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GS SUSTAIN: Avoided Emissions

How quantifying Avoided Emissions can broaden the decarbonization investment universe

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While investing in climate solutions has been one of the most dominant themes among Sustainability investors in recent years, ESG ownership still continues to be largely concentrated in a subset of more-obvious pure play solution providers, mainly solar/wind/water. We believe this has been in part driven by relative lack of metrics available to help investors quantify the impact of less-obvious enablers across multiple industries ranging from Industrials, Materials to Technology. However, our analysis suggests that since 2010, Energy Efficiency has helped to reduce 50% more carbon emissions than renewables generation additions. We believe as Sustainable Investing continues to shift From Aspiration to Action, investors will look to quantify impact, with rising interest in Avoided Emissions for relevant sectors. **In this report, we discuss why we believe incorporating Avoided Emissions into investment decisions could help identify underappreciated enablers in the ecosystem of Green Solutions.**

Avoided emissions impact of Building Insulation and Semiconductors

Both **Building Insulation** and **Semiconductors** can contribute to Avoided Emissions by enabling end-consumers to save more energy. **Our new analysis suggests Building Insulation could help avoid 20X-100X more emissions than they emit.** As per our prior analysis, we believe **Semiconductors could help avoid at least 5X their own footprint.**

Methodology and application of Avoided Emissions analysis likely to see increased focus

Despite the challenging data landscape and lack of conclusive methodologies, we believe preliminary analysis of Avoided Emissions can still be additive to the investment process when applied to industries with strong ties to energy efficiency, which has played a critical role in enabling global Avoided Emissions in recent decades. We discuss early guidelines set by the WRI and WBCSD on how investors can start to measure Avoided Emissions, and provide examples of how corporates and investors are currently leveraging Avoided Emissions to communicate their impact.

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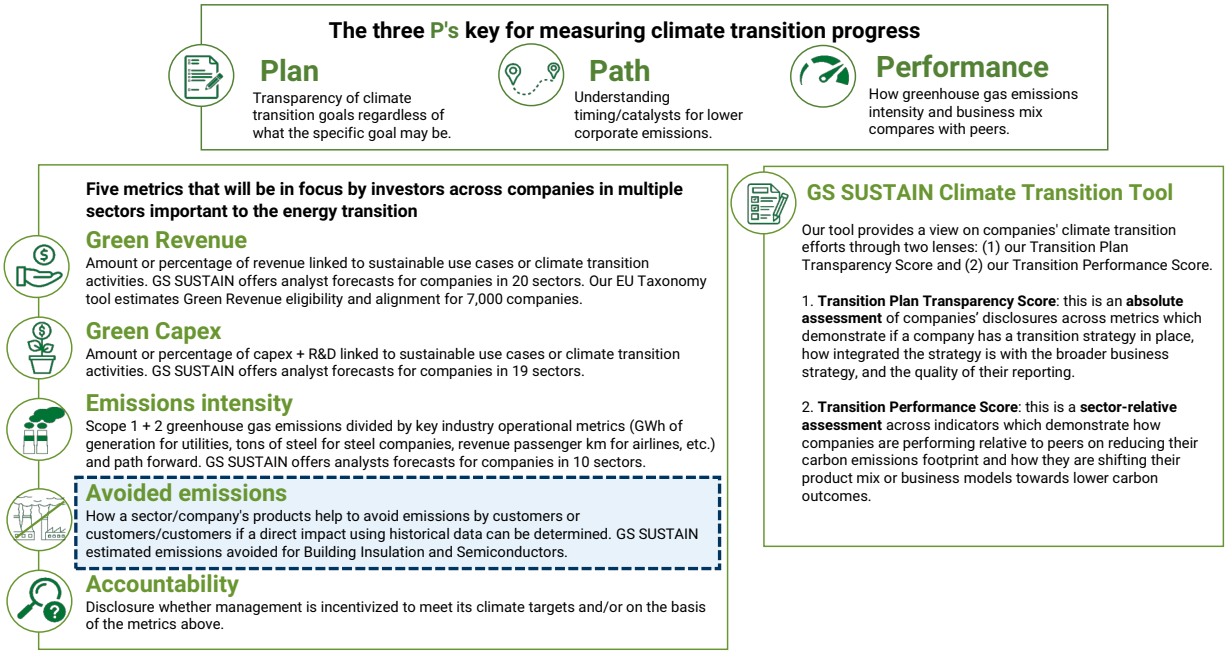
The following is a redacted version of Goldman Sachs Research's report "GS SUSTAIN: Avoided Emissions How quantifying Avoided Emissions can broaden the decarbonization investment universe" originally published Jul. 25 2023 (27pgs). All company references in this note are for illustrative purposes only and should not be interpreted as investment recommendations.

PM Summary

Avoided emissions provide additional insights that can help broaden the decarbonization investment universe

As Sustainability investing matures to the "Measurement" phase of its cycle and becomes more forward-looking, there is rising focus on how to quantify impact — whether environmental or social. Investing in decarbonization has been a strong area of focus in particular, and we continue to see investors and corporates focusing on the 3 Ps — Plan, Path and Performance. We see **avoided emissions** among the five key metrics (Exhibit 1) investors will increasingly consider in order to identify sectors that play a critical role in transition. **Avoided emissions can be additive** to the investment process, providing insights that cannot be measured through conventional emissions reporting boundaries (i.e., Scope 1-3). While the concept has been broadly adopted by the market for pure-play green sectors (in some cases implicitly), application has been relatively limited for less-obvious enabling industries. **We believe adopting avoided emissions analysis for underappreciated enabling sectors can help broaden the decarbonization investment universe longer-term.**

Exhibit 1: We believe avoided emissions is a critical building block metric that can help investors quantify and measure corporates' climate transition progress



Source: Goldman Sachs Global Investment Research

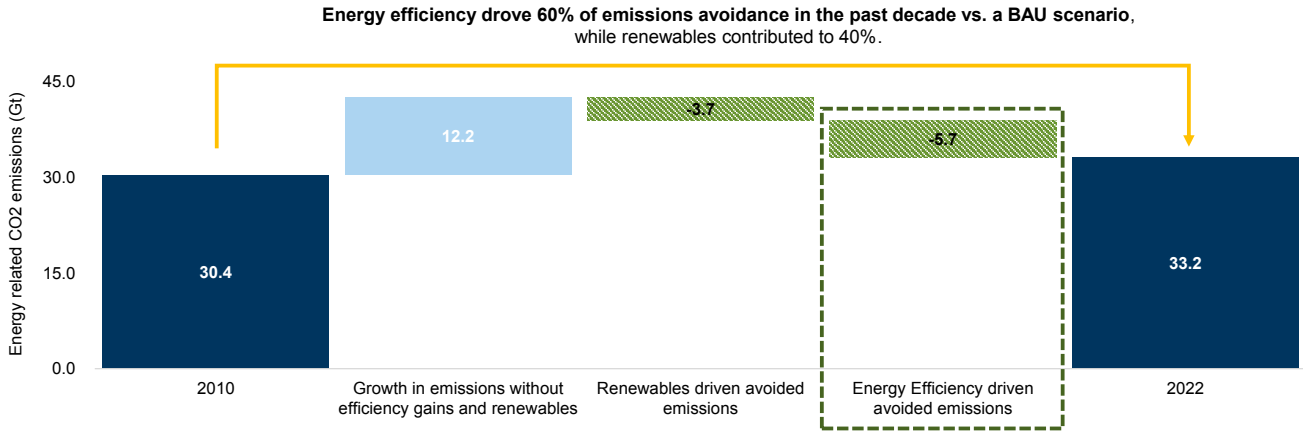
Sectors tied to energy efficiency are critical enablers of avoided emissions

Energy efficiency gains have historically been one of the strongest enablers of avoided emissions, which partly explains why industry stakeholders (e.g., IEA, UN) have coined energy efficiency as the **"first fuel"** policymakers must address in order to promote global climate change mitigation objectives. **For background**, global energy

related CO2 emissions have increased <10% across the past decade (2010-2022), despite a ~40% expansion in real GDP. In other words, although absolute emissions have risen, a significant amount of emissions was avoided globally as a result of renewable energy expansion and energy efficiency gains. While the role of renewables has often been acknowledged by industry participants and investors, we believe energy efficiency enablers have not been as prominently featured in the broader decarbonization debate by market participants.

Our scenario analysis suggests **energy efficiency gains across the economy have contributed to 60% of the avoided emissions globally between 2010-2022**, with renewables contributing the remaining 40% (Exhibit 2). Despite their impact, sectors that enable energy efficiency ranging from Industrials, Materials to Technology are still broadly under-represented in ESG portfolios in part because their benefits are less visible and often unmeasured. We believe sectors tied to energy efficiency can benefit from increasing investor support when assessed through the lens of avoided emissions.

Exhibit 2: Over the past decade, energy efficiency gains across sectors have played a greater role in driving avoided emissions than renewables deployment
Attribution analysis of avoided emissions from renewable energy deployment and energy efficiency gains (2010 baseline)



Source: IEA, World Bank, UN, Goldman Sachs Global Investment Research

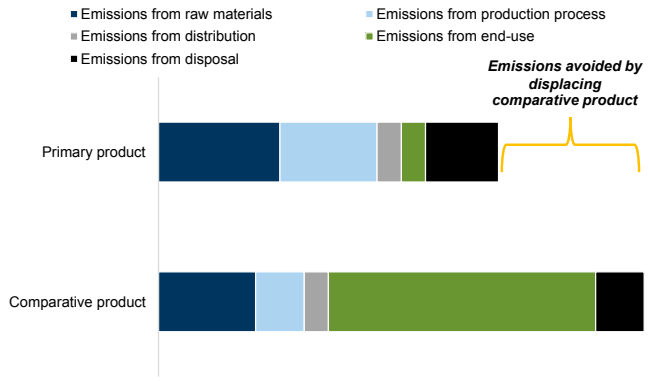
Preliminary frameworks exist to guide investors and corporates looking to adopt avoided emissions

Despite the lack of conclusive methodologies to estimate avoided emissions to date, there are early initiatives to accelerate adoption of these metrics. Unlike conventional corporate GHG inventories (i.e., Scope 1-3) which tend to follow fairly standardized approaches in measurement and reporting, there are multiple approaches that can be leveraged to estimate avoided emissions (also commonly referred to as "Scope 4" emissions). Avoided emissions estimates ultimately require an analysis of factual (or **"base case" estimates** if factual data is not fully unavailable), as well as **"counterfactual" scenarios** to compare how global emissions outcomes would have varied from the base case if certain actions were not taken.

While not exhaustive, our report summarizes broad-based recommendations set by various organizations, including the World Resources Institute (WRI) and the World

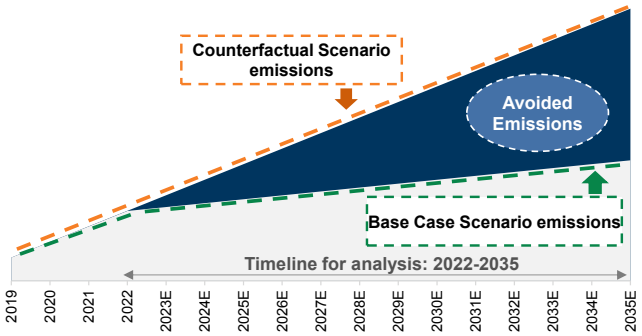
Business Council for Sustainable Development (WBCSD) which have been widely referenced by stakeholders looking to assess avoided emissions. We discuss the key steps that are recommended to assess avoided emissions, starting from life cycle emissions analysis (Exhibit 3) and construction of base case/counterfactual scenarios (Exhibit 4) needed to estimate avoided emissions. Frameworks to measure avoided emissions will likely continue to evolve through industry and government efforts to harmonize standards and increase data availability.

Exhibit 3: Assessing products from a life cycle perspective can help investors gain insights on avoided emissions contributions from enabling vs. alternative products
Illustrative analysis of how life cycle emissions assessments can lead to avoided emissions calculations



Source: Goldman Sachs Global Investment Research

Exhibit 4: Investors can assess how the deployment of certain enabling products could lead to lower levels of global emissions relatived to a scenario where the solution is not deployed
Overview of avoided emissions estimation process



Source: WRI, WBCSD, Goldman Sachs Global Investment Research

GS SUSTAIN analysis on avoided emissions from Building Insulation and Semiconductors

In addition to discussing general frameworks, we analyzed avoided emissions of key products within industries we believe can play a critical role in climate transition, starting with Building Insulation and Semiconductors. On aggregate, our analysis suggests **Building Insulation could help avoid 20X-100X** more emissions than they emit, while **Semiconductors could help avoid at least 5X** their own footprint.

- **Building Insulation** is an enabler of household energy efficiency. Compared to an uninsulated home, **insulated buildings can lead to 40%-45% energy savings for space heating and cooling, per** the Victorian State Government of Australia and our European Infrastructure/Construction & Transport colleagues' conclusions from the 2022 Insulation initiation report. Based on our analysis, incremental **Building Insulation products deployed between 2015-2030 could help reduce annual household energy consumption by 9 EJ, or a 14% reduction** relative to a counterfactual no-insulation deployment scenario. By 2030, our analysis implies this would mean that incremental insulation deployment from a 2015 baseline would lead to 0.9 Gt of CO2 annual avoided emissions in 2030, or **~3% of global energy-related emissions in 2019.**
- **Technological advancement in Semiconductors** has been an important contributor of energy efficiency gains for the modern digital infrastructure. Exponential growth in semiconductor computing performance, combined with gains

in energy efficiency and cost deflation have enabled large scale adoption of semiconductors across multiple technologies which have ultimately benefited from energy efficiency gains. Together, we estimate that **advancements in semis since 2015 contributed to 1-2 Gt of carbon dioxide emissions avoided in 2020** (>3% of global Energy emissions), and see potential for an additional **2-5 Gt of annual avoidance by 2025.**

For more details on our analysis and assumptions, please see:

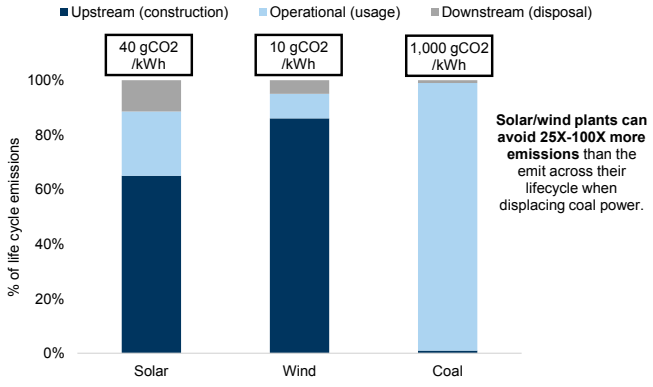
- *GS SUSTAIN Avoided Emissions: Sizing the underappreciated enabling impact of Building Insulation (July 2023)*
- *GS SUSTAIN: Greenablers: The critical role of Semiconductors towards a sustainable future (Nov 2021)*

Scope 4: The next frontier of emissions boundaries that could help quantify the impact of underappreciated enablers

As discussed in our Green Capex research series, we believe decarbonization will be a secular investment theme requiring an all-in approach to deploy a multitude of enabling solutions. **While the ecosystem of Green Capex solutions (Exhibit 7) is vast and inclusive of various industries (many of which are not commonly perceived as "Green")**, the current holdings composition of global ESG funds is **largely concentrated in only a subset of pure-play verticals** (Exhibit 8-Exhibit 9).

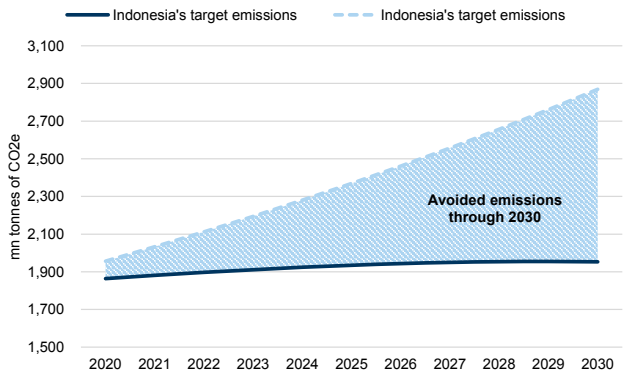
Avoided emissions can be additive in our view, in that they help provide insights that cannot be measured through conventional emissions reporting boundaries (i.e., Scope 1-3). The concept of avoided emissions is not new for investors, companies or governments. This has been broadly adopted, in some cases implicitly, by the market for pure-play green industries — e.g., low-carbon portfolios focusing on renewables and EVs, both of which can lead to avoided emissions for the broader economy when displacing fossil fuel demand. In addition, **governments have used avoided emissions principles to set national decarbonization targets under the Paris Agreement.** Note that many EMs across Asia and elsewhere have decarbonization targets set against a "Business-As-Usual" (BAU) scenario, which means national targets are based on avoiding emissions through climate action relative to a counterfactual do-nothing scenario. Below are two examples illustrating the concept of avoided emissions for **solar/wind power** (Exhibit 5) and **national level avoided emissions targets** (Exhibit 6).

Exhibit 5: When displacing coal power, solar and wind plants can avoid 25X-100X more emissions across their life cycle
Total life cycle emissions and value chain emissions mix of solar, wind and coal power plants



Source: National Renewable Energy Laboratory, Data compiled by Goldman Sachs Global Investment Research

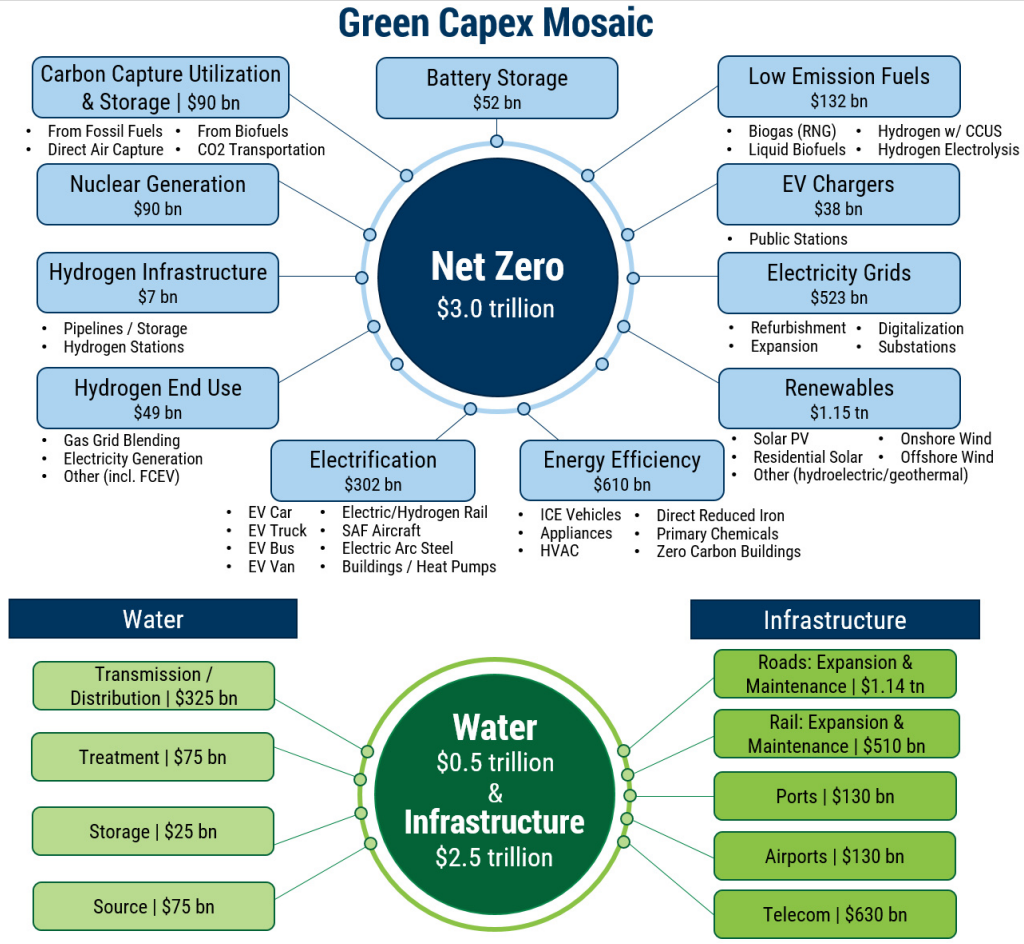
Exhibit 6: Indonesia's target to reduce national emissions by ~32% vs. its BAU scenario by 2030 is an example of a national decarbonization target based on avoided emissions principles
Indonesia's 2030 decarbonization (NDC) target



Source: UNFCCC, Goldman Sachs Global Investment Research

Exhibit 7: The ecosystem of Green Capex solutions is inclusive of multiple sectors and technologies, many of which are not commonly perceived to be "Green"

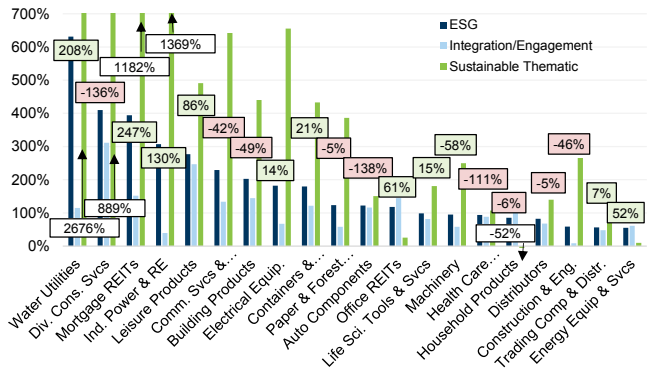
Critical technologies/focus areas and annual investment in the 2020s to achieve Net Zero, Infrastructure and Clean Water needs



Source: IEA, McKinsey, OECD, Company data, Goldman Sachs Global Investment Research

Exhibit 8: Overweight positions by ESG funds are highly concentrated in Water and Renewables

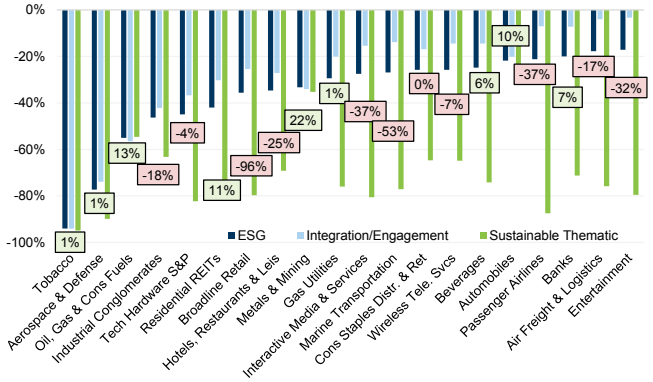
20 most overweight industries (GICS 3) by ESG-linked equity funds; boxes show strategy-wide ESG ownership momentum (vs. Mar 2022)



Source: Morningstar, Thomson Reuters, Goldman Sachs Global Investment Research

Exhibit 9: Underweight positions in ESG funds are highly concentrated in Tobacco, Aerospace & Defense, Oil & Gas and Metals & Mining

20 most underweight GICS 3 industries by ESG funds; boxes show strategy-wide ESG ownership momentum (vs. Mar 2022)



Source: Morningstar, Thomson Reuters, Goldman Sachs Global Investment Research

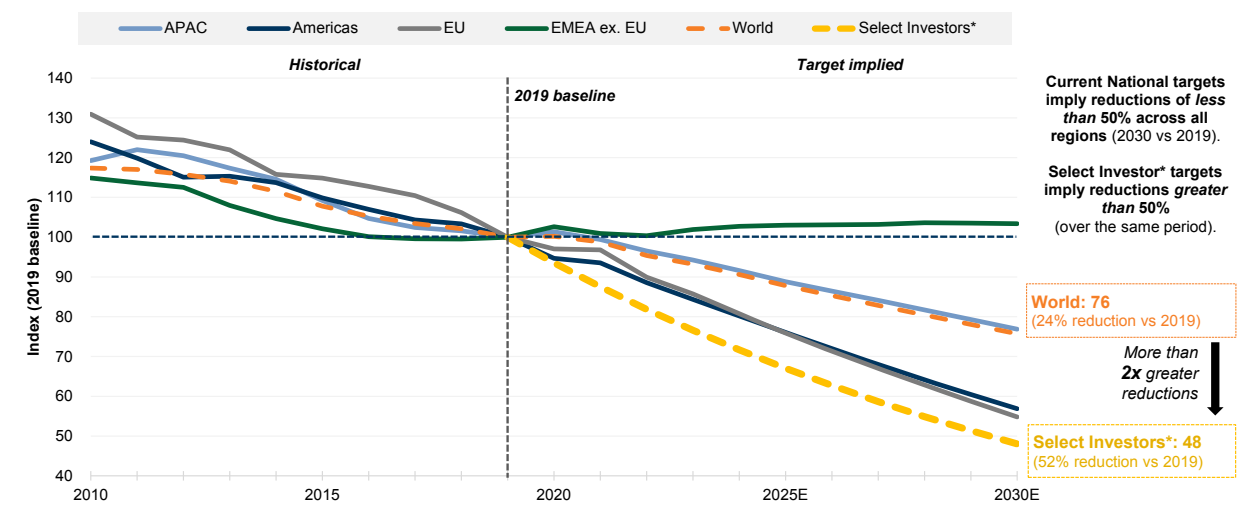
Potential shifts in portfolio net zero target setting methodologies could catalyze focus on avoided emissions

We continue to see mounting evidence from leading global climate bodies that the **window of opportunity for achieving the climate goals of the Paris Agreement is shrinking.** Without sufficient near-term action, the IPCC warns that we will reach 1.5°C warming in the first half of the next decade. With the increase in urgency to decarbonize, we have seen rising investor focus on portfolio decarbonization, with U$72 trillion in AUM incorporating Net Zero considerations into their portfolio management. That said, we observe a widening gap between emissions intensity goals out to 2030 — **select investor targets call for portfolio emissions intensity reductions at a rate that is more than 2X what is implied by national targets**.

Longer-term, we believe this could potentially lead to increasing focus by asset managers on alternative low-carbon investing strategies, with less emphasis on setting quantified portfolio decarbonization targets. This may include increasing investment in climate solutions (i.e., focus on **maximizing avoided emissions** in addition to focusing on **minimizing corporate Scope 1-3 emissions**), upstream enabling technologies, or launching dedicated engagement or "improvers" strategies to work with the highest emitting companies to achieve more aggressive decarbonization outcomes. **Ultimately, increasing focus on investing in climate solutions could drive greater need to incorporate avoided emissions** into investment decisions in order to expand the investment universe beyond a limited set of pure-play green sectors.

For more details, please see GS SUSTAIN: Net Zero Guide: The Decarbonisation Dislocation between investor and national-level 2030 targets.

Exhibit 10: Select investor emissions intensity targets imply a 2x greater reduction than current national-level targets
Indexed (i) regional emissions intensity (per unit of US$ GDP) pathways implied by key economies' stated NDCs and (ii) weighted average emissions intensity targets (per $ mn invested or WACI of holdings) to 2030 vs 2019 baseline.



"Select Investors" represents the weighted average annualised reduction rates of the 104 firms who have publicly set intensity-based emissions reduction targets under the Net Zero Asset Managers initiative as at 24 April 2023. Regional decarbonisation indices are implied pathways based on current 2030 Nationally Determined Contribution (NDC) targets from major economies by region. See Appendix for more information on our methodology.

Source: UNFCCC, European Commission Joint Research Centre, Net Zero Asset Manager initiative, Goldman Sachs Global Investment Research

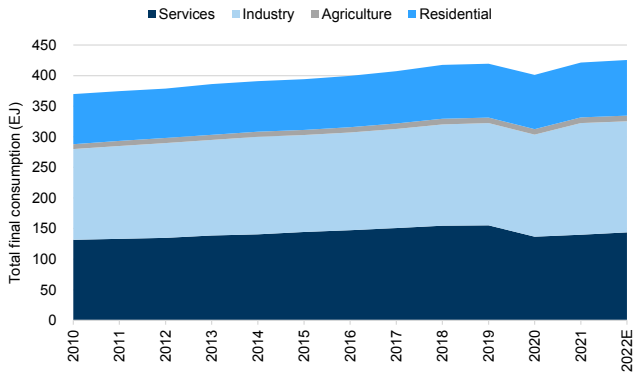
Energy Efficiency: A significant enabler of avoided emissions

While we find that there is little market debate on the role of renewable energy in driving avoided emissions, **the role of Energy Efficiency is often underappreciated.** Focus on Energy Efficiency is starting to accelerate in our view following an energy crisis in 2022 and the outcomes of COP27. Industry stakeholders (e.g., IEA, UN) believe Energy Efficiency will be the **"first fuel"** policymakers must address going forward in order to promote global climate change mitigation objectives. **While climate scientists have long argued the benefits of focusing on energy efficiency, companies in the Energy Efficiency value chain remain broadly under-represented in ESG portfolios.**

As illustrated in Exhibit 11, global energy demand (on a total final consumption (TFC) basis) has expanded by 15% between 2010-2022 on the back of a 37% expansion in real GDP. This implies that across the previous decade, most sectors of the global economy have seen meaningful reductions (~12% on average) in energy intensities (Exhibit 12), resulting in lower energy demand to fuel the growing global economy and population. Reductions in energy intensity across the global economy have ultimately led to avoided emissions.

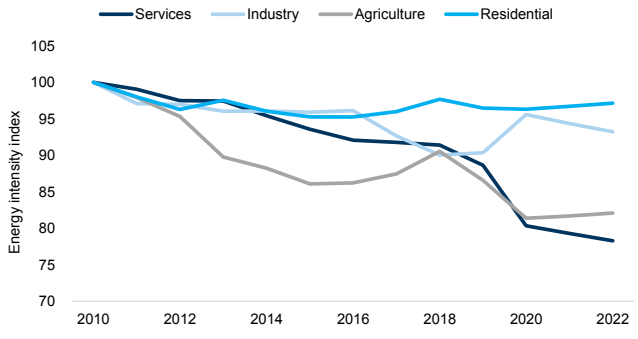
What's underappreciated: Energy Efficiency has likely enabled the majority of the avoided emissions globally over the past decade. Our counterfactual scenario analysis (Exhibit 13) suggests that energy efficiency gains across sectors have potentially driven 60% of the avoided emissions in the global energy sector between 2010-2022. Despite their significant role in enabling better environmental outcomes, energy efficiency products have not received significant focus from Sustainability investors in part because their benefits are less visible and often unmeasured.

Exhibit 11: Global total final consumption of energy has increased by 15% between 2010-2022 on the back of a 37% expansion in real GDP
Total final consumption (TFC) of energy by sector



Source: IEA, World Bank, UN, Goldman Sachs Global Investment Research

Exhibit 12: Energy efficiency gains through innovation has been the key driver of energy savings
Trends in energy intensity reductions, indexed to 2010

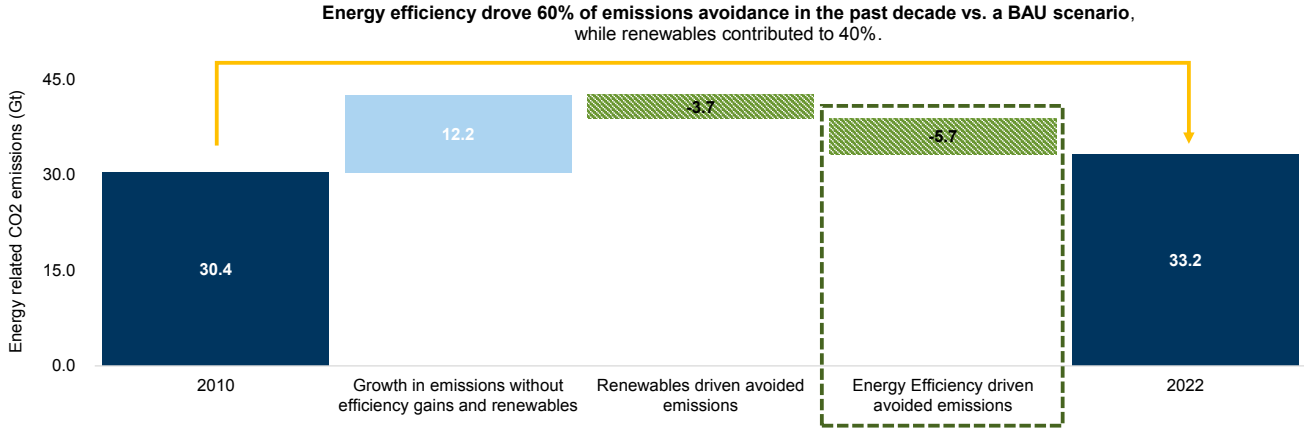


Note: Energy intensity for Services, Industry and Agriculture sectors is measured per unit of GDP in 2020 constant prices. Residential energy is measured on a per capita basis.

Source: World Bank, Goldman Sachs Global Investment Research

Exhibit 13: Over the past decade, energy efficiency gains across sectors have played a greater role in driving avoided emissions than renewables deployment

Attribution analysis of avoided emissions from renewable energy deployment and energy efficiency gains (2010 baseline)



Source: IEA, World Bank, UN, Goldman Sachs Global Investment Research

General frameworks to measure avoided emissions

Unlike conventional corporate GHG inventories (i.e., Scope 1-3) which tend to follow fairly standardized approaches in measurement and reporting, there currently is no universally accepted framework in place to measure avoided emissions. This is in part due to the technical complexities associated with measurement. Avoided emissions estimates ultimately require an analysis of factual (or **"base case" estimates** if factual data is unavailable), as well as **"counterfactual" scenarios** to compare how global emissions outcomes would have varied from the base case if certain actions were not taken (e.g., analysis of emissions outcomes if renewables were not deployed either in the past or future).

While not exhaustive, below we summarize broad-based recommendations set by various organizations, including the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) which have been widely referenced by stakeholders looking to assess avoided emissions. We believe frameworks to measure avoided emissions will continue to evolve through industry/government efforts to harmonize standards and increase data availability.

Defining the difference between Scope 1-3 vs. avoided emissions (commonly referred to as "Scope 4")

Avoided emissions are fundamentally different on what they represent and how they are measured compared to Scope 1-3 emissions. The WRI and WBCSD note that there's significant confusion among stakeholders on how avoided emissions compare against Scope 3 in particular, given they both conceptually cover emissions that happen as a result of a certain product's manufacturing process, distribution and usage.

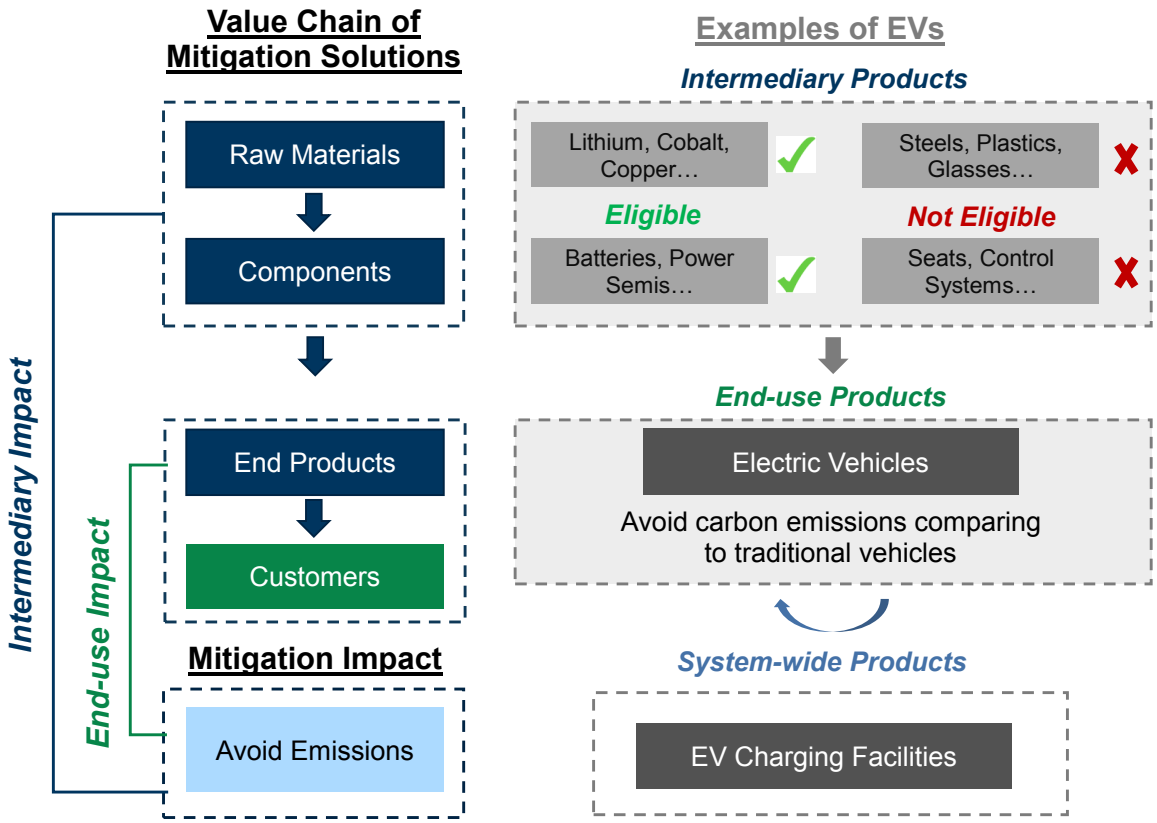
Differences in boundary: Scope 1-3 emissions are reported within the boundaries of a company's own operations and value chain. It ultimately represents upstream and downstream emissions generated to manufacture, sell, use and dispose their products. In contrast, avoided emissions represents the impact a company's products or services can have to the broader society from an emissions avoidance perspective, going beyond the company's own value chain. **Simply put**, if a Solar PV manufacturing company expands its business and sells more panels in future years, its Scope 1-3 emissions are likely going to increase, all things equal (i.e., **absolute emissions will grow for the company**). However, from a Scope 4 perspective the deployment of solar panels enabled by the company could lead to **total emissions reductions for the world** if local grids replace fossil fuels with renewables. The benefits from the latter cannot be measured through the company's Scope 1-3 emissions disclosures.

Identifying the relevant product or service that helps avoid emissions

Based on guidelines from the WBCSD, not all products should be considered as eligible to claim avoided emissions impact, given not every product in the market has significant and/or direct contribution towards climate change mitigation objectives. As such, the **WBCSD recommends products assessed for avoided emissions should have a meaningful and direct role in mitigation**, preferably aligned with existing climate science (e.g., IPCC's Sixth Assessment Report) or established Green Taxonomy frameworks (e.g., EU Taxonomy). The WBCSD categorizes three types of products that could be eligible as products that contribute towards avoided emissions:

- **"End Use" Products** refer to final products that directly help customers reduce carbon emissions relative to existing alternatives. Examples include **EVs**, **renewables**, **plant-based proteins** and **heat pumps**.
- **Intermediary Products** represent upstream components that are needed as building blocks for the "End Use" product. Examples include **EV batteries**, **wind turbine rotors**, **low-carbon building materials**, and **semiconductors.**
- **System-wide Solutions** empower the broader low-carbon ecosystem, or directly improve and optimize system energy usage. Examples **EV charging stations**, **smart grid systems** and **energy management software.**

Exhibit 14: The WBCSD recommends stakeholders to determine what products are eligible vs. non eligible for emissions avoidance assessments based on whether their contribution is direct and significant
WBCSD's illustrative example of eligible business activities that contribute towards avoided emissions in the EV supply chain



Source: WBCSD, Goldman Sachs Global Investment Research

WRI and WBCSD recommended steps to estimate avoided emissions

Once a relevant enabling product is identified, the WRI and WBCSD recommend stakeholders to assess the life cycle emissions of the enabling product in focus vs. an existing alternative product. This is ultimately required to then create a **"base case" scenario** which analyzes global emissions outcomes through usage of the enabling product and a **"counterfactual" scenario** which measures projected emissions outcomes assuming the enabling products are not deployed. While the concept is fairly simple, there are many nuances that can lead to different outcomes depending on what parameters and assumptions are set throughout the various stages of the estimation process which we discuss below.

Three key steps to measuring avoided emissions

Step 1. Establish a timeline: This step is intended to provide clarity on what the avoided emissions calculations represent from a timeline perspective to avoid confusion on whether the impact is measured on a historical vs. forward-looking perspective (or both), and whether figures are represented on an annual or cumulative basis. When measuring avoided emissions of energy efficiency enabling products, establishing timelines provides context on the baseline year that was used as a reference benchmark to assess energy intensity improvements.

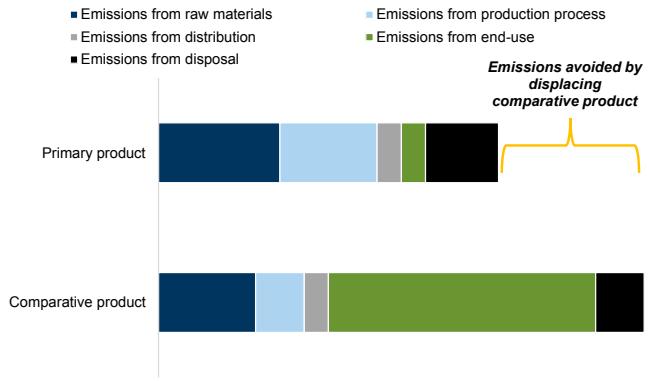
Step 2. Measure the "base case" and "counterfactual" emissions scenarios: After identifying the relevant timeline, stakeholders can then assess the emissions footprint of an enabling product vs. a comparative alternative, usually through a life cycle assessment of both products if data is available (Exhibit 15). This allows stakeholders to then estimate the **"base case"** global emissions scenario which reflects the emissions outcomes assuming the enabling products are used, as well as a **"counterfactual"** scenario which measures emissions outcomes in the absence of the enabling solution. Estimates on base case and counterfactual scenarios will differ depending on whether stakeholders adopt the **Attributional Approach** or the **Consequential Approach** (Exhibit 17) to measure the scenarios. Based on the WRI's view, the consequential approach is more comprehensive and potentially more useful for policy decisions. However, the WRI recommends the **"Attributional Approach" as an interim solution** if data availability is limited.

- The **Attributional Approach** is focused on measuring the **direct emissions** that are avoided through the deployment of a specific climate solution. This approach is relatively easier to execute as indirect/second-derivative factors do not necessarily have to be embedded into the analysis. **For example**, avoided emissions through solar panel deployment could be estimated simply by comparing the life cycle emissions of a solar plant vs. a coal or natural gas plants assuming fossil fuels are being displaced by renewables.
- The **Consequential Approach** is focused on measuring both the **direct and indirect effects** that result from the deployment of an enabling product. This approach considers the changes that could potentially occur within the broader economic system as a consequence of the deployment of the enabling product. **For example**, estimating avoided emissions of solar panel deployment requires

stakeholders to assess indirect consequences of power capacity additions (e.g., higher/lower aggregate power prices that could lead to higher/lower energy usage across the economy following renewables deployment). **In other words, 1 GWh of solar deployment may not always displace 1 GWh of fossil fuels (or any other power source) under the Consequential Approach.**

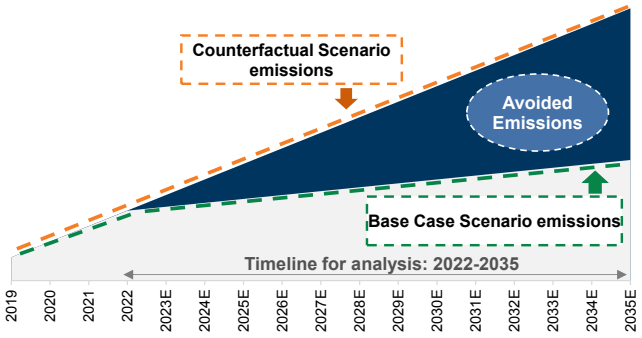
Step 3. Quantify the avoided emissions impact of the enabling product: The differences in emissions outcomes between the base case vs. the counterfactual scenarios ultimately can help quantify the volume of emissions that were potentially avoided through the deployment of the enabling product (Exhibit 16).

Exhibit 15: Assessing products from a life cycle perspective can help investors gain insights on avoided emissions contributions from an enabling vs. alternative products
Illustrative analysis of how life cycle emissions assessments can lead to avoided emissions calculations



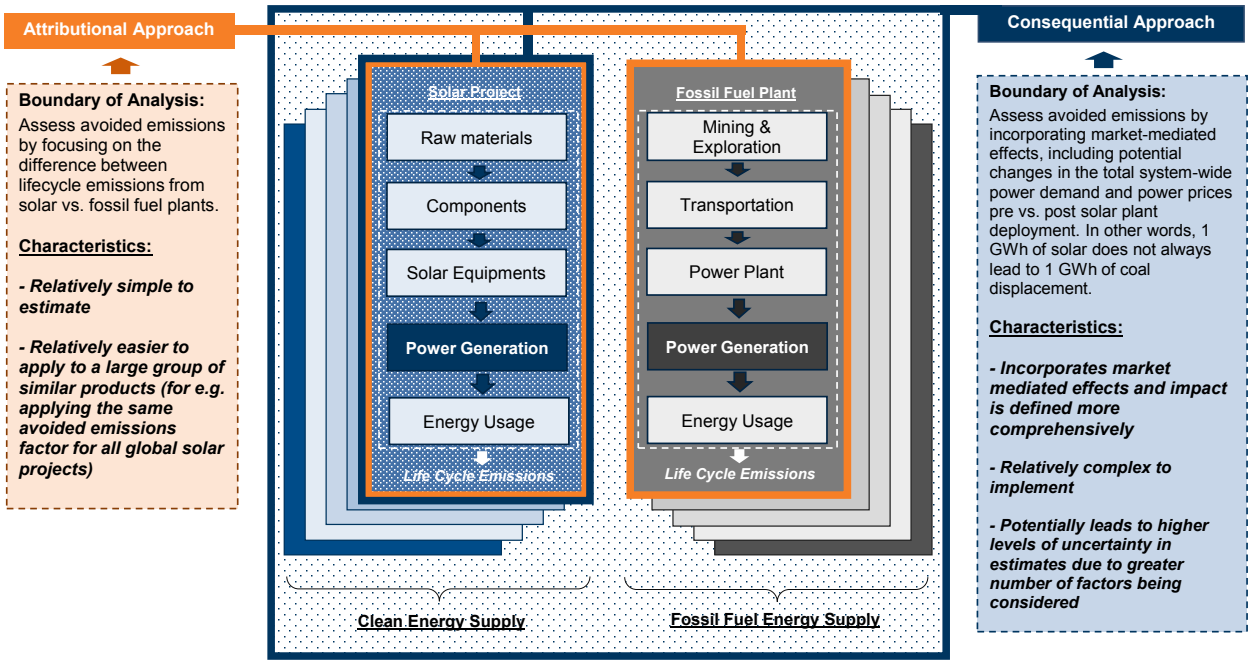
Source: Goldman Sachs Global Investment Research

Exhibit 16: Investors can assess how the deployment of certain enabling products could lead to lower levels of global emissions relative to a scenario where the solution is not deployed
Overview of avoided emissions estimation process



Source: WRI, WBCSD, Goldman Sachs Global Investment Research

Exhibit 17: Comparison of Attributional vs. Consequential Approach in estimating avoided emissions from solar panel deployment



Source: WRI, Goldman Sachs Global Investment Research

Additional factors to consider

Rebound effects: This refers to the potential increase in energy consumption or emissions that may offset some or all of the emissions reductions resulting from the deployment of enabling solutions. **For example,** if a household installs energy efficient appliances and reduces their energy consumption, they may experience cost savings on their energy bills. That said, if the household uses these cost savings to purchase additional appliances, then the emissions reductions resulting from the installation of the energy efficient appliances may be partially or fully offset by the unintended rebound effect. Incorporating rebound effects could ultimately impact the base case scenario estimates when incorporating the Consequential Approach to measure emissions scenarios.

Marginal emissions factors: When converting energy savings into avoided emissions, it is important to consider what fuel sources could have been theoretically displaced as a result of lower energy demand. In most regions across the world, fossil fuel plants (coal and/or natural gas) tend to operate on the margin.

Allocating avoided emissions to the supply chain: Deploying an enabling technology requires a large supply chain of various building blocks and ingredients. For example, to deploy an EV, automakers require power semiconductors, software products, batteries and other autoparts. In practice, allocating avoided emissions across the supply chain of a product are relatively difficult to implement. The WRI and WBCSD generally recommend this to be done only when reliable data is available to do so and if there's industry-wide collaboration to reach a harmonized conclusion.

Challenges in full-scale implementation of avoided emissions and what could change that

Estimating avoided emissions that is fully aligned to existing recommendations may continue to be a challenge in the near-term due to practical limitations. Lack of comprehensive data availability of Life Cycle Assessment (LCA) of emissions footprints of various products is one of the key constraints. In addition, the debate on how to allocate avoided emissions across the supply chain has not been fully harmonized, since existing approaches (e.g., using bill-of-materials or value-add as basis to allocate avoided emissions across the supply chain) do not necessarily reflect "real world" impact. For instance, semiconductors only account for a fraction (~4%) of an EV cost, but it is virtually impossible to deploy the final product without these components. This can raise concerns on whether attributing 4% of avoided emissions from EVs to semiconductor companies accurately reflects their critical role in enabling the ecosystem.

The WRI explicitly states that no specific quantitative approach can be recommended as a final answer, and that **allocating avoided emissions throughout the supply chain** should only be considered as an **optional step**. In our work in estimating avoided emissions for Building Insulation and Semiconductors which we discuss further below, we have taken the sectoral avoided emissions approach rather than allocating proportional contributions to different parts of the value chain.

We believe frameworks to measure avoided emissions will remain fluid and will

continue to evolve over time given current challenges in data availability and lack of harmonization. Progress on the below initiatives could alleviate some of these challenges longer-term, potentially helping investors to increasingly incorporate avoided emissions into their investment decision-making process.

- **Increase in corporate disclosures on LCA emissions footprints:** This is increasingly becoming more common in consumer hardware products (e.g., multinational technology hardware companies are starting to disclose LCA emissions of their products), but data availability is limited in most other sectors.
- **Harmonization of what constitutes as an enabling product from an avoided emissions perspective:** Green Taxonomies across regions are starting to provide frameworks to help investors identify Green economic activities, but this is still relatively early stage in non-EU markets.
- **Harmonization on how to communicate avoided emissions.** While avoided emissions are commonly compared against Scope 1-2 emissions (Scope 3 where available), LCA-based avoided emissions embed forward-looking elements as they take the useful life of a product into consideration. Scope 1-3 emissions on the other hand are mainly historical data, reflecting emissions footprints during a particular fiscal or calendar year, meaning that avoided emissions are not always compatible with how Scope 1-3 are emissions are measured. In addition, avoided emissions are sometimes communicated from a cumulative basis (e.g., companies reporting avoided emissions through products sold for a given period) while others are on an annual-basis (e.g., companies reporting annual avoided emissions from products sold during a fiscal year).

How are companies and asset managers currently assessing avoided emissions?

As discussed above, efforts to measure and report avoided emissions are still relatively nascent and evolving. Companies and investors have taken various approaches to leverage avoided emissions estimates in order to inform their decision-making process and to communicate their impact to stakeholders. **While approaches to estimate avoided emissions vary by organization, we believe these still provide useful initial steps to measure corporate and investors' climate mitigation impacts which cannot be captured through Scope 1-3 emissions disclosures.**

Corporates: Various companies (Exhibit 18) have either disclosed their avoided emissions contributions, or have set future targets to maximize avoided emissions. Among companies that have set quantified avoided emissions targets, some are expressed from a **cumulative standpoint** (e.g., AT&T, Schneider), while others are based on reaching an **annual avoided emissions** contribution in a specified year (e.g., Fuji Electric, Neste). In addition, there are many targets where the avoided emissions volumes are not explicitly stated, but rather implicitly embedded into their target. Examples include **avoided emissions ratio targets** to reach a certain level of avoided emissions relative to the company's Scope 1-3 emissions footprint (e.g., DOW), or to **increase the energy efficiency** of a company's products (e.g., AMD) which would ultimately lead to avoided emissions for customers through less energy use.

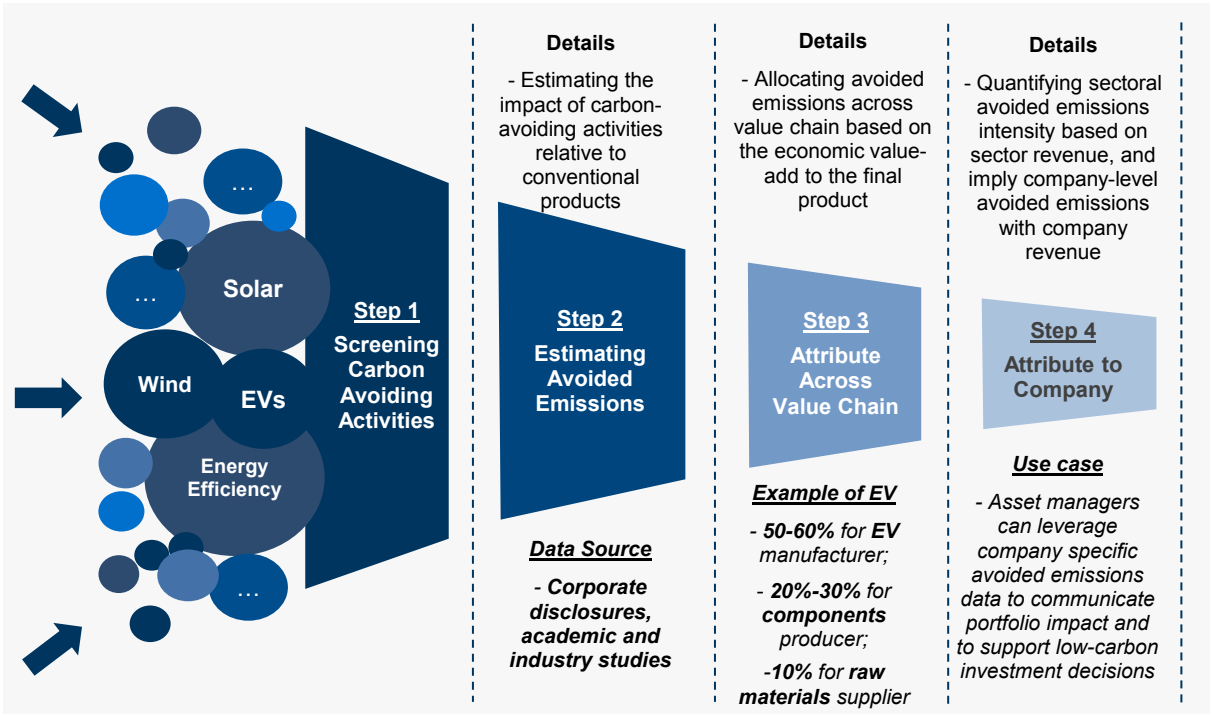
Investors: Investors are increasingly beginning to publicly disclose their avoided emissions methodologies and impact. Given the lack of corporate data availability, investors largely leverage third-party or in-house estimates to attribute avoided emissions for their portfolio. Our client conversations suggest that some investors take a broader sectoral view to identify industries that could meaningfully enable avoided emissions, while others have attributed specific avoided emissions volumes for each company in their portfolio. In (Exhibit 19) we provide an illustrative example of how select asset managers have attempted to estimate **company level avoided emissions** in order to publicly communicate the aggregate impact of their portfolio.

Exhibit 18: Examples of companies disclosing their avoided emissions contributions or avoided emissions related targets

Company	Timeline	Target
AT&T	2035	Deliver **connectivity solutions** that enable business customers to reduce a **gigaton** (1 billion metric tons) of GHG emissions between 2018–2035.
AMD	2025	Increase its **HPC and AI training related products' energy efficiency by 30X** from 2020-2025.
BT	2030	Help customers avoid 60 million tonnes of CO2e by the end of March 2030 **through full fiber broadband, high performance 5G solutions, and IoT.**
DOW	2025	By 2025, Dow's products will offset **three times** more CO2 than they emit throughout their life cycle.
Fuji Electric	2030	Contribute to **59 million tons of annual CO2 reductions** through products sold by 2030.
Ericsson	2030	Enable sectors like transport and manufacturing to reduce carbon emissions by **15 percent** by 2030, using **mobile networks and digital solutions.**
Google	2025	Enable **5 GW** of new carbon-free energy in manufacturing regions by 2030
Neste	2030	Help customers reduce their greenhouse gas emissions by at least **20 million tons** CO2 eq annually by 2030
Schneider	2025	Help customers save and avoid **800 million** tonnes of CO2 by **2025** (cumulatively since 2018)
Siemens	2022	In FY22, helped customers avoid **153 million** metric tons of GHG emissions through **sustainable electrification, automation and digitalization**

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 19: Illustrative example of select asset managers' frameworks to estimate avoided emissions of portfolio companies



Source: Goldman Sachs Global Investment Research

GS SUSTAIN analysis on avoided emissions from Building Insulation and Semiconductors

Below we provide our own estimates on avoided emissions from the Building Insulation and Semiconductors industries. Despite their significant role in improving energy efficiency for consumers, companies across both sectors are largely under-represented in ESG portfolios. In our view, assessing these through the lens of avoided emissions could further catalyze investor support for these underappreciated enablers.

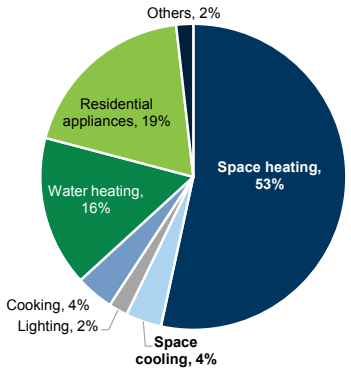
Building Insulation: Efficiency enablers for households

As discussed in our companion report, GS SUSTAIN: Avoided Emissions: Sizing the underappreciated enabling impact of Building Insulation, buildings collectively accounted for 30% of global final energy consumption, and 27% of global energy sector emissions. Most of the energy demand in buildings is dominated by the residential sector, which has been the driving force behind global expansions in building floor space as population levels continue to rise.

Importantly, space heating and cooling are the largest drivers of total energy consumption by households (Exhibit 20) — Building Insulation is a critical enabler that can increase household energy efficiency. Compared to an uninsulated home, **insulated buildings can lead to 40%-45% energy savings for space heating and cooling, per the Victorian State Government of Australia and our European Infrastructure/Construction & Transport colleagues' conclusions from the 2022 Insulation initiation report**. Naturally, heat transfers away from hotter objects into cooler objects (Second Law of Thermodynamics), which is why **insulation materials play a critical role both during summer and winter** in preventing outside heat from coming in (saving indoor cooling energy during summer) and preventing indoor heat from leaking outside (saving indoor heating energy during winter) as illustrated in Exhibit 21.

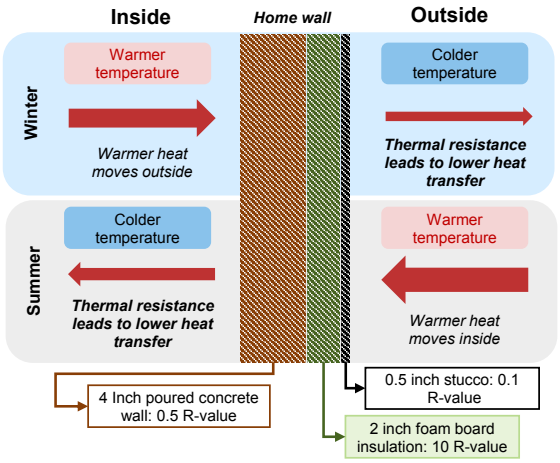
Based on our analysis, incremental Building Insulation products deployed between 2015-2030 could help **reduce annual household energy consumption by 9 EJ, or a 14% reduction relative to a counterfactual no-insulation deployment scenario**. By 2030, our analysis implies that incremental insulation deployment from a 2015 baseline would lead to **0.9 Gt of CO2 annual avoided emissions in 2030, or ~3% of global energy-related emissions in 2019 (Exhibit 22).** Across their lifecycle, industry estimates suggest avoided emissions from Insulation products could be **20X-100X** greater than their embodied emissions.

Exhibit 20: More than half of global residential energy consumption is driven by space heating and cooling
Residential final energy consumption by end-use (2019)



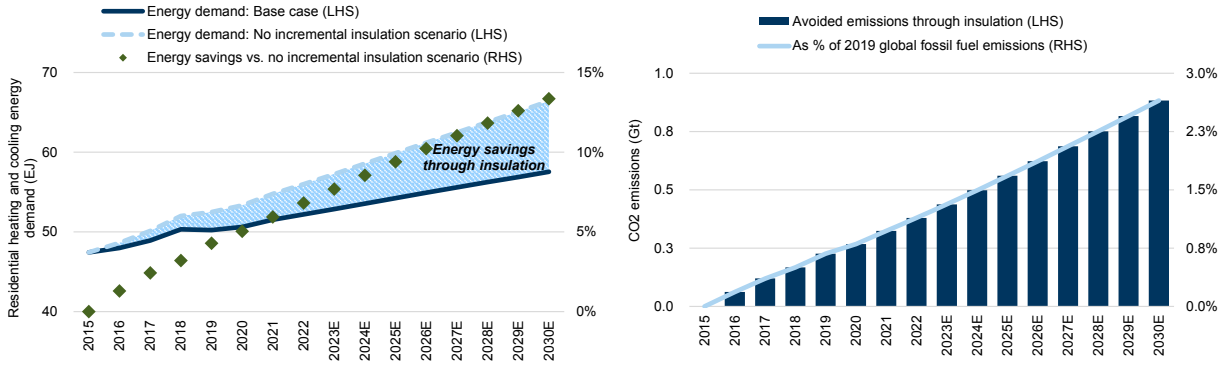
Source: IEA, Data compiled by Goldman Sachs Global Investment Research

Exhibit 21: Insulation contributes to the bulk of the total R-value in houses, helping households save energy during winter and summer
Illustrative example of how insulation plays a critical role in total R-value of home walls



Source: DOE Solar Decathlon, Goldman Sachs Global Investment Research

Exhibit 22: We estimate that deployment of building insulation products between 2015-2030 will lead to a 14% reduction in annual global household heating and cooling energy consumption, driving nearly ~1 Gt of annual avoided emissions by 2030
Analysis of household cooling and heating energy savings and avoided emissions through incremental insulation deployment (2015 baseline)



Source: IEA, EIA, European Commission, National Bureau of Statistics of China, Goldman Sachs Global Investment Research

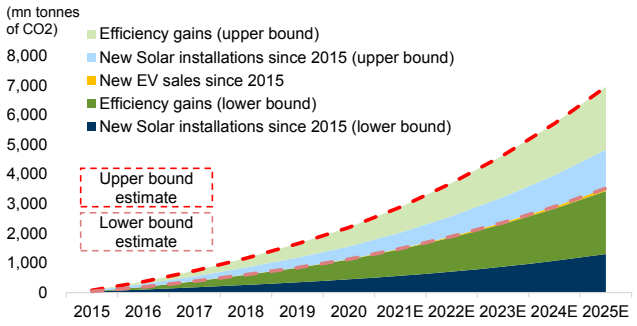
Semiconductors: Efficiency enablers of the modern digital infrastructure

Technological advancements in the Semiconductor industry has been an important contributor of energy efficiency gains for the modern digital infrastructure. As discussed in GS SUSTAIN: Greenablers: The critical role of Semiconductors towards a sustainable future, exponential growth in semiconductor computing performance, combined with gains in energy efficiency and cost deflation have enabled large scale adoption of semiconductors across multiple technologies which have ultimately benefited from energy efficiency gains. Semiconductors have driven meaningful long-term reductions in energy intensity across consumer products (e.g. data center services, PCs, smartphones and light bulbs), and accelerated the expansion of critical green technologies such as solar panels and EVs through power semiconductor advancements.

Our analysis suggests the Semiconductor industry can enable avoidance of 5x

more emissions than they emit (Exhibit 23-Exhibit 24). Semiconductors are critical to energy efficiency, automation, electric vehicles and renewable energy expansion. For every ton of CO2 that semiconductor companies emit, they help avoid emissions by enabling greener and more power efficient end-products against a 2015 baseline. Together, we estimate that semis contributed to 1-2 Gt of carbon dioxide emissions avoided in 2020 (>3% of global Energy emissions), and see potential for an additional 2-5 billion tonnes of annual avoidance by 2025. Innovation in **data centers** is an example of how meaningful their impact has been. Despite a 3X growth in data center demand between 2015-2020, their energy footprint has only increased by 6% during the same period (Exhibit 26). This was in part due to system-level efficiency gains (i.e., better energy performance in CPU/memory devices) as well as increasing migration towards energy efficient hyperscale/cloud services (enabled by innovation in chip performance).

Exhibit 23: We estimate semis contribute to a significant amount of avoided emissions by driving energy efficiency and enabling clean tech
CO2 avoided through new clean technology installations and efficiency gains, including LEDs and solar panels (base year of 2015)



Note: 1) Upper/lower bound avoidance estimates assume efficiency gains and solar installations displace 100% coal/100% gas. 2) Efficiency gains only include those from lamps, data centers, PCs and smartphones.

Source: Goldman Sachs Global Investment Research

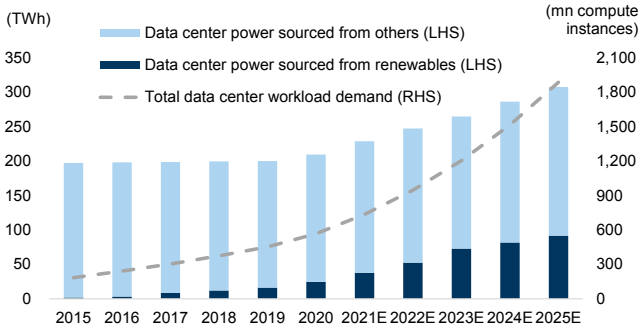
Exhibit 24: Semiconductors helped avoid 5x more emissions than they generated in 2019-2020 based on our estimates
CO2 emissions and avoidance from Semiconductors vs. 2015 baseline

Emissions avoided through Semis (2019-2020)	Emissions generated by MSCI ACWI Semis
High-end 389 mn tonnes of CO2 annualized **Low-end** 204 mn tonnes of CO2 annualized	**2019** 52 mn tonnes of CO2 (Scope 1-2) **2020** 56 mn tonnes of CO2 (Scope 1-2)
296 mn tonnes of CO2 avoided on average each year	*54 mn tonnes of CO2 emitted on average each year*

Note: 1) Includes 64 companies with US$474 bn revenue in 2020. 2) Due to lack of disclosure, we estimated CO2 footprint for 24 companies representing ~13% of MSCI ACWI sector revenue. 3) CO2 emissions and avoidance from Semis excludes LEDs and solar panels; includes data centers, PCs, smartphones and EVs.

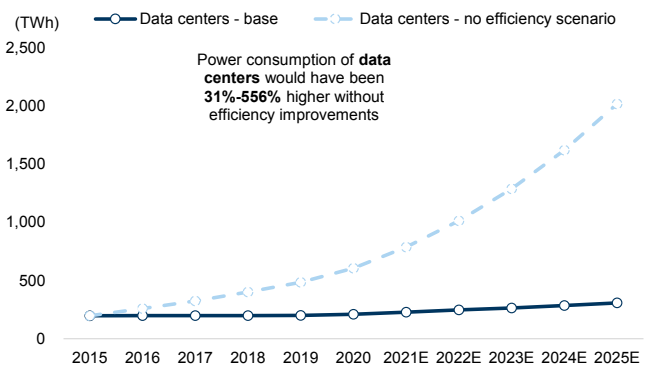
Source: Thomson Reuters, Bloomberg, Goldman Sachs Global Investment Research

Exhibit 25: Global data center workloads have grown 10X in the past decade, and we expect workloads to grow another 3X between 2020-2025
Data center power consumption mix and workload demand (GSe)



Source: Masanet et al. (2020), IEA, Cisco, Goldman Sachs Global Investment Research

Exhibit 26: Data centers' energy footprint has only grown by 6% despite a 3x growth in workload between 2015-2020
Total power consumption of global data centers - base case and no efficiency scenarios



Source: Masanet et al. (2020), IEA, Goldman Sachs Global Investment Research

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Reg AC

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