global/the-leap-nature-risk-assessment-process/

food and energy security. Quantifying these on a global basis is both critically important and highly complex, to the point that no objective and exhaustive metrics are currently available.

While unequivocally acknowledging their relevance, this framework does not yet incorporate them for lack of suitable datasets. We view this is as one of the major evolutions to come in this space.

4. Defining a "Path" to Sustainability

Assuming agreement on the desired outcome of sustainability, it is difficult to form a consensus on solutions expected to have profound economic and societal impact. This multi-decade transition is also subject to major uncertainties such as shifting geopolitics, the pace of technological innovation, and last but not least, a highly unpredictable rapidity and form of climate change. Nowhere is this better illustrated than in the EU debate on the conditional role of gas and nuclear energy in the EU Taxonomy.[4] For example, natural gas has a negative environmental impact, similar to other fossil fuels. Its use emits harmful GHG emissions, including CO_2 and methane. However, it is still less harmful when compared to other fossil fuels like coal; therefore, natural gas is well suited for generating power quickly when renewable energy is not available (e.g., when conditions are not favorable for sun, water or wind power). By utilizing natural gas as a transition resource, this can enable reliable power supply with a lower environmental footprint than other fossil fuel alternatives while cleaner power generation capacity gets developed.

The EU Taxonomy's conclusion on natural gas recognizes that it will play an important role over the next two decades in displacing coal, therefore mitigating the GHG emissions footprint of power generation using more emissions-intensive fossil fuels as feedstocks.

5. The Investable Universe Is Derivatives Based

Investors rarely own physical commodities outside of precious metals. Instead, they tend to achieve exposure via derivatives such as indices referencing listed futures. Typically, those futures are physically deliverable, but most of the traded volume is unwound (or "rolled") before expiration. The impact is less intuitively assessed than it may be for equities or bonds for instance, which bear a direct effect on corporates' capital structures. The EU initiated a debate on this matter involving market participants, but clarity is yet to emerge.[5]

Our work is predicated on the conviction that derivatives are an important link in the chain of commodity supply and demand balances. In particular, the well documented risk premium made accessible to investors by producer hedging illustrates the former's role in providing risk

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022R1214

[5] https://finance.ec.europa.eu/system/files/2022-10/221011-sustainable-finance-platform-finance-report-usability_en_1.pdf

capital to the latter. Acknowledging that this does not equate to a formal provision of equity or debt capital, this observation nonetheless offers a path to explore potential analogies with asset classes such as equities and fixed income. On a qualitative level, it strengthens the case for bearing in mind environmental externalities in designing synthetic futures baskets.

6. The Liquid Investable Universe Is Legacy Based

Signs of transition abound in most commodity sectors: renewable power has gained significant ground, as have biofuels in certain countries. Many jurisdictions have provided incentives to mitigate natural gas induced methane leakage, and renewable electricity is growing as a feedstock for aluminum, to note a few. However, with rare exceptions, liquidity on commodity futures exchanges remains concentrated in contracts referencing legacy deliverable material.

The proposed approach addresses index construction across the current S&P GSCI universe. In this, it is aligned with a market capitalization approach, which reflects the relative importance of each commodity to the global economy and the current distribution of liquidity on the relevant commodity trading exchanges. Other market forces at play that continue to influence the investable universe are potential directions for derivatives market expansion, assessing the potential evolution of power markets, emerging contracts on transition critical materials and carbon allowances.

Measuring the Environmental Impact of Commodities

Investing in commodities poses meaningful challenges for market participants looking to incorporate ESG metrics into their investment criteria. To start, commodities are a broad and diverse asset class with different financial, environmental and social implications. While it may be possible to apply the principles of ESG equity risk metrics to underlying commodities, and by association to commodities derivatives and indices, such sustainability metrics have not been developed with these financial instruments in mind. An approach specific to commodities is needed.

In the first instance, for those market participants looking to incorporate ESG metrics into a commodities strategy, environmental issues (i.e., “E”) will take center stage as arguably the most pressing and directly relevant ESG pillar. However, defining the negative externalities (where the production or consumption of a product results in a cost to a third party) of physical commodities is not straightforward. In the case of commodities, the most common environmental externalities are likely those associated with GHG emissions, water consumption and land use. These issues are identified based on an assessment of their materiality and the data availability across commodity value chains to measure them.

Robust quantitative assessments of these three key environmental impacts would represent a strong foundation on which to access the environmental footprint of existing commodities derivatives and indices, and develop a framework for new climate-aligned commodities financial products.

Introducing the S&P Global Commodity Environmental Dataset

Recognizing the need for increased transparency on environmental issues across commodity value chains, S&P Global Sustainable1, working in partnership with S&P Dow Jones Indices, has developed the S&P Global Commodity Environmental Dataset, covering a range of agricultural, energy, precious metal and industrial metal commodities. The dataset provides robust and comprehensive physical and financial impact data on GHG emissions, water consumption and land use at the commodity-level based on life cycle impact assessment (LCIA) factors and natural capital valuation metrics. The dataset can be a tool to help investors understand the environmental risks and opportunities associated with their investment in specific commodities, as well as across portfolios, indices, and benchmarks. Exhibit 3 outlines the coverage and characteristics of the dataset.

Exhibit 3: Overview of the S&P Global Commodity Environmental Dataset

Metric	Description
Coverage	All commodities included in the S&P GSCI as well as natural gas (global), platinum and palladium. There is also a "traded gold" variation of gold that represents the amount of traded gold that has already been mined.
Scope	GHG emissions, water consumption and land use.
Boundary	Cradle-to-gate and conventional production methods for the "top 10" production locations for each commodity. For energy commodities, the boundary extends to the "in use" stage based on materiality. For GHG emissions, this relates to Scope 1, Scope 2 and Scope 3 upstream emissions associated with commodity production. It does not include the transportation to the consumer, use or disposal. The cradle-to-gate value chain was chosen as the boundary of the assessment to align with the way physical commodities are generally traded in derivative markets, where only a small proportion ever reach delivery.
Specificity	Weighted-average absolute and intensity based physical impact data using country-specific **LCIA** factors and production volumes. Global average LCIA factors are used for locations outside of the "top 10" and when country-specific LCIA factors are not available.
Metrics	Weighting **Natural Capital Valuation** metrics are applied to convert physical impact data into a single monetary value representing the combined environmental externalities of each issue. Natural capital valuation is normalized by production volumes and annual contract value to each commodity to provide a relative metric to compare impacts across different commodity types called the **Commodity Valuation Intensity**.
History	First year of coverage is 2018.
Updates	The dataset is updated on an annual basis to account for changes in the commodity production and contract values, physical impact data and natural capital valuation metrics.

Source: S&P Global Sustainable1. Data as of January 2023. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Natural Capital Valuation

The natural capital valuation metrics presented in the dataset represent the costs to society and the environment of the damage caused by each impact. These are the indirect costs of production that are not borne by polluters, but often incurred by other businesses and society at large through factors such as health impacts, property damages and lost amenities. The natural capital valuation metrics draw on methodologies used in environmental economics and align with the global best practice guidelines outlined in the Natural Capital Protocol, a decision-making framework that helps organizations identify, measure and value their direct and indirect impacts and dependencies on natural capital.[6] Valuation metrics for water consumption and land use are both country specific, whereas the valuation metrics for GHG emissions are based on global averages, due to the way they affect the environment and society.

S&P Global Sustainable1 values GHG emissions using an estimate of the social cost of carbon (SCC). The SCC represents an estimate of the marginal externality cost of GHG emissions as it reflects the global cost of the damages caused by GHG emissions over their lifetime in the atmosphere. This is in contrast with the market prices observed in emissions trading schemes (ETS) or estimates of the marginal abatement cost (MAC) of GHG emissions reductions.

The impact of water consumption is valued based on the consequences of the restricted access to water on human health and the environment.

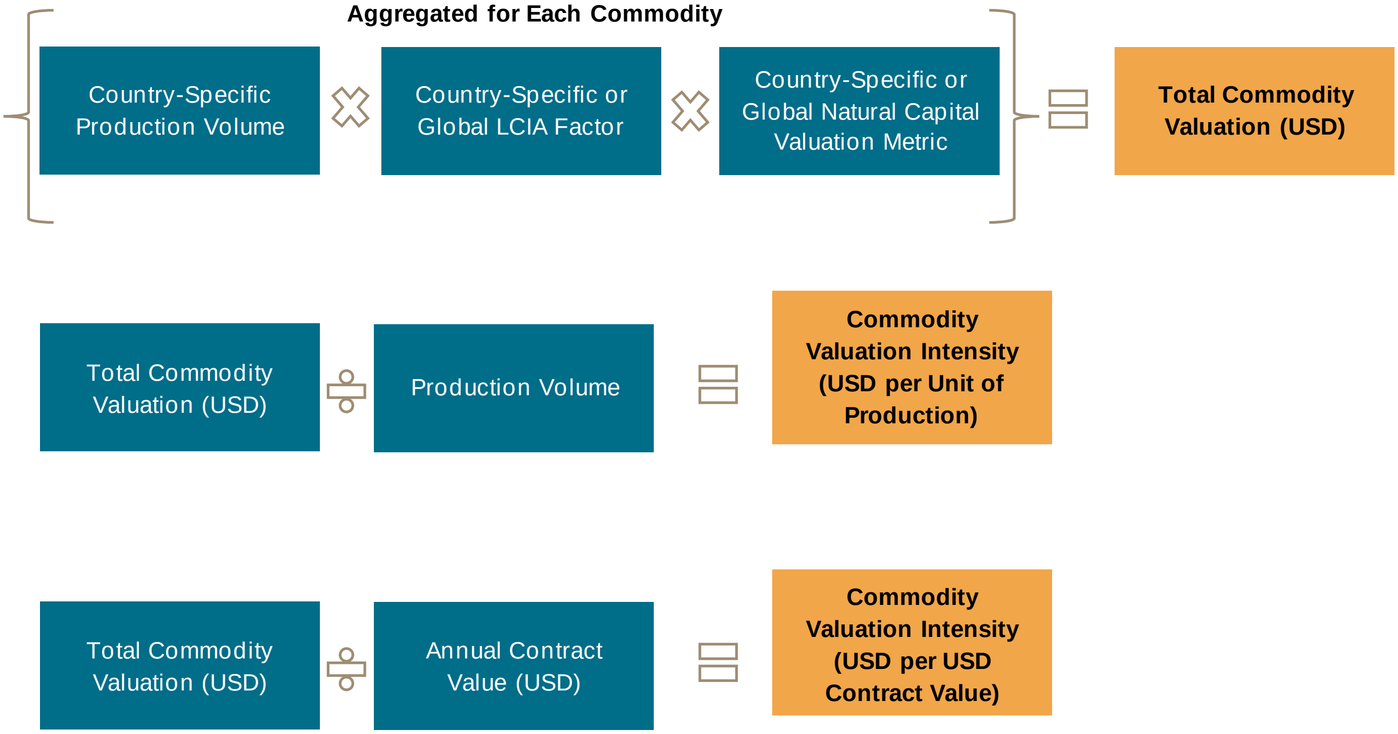
The land use valuation methodology considers the ecosystem services lost when naturally occurring ecosystems are converted to artificial ecosystems or gained when natural ecosystems are restored or conserved. For example, if a rainforest has been converted to pastureland for cattle farming, this is considered a land use change and is covered by the valuation methodology.

Commodity Valuation Intensity

The commodity valuation intensity (CVI) metric ascribes an economic value of each environmental impact on a per unit of commodity production or per dollar invested (or dollar per contract value). This allows for comparison across commodities and across environmental impacts. A high-level overview of the approach is provided in Exhibit 4.

[6] Capitals Coalition, (2016), *Natural Capital Protocol*, Available at: https://capitalscoalition.org/capitals-approach/natural-capital-protocol/?fwp_filter_tabs=training_material.

Exhibit 4: Calculating Commodity Valuation Intensity



Source: S&P Global Sustainable1. Data as of January 2023. Chart is provided for illustrative purposes.

As an example, Exhibit 5 provides the relevant dataset for wheat, natural gas and cattle.

Exhibit 5: S&P Global Commodity Environmental Dataset Sample Data

Metric	Wheat	Cattle	Natural Gas (North America)	Natural Gas (North America) - In Use
Production Volume	764,980,821	67,915,624	1,136,961,552	1,136,961,552
Production Unit	1 MT	1 MT	1 TOE	1 TOE
Annual Contract Value (USD)	133,355,963,745	194,246,027,964	126,987,689,467	126,987,689,467
Latest Production Year	2019	2019	2019	2019
Total GHG Emissions ($kgCO_2e$)	524,954,686,999	1,183,218,361,096	426,530,990,342	2,672,322,364,111
GHG Intensity ($kgCO_2e$ per Unit of Production)	686.23	17,421.89	375.15	2,350.41
Total Water Consumption (m^3)	243,534,959,921	4,967,589,101	439,172,336	N/A
Water Consumption Intensity (m^3 per Unit of Production)	318.35	73.14	0.39	N/A
Total Land Use (m^2)	2,070,116,239,669	3,331,842,676,383	4,639,656,622	N/A
Land Use Intensity (m^2 per Unit of Production)	2,706.10	49,058.56	4.08	N/A
Total Commodity Valuation (USD)	349,615,428,621	651,100,463,798	56,469,950,654	349,639,001,399
Commodity Valuation Intensity (USD per Unit of Production)	457	9,587	50	308
Commodity Valuation Intensity (USD per USD Contract Value)	2.62	3.35	0.44	2.75

Source: S&P Global Sustainable1. Data as of January 2023. Table is provided for illustrative purposes.

Limitations

Assessing the environmental impacts of commodity value chains is a complex process where disclosure is currently limited. In addition, the integration of ESG factors into commodity markets is still in its infancy. As such, there are several important limitations that should be considered when reviewing and using this dataset. Although many of these will be addressed as additional data becomes available and impact assessment methodologies evolve, the key limitations must be recognized.

Perhaps the most significant limitation is that the impact assessments are point-in-time. They also do not consider any positive externalities in both absolute and relative terms, and the role of commodities in the energy transition. This means that known benefits such as the nutritional value of agricultural commodities, as well the important role that some precious and industrial metals may play in the low carbon transition, are not currently considered. Subsequent versions of this dataset will seek to measure positive externalities where possible.

There are limitations to environmental impact data, as discussed. However, methods of environmental externalities quantification are bound to continue evolving as the science develops. Both in terms of exhaustiveness, and with regard to how individual "ecosystem services" are accounted for. For instance, biodiversity is a fast emerging topic, where one would expect substantial research efforts to result in enhanced metrics over time.

Commodity value chains may also embed equally relevant social and governance issues. However, due to the aforementioned limitations, such as data availability and consistency, these issues are not yet included and may be added in future iterations.

The list of commodities in the dataset is not exhaustive and in some cases the commodities included are traded on multiple derivatives exchanges. For ease of implementation in an index, the derivatives exchanges for each commodity to be used are the same as those exchanges used as the basis of the individual S&P GSCI commodities constituents.

Commodity production volumes have been normalized to metric tons (MT) and tons of oil equivalent (TOE) to ease comparison within and across different commodity types. However, there are other normalization factors that could be used each with their own advantages and disadvantages.

Applying Environmental Data to Commodity Indices

Considerations

Once a measure of the environmental impact of an underlying commodity is available, the next step is to incorporate that data into an index framework. But the broader philosophical question is: what is the desired outcome of an index that incorporates such data, beyond maintaining inflation sensitivity and offering diversification benefits.

One way would be for the index to reduce its overall environmental intensity while minimizing tracking error. Another would be for the index to reallocate weight to commodities essential to the energy transition. Both considerations would also have to account for enhancing liquidity and price transparency of certain commodities. These stated outcomes are not mutually exclusive.

The dataset presented above provides an environmental metric for each constituent of the S&P GSCI. It presents this data from both a volume and value perspective, normalizing the natural capital valuation by production volume or annual contract value, presenting a metric referred to as commodity valuation intensity. In the world of company balance sheets and profit and loss statements, it makes sense to consider environmental intensity from the perspective of dollar invested. But in the case of the underlying commodities, there is an alternative, which is to measure the impact per unit of production, such as ton of copper or wheat. The denominator chosen greatly influences the so-called commodity valuation intensity of each constituent. If we consider gold as an example, the CVI per unit of production is high because a metric ton of gold is an extremely large amount, whereas the CVI on a per dollar invested basis is low because of the high value nature of gold.

In the context of a diversified multi-asset investment strategy, any application of environmental metrics to a benchmark such as the S&P GSCI might consider weighing any deviation from the characteristics of the benchmark against index performance and any improvement in environmental footprint, for example a decrease in GHG emissions from the investment strategy when compared to the benchmark.

Commodities have many features that make them unique as an investable asset. That said, we see a need for the application of environmental data to commodity indices to align with equity and fixed income ESG market convention where possible, or in cases where a more bespoke approach is taken, the spirit of such market conventions is preserved and the approach is grounded in science.

There are two broad approaches to reweighting the S&P GSCI to incorporate the new commodities environmental dataset described in the previous section. The first approach is to adopt a purely quantitative framework that allows for the application of available data today while being sufficiently flexible to incorporate new data sets as they become available. The second approach is grounded in the same currently available dataset covering environmental externalities. It then leverages research produced by academic institutions, along with governmental and international organizations to identify plausible demand substitution trends on the path to sustainability and incorporates them in determining portfolio composition.

A final consideration is whether the data should be applied as a point in time manner, such as the approach taken by the S&P 500 ESG Index or incorporated into an index with a transition mechanism, thereby reducing the environmental footprint of the index over time (e.g., S&P PACT Indices). Both approaches are valid, and the preferences could depend on factors such as sustainability goals, data availability, index complexity and replicability.

There are undoubtedly other considerations that will be specific to certain strategies, and we expect the importance and usefulness of these considerations to change over time.

Economic Sectors and Transition Classification

As environmental considerations come under scope, market participants have expressed interest in maintaining diversified exposure to an inflation-sensitive asset in line with their original benchmark, while shifting allocations between commodities that may be substitutes, reflecting as closely as possible behaviors in the physical market that may be central to the transition.

As such, we begin the process of building our index frameworks by redefining new commodity "sectors" to reflect the changing dynamics of the global economy. We divide the components into three economic sectors based on their impact on the environmental transition and currently available substitutions within each category.

- Energy Systems
- Food Supply
- Other

The energy and food sectors account for the majority of global GHG emissions.[7] By regrouping commodities into these three identified economic sectors, the framework articulates potential commodity substitutes that will allow for the identification of levers necessary for a

[7] https://ourworldindata.org/emissions-by-sector

positive environmental transition through reduction of environmental harm, while gaining exposure to commodities that will enable the transition.

Energy Systems

Decarbonizing the energy mix is essential to achieving any scientifically projected environmental transition pathway to avoid significant global warming. Integral to this is the deployment of renewables, which will require innovation, investment and supportive legislation. The move toward more renewable use and electrification will require intensive infrastructure build outs, in which certain metals will be critical raw materials. For example, copper, aluminum and nickel are all essential materials in wind turbines, electric vehicles and solar panel frames. As such, the need for metals as a component of renewable energy supply is typically positively correlated with the path to sustainable energy transition. The IEA acknowledges an exponential increase in the need for certain metals used in renewable energy to meet future sustainability targets.[8] Sugar is also considered important for the energy transition given it is a major feedstock in the production of ethanol.

Food Supply

The United Nations considers food as a nexus of sustainable development.[9] Food is vitally important as the global population increases, and as one of the major sources of GHG emissions, addressing this sector is necessary in any sustainable transition pathway. We combine grains and livestock together as one aggregated sector in this framework.

Other

The remaining commodities within the S&P GSCI have a negative environmental footprint, but there are no clear lower footprint substitutes, at least with investable instruments. For example, the production of cocoa and coffee have clear negative environmental impacts, including GHG emissions and water use. However, there are no clear substitutes for these commodities and they are not essential for nutrition. Similarly, gold's environmental impact may vary, for example gold stored in a bank's safe versus gold that is smelted would not produce the same GHG emissions. There is also no immediate substitute for gold, and its use as a metal is not crucial for energy transition.

8 https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

9 https://sdgs.un.org/partnerships/food-energy-water-few-nexus-partnerships

Reducing the Overall Environmental Footprint Using Optimization (Optimization Approach)

Our first approach to incorporating quantitative environmental data into commodity markets uses index optimization to allocate across the constituents of the S&P GSCI. The goal of the Optimization Approach is to reduce the overall environmental footprint of the index in a transparent rules-based way by targeting a fixed percentage reduction in the environmental CVIs, while minimizing weight deviations from the benchmark. Generally, tracking error will be reduced as a result of seeking minimal weight deviations from the benchmark. Looking forward, there is also an embedded transition mechanism that seeks to decarbonize the index at a rate of 5% year-on-year, anchored to an initial 25% reduction relative to the S&P GSCI as of the rebalance date immediately before index launch, while also maintaining water consumption and land use that are at least no worse than the S&P GSCI. A 5% year-on-year decarbonization target was chosen in recognition that decarbonization needs to be anchored in reality and the fact that the current mix of global commodity production cannot support a large year-over-year reduction without heavy concentration. The benchmark index, the S&P GSCI, is designed to reflect global demand for commodities and is itself expected to decarbonize over time. The transition guide path is an optional enhancement that may not be a requirement for some market participants in the first instance.

An important point worth noting is naively applying an Optimization Approach to the S&P GSCI constituents to deliver environmental impact reductions per dollar invested may have some unintended consequences, namely, that the resultant weights given to certain commodities would defy economic rationale for an environmental solution at the planet level. We identify two potential issues concerning the energy sector and food supply commodities.

1. Relatively Efficient, Yet Cheaper Commodities
    a. Natural Gas Versus Other Fossil Fuels: For a fixed amount of energy production (e.g., per ton of oil equivalent), natural gas has a lower carbon footprint than other energy commodities,[10] but because natural gas is relatively cheaper it has a higher CVI per dollar invested. Therefore, an optimized index may allocate proportionately less to natural gas when targeting a reduction in CVI per dollar, which is counterintuitive given the environmental benefits if the planet were to transition more to natural gas and away from other fossil fuels.
    b. Plant-Based Versus Meat: Likewise, for a given ton of plant-based commodities, the environmental impact is typically lower than for meats,[11] yet they can be assumed to

[10] https://www.iea.org/commentaries/the-environmental-case-for-natural-gas.

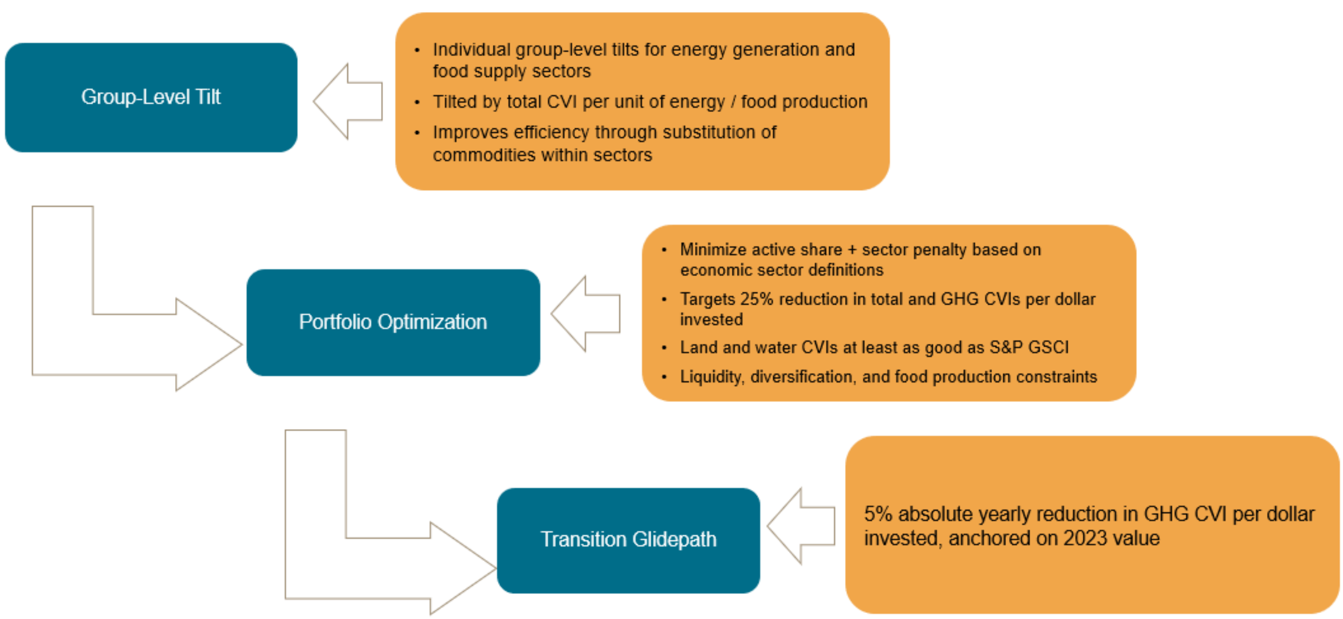
[11] https://www.ethicalconsumer.org/food-drink/climate-impact-meat-vegetarian-vegan-diets#:~:text=Livestock%20uses%20huge%20amounts%20of,used%20by%20agriculture%20by%2075%25.

offer approximately comparable nutritional value. However, due to the typically lower costs of plant-based commodities, they may be characterized by a high CVI per dollar invested. Therefore, in the absence of any intervention, they would be underweighted due to our optimizer's objective. Clearly, this is in conflict to the growing awareness that any global solution to climate change requires a shift toward a more plant-based food supply.

2. Total Food Supply Production. Compared to other S&P GSCI commodities, both plant-based and meat food supply commodities (such as wheat and cattle) are intensive to produce, but necessary to sustain the population. By targeting a reduction in CVI per dollar invested at the index level, the overall group of food supply commodities will therefore be underweighted relative to less intensive non-food commodities. We argue it is not desirable from an economic perspective to construct an index that significantly underweights food supply commodities.

To address the first issue, we adopt a two-step approach to construct the index. In the first step, we apply a tilting procedure that allocates weight more efficiently based on total CVI per unit of production (not per dollar invested) across both the S&P GSCI Energy sector and the food supply commodities group, respectively. This tilting procedure occurs only in these two groups and allocates more weight to commodities with relatively lower CVI per unit of production (e.g., natural gas, corn) and less weight to commodities with higher CVIs on the same basis (e.g., crude oil, cattle, lean hogs). Exhibit 6 provides a schematic representation of this two-step approach.

Exhibit 6: Two-Step Approach to the Optimized Index Construction with Transition Glide Path



Source: S&P Dow Jones Indices LLC. Data as of January 2023. Chart is provided for illustrative purposes.

The tilting process itself computes a Z-score on each rebalancing date from the inverse of each commodity's total CVI per unit of production by subtracting the mean and dividing by the standard deviation of all commodities within the same group. The commodity weights in each group are then tilted from the S&P GSCI benchmark weights by a tilt score, S_i, which is defined by transforming the Z-score as follows:

- if $Z_i > 0, \quad S_i = 1 + \lambda Z_i$
- if $Z_i < 0, \quad S_i = 1/(1 - \lambda Z_i)$
- if $Z_i = 0, \quad S_i = 1,$

where λ is a stretch factor. A higher value of λ corresponds to a more aggressive tilt, with 0.25 being used in this paper. Each commodity's tilt score is multiplied by its weight in the S&P GSCI and rescaled such that weights within the group sum to one.[12]

In the second step, the final optimization seeks reductions in CVI per dollar invested at the index level. However, in this final step the relative proportions of the resultant weights within each tilting group are fixed to those defined by the process in step one. The result is an index that endeavors to meet the environmental objectives of investors, but still provides intuitive relative group weighting appropriate for improving environmental efficiency across global production.

To address the second issue, we impose a further constraint that the weighted average food production per dollar invested of the index must be greater than or equal to that of the S&P GSCI. This constraint is intended to ensure the index does not achieve its intensity reduction objective by severely underweighting the food supply sector. Interestingly, given the increased efficiency of the group created by the tilting process, we find that the total index weight of the food supply commodities can be reduced while production levels are maintained.

The final index weights are found by numerically minimizing an objective function that combines penalties for active share and sector deviations, while targeting a 25% reduction in the GHG and total CVIs per dollar invested at the index level, as well as maintaining water and land CVIs that are at least no worse than the S&P GSCI.[13, 14]

[12] An implicit assumption in tilting food supply commodities by their inverse CVI per unit of production is it assumes a tonne of production of one food commodity is equivalent to a tonne of production of another food commodity in terms of caloric/sustenance value. As discussed elsewhere in the paper, our research suggests caloric/protein values of foodstuffs are fairly similar, making tonnes of production a reasonable approximation.

[13] Due to changes in constituent prices between rebalance dates ("weight drift"), the actual reduction may deviate above or below the 25% target. The final index will have a monthly trigger-based rebalance check in place, where the index will perform an ad-hoc rebalance if the realized total CVI reduction falls below 20%.

[14] Mathematically, the objective function is defined as:

$$\min \left(\frac{1}{n}\sum_i \frac{(\textit{Benchmark Weight}_i - \textit{Optimized Weight}_i)^2}{\textit{Benchmark Weight}_i} + \frac{1}{m}\sum_j \frac{(\textit{Benchmark Sector Weight}_j - \textit{Optimized Sector Weight}_j)^2}{\textit{Benchmark Sector Weight}_j}\right).$$

Finally, there are several additional features within the optimization that are designed to influence the sector weights and improve investability. For instance, since the optimizer applies a quadratic penalty on sector deviations from the benchmark, the new energy systems economic sector has been defined to encourage displacement from fossil fuels to metals and alternative sources of energy considered important for a low-carbon transition. With this sector defined, the reallocation of weight from the fossil fuel group to a metal commodity, for example, which may support the "electrification" of the energy supply, would inhibit no sector penalty. Whereas reallocating weight to other commodities outside this sector would incur a penalty, and therefore the optimal solution found would have minimized these deviations. The remaining sectors use their S&P GSCI sector definitions, except for the food supply group since its relative weights are already fixed through tilting and its total production is constrained (as previously described).

Exhibit 7: Sector Membership for Optimized Approach

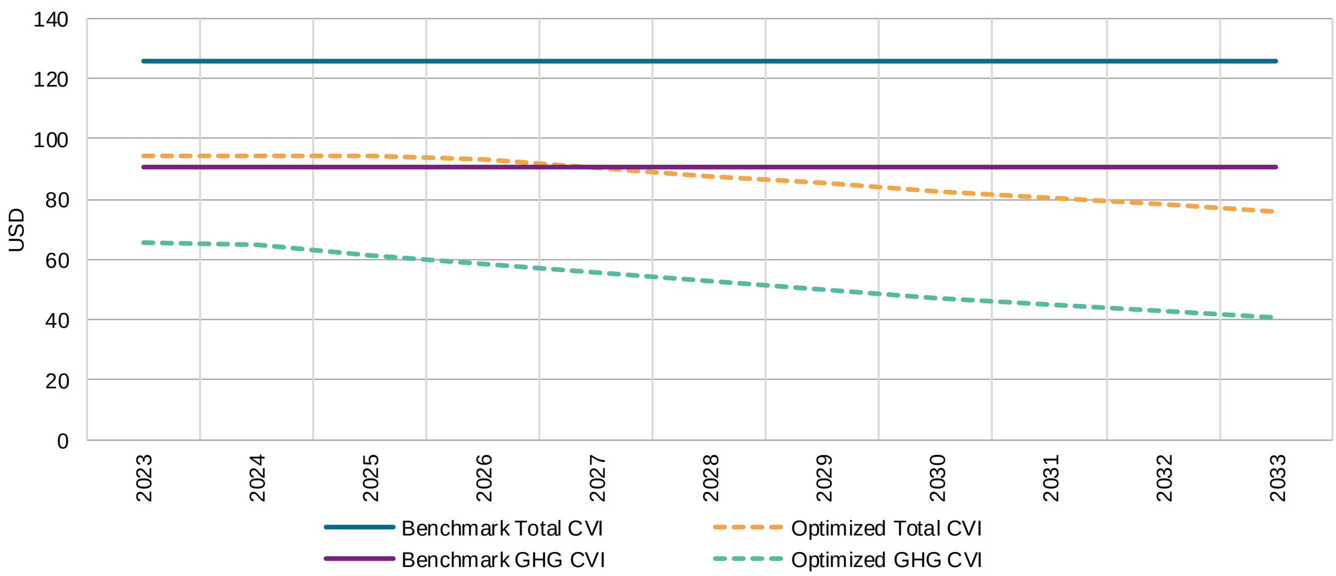
S&P GSCI Constituent	S&P GSCI Sector	Sector Grouping for Optimization
Natural Gas	Energy	Energy Systems
Brent Crude Oil	Energy	
Gasoil	Energy	
Heating Oil	Energy	
WTI Crude Oil	Energy	
Gasoline	Energy	
Sugar	Agriculture	
Copper	Industrial Metals	
Aluminum	Industrial Metals	
Nickel	Industrial Metals	
Zinc	Industrial Metals	
Silver	Precious Metals	
Feeder Cattle	Livestock	Food Supply
Live Cattle	Livestock	
Lean Hogs	Livestock	
Chicago Wheat	Agriculture	
Corn	Agriculture	
Kansas Wheat	Agriculture	
Soybeans	Agriculture	
Cocoa	Agriculture	Agriculture
Coffee	Agriculture	
Cotton	Agriculture	
Lead	Industrial Metals	Industrial Metals
Gold	Precious Metals	Precious Metals

Source: S&P Dow Jones Indices LLC. Data as of January 2023. Table is provided for illustrative purposes.

To maintain liquidity and replicability, we impose a lower and upper bound on the optimized weights of 0.2x and 5x the S&P GSCI weights, respectively. If the optimizer cannot find a feasible solution, these bounds are incrementally relaxed to a range of 0.1x-10x the S&P GSCI weights. All index weights are hard capped such that the maximum largest weight is 32%, and the second-largest maximum weight is 17%.[15] This allows a 3% buffer on the UCITS 35/20 capping rule and aims to reduce the concentration of index positions, which is especially notable in later transition years where positions may become highly concentrated in the lowest intensity commodities.

To summarize, the optimized index seeks to achieve a 25% reduction in the GHG and total CVIs per dollar invested compared to the S&P GSCI, along with the 5% year-on-year decarbonization target, while maintaining total food production and ensuring land and water CVIs per dollar invested are no higher than the S&P GSCI (see Exhibit 8). It seeks to do this by minimizing an objective function that combines two penalties: a quadratic penalty on weight deviations from the benchmark, and a quadratic penalty based on sector deviations from the benchmark. The sector definitions used for the objective function are a hybrid of the S&P GSCI sectors and the newly defined energy systems and food supply economic sectors chosen to encourage displacement from fossil fuels to metals, and from meat to plant-based foods. Additionally, tilted weights are applied to the fossil fuel group and food supply sector to improve their environmental efficiency on a per unit of production basis.

Exhibit 8: CVI Change by Transition Year



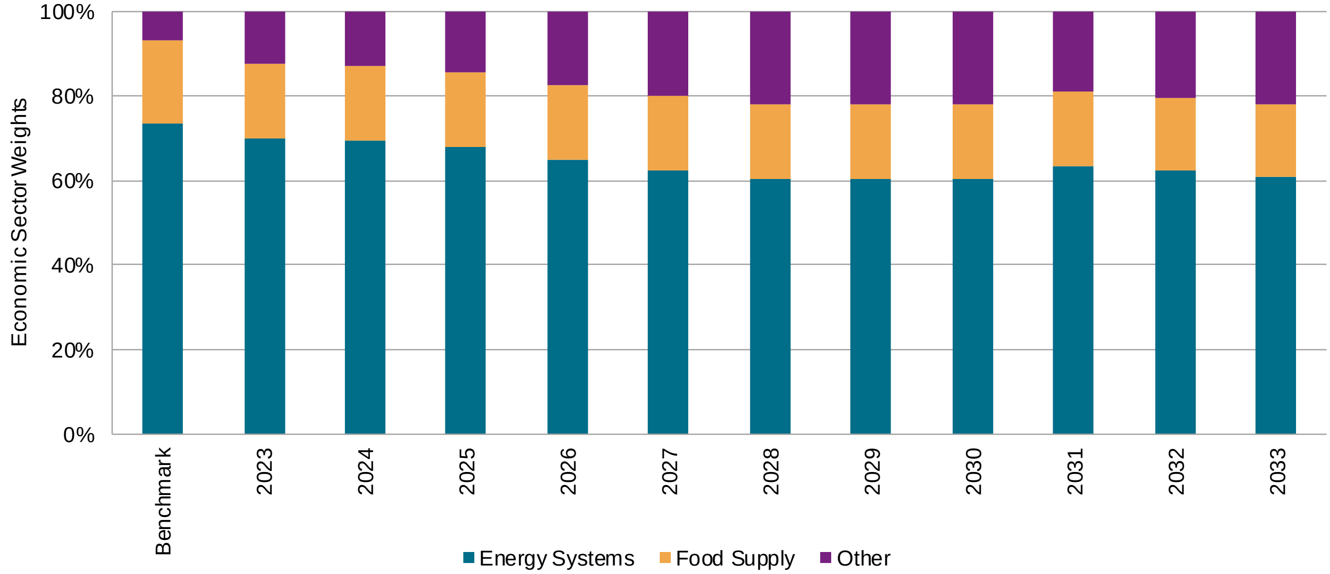
Source: S&P Dow Jones Indices LLC. Data as of January 2023. Chart is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions that may not be realized and are variable. The

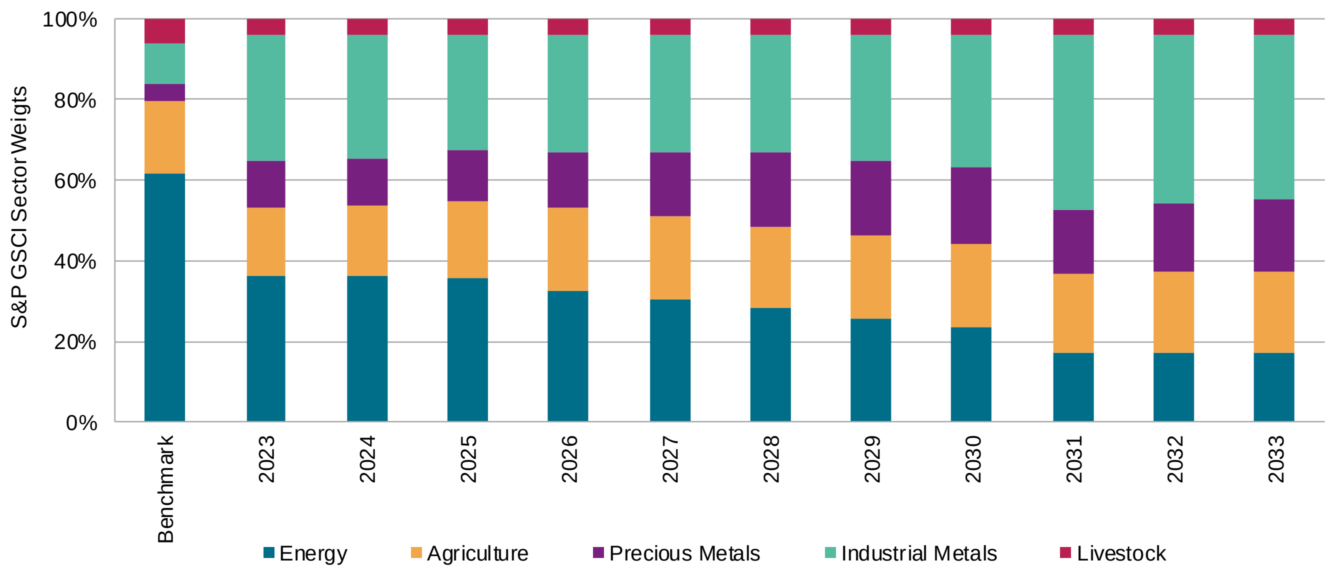
[15] For the hard capping, all petroleum commodities, both wheat commodities and both cattle commodities are treated as a single asset.

assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

The commodity basket is re-optimized annually in January to coincide with the rebalance of the S&P GSCI and the annual update of the S&P Global Commodity Environmental Dataset. The economic sector weights and S&P GSCI sector weights are shown by transition year in Exhibit 9.

Exhibit 9: Optimized Index Weights by Transition Year

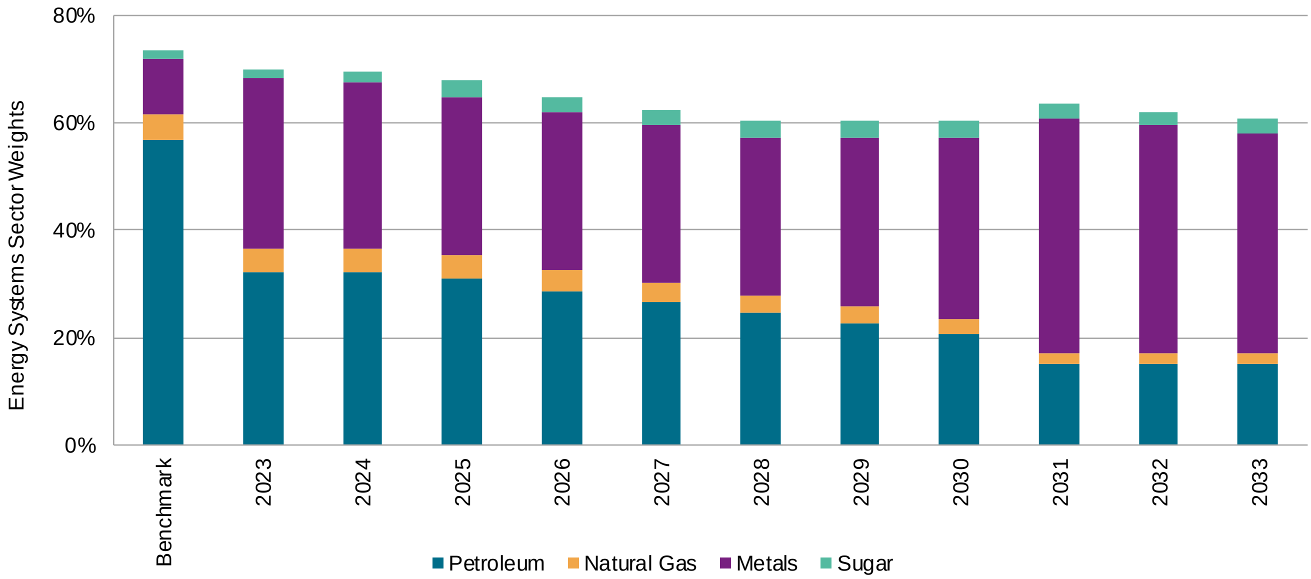




Source: S&P Dow Jones Indices LLC. Data as of January 2023. Charts are provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions that may not be realized and are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

Exhibit 10 shows the composition of the energy systems sector by transition year for the optimized index and the S&P GSCI benchmark. Over time, there is a transition away from petroleum commodities primarily into metals.

Exhibit 10: Energy Systems Sector Weights by Transition Year for the Optimized Approach



Source: S&P Dow Jones Indices LLC. Data as of January 2023. Chart is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions that may not be realized and are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

Exhibit 11 provides summary statistics for the optimized index compared to the benchmark. It is worth noting that the decline in inflation beta over the transition period compared to the benchmark is a function of the reallocation away from fossil fuels to less inflation-sensitive industrial metals. Inflation beta is not a static measure, and it is not unrealistic to assume that as the energy transition accelerates, the inflation sensitivity of individual commodities will change, which may improve the inflation beta of the proposed index.

Active risk is computed as a function of the difference in optimized weights over the benchmark for a given transition year, and the historical covariance matrix of the index constituents. It is assumed the benchmark weights remain static over the transition period, but the benchmark may evolve to reflect new dynamics of commodities markets in the future.

Exhibit 11: Summary Statistics for Optimized Index Over Time

Metric	Benchmark	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Active Share (%)	-	29.9	30.3	33.8	36.6	39.0	41.3	43.7	46.0	49.3	50.7	52.1
Active Risk (% Annualized)	-	8.0	8.0	8.3	9.1	9.8	10.5	11.2	11.9	13.6	13.6	13.7
Inflation Beta	12.6	9.2	9.2	9.1	8.7	8.3	7.9	7.6	7.4	6.8	6.7	6.6
Commodity Valuation Intensities (per USD 100 Invested)												
Total CVI	125.9	94.4	94.4	94.4	93.3	90.6	87.8	85.2	82.7	80.3	78.0	75.9
% Change	-	-25.0	-25.0	-25.0	-25.9	-28.0	-30.2	-32.3	-34.3	-36.2	-38.0	-39.7
GHG CVI	90.7	65.6	64.6	61.4	58.3	55.4	52.6	50.0	47.5	45.1	42.9	40.7
% Change	-	-27.7	-28.8	-32.3	-35.7	-38.9	-42.0	-44.9	-47.6	-50.2	-52.7	-55.1
Water CVI	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
% Change	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land CVI	33.9	27.5	28.5	31.8	33.7	33.9	33.9	33.9	33.9	33.9	33.9	33.9
% Change	-	-18.8	-15.9	-6.4	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: S&P Dow Jones Indices LLC. Data as of January 2023. Table is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions that may not be realized and are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

The potential diversification benefits of the proposed index are in line with the benchmark (Exhibit 12).

Exhibit 12: Correlation of Monthly Asset Returns

Asset	S&P GSCI Optimized Climate Aware Index Concept
S&P GSCI	0.95
Gold	0.19
S&P 500	0.46
Real Assets	0.63
Bonds	-0.11

Source: S&P Dow Jones Indices LLC. Data from June 2012 to October 2022. Index performance based on total return in USD, with the exception of bonds. Gold is represented by the S&P GSCI Gold. Real assets are represented by the S&P Real Assets Index. Bonds are represented by the S&P U.S. Aggregate Bond Index. 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.

Incorporating Positive Externalities and the Concept of Transition and Displaced Commodities (Substitution Approach)

The first framework we presented is designed for multi-asset market participants that are looking for an approach that aligns with common practice in equities and fixed income. This first approach incorporates a comprehensive set of environmental data into the composition of the commodity index such that investors can evaluate and reduce the negative environmental footprint associated with their investments, as well as incorporate further reductions in the environmental footprint over time. The approach acknowledges the expectation that there will be changes to how energy is generated and how food is consumed but does not directly account for positive externalities or directly incorporate commodity displacement and substitution.

Other market participants have approached the topic of commodities and the transition more with a lens in which commodities will both see increased demand and have a positive role to play in decarbonizing the global economy. For those market participants, we present a second approach where we incorporate both negative and positive environmental externalities (avoided environmental externalities from an alternative activity). Specifically, we introduce the concept of the environmental displacement ratio (EDR) to measure the net impact of those commodities that have a net positive role to play in the transition. The concept behind the EDR is that while consumption of any commodity comes with negative environmental impacts (the denominator), the alternative may have a more punitive impact on the environment (numerator).

This approach also incorporates a glidepath to changing allocations over time, with investors in control over how much the weights will deviate from the initial benchmark at any point in time. Once again, we begin our framework with the S&P GSCI as its world production weighting methodology seeks to provide an investable benchmark that is grounded in production and consumption in the world economy.

We have accounted for these investor/market-led factors in the approach outlined below.

1. Segment Components into Economic Sectors: Energy Systems, Food Supply and Other
2. Group Constituents Based on Transition Role: Transition, Displaced and Other
3. Calculate EDR for Transition Commodities
4. Select Target Reduction for Displaced and Other Commodities: 35%/5%
5. Blend EDR with Index Weight to Determine New weights for Transition Commodities
6. Allocate Residual Weight from Other Category to Carbon Allowance Futures (e.g., EUAs)

1. Economic Sectors

We maintain the same economic sectors that were utilized in the Optimized Approach, namely energy systems, food supply and other.

2. Transition Role and Related Displaced Commodities

In addition to segmenting commodities into economic sectors, we further categorize components in energy systems and food supply into the categories of transition and displaced commodities (see Exhibit 13). Displaced commodities are those that are recognized as contributing significantly to climate change and other serious environmental challenges, while transition commodities may have a negative environmental footprint, but by substituting displaced commodities with these transition commodities, reductions in environmental harm can be achieved. This substitution principle (transition for displaced commodity) is the basis of the framework.

- Under displaced: Exposure to commodities with high negative externalities including high GHG emissions, water consumption and land use are decreased, e.g., less oil or cattle.
- Under transition: The amount decreased from the displaced categories are allocated across the transition category through an EDR that accounts for both negative externalities (GHG emissions, water consumption and land use) and for positive ones, for example, fossil fuels displaced into natural gas and metals required for the transition, or lean hogs/ cattle displaced into wheat, corn and soybeans.

Exhibit 13: Transition and Displaced Commodities by Sector

Energy Systems		Food Supply		Other	
Displaced Commodities	**Transition Commodities (Displacement Reference)**	**Displaced Commodities**	**Transition Commodities (Displacement Reference)**	**Displaced Commodities**	**Transition Commodities**
WTI	Natural Gas (Coal)	Lean Hogs	Wheat (Live Cattle)	Gold	Carbon Allowance Futures (e.g., EUAs)
Brent	Sugar (Gasoline)	Live Cattle	Kansas Wheat (Live Cattle)	Lead	
Heating Oil	Silver (Fossil Fuels)	Feeder Cattle	Corn (Live Cattle)	Cotton	
Gasoil	Aluminum (Fossil Fuels)		Soybean (Live Cattle)	Coffee	
Gasoline	Copper (Fossil Fuels)			Cocoa	
	Nickel (Fossil Fuels)				
	Zinc (Fossil Fuels)				

Source: J.P. Morgan. Data as of January 2023. Table is provided for illustrative purposes.

Energy Systems

Fossil fuels currently account for approximately 84% of global energy consumption,[16] and their usage is responsible for a majority of global GHG emissions.[17] Therefore, discussions on decarbonizing the global economy often start with the energy transition and a push to migrate from fossil fuels to renewable energy.

Fossil fuels are often lumped together in terms of their environmental impact but are generally used for a broad range of applications throughout the economy. In some areas, they may be substitutes for each other (coal versus natural gas in power generation, or heating oil versus natural gas for heating). Likewise, in some sectors, fossil fuel use has greater current potential to be displaced by renewable energy than in others.

As decarbonization accelerates and new technologies emerge, historical relationships also evolve. Examples include growth in electric vehicles and creating opportunities for energy used within the power stack to displace transportation fuels. The importance of technology is reflected in IPCC's analysis stating, "the net-zero challenge calls for a step change in technology innovation in critical areas such as enhancing energy efficiency, making low-carbon electricity the main source for heating buildings and powering vehicles, capturing, storing and utilizing carbon dioxide before it escapes into the atmosphere, realising the potential of clean hydrogen across many industries, and massively expanding the use of sustainable bioenergy."[18] Over time, to reach 2050 decarbonization goals, a significant amount of the decrease in CO_2 is estimated to be attributed to technology's contribution to transport electrification, energy efficiency and different types of carbon removal. Reduction of fossil fuels, while important, will have to work in conjunction with technological advances to reach the necessary decrease in CO_2 emissions to achieve various sustainable transition pathway assumptions.[19]

Natural Gas as a Temporary Less-Polluting Replacement for Coal

The energy sector is responsible for three quarters of GHG emissions today.[20] The most polluting fuel source is coal. To reach Net Zero by 2050, the International Energy Agency (IEA) estimates the need for a three-fold increase in renewable energy production by 2030.[21]

[16] https://ourworldindata.org/energy-mix

[17] https://ourworldindata.org/emissions-by-sector. The energy (electricity, heat and transport) sector accounted for 73.2% of global GHG emissions.
https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer, "In 2020, global emissions from fuel combustion were dominated by coal (45%), followed by oil (32%)."

[18] https://www.ipcc.ch/2020/07/31/energy-climatechallenge/

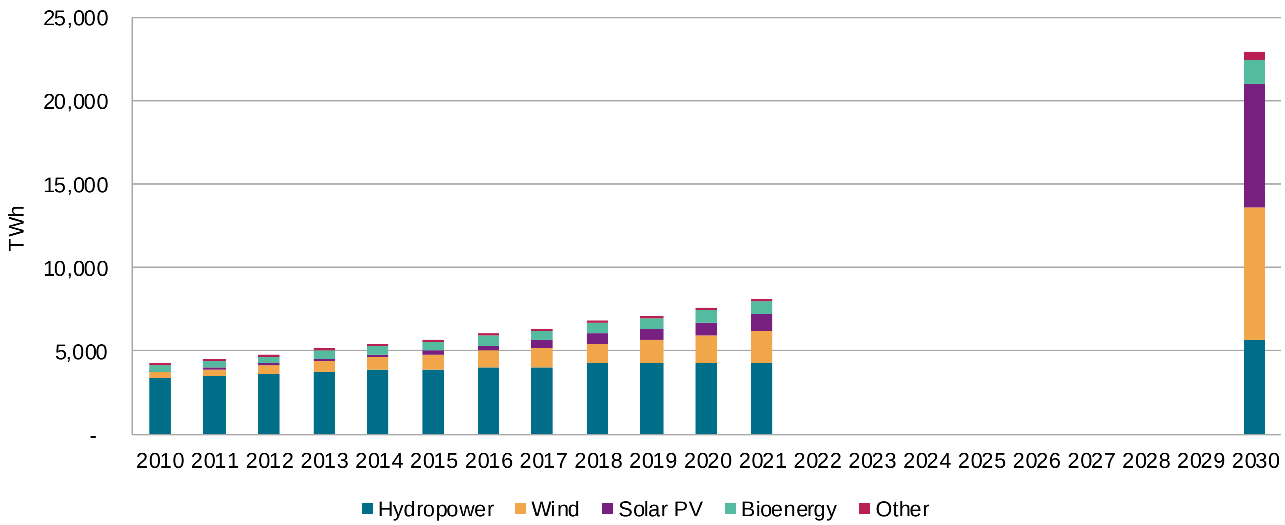
[19] IPCC, https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/

[20] https://ourworldindata.org/emissions-by-fuel

[21] https://www.iea.org/reports/net-zero-by-2050

However, given renewable energy generating capacity today, there is still a large gap in production capacity that remains. The IEA calculates that in 2020, renewable electricity generation increased by 7%, but to meet net zero targets with renewables, a 12% per year increase in generating capacity is needed until 2030.[22] Exhibit 14 considers the net zero pathway, which contrasts with the Stated Policies Scenario (STEPS) pathway we have used in the framework and is more conservative because using net zero or Sustainable Development Scenario (SDS) could potentially overstate the demand for metals in the transition.[23] Regardless, even though the net zero pathway reflects a more aggressive demand scenario than the one used for our model, it illustrates the need for potential substitutes while supply of renewable energy infrastructure catches up to needed demand for the transition.

Exhibit 14: Renewable Power Generation by Technology in Net Zero Scenario 2000-2030



Source: IEA. Data as of September 2022 (https://www.iea.org/data-and-statistics/charts/renewable-power-generation-by-technology-in-the-net-zero-scenario-2010-2030). Data not available for STEPS, only for NZ and SDS. Chart is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions which may not be realized, and which are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

The role of natural gas in the transition is a temporary but potentially impactful one, as it provides a transition path from coal in the short term while the renewable energy source supply gap is filled. The IEA recognizes the relevance of gas as a transition commodity to replace coal-powered energy systems due to two main factors: (1) lower GHG emissions from natural gas versus coal as evidenced in Exhibit 15, and (2) natural gas can use existing energy infrastructure to provide equivalent energy services but with less emissions; thereby providing a technologically feasible and immediately scalable tool to cut emissions in the short term.[24]

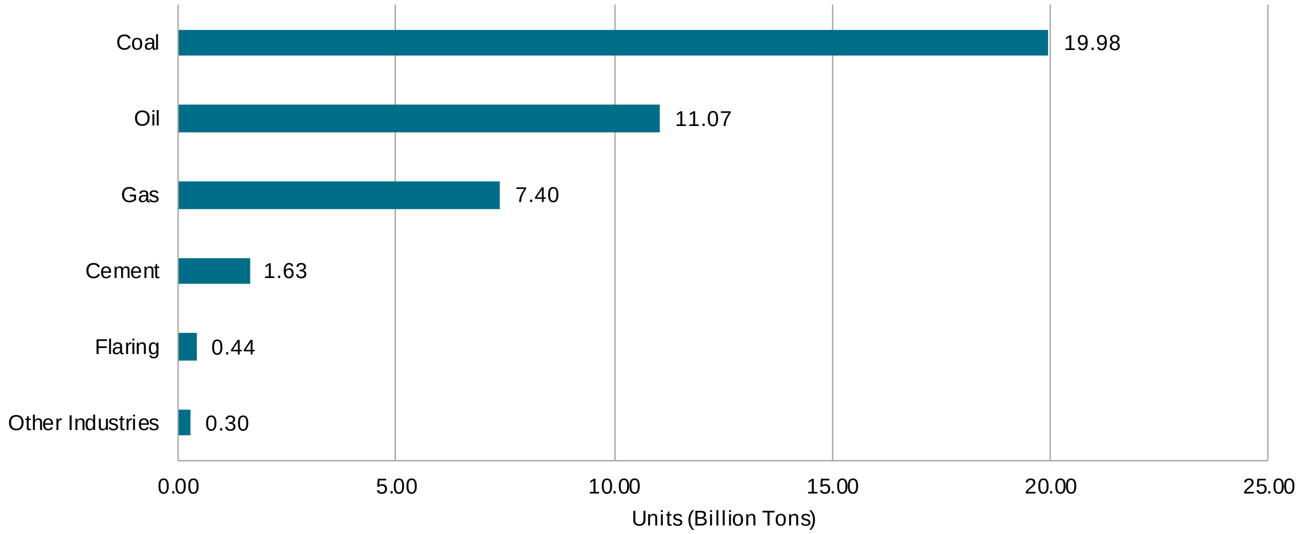
[22] https://www.weforum.org/agenda/2021/12/doubling-renewable-energy-net-zero-emissions/

[23] https://www.iea.org/reports/global-energy-and-climate-model/stated-policies-scenario-steps

[24] https://www.iea.org/fuels-and-technologies/gas

Alongside the IEA, the EU has also added natural gas and nuclear energy, with certain restrictions, as transitional activities under the EU Taxonomy.

Exhibit 15: Global CO_2 Emissions by Fuel



Source: Ritchie, Roser and Rosado. Data as of December 2022. "CO_2 and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions. Chart is provided for illustrative purposes.

While coal is not part of the S&P GSCI, we calculate the EDR for natural gas based on its role in displacing coal, in line with the analysis from the IEA and others. In the long term, to reach sustainability targets, renewable energy needs to bend the growth profile of coal and natural gas-fired power. As such, in this framework natural gas is expected to migrate from being a transition commodity to a displaced commodity toward the end of the decade, in line with the EU Taxonomy.

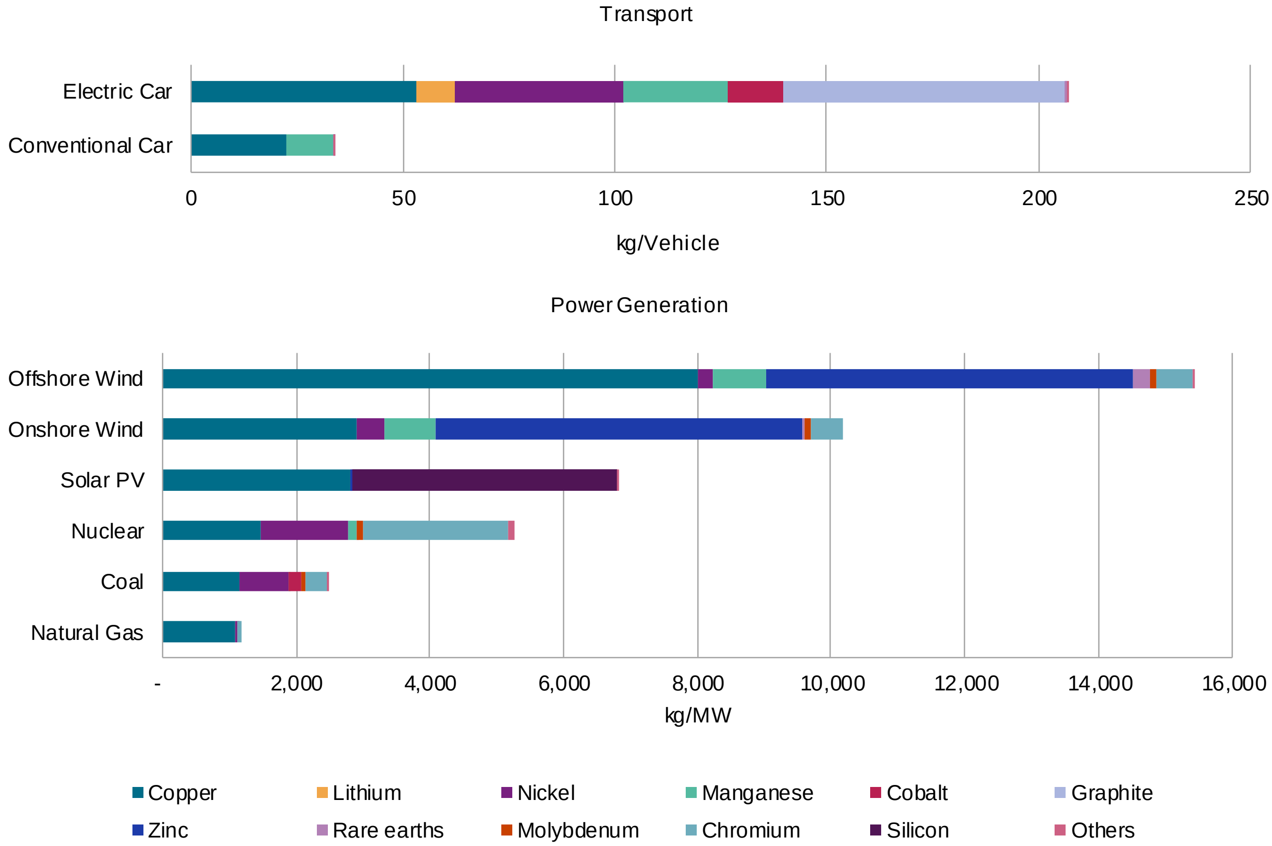
Metals Needed for Transition

Two major trends underlie most projections to net zero:

1. An increased share of electricity for end use in the economy (“electrification”); and
2. Renewable energy sources need to contribute a higher proportion of power generation.

Both point to substantially larger consumption of metals, as illustrated in Exhibit 16.

Exhibit 16: The Role of Critical Minerals in Clean Energy Transitions



Source: IEA. Data as of September 2022 (https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions). Charts are provided for illustrative purposes.

To highlight a few examples:

- Nickel is crucial to battery storage;
- Copper and aluminum are essential to electricity networks;
- Zinc is used in offshore wind development; and
- Silver is used in solar photovoltaic technology.

As of now, fossil fuels represent a much larger portion of world GDP than energy transition minerals. However, according to the IEA's report, increased demand from energy transition metals is expected to overtake fossil fuels by 2040. The STEPS scenario, used for our model, assumes a doubling of mineral demand from low-carbon power generation.[25] Projections are subject to large uncertainties, including the aggressiveness of the scenarios used. For example, in the net zero by 2050 emissions scenario, the demand boom would lead to a six-fold increase in the value of metal production—totaling approximately USD 12.9 trillion over the next two decades[26] for the four energy transition metals alone (on copper, nickel, cobalt and

[25] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions

[26] https://www.imf.org/en/Blogs/Articles/2021/11/10/soaring-metal-prices-may-delay-energy-transition

lithium), providing significant windfalls to producers. This would rival the potential value of global oil production in that scenario.[27] In line with these projections, the index counts S&P GSCI's industrial metals (excluding lead) and silver as transition commodities displacing fossil fuels. It is important to acknowledge that not all metal demand will be from the clean energy transition. Traditional demand, along with undefined future needs in metals, will remain as they are essential raw materials in construction, electronics and medicine, among others.

The same IEA report articulates projections around several scenarios drawn out to 2040. Comparing the STEPS scenario with a hypothetical scenario where the current primary energy supply prevails unaltered, we then compute avoided environmental impacts. This in turn informs the calculation of EDRs for metals.

Alternative Fuels: Sugar, Sugar Cane and Beet

Biofuels have long been part of the automotive fuels mix in certain regions, such as Brazil and North America. The wider transport sector is increasingly aware of their potential as a means to abate emissions: continued enhancements in "ethanol to jet" technologies are helping airlines source sustainable aviation fuel; and seaborne freight is turning to bio-methanol as an alternative to fuel oil, etc.[28]

Many types of feedstocks can be used, including food chain waste products in some cases. Local agricultural supply chains typically drive the choice of inputs, with sugarcane, corn, wheat and beet playing major roles globally. In some instances, this can give rise to a fuel versus nutrition debate regarding the most appropriate usage of those raw materials.

While sugar is a food commodity, it is often considered a discretionary item, as compared to grains that play a critical part in human and animal nutrition. Therefore, using some of the sugar supply for fuel is at less risk of exacerbating food scarcity issues. In Brazil, where highly efficient sugarcane mills are often co-located on plantations, the LCA of bioethanol GHGs is also typically estimated to be lower than that observed using North American grain feedstocks.[29]

Because of this, we select sugar as a proxy for sugarcane and compare ethanol with gasoline. Leaving aside their respective production LCAs, in-use gasoline obviously emits large amounts of GHGs. The same is true of bioethanol, however that CO_2 has been sequestrated in the first place through photosynthesis in the field. This all-in LCA comparison again informs the calculation of the relevant EDR.

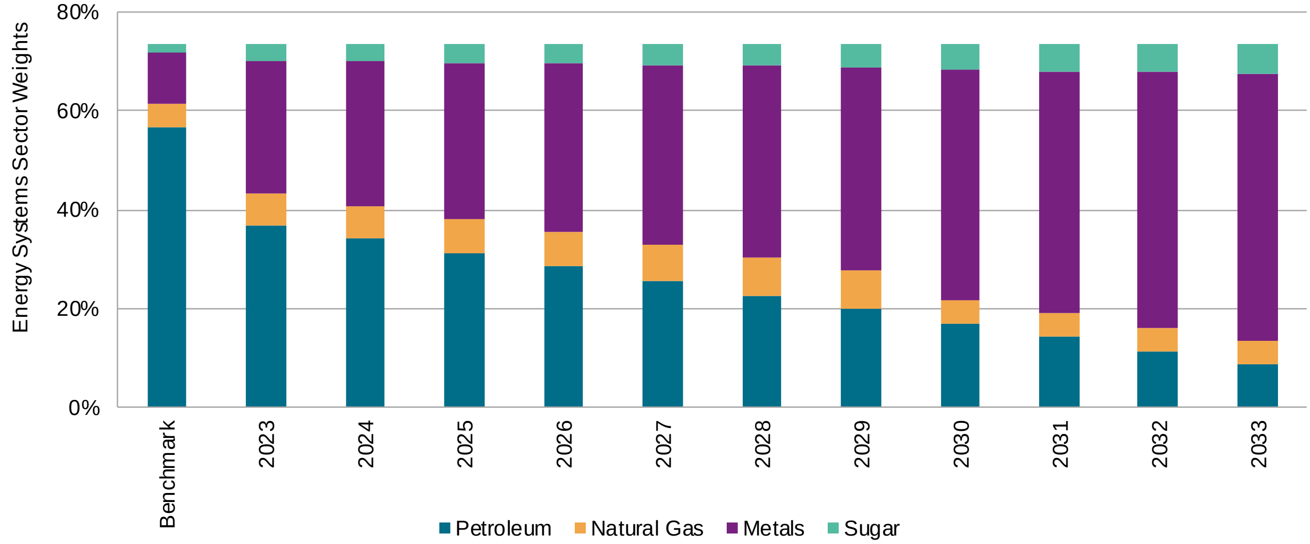
[27] International Monetary Fund. World Economic Outlook, October 2021: Recovery During A Pandemic. Please note their analysis was based on the net zero by 2050 emissions scenario.

[28] iata.org, Sustainable Aviation Fuel

[29] Department of Energy's Office of Scientific and Technical Information (OSTI) https://www.osti.gov/biblio/1512665

Exhibit 17 outlines a comparison of benchmark weights per sector attributed to energy systems versus new weights over time upon applying substitutions of transition to displaced commodities. It assumes an overall target reduction of 35% in year one with incremental 5% reductions thereafter. The total weight for energy transition by design is stable.

Exhibit 17: Energy Systems Sector Weights by Transition Year



Source: J.P. Morgan. Data as of January 2023. Chart is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions which may not be realized, and which are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

Food Supply

Although food is vitally important as the global population increases, its production and consumption have a large negative environmental impact,[30] including the following aspects.

- GHG Emissions: Food accounts for over one-quarter (26%) of global GHG emissions;
- Land Use: Half of the world's habitable land is used for agriculture; and
- Water Usage and Pollution: 70% of global freshwater withdrawals are for agricultural uses and 78% of pollution of waterways with nutrient rich pollutants (eutrophication) is caused by agriculture.

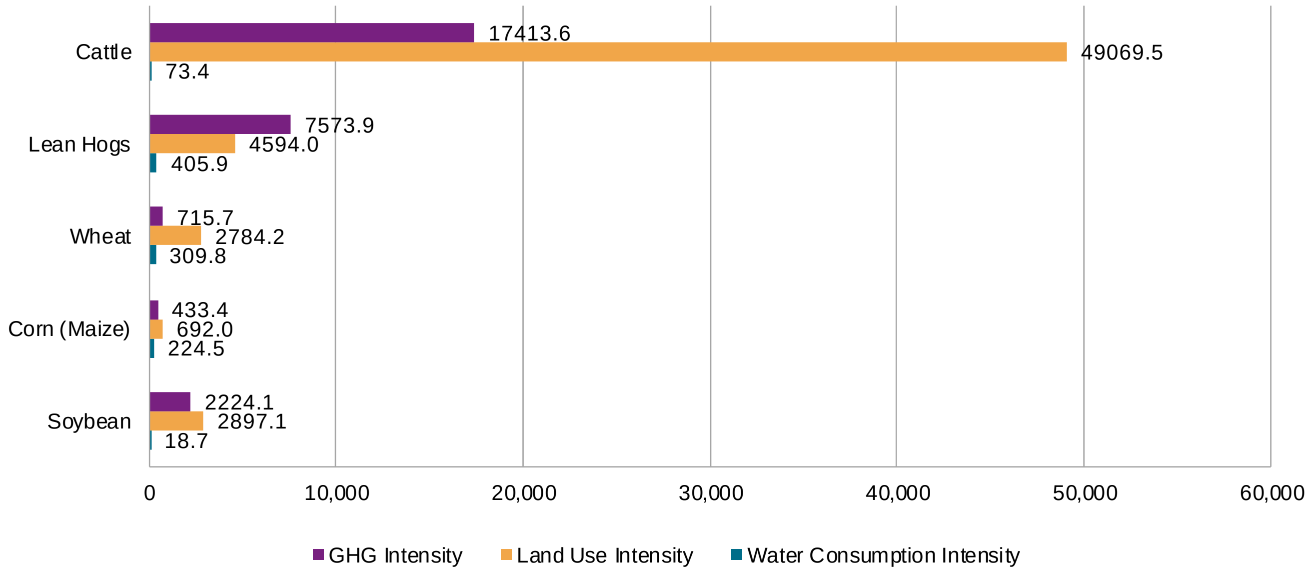
Given these considerations, the food system has an integral role to play in tackling environmental stresses. While sustainability gains can be achieved through improved farming and land management practices, the largest gains stand to be made from reducing meat consumption in favor of plant-based food sources. Excluding animal products from diets would cut GHG emissions from the food supply chain by 50%, and reducing animal consumption by

[30] https://ourworldindata.org/environmental-impacts-of-food

50% would achieve a 71% reduction if above median impact production were curtailed.[31] While the universe of food commodities is quite broad, for the purposes of this paper, we focus our analysis on those commodities included in the S&P GSCI, specifically those that are essential to nutrition (i.e., grains and livestock, excluding soft commodities).

Exhibit 18 illustrates the environmental impact (GHG emissions, water consumption and land use) from the production of a selection of plant- and animal-based food commodities.

Exhibit 18: Sample of Externality Intensity of Select Agricultural Commodities



Source: S&P Global Sustainable1. Data as of January 2023. GHG ($kgCO_2e$ per unit of production); water (m3 per unit of production); land use (m2 per unit of production). Chart is provided for illustrative purposes.

Overall, animal-based foods account for more negative environmental externalities than plant-based foods. Plant-based foods are also used as feedstock for animals, including cattle and hogs, further increasing GHG emissions attributed to meat. Therefore, the substitution of low impact food sources versus high environmental impact sources is likely to deliver greater environmental benefits.

At the same time, while the environmental footprint of livestock production is high and the need to reduce meat consumption is widely accepted, it is not as clear cut as for fossil fuels, e.g., not all land available for livestock is suitable for plant-based food production, and crop monocultures can be detrimental to biodiversity.

Opponents of a consumer behavior led decarbonization of our food supply chains might argue that plant-based diets are not equipped to meet nutritional needs, especially with regard to

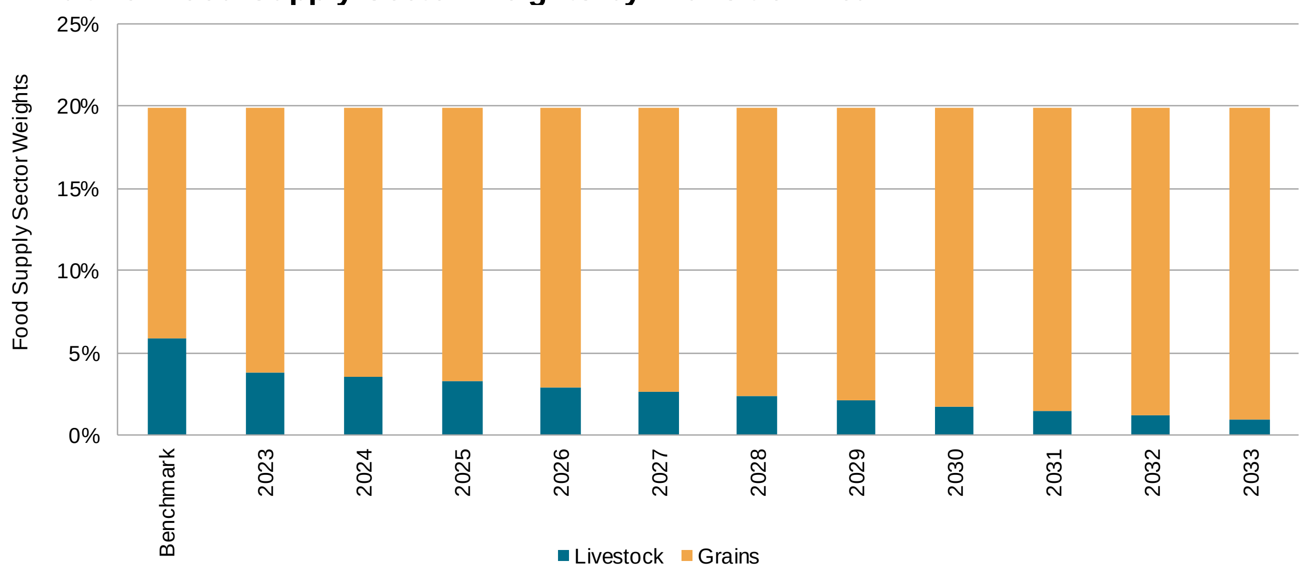
[31] Poore & Nemecek's *Reducing food's environmental impacts through producers and consumers* (2018), Poore, University of Oxford researcher https://josephpoore.com/. Nemecek, PhD Agricultural Systems and Technology Sciences and Leads Life Cycle Assessment Group, Agroscope https://www.agroscope.admin.ch/agroscope/en/home.html

protein consumption. However, wheat already accounts for 41% of global protein intake.[32] Additionally, environmental impact normalized by mass, caloric and protein values demonstrate a consistent pattern of higher environmental cost for animal versus plant-based food commodities- regardless of the unit of measurement. As an example, wheat has approximately the same quantity of protein per MT as live cattle (approximately 12.5% each for soft red winter wheat and live cattle, with hard red winter wheat at approximately 14.5%).[33]

Therefore, for the purposes of determining the EDR of the agricultural commodities in the food supply sector, we assume a displacement ratio of 1 MT to 1 MT from animal-based to plant-based food supply related commodities.

Exhibit 19 compares the original benchmark weights with sector weights of the substitution over time from meats to grains using a 35% overall reduction target in year one with incremental 5% reductions thereafter.

Exhibit 19: Food Supply Sector Weights by Transition Year



Source: J.P. Morgan. Data as of January 2023. Chart is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions which may not be realized, and which are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

[32] Poore & Nemecek's *Reducing food's environmental impacts through producers and consumers* (2018)

[33] USDA, Food Data Central Search Database (https://fdc.nal.usda.gov/fdc-app.html#/) and *Cattle:* https://extension.psu.edu/understanding-beef-carcass-yields-and-losses-during-processing#:~:text=As%20a%20general%20rule%2C%20most,may%20affect%20the%20carcass%20weight

3. Select Target Reduction for Displaced and Other Commodities

This framework can be used to assess the aggressiveness of transition desired for an index. The reduction target is a function of a percentage decrease in exposure to all commodities in the displaced category.

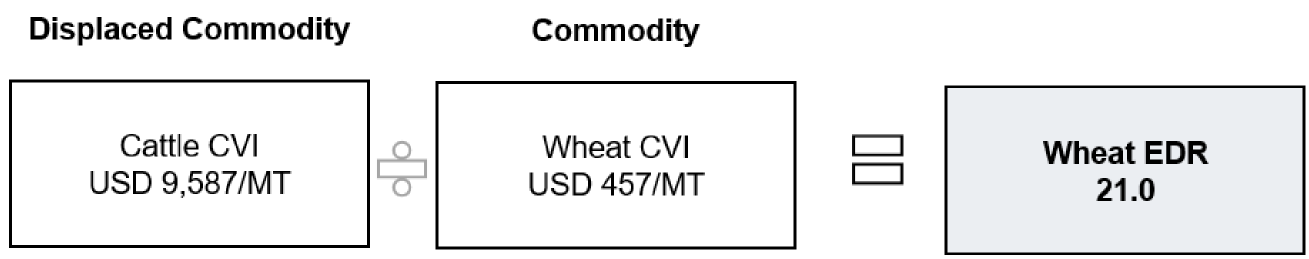
Sample Target: 35%/5%

Using 35%/5% as a potential target accounts for desired diversification per commodity and maintains (i) no more than 20% allocation in any one commodity related constituent, and (ii) only one commodity and its related constituent that may exceed 20% up to 35%.

4. Calculated EDR for Transition Commodities

For transition commodities, such as copper or wheat, we calculate a displacement value from the positive environmental impact due to the abatement of consumption of the displaced commodity (e.g., fossil fuels or cattle). The EDR is the displaced (avoided) environmental impact divided by the environmental footprint coming from the consumption of the commodity. Negative externalities are measured using S&P Global Sustainable1's CVI per unit of production data. To calculate the displacement value (numerator), we calculate the environmental footprint of the commodity that has been displaced (substituted). For example, if we assume 1 MT of wheat displaces 1 MT of cattle, the EDR for wheat would be the environmental footprint of cattle divided by the environmental footprint for wheat. In this instance, the S&P Global Sustainable1 CVI per unit of the relevant commodity is used as the numerator and the denominator (see Exhibit 20).

Exhibit 20: Calculating the Environmental Displacement Ratio



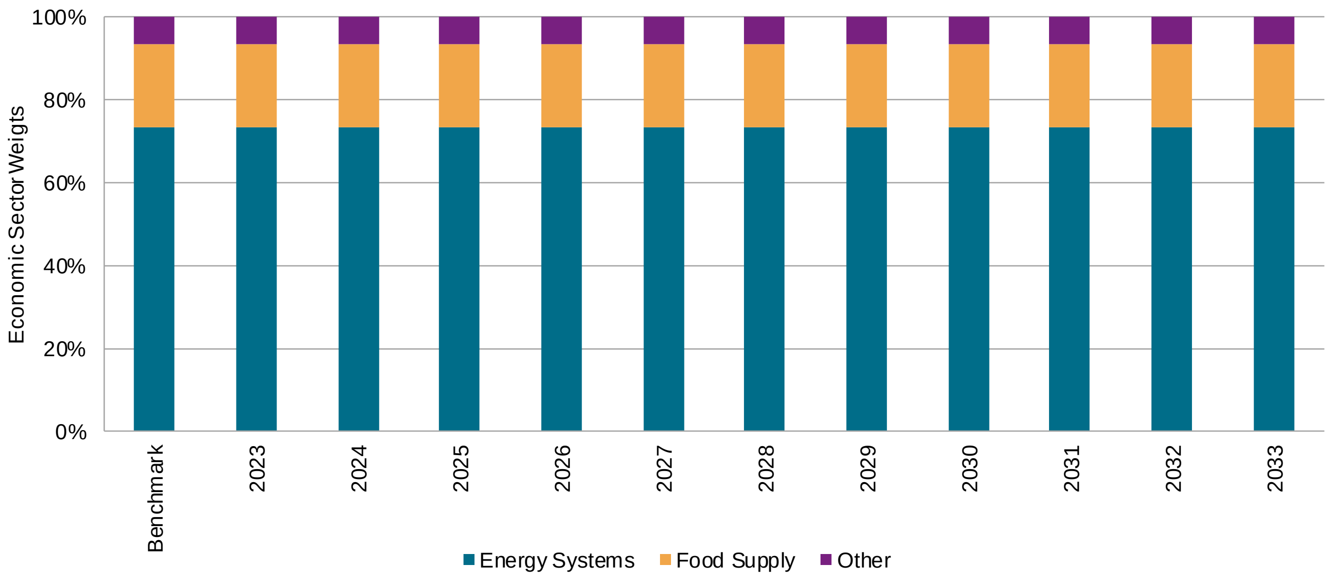
Source: J.P. Morgan, S&P Global Sustainable1. Data as of January 2023. Chart and table are provided for illustrative purposes.

5. Blend EDR with Index Weight to Determine New Weights for Transition Commodities

To determine the weight of transition commodities, we allocate the residual index weight from reductions in the displaced commodities, proportionally based on a blend of the respective EDR and the weight of the component in the S&P GSCI.

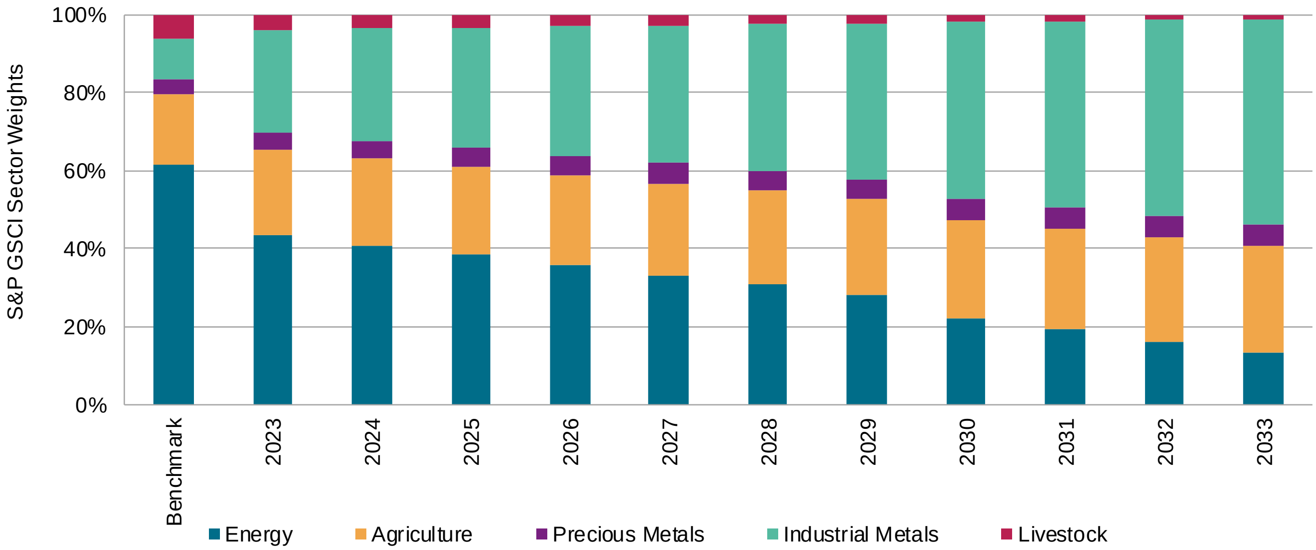
Exhibit 21 illustrates the calculation reflecting a 35% decrease as the selected reduction target for displaced commodities. This target is further reduced by 5% per year. By design, as reduction targets increase, weights for displaced commodities (petroleum and livestock) decrease, while weights for transition commodities (natural gas, base metals, sugar, grains and oilseeds) increase, with allocations per economic sector kept stable over time.

Exhibit 21: Illustrative Weights for New Index with Sample Target Reduction of 35%



Source: J.P. Morgan. Data as of January 2023. Charts are provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions which may not be realized, and which are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

Exhibit 21: Illustrative Weights for New Index with Sample Target Reduction of 35% (cont.)



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6. Allocate Residual Weight from Other Category to Carbon Allowances (e.g., EUAs)

The index's other sector accounts for soft commodities excluding sugar (coffee, cotton, cocoa) and metals (gold, lead), while including new instruments such as EUAs, which will be a factor in the energy transition.

Although there are negative environmental externalities associated with these commodities, their impact when compared to the aforementioned fossil fuel commodities and livestock tends to be less. For this version of the index, other than potential carbon offsets achieved through tradeable instruments like EUAs, no further substitutions are made in these commodities. EUAs are used versus carbon credits in the voluntary carbon markets (VCM) space due to liquidity considerations. Exhibit 22 shows a sample set of weights for a 10% reduction in commodities in the other sector.

Exhibit 22: Other Sector Weights by Transition Year

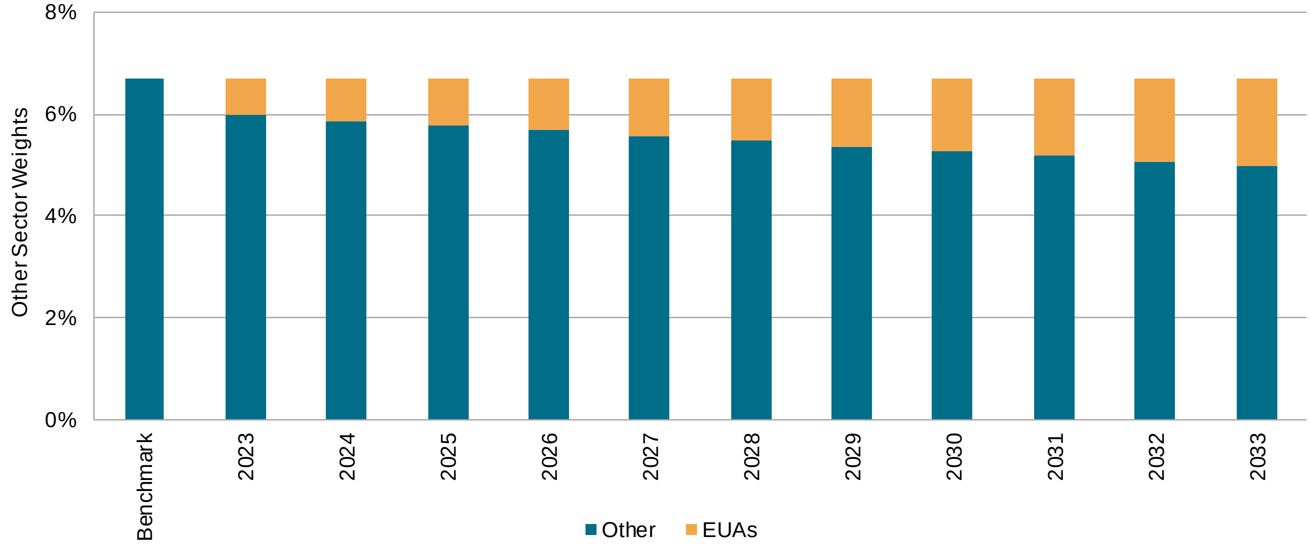

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Exhibit 23 provides summary statistics for the EDR index compared to the benchmark.

Exhibit 23: Summary Statistics for Substitution Index Over Time

Metric	Benchmark	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Active Share (%)	-	22.6	25.8	29.1	32.3	35.5	38.8	42.0	45.2	48.5	51.7	54.9
Active Risk (% Annualized)	-	6.0	6.8	7.7	8.6	9.4	10.3	11.1	12.3	13.2	14.1	15.0
Inflation Beta	12.6	10.4	10.1	9.8	9.5	9.2	8.9	8.6	8.0	7.6	7.3	7.0
Commodity Valuation Intensities (per USD 100 Invested)												
Total CVI	125.9	117.6	116.4	115.2	114.0	112.9	111.7	110.5	100.0	98.1	96.3	94.4
% Change	-	-6.6	-7.5	-8.5	-9.4	-10.3	-11.3	-12.2	-20.6	-22.0	-23.5	-25.0
GHG CVI	90.7	81.9	80.7	79.4	78.2	76.9	75.7	74.4	63.5	61.6	59.6	57.7
% Change	-	-9.7	-11.0	-12.4	-13.8	-15.2	-16.6	-17.9	-30.0	-32.1	-34.2	-36.4
Water CVI	1.2	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.8
% Change	-	18.7	21.3	24.0	26.7	29.3	32.0	34.7	38.9	41.6	44.4	47.2
Land CVI	33.9	34.2	34.2	34.3	34.3	34.3	34.4	34.4	34.8	34.8	34.9	34.9
% Change	-	0.7	0.8	0.9	1.0	1.1	1.2	1.3	2.4	2.6	2.8	2.9

Source: J.P. Morgan. Data as of January 2023. Table is provided for illustrative purposes. Any forward-looking financial projection is subject to a number of risks and uncertainties, and actual results may differ materially. This forecast is only a prediction and only speaks as of the date provided. No assurances can be given that the future results indicated will be achieved. While sometimes presented with numerical specificity, these projections are based upon a variety of assumptions which may not be realized, and which are variable. The assumptions underlying the projections are subject to significant uncertainties and contingencies that are beyond the reasonable control of S&P DJI.

Next Steps

The focus of this paper has been to explore various approaches to adjusting the S&P GSCI to incorporate environmental footprint data. Its scope has been deliberately narrow, and we acknowledge that there is significant need for additional research and discussion. The following topics deserve specific consideration.

1. The focus on the environmental impact of commodities in the first instance is logical, but the social and governance issues associated with commodities are wide, varied and a natural evolution of this paper.
2. The environmental data presented in this paper, like all environmental data, is open to interpretation and potential debate. Likewise, the calculation of both negative and positive externalities has been made based on existing data and will undoubtedly be refined over time.
3. This paper is based on the hypothesis that commodity futures have an indirect environmental footprint, predicated on futures' role in enabling producer to investor risk transfer. Quantifying this effect is an important topic, worthy of further investigation.
4. The evolution of new tradeable derivatives such as voluntary carbon futures, but also differentiated contracts (e.g., sustainable cocoa futures contract) are likely to present opportunities for new climate aware commodities indices notwithstanding the initial liquidity challenges.

Conclusion

In this paper, we presented a potential environmental transition framework for commodities. Two possible methodologies were articulated: the first takes an Optimization Approach and accounts for only negative environmental externalities; and the second considers a Substitution Approach, which includes the first method and adds a positive environmental externality factor through the concept of EDR. Assumptions on commodity substitutions and limitations to the current model, including the lack of social and governance variables, are stated alongside potential next steps in further iterations of the framework. Glidepaths based on different desired decreases of harmful GHG impact were outlined and reflected in new weightings of individual commodities and categories within the index.

References

S&P GSCI Methodology

S&P Global Sustainable1 Commodity Environment Data Methodology

Performance Disclosure

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