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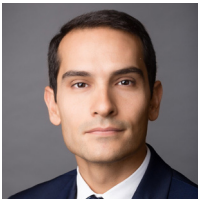
Climate Solutions Investments

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and Hui (Stacie) Wang



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Climate Solutions Investments

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KEY FINDINGS

- We demonstrate how investors can build a portfolio of climate solutions using a framework that identifies publicly traded pure-play companies providing decarbonization products or services from key business areas central to climate change solutions.
- We find such a portfolio of climate solutions is characterized by almost half of market value in emerging markets, higher revenue growth, and higher investments but lower profitability margin, relative to the market portfolio.
- The portfolio exhibits superior stock market performance since 2018, driven by solutions in energy, fuels, battery, and transportation.

ABSTRACT

An increasing number of companies are providing products and services that help reduce carbon emissions in the economy. The authors develop a methodology to identify those companies and create a sample of publicly listed climate solutions companies, allowing the authors to study their geographic composition, accounting fundamentals, valuation ratios, and stock performance over time. The sample is equally split between developed and emerging markets, with a significant number of companies located in China. A portfolio of climate solutions companies exhibits higher revenue growth, higher investments in research and development and talent, and lower profitability margin. Portfolio returns are higher for solutions in energy, fuels, battery, and transportation themes and exhibit very little correlation with the returns of portfolios that seek to reduce their carbon emissions by underweighting high-carbon-emission companies, suggesting that climate solutions portfolios are distinct from low-carbon-emission indexes.

Climate change and the associated policy, technological, legal, consumer, and employee responses to it have given rise to increasing requests by asset owners to lower carbon emissions in portfolios and reduce exposure to transition risk. In turn, an increasing number of climate funds and indexes have been launched. Most of these financial products seek to reduce the carbon footprint of a portfolio by excluding firms with very high carbon intensity (i.e., carbon emissions scaled by firm revenue to account for the fact that emissions scale with economic activity). Examples of these products include MSCI All Country World Index (ACWI) Low Carbon Index and MSCI ACWI Climate Change Index. Some products compare firms irrespective of industry membership, whereas others create best-in-class benchmarking, thereby allowing representation of all industries. A key characteristic of these products is that they achieve significant lowering of portfolio carbon emissions relative to the

benchmark while still achieving very low tracking error. In that sense, they allow an investor to reduce exposure to policy responses, such as carbon taxes, while offering risk–return profiles similar to the market (Andersson, Bolton, and Samama 2016).

Such low-carbon portfolios, although they could lower exposure to climate risk, do not necessarily provide an investor with exposure to climate opportunities. The transition to a low-carbon economy requires the development, deployment, and scaling of several key new technologies, products, and services. These climate solutions include renewable energy, electrification of transportation and processes, battery technology, energy and process efficiency, circularity, new agricultural practices, and plant-based protein alternatives to meat. These solutions should see top-line revenue growth as the world proceeds to decarbonize and meet the goal of reaching net-zero emissions close to mid-century, a goal that the scientific community agrees to be necessary to stay well below a 2°C increase in temperature before the end of the century (Intergovernmental Panel on Climate Change 2021). It is estimated that the next-generation climate-related technologies could attract \$1.5 trillion to \$2 trillion of capital investment per year by 2025 (Hellstern et al. 2021). To access these markets, considerable understanding of the new technologies, policies, and market demand is needed, which could be a formidable task for investors.

Several *pure-play* portfolios and indexes provide exposure to such climate solutions, such as companies engaged in clean tech, renewable energy, and energy storage. Examples include S&P Clean Global Clean Energy and NASDAQ Clean Edge Green Energy. However, to our knowledge, there is currently an absence of a systematic process through which an investor could identify climate solutions companies, making it challenging to scope the size of the market and its geography. In turn, the lack of process for constructing a sample of climate solutions companies inhibits the systematic study of their accounting and stock market performance over time.

In this article, we develop a process that allows us to identify a large set of companies that are publicly listed around the world. We limit our analysis to companies that are publicly listed because of data availability. However, we note that there are many climate solutions companies that are privately held, a limitation of our analysis.

Our process relies on reviewing international reports, regional net-zero frameworks, research papers, and relevant news, from which we identify 9 business areas central to climate change solutions: agriculture and food; building and housing; carbon capture, utilization, and storage (CCUS); energy generation; energy storage; materials; nature-based solutions; recycling and circularity; and transportation. Within each business area, we conduct a thorough investigation to assess the landscape of climate technology and innovation. From this research, we generate a list of 164 relevant keywords and phrases specific to these business areas and identify those in company business descriptions. To keep our sample and analysis as sensitive as possible to exposure to climate opportunities, we exclude companies for which only part of their business is related to climate solutions, for example, an automobile manufacturer that provides both electric and internal combustion engine vehicles. The drawback of this choice is that our sample underestimates the total number of companies and size of the publicly listed climate solutions market. However, this is outside the scope of our article. We knowingly make a tradeoff to construct a purer but incomplete climate solutions sample, compared to a complete but contaminated with non–climate solutions sample.

After excluding companies with very limited stock market liquidity and very low market capitalization, we are left with 632 companies. This represents a much larger sample compared to the 50–60 companies usually found in pure-play climate products, allowing an investor to deploy more capital across a more diverse set of economic activities and regions. Related to regions, one significant finding is the presence of climate solutions companies in emerging markets. Almost half of companies

(and market capitalization) of the sample are in emerging markets, with China representing the biggest country allocation on an equally weighted basis and roughly equal to the US on a market capitalization basis. This finding has implications for the geographic location of where the innovation and solutions for climate are created as well as the political, currency, and regulatory risks that investors might assume as they seek exposure to climate solutions.

We find that climate solutions companies are less profitable but experience higher revenue growth than their industry peers. Moreover, they have both higher capital and research and development (R&D) expenditure intensities (e.g., scaled by firm revenues). Collectively, this evidence is consistent with a portfolio of climate solutions companies exposing an investor to lower profitability, higher top-line revenue growth, and investment firms that are focused on developing scale to provide solutions for their customers. Examining two key valuation ratios, earnings yield and book-to-market (BTM), complements this picture. The climate solutions portfolio exhibits lower earnings yield and BTM, consistent with the market reflecting the higher anticipated growth prospects and expecting that growth premium to materialize in the future. The one exception is that, on an equally weighted basis, the climate solutions portfolio exhibits higher BTM, a reflection of some smaller climate solutions companies facing financial difficulties.

We next turn to an analysis of stock performance using data from 2011 to July 2022. The climate solutions portfolio exhibits several characteristics that provide validation for its construction. First, it is highly correlated with pure-play indexes, such as S&P Global Clean Energy and NASDAQ Clean Edge Green Energy. Moreover, it shares with those indexes a high tracking error relative to the market index. Importantly, after accounting for market returns, there is close to zero correlation between the returns of the climate solutions portfolio and low-carbon indexes, suggesting that the two products are distinct. Although the low-carbon index seeks to reduce the exposure of an investor to high-carbon businesses that might be disrupted by regulatory and technological developments, the climate solutions portfolio provides an investor with exposure to innovative and growing businesses that seek to capitalize on the transition to a low-carbon economy.

We decompose the stock performance of the climate solutions portfolio and find that its superior performance, relative to market and other factor exposures (i.e., value, size, momentum, investment, profitability), is concentrated in several ways: from a timing perspective, in the last 4 years; from a geographic perspective, in developed markets primarily but also in emerging markets excluding China; and from a solutions perspective, in energy, fuels, battery, and transportation. These results provide a deeper understanding of the performance of the climate solutions portfolio.

SAMPLE SELECTION AND DATA

To construct our sample, we first set out to better understand the breadth of climate change solutions within the global economy. We reviewed international reports, regional net-zero frameworks, research papers, and relevant news, from which we identify 9 business areas central to climate change solutions: agriculture and food; building and housing; CCUS; energy generation; energy storage; materials; nature-based solutions; recycling and circularity; and transportation. Within each business area, we conduct a thorough investigation to assess the landscape of climate technology and innovation. From this research, we generate a list of 164 relevant keywords and phrases specific to these business areas: 23 keywords and phrases relate to agriculture and food (e.g., plant based); 6 to building and housing (e.g., green building); 17 to CCUS (e.g., carbon sequestration); 51 to energy generation (e.g., solar

power); 28 to energy storage (e.g., lithium oxygen battery); 8 to materials (e.g., sustainable cement); 5 to nature-based solutions (e.g., carbon offset); 11 to recycling and circularity (e.g., circular economy); and 14 to transportation (e.g., electric vehicle [EV]). In addition, we identify 23 keywords and phrases related to general climate change solutions (e.g., low carbon) to account for any unacknowledged solutions both within and outside of the 9 business areas. Our final list consists of 187 climate change solution terms.¹

Using global corporate databases provided by Worldscope and S&P Global Market Intelligence, we identify firms as of March 2, 2021, with business descriptions that incorporate at least one term from our list.² Of these firms, we limit our sample to only those publicly listed at present or those publicly listed at any point in the past. Specifically, we include only active and inactive public firms, thereby excluding firms that have always been private because these companies do not have data for the analyses we perform. We keep inactive firms to mitigate survivorship bias. For these companies, we download financial data from Worldscope and S&P Global Market Intelligence and supplement these data using Bloomberg, FactSet Research Systems, S&P Capital IQ, and the International Securities Identification Number (ISIN) Database.³

To continue refining our sample, we remove companies primarily operating in industries traditionally unrelated to climate change solutions. These industries include health care, communications, and financials.⁴ In addition, duplicate observations are identified and removed based on company name, ISIN, and six-digit Committee on Uniform Securities Identification Procedures (CUSIP) number.⁵ At this stage, the sample contains a unique list of active and inactive public firms operating within climate change solution industries.

To limit our sample to pure-play companies, we employ negative and positive screening techniques. We are interested in constructing a sample of pure-play companies, so the economics of the business are driven by the climate solutions they are providing instead of those solutions representing a small part of the business. For example, although BMW offers some EVs, BMW is not classified as a climate solutions company, given that the company's primary set of products is internal combustion engine vehicles. For each screen, we search business descriptions for relevant terms. We utilize all S&P Global Market Intelligence and Worldscope data in our screening process, including data from observations removed in prior steps. Hence, companies with observations from both S&P Global Market Intelligence and Worldscope often

¹These 187 keywords and phrases include conventional spelling and grammar variations for relevant terms. For example, net zero and net-zero are frequently used interchangeably. Both have been included in our list.

²The Worldscope corporate data were downloaded for all active and inactive public companies for the year 2019 from Worldscope Annual Fundamentals accessed via Wharton Research Data Services (WRDS). S&P Global Market Intelligence corporate data were downloaded for all active and inactive public companies as of March 2, 2021, from the S&P Global Market Intelligence web platform.

³The supplemental ISIN data were obtained from Bloomberg, FactSet Research Systems, S&P Capital IQ, and the ISIN Database.

⁴Due to inconsistencies in availability of industry-level data provided by Worldscope and S&P Global Market Intelligence, we map two-digit Standard Industrial Classifications (SICs) onto Global Industry Classification Standard (GICS) Level 1 Sectors. In doing so, we are able to assign a GICS Level 1 Sector to all observations in the data. We then remove the following GICS Level 1 Sectors: health care, communications, and financials. In addition, for observations with S&P Global Market Intelligence Second Level Primary Industry data, we remove companies operating in the media industry. The S&P Global Market Intelligence Second Level Primary Industry variable is only populated for observations downloaded from S&P Global Market Intelligence.

⁵The first six digits of a CUSIP are unique to the issuing firm of a given security. Legal entity types traditionally used in company names are standardized across sources to better identify duplicate observations. For example, company names ending in incorporated and incorporation are all given the common suffix Inc.

have multiple business descriptions. Before conducting these screens, we systematically review the content and structure of the business description data to ensure each description is informative of firm operations. We find that business descriptions from Worldscope associated with current and former special purpose acquisition companies are generic and often uninformative of current company operations. For these firms, we download new business descriptions from Bloomberg and use these descriptions in place of those from Worldscope.

We first employ a negative screen to exclude companies that engage in business practices unrelated to climate change solutions.⁶ Companies are removed from the sample if any of their business descriptions contain at least one of the 21 negative terms. Examples of negative terms include coal, petroleum, and refinery. Conceptually, companies are not considered pure-play if they are described as operating in business segments external to climate change solutions.

Alternatively, to ensure that a company's primary business operations are climate solution centric, we employ a positive screen. Upon analyzing the business description data, we recognize that the first sentence of each description often begins with the company name followed by an explanation of primary business activities.⁷ Thus, we are able to use the content of the first sentence to assess whether a company is predominantly focused on climate solutions. Due to variation in punctuation usage within the business description data, we elect to search a string of characters approximately equivalent in length to that of the first sentence. We estimate the length of the first sentence to be approximately 100 characters. To be conservative and to treat companies with short and long names alike, we screen the sum of 200 characters and the number of characters in the company name.⁸ In the initial sample, a company name is on average approximately 25 characters in length. Thus, we search approximately the first 225 characters of each business description for any of the terms related to climate change solutions.⁹ Companies are included in the sample if any of their business descriptions contain at least one of the positive terms within the relevant portion of text. Following the positive screen, the sample consists of 944 firms.

We acknowledge the challenges associated with using industry data and business descriptions to identify pure-play climate change solution companies. Hence, we conduct a manual audit of the remaining firms in both samples to ensure continuity. From this review, we remove 27 firms. We also add 29 pure-play firms to the sample, identifying such firms through lists compiled by industry publications. Following these manual adjustments, the final sample consists of 946 firms.

⁶Unrelated business practices include those harmful to the climate as well as those external to climate change.

⁷Only a small portion of observations from S&P Global Market Intelligence include business descriptions that deviate from this structure.

⁸For observations in which the first sentence of the business description does not describe company operations, we analyze the structure, function, and length of the first sentence. We find these observations primarily consist of firms previously involved in acquisitions or firms previously having filed for bankruptcy. In either case, the second sentence in these descriptions contains an explanation of the company's primary business activities in the common structure (i.e., company name followed by a description of business activities). This sentence is preceded by one describing the bankruptcy filing or acquisition. We estimate the length of the first sentence for each case independently. Regardless of case, we find the first sentence of these business descriptions measures approximately 60 characters in length. For these observations, we screen the sum of the first 160 characters of the business description and the number of characters in the company name.

⁹The 187 keywords and phrases are the same as those used in the initial sample identification. For observations in which the first sentence of the business description does not describe company operations, we search approximately the first 185 characters (125 characters plus an additional 60 characters for the estimated length of the first sentence) of each business description for any of the positive keywords and phrases.

EXHIBIT 1**Sample Selection**

Screening Criteria	Number of Observations
Firms Identified in Keyword Search	
Thomson Reuters—Worldscope	3,041
S&P Global Market Intelligence	3,573
Active and Inactive Public Firms	6,614
Remove Observations in Unrelated Industries	
Less: Communication Services	43
Less: Financials	300
Less Health Care	10
Firms in Climate Solutions Industries	6,261
Remove Firm Duplicates	
Less: Duplicates	2,107
Unique Firms in Climate Solutions Industries	4,154
Business Description Keyword Screening	
Less: Negative Keyword Screen	2,184
Less: Positive Keyword Screen	1,026
Climate Solutions Firms	944
Manual Adjustments	
Additions	29
Removals	27
Climate Solutions Firms	946
Match Firms with Primary Securities in DataStream	
Less: Stocks Not Matched by ISIN	72
Less: Stocks Delisted before January 1, 2011	8
Climate Solutions Stocks	866
Illiquidity Stock Screening	
Less: Stocks Only Traded over the Counter or Exchange Not Identified	178
Less: Observations by Date and Stock with price <\$1 in DM and <\$0.10 in EM	56
Final number of climate solutions stocks	632

NOTES: This exhibit presents the sample selection process. Sample data are from Thomson Reuters Worldscope access via WRDS and S&P Global Market Intelligence. Worldscope Annual Fundamental data were downloaded for the year 2019. S&P Global Market Intelligence data were downloaded as of March 2, 2021. Active and inactive public firms are identified by searching Worldscope and S&P business description fields for a predefined list of 187 climate change solution terms. Duplicate observations are identified and removed based on company name, ISIN, and six-digit CUSIP. The negative screen includes 21 terms specific to business practices external to climate change solutions. The negative screen is applied to each full-length business description. The positive screen is applied to only a portion of each business description. The identified companies are then matched to their primary securities based on ISIN from DataStream. Observations are dropped from this study for the stocks that are only traded over the counter or miss trading exchange information or if the stock price is less than \$1 in the developed markets (DMs) or less than \$0.10 in the emerging markets (EMs).

Next, we match the companies by ISINs in our sample with their primary equity securities in DataStream from 2011 to Q1 2022. The total returns and market capitalizations in US dollars as well as primary exchange and delist information for these securities are collected from DataStream as well. On the basis of this matching, we are able to identify 874 stocks in this process. After removing eight stocks that were delisted before January 2011, we are left with 866 stocks.

We notice this sample of 866 stocks contains a number of illiquid securities that trade irregularly with low volume and exhibit extremely volatile returns. Some of these stocks are only traded over the counter or have the trading exchange information missing in DataStream. Moreover, because we have delisted stocks in our sample, even though we have filtered them out after their delist dates, we find that these securities could have little or no trading activity and price movement long before they are finally delisted. Given these considerations and that most investors would not invest in these very illiquid stocks, we drop stocks that are only traded over the counter or for which we cannot identify a trading exchange. In addition, we apply a filter requiring that prices be equal or greater than \$1 for the observations in developed markets and \$0.10 for the observations in emerging markets. After this process, we have a total of 632 stocks matched for our sample companies. Exhibit 1 summarizes the sample selection process.

Other data used in this study include valuation multiples such as earnings yield, BTM, and accounting ratios containing return on equity; 1-year revenue growth; selling, general, and administrative (SG&A) expenses/revenue; capital expenditure/revenue; and R&D/revenue, all obtained from the Refinitiv Worldscope Point in Time database.

PORTFOLIO CONSTRUCTION

On the basis of the list of stocks we identified from the previous section, we construct value-weighted and equally weighted climate solutions portfolios. These portfolios are formed at the end of 2010 and rebalanced monthly. On the rebalance day, which is the last business day of the month, the value-weighted portfolio is calculated based on the market capitalization weights of stocks in our sample from the previous business day, whereas the equally weighted portfolio is calculated based on an equal weighting of stocks in the sample from the previous trading day.

To have a better understanding of the evolution of climate solutions portfolios, we report characteristics and performance of these portfolios for our full sample period from January 2011 to July 2022 and also two subperiods—from January 2016 to July 2022 and from January 2018 to July 2022. We zoom in on the most recent subperiods because climate solutions businesses and activities of interest have only begun to develop recently. This is because developing a new technology in climate solutions and successfully bringing it to market can be a long drawn-out process.¹⁰ For example, in solar power generation, it took three decades of research and investment to achieve cost parity with coal in 2013 and gas power in 2015.¹¹ Therefore, we also look at the period since 2016, which is after the adoption of the Paris Agreement at Conference of the Parties of the UNFCCC (COP) 21 in December 2015, and since 2018, during which these climate solutions companies have started to gain momentum.

In addition, we also build portfolios for developed markets and emerging markets as well as for a few major regions such as the US, Europe, China, and emerging markets excluding China, respectively, to understand the market and regional differences.

KEY INSIGHTS

In this section, we document the key observations and findings based on our climate solutions portfolios. We start by examining statistics for our sample constituents by market/region and then focus on the fundamental characteristics by accounting and market valuation ratios. Furthermore, we document our findings regarding the tracking errors, correlations, and market performance of the climate solutions portfolios relative to market benchmarks and other climate change indexes.

The Anatomy of a Climate Solutions Portfolio

Panels A and B in Exhibit 2 present the average statistics for our sample climate solutions stocks from January 2011 to July 2022 by country/region. On average, we have 440 stocks across any given month, representing \$603 billion of market capitalization. Emerging markets have a very large presence—about 44% of the portfolio's market value is in emerging markets and about 55% in number of stocks while the rest is in developed markets, as shown in Panel B of Exhibit 2.¹² When breaking down by regions, we observe that the US and China have the largest share, about 35% each, followed by Europe at 12.9% and emerging markets ex China at 8.9% on average during this period.

This finding challenges the impression that developed markets dominate emerging markets in the domain of climate solutions. In fact, companies in emerging markets have been actively participating in transitioning to low carbon by providing climate-smart products and services. For example, China, relying on its growing economic and technological strength, is leading many developed countries in combating climate change with new technologies in batteries and EVs, stimulated by the government's preferential policies toward these new-energy technologies and businesses.¹³

¹⁰ According to the International Energy Agency (IEA). See <https://www.iea.org/reports/clean-energy-innovation/innovation-needs-in-the-sustainable-development-scenario>.

¹¹ Levelized cost of energy, levelized cost of storage, and levelized cost of hydrogen. Lazard, October 19, 2020, [lazard.com](https://www.lazard.com).

¹² Developed markets include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the US. All other regions and markets are classified as emerging markets in this study.

¹³ "China Becomes a Leader in Global War against Climate Change," Global Times.

EXHIBIT 2

Summary Statistics

Panel A: By Market (from January 2011 to July 2022)

ISO Alpha-2 Country Code	Average Market Cap (in million USD)	Average Market Cap as % of Total Sample	Average Number of Stocks	Average Number of Stocks as % of Total Sample
AU	1,262.59	0.21%	13.82	3.14%
BA	199.42	0.03%	3.00	0.68%
BE	217.98	0.04%	1.00	0.23%
BG	4.02	0.00%	1.00	0.23%
BR	6,959.06	1.15%	6.25	1.42%
CA	9,978.84	1.65%	32.34	7.35%
CH	4,016.75	0.67%	3.36	0.76%
CL	2,005.80	0.33%	1.88	0.43%
CN	210,510.68	34.90%	80.54	18.30%
CO	1,477.60	0.24%	1.19	0.27%
CY	49.92	0.01%	1.39	0.32%
CZ	9.49	0.00%	0.94	0.21%
DE	4,160.91	0.69%	14.32	3.25%
DK	20,571.18	3.41%	2.27	0.52%
ES	14,831.09	2.46%	6.10	1.39%
FI	894.31	0.15%	2.24	0.51%
FR	4,444.19	0.74%	8.89	2.02%
GB	2,062.84	0.34%	8.18	1.86%
GR	735.12	0.12%	1.00	0.23%
HK	15,032.51	2.49%	19.80	4.50%
HU	46.90	0.01%	1.00	0.23%
ID	138.00	0.02%	0.17	0.04%
IE	320.78	0.05%	0.43	0.10%
IL	1,706.04	0.28%	8.31	1.89%
IN	13,892.12	2.30%	52.49	11.92%
IT	5,238.98	0.87%	8.65	1.96%
JP	21,250.29	3.52%	10.68	2.43%
KR	6,293.04	1.04%	11.41	2.59%
LK	94.74	0.02%	4.00	0.91%
MA	201.23	0.03%	1.00	0.23%
MY	263.23	0.04%	6.97	1.58%
NL	179.19	0.03%	1.04	0.24%
NO	2,809.22	0.47%	7.10	1.61%
NZ	6,076.37	1.01%	3.48	0.79%
PE	1,459.74	0.24%	1.00	0.23%
PH	1,822.29	0.30%	0.71	0.16%
PK	316.33	0.05%	6.00	1.36%
PL	492.26	0.08%	8.27	1.88%
PT	9,131.18	1.51%	1.00	0.23%
RU	6,546.16	1.09%	3.00	0.68%
SE	858.16	0.14%	10.39	2.36%

(continued)

EXHIBIT 2 (continued)

Summary Statistics

ISO Alpha-2 Country Code	Average Market Cap (in million USD)	Average Market Cap as % of Total Sample	Average Number of Stocks	Average Number of Stocks as % of Total Sample
SG	304.45	0.05%	2.88	0.65%
TH	3,772.35	0.63%	9.51	2.16%
TN	1.15	0.00%	0.69	0.16%
TR	429.53	0.07%	4.86	1.10%
TW	5,966.86	0.99%	31.81	7.23%
US	213,717.62	35.43%	32.82	7.46%
ZA	392.25	0.07%	1.00	0.23%
Total	603,144.74	100.00%	440.21	100.00%

Panel B: By Region (from January 2011 to July 2022)

Region	Average Market Cap (in million USD)	Average Market Cap as % of Total Sample	Average Number of Stocks	Average Number of Stocks as % of Total Sample
DM	339,065.46	56.22%	199.10	45.23%
EM	264,079.28	43.78%	241.12	54.77%
US	213,717.62	35.43%	32.82	7.46%
Europe	77,996.19	12.93%	94.06	21.37%
China	210,510.68	34.90%	80.54	18.30%
EM Ex China	53,568.60	8.88%	160.57	36.48%
Total Sample	603,144.74		440.21	

NOTES: Panels A and B list the average market capitalization and number of stocks for the global sample of climate solutions companies identified from sample selection and data section and aggregated by market and region from January 2011 to July 2022. Developed markets (DMs) include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the US. All others are classified as emerging markets (EMs) in this study. ISO = International Organization for Standardization.

In our sample, we have Contemporary Amperex Technology Co. Ltd., a Chinese company actively engaged in R&D, production, and sale of batteries in China and internationally. The company is ranked number 1 in the global EV battery installation volume according to SNE Research in 2021.¹⁴

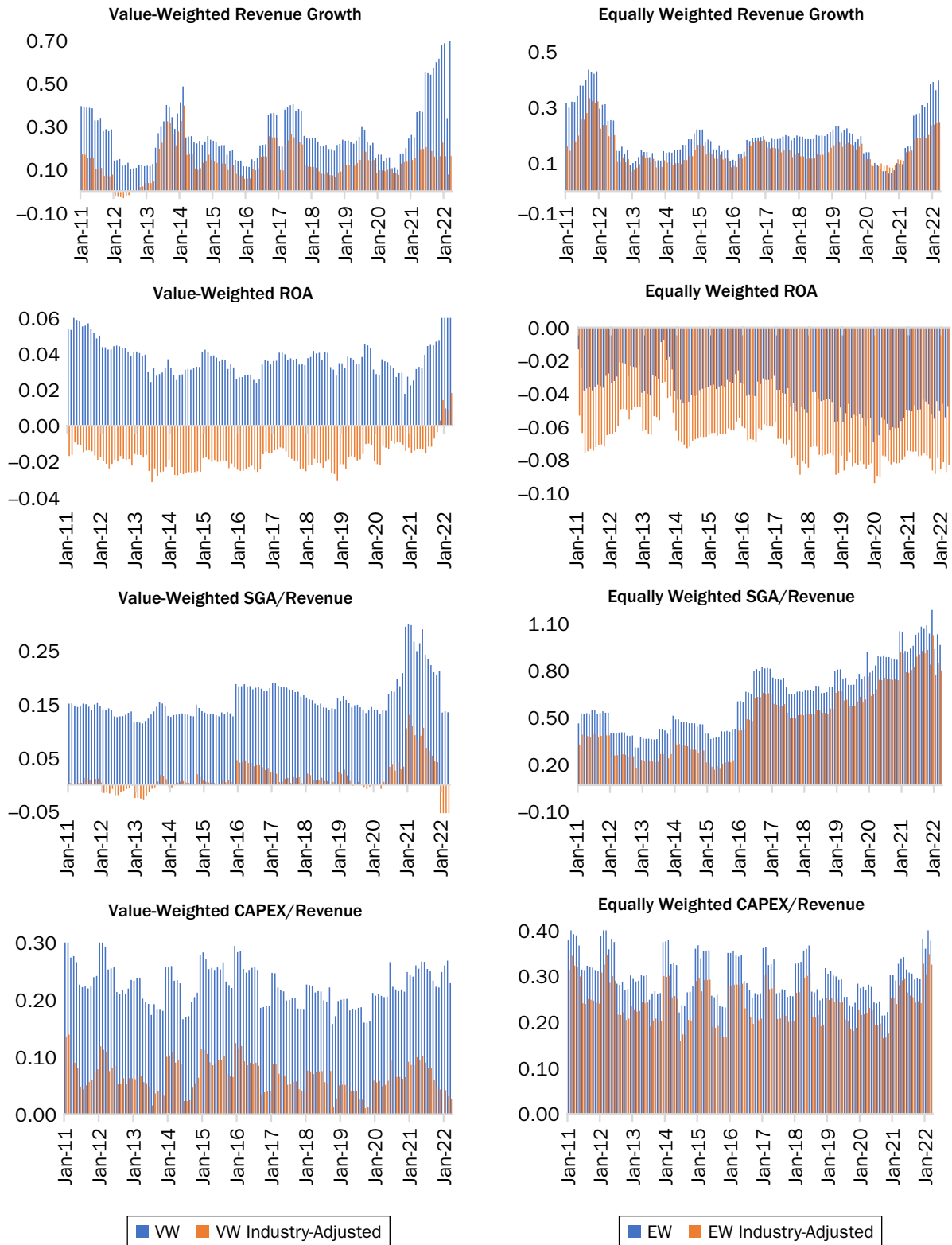
Accounting Analysis

To gain a deeper understanding of the climate solutions portfolio, we analyze the profitability, business growth, and investment profile by calculating the value-weighted and equally weighted return on assets (ROA), 1-year revenue growth, SG&A expenses to revenue (SG&A/revenue), capital expenditure to revenue (CAPEX/revenue), and R&D to revenue (R&D/revenue). These financial ratios are sourced from the Refinitiv Worldscope Point in Time database and winsorized at 2% and 98% to reduce the influence of outliers.¹⁵ As shown in Exhibit 3, we present these accounting ratios before and after industry adjustment, allowing us to control for industry effects and understand the relative performance of climate solutions

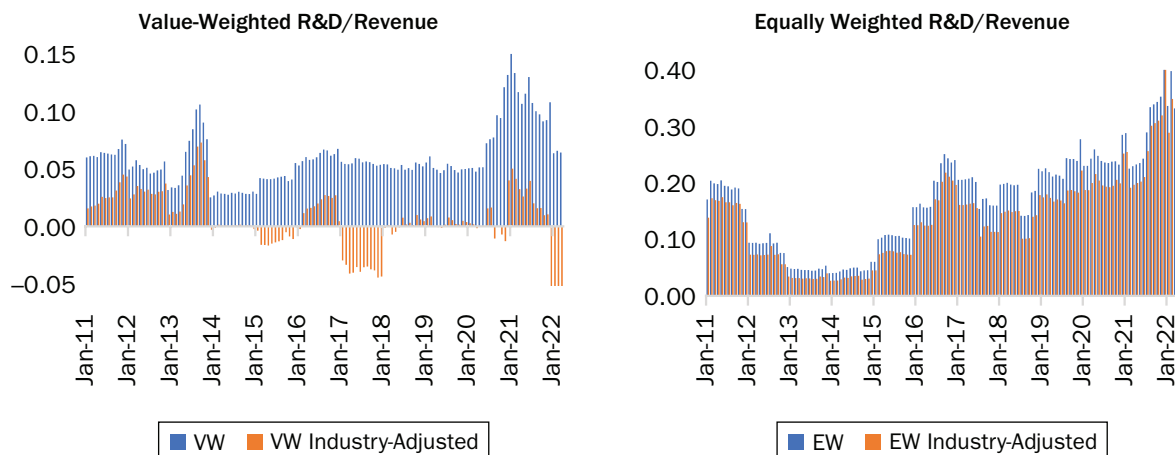
¹⁴ See [http://www.sneresearch.com/_new/eng/sub/sub2/sub2_04_view.php?sub_cat=3&bb-
sld=45397&tbi=bbs&indepth_part=1](http://www.sneresearch.com/_new/eng/sub/sub2/sub2_04_view.php?sub_cat=3&bb-
sld=45397&tbi=bbs&indepth_part=1).

¹⁵ We pulled a monthly snapshot of these fundamental data from Worldscope, based on the nearest data before the value date, which could be based on either annual, semiannual, or quarterly earnings report of a company.

EXHIBIT 3
Accounting Ratios



(continued)

EXHIBIT 3 (continued)**Accounting Ratios**

NOTES: This exhibit presents the accounting and financial ratios, including return on assets (ROA), 1-year revenue growth, SG&A/revenue, CAPEX/revenue, and R&D/revenue for the global sample of climate solutions companies from January 2011 to March 2022. Data were obtained from the Refinitiv Worldscope Point in Time database, with monthly frequency based on the most recent annual, semiannual, or quarterly earnings report from the value date and were winsorized at 2% and 98% values. The industry adjustment is calculated by subtracting the industry median of global investable universe based on SIC four-digit industry code at the company level first and then aggregated up based on either value or equal weighting.

companies compared to their industry peers. The industry adjustment is calculated by subtracting the industry median value of the accounting number for a global investable universe based on SIC four-digit industry code at the company level first and then is aggregated up based on either value or equal weighting. Differences over time are driven by changes in company profitability, growth, and investment behavior; the composition of the sample; and, in the case of value-weighted portfolios, changes in the weights. Note that, given the evolving universe of companies we track, the results should be interpreted as delineating the characteristics that an investor in public markets is exposed to and how those change over time, rather than solely how climate solutions companies are changing.

We find that the climate solutions companies have higher revenue growth but are less profitable on average than their industry peers. Both equally and value-weighted sales growth for these companies is positive after industry adjustment, suggesting climate solutions companies have faster revenue growth than other companies in the same industry. At the same time, similar to many high growth companies, climate solutions companies in our portfolio are trailing their peers in profit generation, reflected in the negative equally and value-weighted industry-adjusted ROA. However, since late 2019, we see a positive trend in the value-weighted and industry-adjusted ROA for these portfolios, with larger companies in our portfolio starting to reach median industry profitability. For example, Tesla, the largest market capitalization company in our sample by 2021, reported its first positive earnings in Q1 2021. By the end of 2021, the value-weighted ROA for the climate solutions portfolio has turned positive. In contrast, the equally weighted portfolio becomes even less profitable over time.

Moreover, we note that the portfolio of climate solutions companies has higher capital expenditures and higher R&D investments as well as greater SG&A expenses than their industry peers. This observation is consistent with our understanding that companies that provide decarbonization solutions to the market are transforming

industries with new technologies and that these innovations require significant investment in human, intellectual, and physical capital.

For example, in our sample we have Beyond Meat (BM), a company that sells plant-based products as meat substitutes. It is estimated that the greenhouse gas emissions of a BM burger are only 7.9% of those of a regular beef burger, substantially reducing the product carbon footprint.¹⁶ Compared to traditional players in this industry such as Tyson Foods (TF), BM has an R&D/revenue ratio of 6.8% in 2020, 6.1% in 2019, and 10.9% in 2018, much higher than that for TF at 0.2%, 0.2%, and 0.3% in respective years.¹⁷ The capital expenditure to revenue ratio for BM is on average 5.5 times larger than that for TF, and the SG&A/revenue for BM is about 5.1 times larger than that for TF from 2018 to 2021. When it comes to 1-year net revenue growth, BM is about 148.4% annually, compared to a 4.1% growth rate for TF from 2018 to 2020. However, BM is much less profitable than TF, with an ROA of -29.0% in 2018. Although BM has improved significantly in 2019 and 2020 to an average of -7.2%, it is still not generating profits, whereas TF's ROA is on average 8.88% during these years.

Collectively, these findings are consistent with a portfolio of climate solutions companies exposing an investor to lower profitability, higher top-line revenue growth, and investment firms focused on developing scale to provide solutions for their customers. On an equally weighted basis, the portfolio provides exposure to companies that invest heavily in innovation and talent but also exposure to higher losses.¹⁸

Valuation Analysis

Turning to two key valuation ratios, earnings yield and BTM as presented in Exhibit 4, we find that the climate solutions portfolio have lower earnings yield and BTM compared to their industry peers. This observation is consistent with our findings earlier that these companies are less profitable but have a higher growth rate and that investors anticipate fast business growth leading to better financial performance and profitability in the future. An exception, though, exists in the case of the equally weighted BTM, in which the climate solutions portfolio has a higher value than the industry peers despite on average faster revenue growth, suggesting some smaller climate solutions companies potentially experiencing financial distress. In the example of BM and TF, TF's BTM ratio is about 15 times that of BM at the end of 2020; also, TF has much higher earnings yield, about 9.1% at the end of 2020, whereas BM's value is still negative, at -0.3%. Therefore, investors, on average, are recently factoring the high growth rate of the climate solutions companies into prices, even though most of these companies are still not profitable.

Correlation Analysis

Exhibit 5 presents the correlations of the climate solutions portfolios—value-weighted global, developed market, and emerging markets portfolios and equally weighted global, developed market, and emerging markets portfolios and the correlations of those with prevalent market benchmarks and climate change indexes,

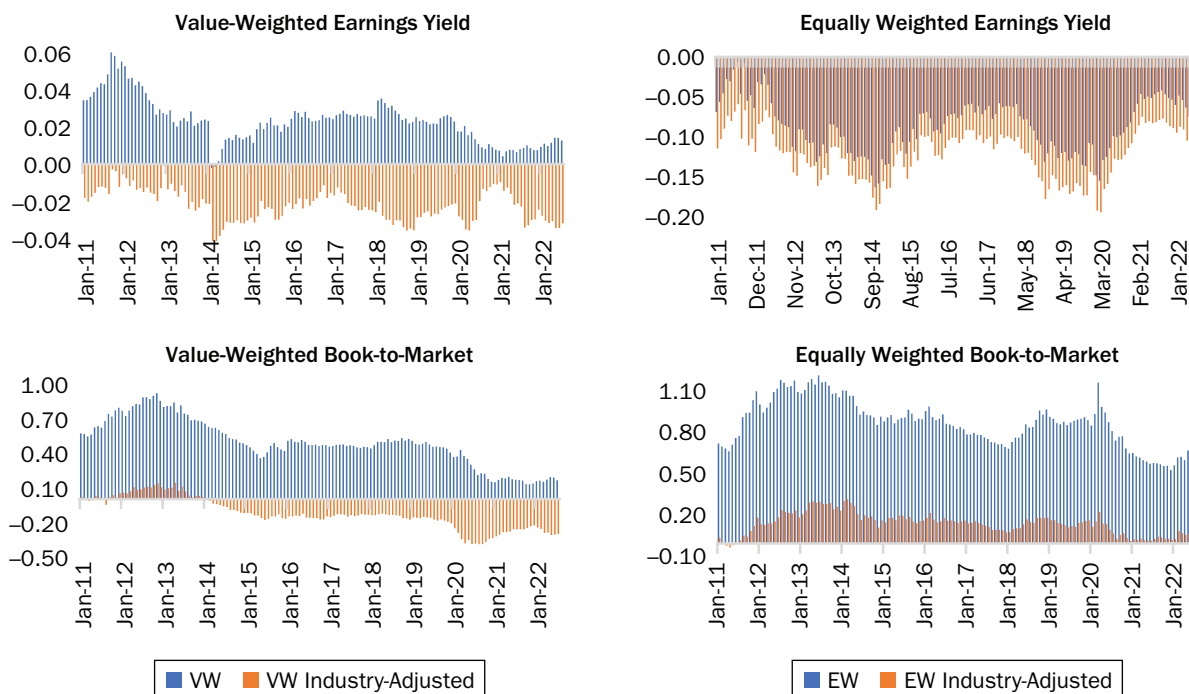
¹⁶ See <https://consumerecology.com/beyond-meat-burger-carbon-footprint-environmental-impact/>.

¹⁷ For BM, we use the annual reporting with calendar year end on December 31 from 2018 to 2020. For TF, we use the annual reporting with calendar year end on September 30 from 2018 to 2020.

¹⁸ Besides having higher SG&A/revenue (of which the largest part is typically expenditure on employee salaries), we observe that the portfolio of climate solutions companies also has higher employee 1-year growth rate than their industry peers, which collectively supports that these companies are investing more in talent.

EXHIBIT 4

Valuation Ratios



NOTES: This exhibit presents the earnings yield and BTM for the global sample of climate solutions companies from January 2011 to June 2022. Data were obtained from the Thomson Worldscope Point in Time database, with monthly frequency based on the most recent annual, semiannual, or quarterly earnings report from the value date and were winsorized at 2% and 98% values. The industry adjustment is calculated by subtracting the industry median of global investable universe based on SIC four-digit industry code at the company level first and then aggregated up based on either value or equal weighting.

including MSCI ACWI, MSCI ACWI Low Carbon,¹⁹ MSCI ACWI Climate Change,²⁰ S&P Global Clean Energy,²¹ and NASDAQ Clean Edge Green Energy²² from 2011 to July 2022.

We observe generally high correlations among the climate solutions portfolios, regardless of portfolio construction or market segment, except the equally weighted portfolio for emerging markets. The value-weighted climate solutions portfolio with the global sample has a high correlation (0.85) with both value-weighted developed markets and emerging markets portfolios. The lowest correlations we observe are between the value-weighted and the equally weighted climate solutions portfolios; in particular, we see low correlations with the equally weighted emerging markets

¹⁹The MSCI ACWI Low Carbon Target Index aims to track MSCI ACWI with a target tracking error of 0.3% while minimizing the carbon exposure by overweighting companies with low carbon emissions (relative to sales) and those with low potential carbon emissions (per dollar of market capitalization). For more details, see [MSCI ACWI Low Carbon Target Index](#).

²⁰The MSCI ACWI Climate Change Index aims to represent the performance of an investment strategy that reweights securities based upon the opportunities and risks associated with the transition to a lower carbon economy while seeking to minimize exclusions from the MSCI ACWI. For more details, see [MSCI ACWI Climate Change Index](#).

²¹The S&P Global Clean Energy Index targets constituent counts of 100 to measure the performance of companies in global clean energy-related businesses from both emerging markets and developed markets. For details of index construction, see [Table of Contents \(spglobal.com\)](#).

²²The NASDAQ Clean Edge Green Energy Index is a modified market capitalization-weighted index designed to track the performance of companies that are primarily manufacturers, developers, distributors, and/or installers of clean energy technologies, as defined by Clean Edge. For more details, see [CELS Methodology \(nasdaqomx.com\)](#).

EXHIBIT 5**Correlations of Climate Solutions Portfolios****Panel A: With Other Market Indexes**

		Climate Solutions Indexes					
		VW CSI	VW CSI DM	VW CSI EM	EW CSI	EW CSI DM	EW CSI EM
Climate Solutions Indexes	VW CSI	1.00	0.85	0.85	0.92	0.85	0.65
	VW CSI DM	0.85	1.00	1.00	0.73	0.64	0.67
	VW CSI EM	0.85	1.00	1.00	0.73	0.64	0.67
	EW CSI	0.92	0.73	0.73	1.00	0.96	0.66
	EW CSI DM	0.85	0.64	0.64	0.96	1.00	0.50
	EW CSI EM	0.65	0.67	0.67	0.66	0.50	1.00
Other Market Indexes	MSCI ACWI	0.67	0.81	0.81	0.66	0.55	0.68
	S&P Global Clean Energy	0.81	0.76	0.76	0.75	0.64	0.78
	NASDAQ Clean Edge Green Energy	0.85	0.74	0.74	0.87	0.81	0.67
	MSCI ACWI Climate Change	0.70	0.81	0.81	0.69	0.58	0.69
	MSCI ACWI Low Carbon	0.67	0.81	0.81	0.66	0.55	0.68

Panel B: Other Market Indexes, Residuals

		Climate Solutions Indexes (residuals)					
		VW CSI	VW CSI DM	VW CSI EM	EW CSI	EW CSI DM	EW CSI EM
Climate Solutions Indexes (return residuals)	VW CSI	1.00	0.70	0.69	0.85	0.78	0.35
	VW CSI DM	0.70	1.00	1.00	0.45	0.40	0.28
	VW CSI EM	0.69	1.00	1.00	0.45	0.39	0.28
	EW CSI	0.85	0.45	0.45	1.00	0.95	0.38
	EW CSI DM	0.78	0.40	0.39	0.95	1.00	0.21
	EW CSI EM	0.35	0.28	0.28	0.38	0.21	1.00
Other Market Indexes	MSCI ACWI	0.03	-0.01	-0.01	0.00	0.01	-0.12
	S&P Global Clean Energy	0.52	0.40	0.40	0.44	0.35	0.38
	NASDAQ Clean Edge Green Energy	0.53	0.30	0.29	0.54	0.51	0.18
	MSCI ACWI Climate Change	0.07	-0.01	-0.01	0.05	0.05	-0.10
	MSCI ACWI Low Carbon	0.03	-0.01	-0.01	0.00	0.01	-0.11

NOTES: This exhibit presents the correlations of climate solutions portfolios with MSCI ACWI, MSCI ACWI Low Carbon, MSCI ACWI Climate Change, S&P Global Clean Energy, and NASDAQ Clean Edge Green Energy Index from January 2011 to July 2022, based on monthly frequency data. Panel B presents the correlations of climate solutions portfolio return residuals after regressing out the MSCI ACWI returns. VW = value weighted; EW = equally weighted; DM = developed market; EM = emerging market.

portfolio, which may reflect the illiquidity of emerging markets small-cap stocks. Moreover, as expected, the value-weighted global climate solutions portfolio is highly correlated with pure-play indexes such as S&P Global Clean Energy (0.81) and NASDAQ Clean Edge Green Energy (0.85), more than with other climate change indexes that aim to gain more balanced or broad market access such as MSCI ACWI Low Carbon (0.67) and Climate Change (0.70). This pattern is even more noticeable in Panel B of Exhibit 5, where we present the correlations of climate solutions portfolio return residuals after regressing out the MSCI ACWI returns. The correlations of these residuals with MSCI ACWI Low Carbon and Climate Change are close to zero once we strip out the effect from market comovement, whereas they are still highly correlated with pure-play indexes, S&P Global Clean Energy, and NASDAQ Clean Edge Green Energy.

Tracking Error Analysis

As expected, we find that the climate solutions portfolios demonstrate large tracking errors versus the market portfolio using MSCI ACWI as a proxy, varying from 11.2% to 29.5% by construction and sample period, as shown in Exhibit 6. For comparison,

EXHIBIT 6**Tracking Errors with MSCI ACWI**

		Since 2011	Since 2016	Since 2018
Climate Solutions Portfolios	VW CSI	16.22%	18.30%	20.80%
	VW CSI DM	20.51%	25.25%	29.47%
	VW CSI EM	20.81%	21.95%	23.98%
	EW CSI	11.20%	11.56%	12.78%
	EW CSI DM	11.22%	11.53%	12.69%
	EW CSI EM	14.80%	15.15%	16.55%
Other Market Indexes	S&P Global Clean Energy	16.73%	17.66%	19.94%
	NASDAQ Clean Edge Green Energy	23.04%	24.60%	27.98%
	MSCI ACWI Climate Change	1.35%	1.44%	1.64%
	MSCI ACWI Low Carbon	0.45%	0.45%	0.46%

NOTES: This exhibit presents the tracking errors of climate solutions portfolios and other market indexes with MSCI ACWI for three periods: January 2011 to July 2022, January 2016 to July 2022, and January 2018 to July 2022, based on daily frequency data. VW = value weighted; EW = equally weighted.

we also report tracking errors of other climate change indexes or factors relative to MSCI ACWI.²³ Not surprisingly, MSCI ACWI Low Carbon and MSCI ACWI Climate Change track MSCI ACWI most closely, with tracking errors of 45 basis points (bps) and 135 bps, respectively, from 2011 to July 2022. S&P Global Clean Energy and NASDAQ Clean Edge Green Energy, on the other hand, have large deviations from the ACWI, similar in magnitude to the climate solutions portfolios.

The dichotomy of the low and high tracking errors of these strategies characterizes two different methodologies for building a climate change–related index. Most of the existing financial instruments for climate change in the market aim to lower a portfolio’s carbon footprint by excluding or downweighting companies with high carbon emissions (relative to revenue or market capitalization), represented by the MSCI ACWI Low Carbon Index and MSCI ACWI Climate Change Index as well as the decarbonization factors in Cheema-Fox et al. (2021a, 2021b).²⁴ A key characteristic of these products is that they can achieve considerable reduction in portfolio carbon emissions relative to the benchmark while maintaining a low tracking error.

On the other hand, our climate solutions portfolios represent a different approach that does not focus on the immediate carbon reduction based on the status quo but rather long-term climate change opportunities with pure-play companies from the 9 most relevant business areas, such as energy generation and storage, batteries, and transportation. These companies are key businesses that provide solutions to lower carbon emissions. Therefore, these portfolios are characterized by high tracking errors, high growth potential, and concentrated industry/sector membership as demonstrated through the climate solutions portfolios.

Stock Performance Analysis

Now, turning to the portfolio performance results in Exhibit 7, we find the climate solutions portfolios have evolved substantially over the sample period from 2011 to July 2022, with significant upside, particularly since 2018. This finding is consistent

²³Note, not all of these indexes or strategies track MSCI ACWI. We report the tracking errors to show how active or passive these portfolios are relative to the market portfolio.

²⁴We find the correlation and tracking error analysis results for the decarbonization factors (Cheema-Fox et al. 2021a, 2021b) to be very similar to MSCI ACWI Low Carbon and Climate Change and thus are omitted here.

with our prior one that the development of key climate change technologies and innovations requires considerable investment and time to lower cost in production and gain momentum in the market. Recent policy trends seem likely to provide tailwinds for these climate solutions business as well, particularly after the Paris Agreement.

Using multifactor regressions, we calculate alphas for climate solutions portfolios after controlling for the Fama–French five factors for developed markets and

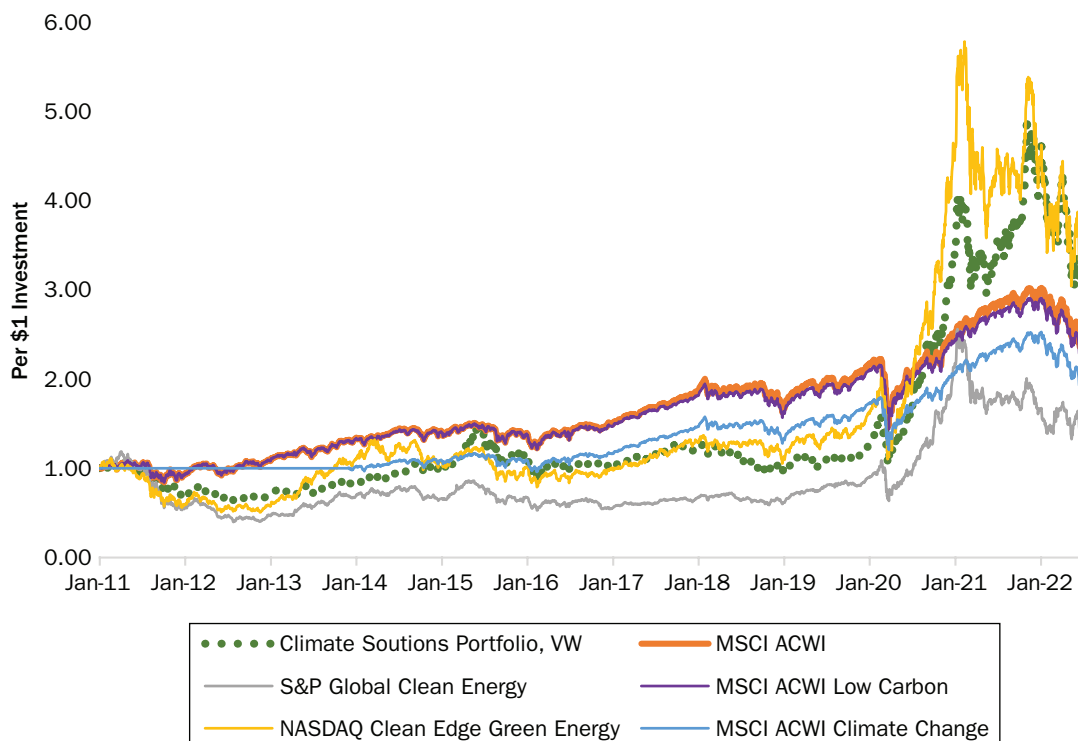
EXHIBIT 7

Climate Solutions Portfolio Performance

Panel A: Performance for Climate Solutions Portfolios

	Since 2011	Since 2016	Since 2018
Value Weighted			
Returns	11.9%	19.3%	27.2%
Risk	20.2%	23.1%	26.4%
Sharpe Ratio	0.59	0.83	1.03
Max Drawdown	40.7%	37.5%	37.5%
Alpha	11.5%	15.6%	23.5%
Alpha t-Stat	1.96	1.58	1.85
Equally Weighted			
Returns	13.3%	17.6%	16.9%
Risk	12.2%	12.3%	13.5%
Sharpe Ratio	1.09	1.42	1.25
Max Drawdown	35.8%	31.9%	31.9%
Alpha	12.1%	11.7%	15.7%
Alpha t-Stat	3.46	2.18	2.23

Panel B: Cumulative Performance for Value-Weighted Climate Solutions Portfolios and Other Climate-Related Indexes, January 2011–July 2022



(continued)

EXHIBIT 7 (continued)**Climate Solutions Portfolio Performance**

Panel C: Climate Solutions Portfolios Performance Excluding Tesla			
	Since 2011	Since 2016	Since 2018
Value Weighted			
Returns	6.3%	10.4%	14.3%
Risk	16.6%	17.2%	18.9%
Sharpe Ratio	0.38	0.60	0.75
Max Drawdown	41.2%	32.2%	32.2%
Alpha	11.3%	15.0%	22.0%
Alpha t-Stat	1.88	1.74	2.25

NOTES: Panel A presents the portfolio performance statistics for value-weighted and equally weighted climate solutions portfolios based on the global sample for three periods: January 2011 to July 2022, January 2016 to July 2022, and January 2018 to July 2022. These portfolios are formed at the end of 2010 and rebalanced on a monthly basis. On the rebalance day, which is the last business day of the month, the value-weighted portfolio is calculated based on the market capitalization weights of stocks in our sample from the previous business day, whereas the equally weighted portfolio is calculated based on an equal weighting of stocks in the sample from the previous trading day. We allow portfolios to drift between rebalance dates. We calculate alphas for climate solutions portfolios using multifactor regressions controlling for the Fama–French five factors for developed markets and emerging markets, including market, value, size, profitability, and investment as well as developed markets and emerging markets momentum factors. The multifactor regression results are reported in Exhibit A1. The *t*-statistics for alphas are estimated based on heteroskedasticity and autocorrelation consistent (HAC) standard errors. Panel B presents the cumulative performance for value-weighted climate solutions portfolios and other climate-related indexes from January 2011 to July 2022 per \$1 investment at the end of 2010. Panel C presents the portfolio performance for value-weighted climate solutions portfolio excluding Tesla in the sample.

SOURCES: DataStream, Bloomberg.

emerging markets, including market, value, size, profitability, and investment as well as developed markets and emerging markets momentum factors.²⁵ The value-weighted portfolio generates a total return of 11.9% annually, an alpha of 11.5% (significant at a 5% level), and a Sharpe ratio of 0.59 for the full sample period, whereas the period since 2018 has seen a much greater reward with 27.2% total return, 23.5% alpha (significant at a 10% level), and 1.03 Sharpe ratio.²⁶ The equally weighted portfolio produces more statistically significant alphas, 12.1% for the full period and 15.7% since 2018. To put this into context, MSCI ACWI has a return of 8.2%, a risk level of 14.5%, and a Sharpe ratio of 0.57 annually during the full sample period.

Compared to the two climate clean tech/green energy indexes included in this study, we find that our climate solutions portfolios (both equally weighted and value weighted) have outperformed in risk-adjusted terms. The S&P Global Clean Energy has an annual return of 4.9%, a risk of 24.0%, and a Sharpe ratio of 0.20 since 2011. The NASDAQ Clean Edge Green Energy generates higher total returns at 13.0% per annum, and the risk level is much higher at 31.6%, resulting in a modest Sharpe ratio of 0.41. Both indexes have lower Sharpe ratios than those for the value-weighted and equally weighted climate solutions portfolios. Data from the most recent periods point to similar findings. Also, notably, the climate solutions portfolios start to diverge from other climate clean tech/green energy indexes since the beginning of 2021. Both S&P Global Clean Energy and NASDAQ Clean Edge Green Energy have experienced severe drawdowns of 48.2% and 47.4%, respectively, since 2021, leading to cumulative losses for 2021 and in the first 7 months of 2022 of –18.4% and –10.6%, respectively. On the other hand, the climate solutions portfolios not only

²⁵ We also tested a model with Pastor–Stambaugh liquidity factor from January 2011 to December 2020. We did not find significance of liquidity factor in the global climate solutions portfolios.

²⁶ The insignificance could be due to the small number of observations with monthly return data since 2018.

have experienced smaller drawdowns (37.5% for value weighted, 19.9% for equally weighted), but they have also exhibited greater resilience, bouncing back with positive cumulative returns of 9.2% and 15.2%, respectively, for the same period.

In terms of factor exposures, both equally and value-weighted climate solutions portfolios with the global sample have positive and significant loadings on the developed markets and emerging markets factors, and the emerging markets size factor had negative and significant loadings on the developed markets value and developed markets profitability factors.²⁷ These results are consistent with our observations earlier that the pure-play climate solutions companies are characterized with relatively smaller size, higher growth rate, and lower profitability. The multifactor regression results are reported in Exhibit A1.

One company in our sample—Tesla—has experienced phenomenal growth in valuation in recent years, and the market size quickly swells to about 44.5% of our global sample at the end of July 2022. For robustness checks, we have constructed a value-weighted portfolio without Tesla and find similar performance and factor exposures to the one including Tesla. As shown in Panel C of Exhibit 7, the ex Tesla portfolio generates an alpha of 11.3% since 2011 and 22.0% since 2018, with the latter statistically significant at a 5% level. Leaving out Tesla does not change the results for the equally weighted portfolio either because any given company has very limited influence on the portfolio. It is worth noting that the equally weighted portfolios, although they exhibit lower returns, also have lower volatility and more significant alphas.

Geographic Variation

To understand the performance of climate solutions portfolios, we build portfolios for developed and emerging markets²⁸ and for a few major countries and regions, including the US, Europe, China, and emerging markets excluding China. Results are reported in Panels A and B of Exhibit 8. When comparing developed markets with emerging markets, we find the developed markets portfolios have outperformed the emerging markets portfolios under the value-weighted construction. Notably, the developed markets portfolio generates a total return of 36.6% annually and a substantial alpha of 28.7%, statistically significant, with the data since 2018. Similarly, the equally weighted portfolio for developed markets demonstrates positive performance as well, with statistically significant and increasing excess returns from 2011 to July 2022. The results for the emerging markets portfolios are less clear cut—across the value-weighted and equally weighted constructions and the three sample periods, even though excess returns are, on average, positive, only the equally weighted portfolio with the full sample has a significant alpha.²⁹

Across the regions, we observe that the US and European portfolios have positive and improving performance over time. Particularly, the US climate solutions companies have experienced a substantial uptick in price in most recent years, with an annual return of 55.5% since 2018 under the value weighting, compared to European peers at 13.8%. Although this growth is accompanied by considerable risk (53.9%),

²⁷We have also considered European Union Allowance (EUA) futures prices downloaded from Bloomberg, but we do not find a significant relationship between climate solutions portfolio returns and EUA future returns.

²⁸The developed markets in our sample include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the US. All other countries and regions in our sample are classified as emerging markets.

²⁹One caveat of this conclusion is that we define region or country based on where the security is traded, instead of where the company is incorporated or headquartered. Therefore, a Chinese EV company mainly traded on the NASDAQ is categorized in the developed markets sample.

EXHIBIT 8

Climate Solutions Portfolios Performance

Panel A: Performance for Climate Solutions Portfolios

	DM Portfolios			EM Portfolios		
	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018
Value Weighted						
Returns	16.73%	27.49%	36.55%	7.33%	11.21%	17.36%
Risk	26.76%	31.83%	36.86%	20.19%	20.95%	22.72%
Sharpe Ratio	0.62	0.86	0.99	0.36	0.53	0.76
Max Drawdown	46.43%	44.70%	44.70%	54.84%	36.13%	34.89%
Alpha	11.31%	17.55%	28.65%	10.68%	11.32%	21.12%
Alpha <i>t</i> -Stat	1.83	1.84	2.25	1.43	1.04	1.68
Equally Weighted						
Returns	14.02%	21.39%	20.25%	12.20%	13.96%	13.46%
Risk	15.09%	15.65%	17.36%	13.33%	13.17%	13.97%
Sharpe Ratio	0.93	1.36	1.16	0.91	1.05	0.96
Max Drawdown	42.41%	36.21%	36.21%	36.61%	36.61%	36.61%
Alpha	11.24%	16.98%	23.97%	11.15%	7.75%	12.16%
Alpha <i>t</i> -Stat	2.07	2.20	2.35	3.09	1.31	1.65

Panel B: By Region/Country

	US			Europe			China			EM Ex China		
	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018
Value Weighted												
Returns	26.17%	37.04%	55.54%	4.66%	12.28%	13.82%	9.63%	10.27%	17.83%	2.49%	14.47%	14.82%
Risk	41.33%	47.42%	53.86%	21.96%	22.17%	24.16%	24.30%	24.20%	26.05%	16.19%	16.62%	18.16%
Sharpe Ratio	0.63	0.78	1.03	0.21	0.55	0.57	0.39	0.42	0.68	0.15	0.87	0.81
Max Drawdown	56.90%	56.90%	56.90%	55.52%	43.53%	43.53%	62.58%	44.01%	38.70%	54.06%	35.10%	35.10%
Alpha	9.72%	12.55%	27.59%	1.46%	9.17%	16.81%	3.93%	4.17%	5.59%	2.00%	8.61%	15.22%
Alpha <i>t</i> -Stat	1.02	0.82	1.26	0.31	1.58	2.24	1.25	1.05	1.05	0.51	1.44	2.06
Equally Weighted												
Returns	14.33%	16.67%	23.03%	9.90%	17.57%	18.80%	11.08%	6.15%	10.86%	11.30%	16.45%	13.18%
Risk	30.47%	31.85%	35.27%	17.19%	17.46%	19.10%	27.38%	25.58%	26.27%	11.91%	11.97%	12.83%
Sharpe Ratio	0.47	0.52	0.65	0.57	1.00	0.98	0.40	0.24	0.41	0.95	1.37	1.02
Max Drawdown	64.44%	64.44%	64.44%	49.37%	36.90%	36.90%	65.87%	54.25%	48.43%	39.76%	39.76%	39.76%
Alpha	8.87%	7.59%	16.13%	8.14%	14.87%	22.27%	7.01%	2.78%	3.15%	8.06%	5.13%	6.97%
Alpha <i>t</i> -Stat	1.10	0.71	1.18	1.73	2.22	3.04	1.35	0.39	0.41	2.28	1.14	1.35

NOTES: Panel A presents the portfolio performance for value-weighted and equally weighted climate solutions portfolios based on the developed markets sample and the emerging markets sample for three periods: January 2011 to July 2022, January 2016 to July 2022, and January 2018 to July 2022. These portfolios are formed at the end of 2010 and rebalanced on a monthly basis. On the rebalance day, which is the last business day of the month, the value-weighted portfolio is calculated based on the market capitalization weights of stocks in our sample from previous business day, whereas the equally weighted portfolio is calculated based on an equal weighting of stocks in the sample from the previous trading day. We allow portfolios to drift between rebalance dates. For the DM portfolios, we calculate alphas for climate solutions portfolios using multifactor regressions controlling for the Fama–French five factors for developed markets, including market, value, size, and profitability as well as the developed markets momentum factor. For the emerging markets portfolios, we calculate alphas controlling for the Fama–French emerging markets five factors and the emerging markets momentum factor. The *t*-statistics for alphas are estimated based on HAC standard errors. In Panel B, the alphas for the regional portfolios are calculated after controlling for regional factors: for the US using the US Fama–French five factors and US momentum factor, for Europe using the European Fama–French five factors and European momentum factor, for China using the MSCI China A Onshore Index (USD) and emerging markets Fama–French five factors excluding the market and emerging markets momentum factor, and for emerging markets ex China using emerging markets Fama–French five factors and emerging markets momentum factor. DM = developed market; EM = emerging market.

rewards exceed risks such that the Sharpe ratio is about 1.03 and the Sortino ratio is about 1.55 for the US portfolio. After controlling for traditional risk factors, we find the value-weighted US and European portfolios have excess returns of 27.6% and 16.8%, respectively. Because the US portfolio has a substantial exposure to the market risk factor, we only observe the European portfolio exhibits a statistically significant alpha.³⁰ Similar results are observed for the equally weighted portfolios.

Within emerging markets, we find evidence of improving performance in climate solutions portfolios in emerging markets excluding China, with excess returns of 2.0%, 8.6%, and 15.2% for the since-2011, since-2016, and since-2018 periods, respectively, and a statistically significant alpha for the most recent sample. For the Chinese market, although the climate solutions portfolios generate positive returns, alphas are not significant after controlling for common risk factors.

To summarize, we find that developed markets climate solutions portfolios have outperformed those in emerging markets. This differential is driven by several factors. First, the European climate solutions portfolio has performed well. Second, the China climate solutions portfolio has performed subpar relative to other emerging markets while being a very big part of the portfolio. Third, the US climate solutions portfolio has performed exceptionally well, partly due to Tesla.

Solutions Variation

From a solutions perspective, we find that climate solutions companies in energy, alternative fuels, battery, transportation, and housing have better performance than agriculture and food and sectors such as nature-based solutions, recycling and circularity, and industrials, which are combined together and labeled as Others due to smaller sample size, as shown in Exhibit 9.³¹ For example, the battery sector generated an annualized return of 37.1% since 2011, of which the most recent years have seen 65.6% returns on average.³² The two subperiods results are reported in the appendix in Exhibit A2.

Although the transportation and energy storage portfolios have delivered superior performance, on both an equally weighted and value-weighted basis, energy, alternative fuels, and materials portfolios outperformed on an equal-weighted basis. In general, equally weighted portfolios show more consistent outperformance across solutions, with significant positive alphas. In addition, we find investment concentrated in one or two categories could expose an investor to substantial risk—the agriculture, batteries, and materials segments have experienced 39% or higher volatility since 2018. Thus, a portfolio of climate solutions companies across various business areas can provide a meaningful diversification effect.

³⁰For the US portfolios, we are controlling for US Fama–French five factors, US momentum factor, and the liquidity factor. For the European portfolios, we are controlling for European Fama–French five factors, European momentum factor, and the liquidity factor. For both the China and emerging markets ex China portfolios, we are controlling for the emerging markets Fama–French five factors, emerging markets momentum factor, and the liquidity factor.

³¹We have combined nature-based solutions, industrials, and recycling and circularity sectors into others given that these sectors have a relatively small sample size, with the number of companies fewer than 20.

³²We have classified Tesla in battery instead of transportation, given the company's battery production advantage being a major competitive driver. Moreover, the company's increasing range of solutions is more broadly in the sustainable energy space, which makes it challenging to classify the company as a pure car manufacturer. Reclassifying Tesla to transportation would raise both return and risk for that solution.

EXHIBIT 9**Climate Solutions Portfolios Performance by Categories (January 2011–July 2022)**

	Agriculture and Food (A)	Batteries (B)	Energy (E)	Fuels-Alternate (F)	Housing (H)	Materials (M)	Transportation (T)	Others
Value Weighted								
Returns	−4.98%	37.07%	6.93%	6.74%	9.31%	−6.63%	9.37%	−0.56%
Risk	48.56%	44.64%	14.95%	25.24%	27.35%	33.68%	29.53%	28.33%
Return/Risk	−0.10	0.83	0.46	0.27	0.34	−0.20	0.32	−0.02
Max Drawdown	84.76%	57.57%	38.66%	54.52%	54.40%	78.43%	69.73%	71.23%
Alpha	15.92%	32.62%	7.21%	10.14%	2.74%	6.92%	31.73%	−2.21%
Alpha t-Stat	0.93	1.89	1.54	1.30	0.32	0.62	2.55	−0.41
Equally Weighted								
Returns	3.18%	20.75%	11.94%	13.65%	10.07%	10.48%	19.29%	9.07%
Risk	25.08%	23.47%	12.00%	17.96%	26.79%	24.11%	19.71%	19.89%
Return/Risk	0.13	0.88	1.00	0.76	0.38	0.43	0.98	0.46
Max Drawdown	58.82%	39.18%	37.98%	40.76%	47.58%	55.53%	42.32%	51.42%
Alpha	10.81%	22.53%	9.13%	14.63%	10.36%	14.09%	26.61%	2.31%
Alpha t-Stat	1.13	2.69	2.87	2.95	1.46	2.28	3.43	0.54
Number of Stocks	10.7	28.5	280.5	31.8	10.9	14.8	43.9	15.7

NOTES: This exhibit presents the performance for climate solutions portfolios by different categories from January 2011 to July 2022. For some of the categories with the number of observations fewer than 20 companies, we combine them into the category Others, including nature-based solutions, industrials, recycling and circularity, and carbon capture and storage. Alphas are calculated after controlling for the Fama–French five factors for developed markets and emerging markets, including market, value, size, profitability, and investment as well as developed markets and emerging markets momentum factors.

IMPLICATIONS

Our analysis reveals several insights about the growing market for decarbonization. First, investors in public markets increasingly can gain exposure to climate solutions companies. Both the number and the market capitalization of those companies in public markets have increased over time. Although just 10 years ago, we found fewer than 300 such companies with enough liquidity and size for institutional investment, this number has doubled in recent years. Of course, this underestimates the total climate solutions revenues that an investor can gain exposure to in public markets because many companies are developing products and services to decarbonize the economy, but those might represent only a (small) fraction of their overall revenues.

Second, a significant percentage of these companies, almost half, are in emerging markets. Within this set, many companies are in China. In fact, more climate solutions companies are in China rather than the US. Again, a caveat to this result applies because it could be that more companies in the US are developing climate solutions, but those companies are also providing other services, and therefore they are not included in our sample (or they are private companies), and the relative prevalence of those companies might be higher in the US relative to China.

Third, most companies provide energy low-carbon solutions, such as solar or wind power generation. Only recently, investors can gain exposure in public markets to an increasing number of companies that provide other solutions, such as batteries and storage, food, materials, and transportation.

Fourth, those companies exhibit high growth, high investment, and low profitability. Therefore, they are likely to exhibit higher risk, especially if that growth stalls and

expectations for regulatory climate action or shifting consumer preferences toward low-carbon products do not materialize. Coupling this with the fact that many companies are in emerging markets, exposing investors to political, regulatory, and currency risks, also elevates the risk profile of these portfolios.

Fifth, our results suggest that it is important to clearly differentiate climate solutions investments from more broadly based, less pure-play investment products that take climate change into account: They provide investors with different exposures. Specifically, the returns of a climate solutions portfolio exhibit zero correlation, after accounting for market returns, with those of indexes that lower the carbon emission exposure. Labeling those products clearly and differently could serve investors well. Generic labels, such as *climate change*, fail to communicate what the products are seeking to achieve and could lead investors to allocate capital away from their preferences. We recommend that products seeking to decarbonize portfolios by underweighting high-carbon companies are clearly labeled as low-carbon-exposure portfolios. In contrast, products that include companies that provide solutions to decarbonize the economy are labeled as climate solutions portfolios.

CONCLUSION

In this article, we develop a process to identify a list of publicly traded pure-play companies that provide climate solutions products or services and contribute to the transition to a low-carbon world. Our sample of global companies is mainly in 9 business areas central to climate change solutions, including agriculture and food, building and housing, CCUS, energy generation and storage, materials, nature-based solutions, recycling and circularity, and transportation.

We find emerging markets have a significant presence in our sample—almost half of the climate solutions companies are from emerging markets. This suggests that many emerging markets businesses have been actively participating in the market of decarbonization, which allows investors to deploy capital not only to developed markets but also across a more diverse set of regions.

On the basis of this list of climate solutions companies, we build value-weighted and equally weighted climate solutions portfolios for the global sample as well as by different market, region, and sector segments. We find these pure-play climate solutions companies are characterized with lower profitability, higher revenue growth, and higher investment and capital expenditure relative to their industry peers, which is also reflected in their relative lower valuation ratios, such as earnings yield and BTM.

Our stock selection and portfolio construction for climate solutions portfolios aim to gain exposure to long-term climate change opportunities and innovations as economies attempt to transition to a low-carbon economy rather than to achieve immediate carbon reductions. This represents a different approach from existing indexes in the market that overweight low-carbon companies and underweight high-carbon companies. As expected, we observe that our climate solutions portfolios have large tracking errors to MSCI ACWI due to more active security selection and portfolio weights.

Last, we examine the stock performance of the climate solutions portfolios from January 2011 to July 2022 and find evidence of outperformance of climate solutions portfolios, particularly noticeable in the past 4 years, in both developed markets and emerging markets excluding China, as well as in energy, fuels, battery, and transportation segments.

We hope our study provides investors with a practical examples of how to identify pure-play climate solutions companies, how to build portfolios to gain exposure to climate change opportunities, and a better understanding of the properties and financial performance of these portfolios.

APPENDIX

EXHIBIT A1

Multifactor Regressions

Panel A: Global Climate Solutions Portfolios

	Global					
	Value Weighted			Equally Weighted		
	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018
Alpha	11.50%	15.56%	23.49%	12.08%	11.67%	15.68%
	1.96	1.58	1.85	3.46	2.18	2.23
DM Mkt-RF	0.57	0.79	0.74	0.31	0.32	0.36
	2.92	2.49	2.06	3.96	3.08	2.32
DM SMB	-0.12	-0.66	-0.51	0.04	-0.05	0.07
	-0.34	-1.28	-0.93	0.17	-0.18	0.23
DM HML	-0.77	-1.27	-1.38	-0.36	-0.49	-0.66
	-1.24	-1.66	-1.25	-1.63	-1.79	-1.77
DM RMW	-0.94	-1.43	-1.18	-0.38	-0.44	-0.50
	-1.90	-2.39	-1.66	-1.58	-1.32	-1.17
DM CMA	-0.38	0.34	0.64	0.10	0.39	0.63
	-0.45	0.34	0.45	0.35	1.20	1.53
DM WML	-0.07	-0.01	-0.12	-0.17	-0.18	-0.24
	-0.22	-0.02	-0.19	-1.32	-1.16	-1.15
EM Mkt-RF	0.49	0.57	0.62	0.65	0.77	0.73
	2.69	2.05	1.74	6.66	5.31	3.44
EM SMB	0.65	0.81	0.71	0.77	0.84	0.91
	2.03	1.65	1.23	4.75	3.47	2.90
EM HML	0.12	-0.03	-0.14	0.13	-0.01	-0.02
	0.40	-0.09	-0.34	0.68	-0.03	-0.10
EM RMW	-0.70	-0.45	-0.60	-0.31	-0.32	-0.23
	-1.40	-0.67	-0.75	-1.53	-1.16	-0.78
EM CMA	-0.05	0.07	0.08	-0.20	0.02	-0.02
	-0.08	0.10	0.11	-0.63	0.06	-0.05
EM WML	0.09	-0.04	0.04	0.03	0.14	0.09
	0.42	-0.14	0.10	0.30	1.05	0.53
Adjusted R-squared	58.77%	55.56%	51.49%	80.41%	80.59%	78.92%
N	139	79	55	139	79	55

Panel B: DM and EM Climate Solutions Portfolios

	DM						EM					
	Value Weighted			Equally Weighted			Value Weighted			Equally Weighted		
	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018
Alpha	11.31%	17.55%	28.65%	11.24%	16.98%	23.97%	10.68%	11.32%	21.12%	11.15%	7.75%	12.16%
	1.83	1.84	2.25	2.07	2.20	2.35	1.43	1.04	1.68	3.09	1.31	1.65
DM Mkt-RF	1.43	1.78	1.83	1.16	1.26	1.30						
	6.27	5.41	5.39	11.43	8.29	8.34						
DM SMB	0.07	-0.63	-0.47	0.61	0.70	0.87						
	0.15	-1.06	-0.67	2.12	2.23	2.46						
DM HML	-1.03	-1.74	-1.81	-0.67	-0.99	-1.09						
	-1.30	-1.71	-1.29	-2.11	-2.42	-2.22						
DM RMW	-1.15	-1.70	-1.95	-1.14	-1.48	-1.99						
	-2.51	-2.47	-2.45	-3.53	-2.80	-3.21						
DM CMA	-0.21	0.76	0.81	0.31	0.78	0.79						
	-0.20	0.59	0.45	0.70	1.55	1.34						
DM WML	-0.10	-0.12	-0.10	-0.20	-0.14	-0.17						
	-0.27	-0.24	-0.15	-0.97	-0.48	-0.46						

(continued)

EXHIBIT A1 *(continued)***Multifactor Regressions**

	DM						EM					
	Value Weighted			Equally Weighted			Value Weighted			Equally Weighted		
	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018	Since 2011	Since 2016	Since 2018
EM Mkt-RF							0.78	0.83	0.80	0.84	0.87	0.84
							5.84	4.92	4.98	13.95	12.38	12.08
EM SMB							0.91	0.80	0.78	1.18	1.14	1.21
							2.52	1.92	1.76	7.03	5.40	5.06
EM HML							-0.16	-0.45	-0.86	0.26	0.25	0.12
							-0.40	-0.87	-1.55	1.12	0.87	0.38
EM RMW							-0.44	-0.17	0.05	0.18	0.27	0.47
							-1.00	-0.42	0.11	0.66	0.82	1.44
EM CMA							-0.44	0.05	0.47	-0.36	-0.13	-0.05
							-1.08	0.09	0.87	-1.58	-0.45	-0.17
EM WML							-0.03	0.09	0.11	-0.09	0.11	0.05
							-0.16	0.27	0.25	-0.81	0.80	0.31
Adjusted R-squared	55.45%	55.99%	56.23%	70.62%	71.15%	74.19%	39.16%	33.27%	33.60%	70.12%	70.15%	69.33%
N	139	79	55	139	79	55	139	79	55	139	79	55

NOTES: Panel A presents the portfolio performance for value-weighted and equally weighted climate solutions portfolios based on the global sample for three periods: January 2011 to July 2022, January 2016 to July 2022, and January 2018 to July 2022. For the global portfolio, we calculate alphas for climate solutions portfolios using multifactor regressions, controlling for the Fama–French five factors for developed markets and emerging markets, including market, value, size, profitability, and investment as well as developed markets and emerging markets momentum factors. Panel B presents the portfolio performance for value-weighted and equally weighted climate solutions portfolios based on the developed markets sample and the emerging markets sample for three periods: January 2011 to July 2022, January 2016 to July 2022, and January 2018 to July 2022. For the developed markets portfolios, we calculate alphas for climate solutions portfolios using multifactor regressions controlling for the Fama–French five factors for developed markets, including market, value, size, and profitability as well as the developed markets momentum factor. For the emerging markets portfolios, we calculate alphas controlling for the Fama–French five factors for emerging markets and the emerging markets momentum factor. The *t*-statistics for alphas are estimated based on HAC standard errors. DM = developed market; EM = emerging market; Mkt-RF = market minus risk-free rate, or market factor; SMB = small minus big, or size factor; HML = high minus low, or value factor; RMW = robust minus weak, or profitability factor; CMA = conservative minus aggressive, or investment factor; WML = winner minus loser, or momentum factor.

EXHIBIT A2**Climate Solutions Portfolio Performance**

	Agriculture and Food (A)	Batteries (B)	Energy (E)	Fuels-Alternate (F)	Housing (H)	Materials (M)	Transportation (T)	Others
Panel A: By Category (January 2016–July 2022)								
Value Weighted								
Returns	-19.10%	45.03%	11.38%	6.17%	20.85%	4.75%	7.61%	-2.90%
Risk	53.37%	51.69%	14.92%	25.81%	28.86%	36.31%	32.14%	27.43%
Return/Risk	-0.36	0.87	0.76	0.24	0.72	0.13	0.24	-0.11
Max Drawdown	84.34%	57.57%	24.86%	54.52%	53.48%	58.62%	53.14%	71.23%
Alpha	-11.68%	35.15%	8.71%	13.76%	8.30%	16.19%	36.03%	-0.87%
Alpha <i>t</i> -Stat	-0.88	1.24	1.38	1.68	0.78	0.88	1.97	-0.10
Equally Weighted								
Returns	3.74%	30.71%	16.32%	20.13%	18.67%	16.69%	18.26%	11.19%
Risk	26.23%	23.08%	11.96%	17.32%	24.98%	19.09%	19.62%	20.02%
Return/Risk	0.14	1.33	1.36	1.16	0.75	0.87	0.93	0.56

(continued)

EXHIBIT A2 (continued)**Climate Solutions Portfolio Performance**

	Agriculture and Food (A)	Batteries (B)	Energy (E)	Fuels- Alternate (F)	Housing (H)	Materials (M)	Transportation (T)	Others
Max Drawdown	58.82%	39.18%	29.42%	30.15%	43.53%	44.12%	42.32%	51.42%
Alpha	5.01%	27.33%	7.65%	15.24%	14.01%	12.98%	26.64%	5.75%
Alpha t-Stat	0.43	2.14	1.48	2.05	1.64	1.64	2.72	1.02
Number of Stocks	12.8	30.8	309.3	35.2	13.0	15.7	52.7	17.1
Panel B: By Category (January 2018–July 2022)								
Value Weighted								
Returns	-27.75%	65.59%	15.78%	7.37%	22.07%	-5.17%	15.51%	-11.80%
Risk	56.18%	59.19%	16.08%	29.19%	31.62%	39.35%	35.79%	29.24%
Sharpe Ratio	-0.49	1.11	0.98	0.25	0.70	-0.13	0.43	-0.40
Max Drawdown	82.88%	57.57%	24.86%	54.52%	53.48%	58.48%	50.33%	71.23%
Alpha	-15.74%	49.49%	15.57%	20.38%	15.25%	16.48%	48.45%	-7.99%
Alpha t-Stat	-0.88	1.37	2.20	1.91	1.33	0.69	2.25	-0.70
Equally Weighted								
Returns	-1.19%	32.51%	17.68%	14.89%	14.55%	2.58%	14.56%	4.78%
Risk	26.77%	24.19%	12.98%	18.31%	25.19%	19.71%	20.85%	21.11%
Sharpe Ratio	-0.04	1.34	1.36	0.81	0.58	0.13	0.70	0.23
Max Drawdown	58.82%	36.70%	29.42%	30.15%	43.53%	44.12%	42.32%	51.42%
Alpha	9.33%	31.68%	13.62%	13.81%	12.42%	1.96%	29.79%	2.63%
Alpha t-Stat	0.71	1.94	2.20	1.49	1.12	0.23	2.41	0.32
Number of Stocks	14.5	31.8	319.4	36.9	14.4	15.9	58.2	18.3

NOTES: This exhibit presents the performance for value-weighted and equally weighted climate solutions portfolios by different sectors/industries based on the global sample for January 2016 to July 2022 and January 2018 to July 2022. For some of the categories with the number of observations fewer than 20 companies, we combine them into the category Others, including nature-based solutions, industrials, recycling and circularity, and carbon capture and storage. Alphas are calculated after controlling for the Fama–French five factors for developed markets and emerging markets, including market, value, size, profitability, and investment as well as developed markets and emerging markets momentum factors.

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