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Collaborative Insights
Robotics

AHEAD OF THE CURVE® SERIES

DEUS EX MACHINA, PART IV - ROBOTICS AS TOOLS IN CLIMATE FIGHT

MAY 11, 2022

Robotics will emerge as a critical tool to meet customer ESG / climate goals as plans are formalized and ESG investing expands.

Our joint survey with MassRobotics shows buy in by end users, though most have not yet deployed, suggesting the opportunity is ahead.

Through discussions with Locus Robotics, we developed a proprietary framework to model the carbon impact of robotic deployment.

Input from 12 analysts across Cowen and WRG; ABB and CGNX are favorites in our coverage; many players are still private.

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COLLABORATIVE INSIGHTS

May 2022

VIDEO

■ Diversified Industrials, Automation & Robotics

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ROBOTICS AS TOOLS IN CLIMATE FIGHT - AHEAD OF THE CURVE SERIES + VIDEO

THE COWEN INSIGHT

Part IV of a collaborative series examining the global robotics landscape (see I, II, and III). Climate change is a universal threat that companies are now beginning to more formally prepare for and combat. The tools employed will be broad, but robotics will be a critical element to ensure demand is fulfilled in a carbon-efficient manner as GDP, and customer desires, continue to expand.

Our Thesis (Joe Giordano)

Robotic deployment in non-traditional markets (ex autos, etc.) is still in the growth phase and the landscape is full of new, upstart companies. The pitch has always been speed and efficiency. With the emergence of climate focuses by end users, we believe robotic solutions will be evaluated in a more holistic, ESG-centric fashion and viewed as tools to help accomplish climate goals. While most are still targeting big items like plane / truck usage, etc. robotic solutions are part of the equation to maximize output per unit of carbon, and newer companies who typically don't think in these terms will be forced to do so much earlier in their journeys.

Using Cowen's recently updated retail / ecommerce estimates as a foundation (HERE), we evaluated a leading ecommerce robotic solution and our work suggests that if it is 100% deployed in the market using solar power as its energy source, just this one application would reduce average annual carbon output over the 2022-2050 evaluation period by over 10MM metric tons. This is equivalent to 25+% of UPS's total 2020 output and over 15% of Amazon's. While we acknowledge that 100% deployment of any technology is unlikely and many deployments will not use solar / fully renewable energy, this is only one solution we are evaluating. The potential for the robotics industry to be a change agent is substantial.

What Is Proprietary?

We again worked with our partners at MassRobotics to survey both robot manufacturers and end users to understand how robust existing and/or publicly communicated climate plans are, where robotics falls in the climate toolkit, and what applications will be targeted. The runway appears long - over 90% of participants expect to use or develop robotics to achieve climate objectives, but less than 50% have actually deployed or are in process of deploying them. An interesting extension of this result is that over 90% of robot users surveyed have or plan to establish in 2022 public climate commitments, but over 40% of robot manufacturers do not plan to commit to objectives. We think it will be critical for the "tools" employed (robotic tech) to be models of the solution as well (be sustainable in their own manufacture/operation). Most viewed their public commitments as highly formalized - something that feels inconsistent with anecdotal evidence and our conversations in the industry.

We also developed a framework using Cowen's ecommerce growth estimates to evaluate robotic technology with a climate lens. We collaborated with Locus Robotics (private) and spoke with one of their key customers (DHL) to understand the impacts of this technology on existing operations. We leveraged these conversations to develop a model that could be applied to various types of technologies to determine the carbon impact deployment could have.

Finally, we collaborated with 3 members of Cowen Washington Research Group and 8 senior research analysts to explore policy implications for carbon emissions and how robotics are being deployed across end-markets spanning retail, transportation, machinery, clean energy, and cybersecurity.

Financial & Industry Model Implications

Our carbon model determines projected carbon impact from technology adoption by focusing on energy requirements to operate the solution, the reduction in required labor to satisfy demand (through commutes avoided), and the benefits of higher precision in the task itself (lower error rates translating to fewer returns, etc.). The model is underpinned by Cowen's recently published updated ecommerce growth estimates and square footage requirements to support it.

The results suggest a two pronged benefit for robotics providers - their technologies will need to be developed to serve demand even without climate implications given the tight labor market that already exists (and will continue to), and in that sense the climate benefits can (at least initially) be a secondary bonus of deployment. Users of these technologies may over time see a reduction in capex, as many of these tools are offered via subscription (Locus was a leader in this regard), and likely a better ability to forecast cash outlays. Overall market penetration should also benefit (from low levels today outside of large early adopters) as upfront costs are mitigated.

What To Watch

We've discussed the concept of ecosystem development before (HERE most recently) and it will be interesting to watch how this plays out. Much of the available technology will either need to scale into a comprehensive portfolio or be acquired by larger players. Single point solutions going at it alone will be a challenging end-game. As solutions prove out, we expect consolidation, perhaps accelerated as ESG-related disclosure highlights carbon output and related mitigation.

As we move along publicly committed timelines (2030 most notably), we will also have to see more concrete plans on how companies are going to achieve targets and what solutions they will utilize to do so. Despite the skew of our survey towards a view of "highly formalized" strategies, our actual discussions suggest otherwise.

Stock Conclusions

We see a company like **ABB** (a top pick), with a broadening portfolio of traditional, collaborative, and service / mobile robotics, as well as a core focus on ESG, as well positioned to capitalize on the trends highlighted in this report. We also believe the concept of "maximizing output per unit of carbon" has positive implications for **CGNX** within our coverage. Other public participants in the market, such as ZBRA, BGRY, and STRC, and private companies tackling applications like mobile robotics, Autonomous Storage and Retrieval systems (ASRS), autonomous tuggers/forklifts, picking systems - many of whom we've highlighted in prior reports - as well as the integration specialists who deploy them (or develop internally), are depicted on page 8.

Other stock picks highlighted by contributing analysts:

Helane Becker - FDX - Outperform-rated FDX continues to invest in automation and robotics, especially in their fulfillment centers to reduce their reliance on human capital. The goal is to make extensive use of automation to enable volume growth without adding to labor costs.

John Blackledge - AMZN - Amazon is the leading US eCommerce platform with ~39% market share; unit sales grew ~47% In '20 amid a massive pandemic pull-forward, and sales are now growing off an eCommerce base that is permanently larger (albeit growing at a slower rate near-term). Meanwhile, Amazon is near the tail end of a historic fulfillment and logistics investment cycle; we estimate ~$78BN in eCommerce logistics investments in '20/'21 vs. ~$58BN the prior 5 years combined.

These logistics investments should drive faster 1 Day and Same Day delivery speed, and much of this investment comprises advanced technology to increase efficiency, including efforts to limit AMZN's carbon footprint. As of June '21, 90 fulfillment facilities were powered by solar; AMZN also employs data analytics to optimize HVAC usage, and more broadly, the company continues to iterate on its robotics technologies that help people and machines work closer together, including intelligent vests that alert robots when a human worker is nearby and the robot needs to slow down or change course.

Andrew Charles - SG, CMG - We highlight Outperform-rated sweetgreen as the biggest beneficiary of robotics in the restaurant industry. One differentiated aspect of the sweetgreen story is the September 2021 acquisition of Spyce, a two-store concept powered by kitchen robotics technology. sweetgreen believes Spyce's technology is scalable to the flagship concept's digital assembly lines to prepare orders. Our 2022-25E embeds Spyce-related G&A and CapEx, but no revenue or margin benefits.

Oliver Chen - WMT - Outperform-rated WMT is focused on reaching zero emissions across global operations by 2040, without relying on carbon offsets. To reach this goal, WMT will lean into robotics and automation to drive efficiencies, and sustainably grow the business. Examples include plans to build a fleet of 100% all-electric delivery vans, and WMT aims to be supplied by 100% renewable energy by 2035 across its global operations. Further, we expect increased investments in robotics and automation following the closure of its inaugural $2bn green bond offering.

Matt Elkott - CAT - We expect the incremental revenue opportunity for CAT from autonomy and automation to be ~$35Bn over the next 10 years. This would be back-end loaded, with steady increases over the period. The company's Mining Resources segment would be the biggest beneficiary, followed by Construction Industries and Energy & Transportation.

Shaul Eyal - FORG - Although still nascent and with a small TAM of $3B of FORG's overall $71B TAM, we view FORG's IoT solutions as a sizable opportunity to propel overall ARR growth beyond 25% y/y in the coming years. As companies' overall connected devices (industrial controllers, printers, servers, sensors) outnumber the human identities, there is a growing need to secure the data flowing in and outside the various corporate networks. ForgeRock IoT creates strong, trusted relationships between devices, systems and people. It increases the security of IoT devices and non-human entities. As the IoT use case becomes ubiquitous, we view FORG as well positioned to benefit from positive tailwinds impacting its overall industry.

Krish Sankar - TER - Teradyne's cobots are well suited for smaller scale (ROI, ease-of-use) operations such as bin/part picking in the industrial market and as a "manual labor" replacement where UR's simple teach-to-program UI and fast deployment time remain industry benchmarks.

We model UR sales growing 13% Y/Y to $350MM as component shortages continue to be a headwind for the industry, before reaching +37%-40% Y/Y growth in CY23/24. We model $670MM IA sales by CY24, which could contribute ~$0.15 in EPS.

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Executive Summary – Joe Giordano

Deus Ex Machina Series:
Part I – Robotic Arms – LINK
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Part III – Human Collaboration and Augmentation - LINK

Key Investment Considerations for PMs:

1. A confluence of trends is occurring – companies are making public sustainability commitments, new robotic technologies are being developed at a rapid pace, and ESG centric investing is taking share. (link)
2. Our joint survey with MassRobotics suggests that end users overwhelmingly expect to use robotics as a tool to achieve climate goals, though most have yet to deploy. Plans are generally viewed as highly formalized, though anecdotal evidence suggests otherwise. (link)
3. We developed a proprietary framework to evaluate the potential carbon impact of robotic development using Locus Robotics as our test case. Fully deployed, such a technology could save the equivalent of ~25% of UPS's current output, on average through 2050, and this is just one potential application – others would be additive. (link)
4. Our colleagues at Cowen Washington Research Group and our senior sector analysts explore how robotics are being deployed across markets, as well as DoD and geopolitical ramifications. (link)

For more analysis of Earth's prospects – see our climate Primer HERE

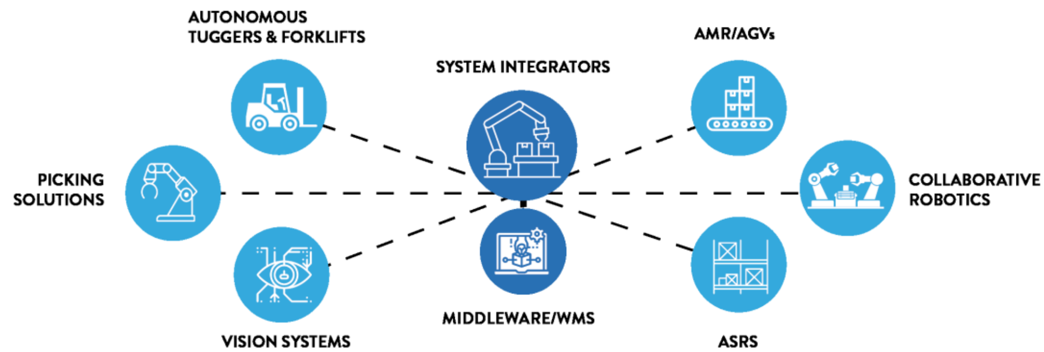
Part IV of our robotics series explores the potential interplay between robotics and climate change – specifically the world's response and plans for mitigation. In this report we partnered with MassRobotics to conduct a proprietary survey of robotics users and manufacturers to provide insight into where robotics fits within public commitments to target climate challenges. We also held discussions with Locus Robotics and key customer DHL to understand how robotic technologies are transforming operations – which we then leveraged into a model that can be used as a framework to evaluate the carbon impact of robotic deployment. Our work suggests that just this one technology (Locus bots, or equivalent) if fully deployed (100% share of TAM) into US ecommerce applications via green energy could save ~10MM metric tons annually, on average, through 2050 – or over 25% of UPS's total annual output in 2020. Although most companies are currently focused on "bigger ticket" items like planes and trucks (understandable) – this is a meaningful number that will become a larger focus as those initial areas are addressed.

We've actually come quite a long way in terms of doing things in a less carbon intensive way. The amount of carbon required to generate $1B in inflation adjusted dollars today vs. the 1960s is down over 50%. The robotic technologies we explore in this report are geared to that end – not actively reducing carbon itself – but maximizing the output (GDP) per unit of carbon and minimizing carbon needed to achieve a targeted level of activity. *And herein lies the rub* – while we are getting better at producing/transacting more efficiently, we are bumping up against hard caps of actual gross carbon output that will ultimately require significant new technologies and/or changes in behavior. In the meantime, however, technologies that allow demand trends to continue while limiting the impact will be a clear focus. This is also coinciding with the rise of ESG centric investment, which has swelled to nearly $4T in July 2021 from ~$1T in Jan 2020. Technologies that can help companies achieve public commitments on climate will not only be in demand from an operational standpoint from customers, but from investors as they allocate capital increasingly within those frameworks.

Companies clearly have the desire to move in this direction – over 90% of survey participants expect to use robotics to meet stated climate objectives – but less than 50% have actually deployed, so we are still at the beginning stages. Our conversations suggest that publicly committed climate plans are pretty "loose", where the details are being figured out in real time – though that's in contrast to the majority of participants who view their plans as "highly formalized". Over 40% of robot manufacturers surveyed do not plan on committing to climate objectives themselves – part of that is likely due to the early stage of those organizations, but we believe it will be important for those businesses to mirror the values of their customers in order to be successful – that mindset likely needs to be embraced earlier than what we've seen historically.

Our report includes contributions from three analysts from Cowen's Washington Research Group, focusing on the development of ESG frameworks, how robotics could impact US/China trade, and adoption/deployment trends within the DoD, as well as 8 colleagues across Cowen's sector research platform providing insight into robotic trends by market.

Figure 1 Robot Ecosystem Overview



SYSTEM INTEGRATORS	Ownership	Amount Rasied ($MM)*
Bastian Solutions (Toyota Industries)	Acquired	$260
BEUMER Group	Private	-
Daifuku	Public	-
Dematic (Kion)	Acquired	$2,160
Fortna (Merging w/MHS Global)	Merger	$8
Intelligrated (Honeywell)	Acquired	$1,500
JR Automation (Hitachi)	Acquired	$1,430
KNAPP AG	Private	-
MHS Global (Merging w/Fortna)	Merging	$195
Murata Machinery	Private	-
Siemens Logistics	Private	-
SSI Schaefer	Private	-
Vanderlande (Toyota Industries)	Acquired	$1,310

AMR/AGVs	Ownership	Amount Rasied ($MM)*
6 River Sytems (Shopify)	Acquired	$394
ASTI Robotics (ABB)	Acquired	$196
Berkshire Grey	Public	-
Caja	Private	$26
Fetch Robotics (Zebra)	Acquired	$290
Geek+	Private	$531
GreyOrange	Private	$196
IAM Robotics	Private	$21
Locus	Private	$312
Tompkins Robotics	Private	$25
Waypoint Robotics (Locus)	Acquired	-

VISION SYSTEMS	Ownership	Amount Rasied ($MM)*
Adept Technologies (Omron)	Acquired	$200
CloudMinds	Private	$470
Cognex	Public	-
Flexiv	Private	$132
Incesoft	Private	$41
ISRA Vision (Atlas Copco)	Acquired	$1,130
Xnor.ai (Apple)	Acquired	$200
Zebra	Public	-

PICKING SOLUTIONS	Ownership	Amount Rasied ($MM)*
Covariant	Private	$147
Dexterity	Private	$212
inVia Robotics	Private	$60
Pickle Robot Co.	Private	$21
RightHand Robotics	Private	$100
XYZ Robotics	Private	$63

MIDDLEWARE / WMS	Ownership	Amount Rasied ($MM)*
Blue Yonder (Panasonic)	Acquired	$7,100
CYNGN	Public	-
Highjump (Körber)	Acquired	$750
Manhattan Associates	Public	-
READY Robotics	Private	$44
SVT Robotics	Private	$32

ASRS	Ownership	Amount Rasied ($MM)*
Alert Innovations	Private	-
Autostore	Public	$328
Exotec	Private	$448
Fabric	Private	$336
KNAPP AG	Private	-
Ocado	Public	$3,440
OPEX Corp	Private	-
Swisslog (Kuka)	Acquired	$330
Takeoff Technologies	Private	$171
Urbx	Private	-

*If available for private companies, Acquired using takeout price

AUTONOMOUS TUGGERS & FORKLIFTS	Ownership	Amount Rasied ($MM)*
AGILOX Systems	Private	-
Autoguide (Teradyne)	Acquired	$189
Fox Robotics	Private	$13
MAXAGV	Acquired	-
MiR (Teradyne)	Acquired	$198
Omron	Public	-
OTTO Motors (Clearpath Robotics)	Private	$82
Seegrid	Private	$152
Third Wave Automation	Private	$59
Vecna	Private	$139

COLLABORATIVE ROBOTICS	Ownership	Amount Rasied ($MM)*
ABB	Public	-
Fanuc	Public	-
Franka Emika	Private	-
KUKA	Public	-
Mitsubishi	Public	-
Staubli	Private	-
Universal Robots (Teradyne)	Acquired	$315
Yaskawa	Public	-

*Note many companies offer solutions which fit into multiple categories shown above

Source: Company reports, Cowen and Company

ESG Mandates And The Impact On Corporate Carbon Emissions – John Miller – Cowen Washington Research Group

Pressure on companies to reduce greenhouse gas (GHG) emissions from ESG-oriented asset managers is growing. The contours and dimensions of that ask are evolving rapidly. We expect both trends to accelerate. Simultaneously, mandatory requirements for companies to disclose climate related risks - including GHG emissions- are increasing. Growing ESG scrutiny combined with forced data transparency are likely to accelerate adoption of corporate decarbonization plans.

ESG investment frameworks frequently incorporate macro climate change risks, which are then allocated down to individual company-level assessments. Macro climate risks are often translations of the UN's 2015 Paris Agreement (Paris Agreement) - which commits signatory countries to limiting average temperature increases to well below 2C (above a pre-industrial base). The Paris Agreement was followed by a 2018 Intergovernmental Panel on Climate Change (IPCC) special report focused on the dangers of warming above 1.5C. To meet well below 2C, or 1.5C targets, the Paris Agreement outlines that countries should seek to achieve a balance between anthropogenic (human produced) GHG emissions and GHG sinks by the second half of this century. This balance between sources and sinks serves as the basis for the ESG push to incorporate 'net-zero' decarbonization pathways - which are frequently anchored to 2050, or sooner.

ESG investment frameworks have long advocated for voluntary disclosure of company-level GHG emissions. The Global Reporting Initiative (GRI), CDP, and the Sustainable Accounting Standards Board (SASB) all request emissions data either in absolute or intensity terms. Voluntary standards are now being replaced by regulatory obligations which mandate disclosure. The EU's Non-Financial Reporting Directive, Corporate Sustainability Reporting Directive, and EU Taxonomy Regulation all require incremental climate disclosures.

In March 2022 the US SEC proposed mandatory disclosure for a broad slate of climate risks, including Scope 1, 2, and in select instances, Scope 3 emissions. The SEC proposal goes further, requiring a narrative description of the company's risk assessment process and findings. The SEC intends to propose additional ESG disclosure requirements, targeting human capital and governance. Proposed rules covering these topics are likely through the end of 2022.

Why are ESG investment frameworks focused on company-level GHG emissions reductions?

We observe two trends:

- **Risk Minimization** –To achieve Paris Agreement targets, governments will need to introduce a range of policy actions (such as carbon pricing) which will have the effect of increasing the costs of GHG pollution, thereby re-orienting economic activity away from fossil fuels. From the perspective of an ESG asset manager, companies with plans to reduce emissions exposure, either within their own operations or power consumption (Scope 1 and Scope 2), or those within their value chain – including produced goods and services - (Scope 3), are better positioned to de-risk this inevitable outcome. Alternatively, those with weak - or no - plans are at a greater risk of increased costs or decreased revenues. In this formulation, companies with the most detailed, science-based emissions reductions targets are viewed as lower long-term investment risks.

- **Opportunity Capture** – This is effectively the inverse of risk minimization. Building from the same premise that governments will need to introduce a range of policy actions to price (cut) GHG emissions, opportunity capture represents the view that early movers on company-level decarbonization will find themselves better positioned. This positioning can be achieved either through reducing exposure to fossil fuel input costs (and volatility), or by repositioning a company's goods and services to better capture increased revenue as the economy decarbonizes. In this formulation, companies with the most detailed, science-based emissions reductions targets are viewed as higher opportunity long-term investments.

What are ESG investment frameworks asking companies to do?

We observe the contours and dimensions of the ESG ask as evolving rapidly. Whereas initial company-level decarbonization asks deferred many key parameters to company management, current iterations are prescriptive, and require targets to align with independent sector-based decarbonization pathways. The Science Based Targets Initiative (SBTi) is a leading third-party validator of company-level decarbonization plans.

Key SBTi plan requirements include:

- **Defined base and target year** – SBTi recommends the most recent year for which emissions data is available serves as the base year (can be no earlier than 2015), while the near-term target year can be no more than 15 years from current date.
- **Scope of coverage** – SBTi mandates that targets cover Scope 1 and 2 emissions, if Scope 3 emissions account for more than 40% of companies' total GHG footprint, they become mandatory as well. If a company is exposed to the sale or distribution of fossil fuels, it must include Scope 3, even if this does not meet the 40% threshold. Coverage is company-wide, and should be fully consistent with the extent of a company's financial accounting.
- **Decarbonization pathway** – Near-term pathways (<15 years) are to be consistent with decarbonization needed to limit warming to 1.5C. Long-term targets (out through 2050) including Scope 3 must be consistent with decarbonization needed to limit warming to 2C. Pathways can use intensity targets only if those are approved by validated sector pathways, otherwise absolute targets are required.
- **Credits and offsets** – SBTi does not allow for the use of carbon credits or offsets to be counted as emissions reductions associated with near-term pathways. Credits and offsets can be used to neutralize residual emissions or finance climate mitigation outside SBTi targets.
- **Fossil fuels** – SBTi does not validate targets for companies involved in the exploration, extraction, mining/producing of oil, gas, or coal.

In this construct, third-party, sector-based pathways are emerging as the key check on a company's decarbonization compliance. We anticipate ESG asset managers will increasingly demand companies and funds align with sector and economy-wide third-party decarbonization pathways. SBTi has produced its own pathways, generally leveraging IEA's Sustainable Development Scenario (SDS) or Net Zero Emissions by 2050 Scenario (NZE). Other accepted sector-based pathway providers include the Transition Pathway Initiative (TPI) and PRI's inevitable policy response 'value drive database.' TPI pathways for the airline and steel sector are below.

Figure 2 Airline Sector Emissions Pathways

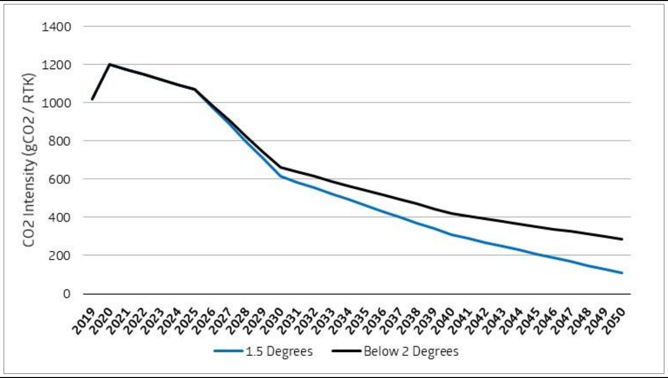
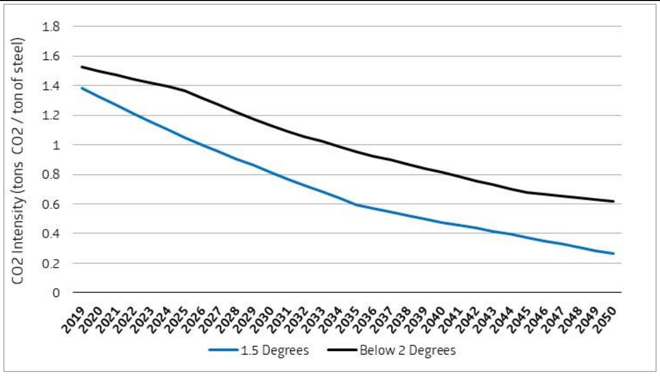


Figure 3 Steel Sector Emissions Pathways



Source: TPI, Cowen and Company

MassRobotics And Cowen 2022 Robot Manufacturer And User Survey Results – Joe Giordano

The rise in ESG mandated AUM and support for shareholder proposals on GHG emissions has led many corporations to commit to climate change related goals. Many have committed to carbon neutrality or zero emissions by 2050 – the path to this goal is significant. We partnered with MassRobotics to survey both robot manufacturers and users to understand how they view various climate and robot related topics. Nearly 75% of respondents expect that current and potential customers will discuss climate change in conversations going forward.

Overall, we found 5 main takeaways from our survey work:

1) Nearly all respondents expect to use (or develop) robotic technology to help achieve climate related targets, but less than half have actually deployed so far.

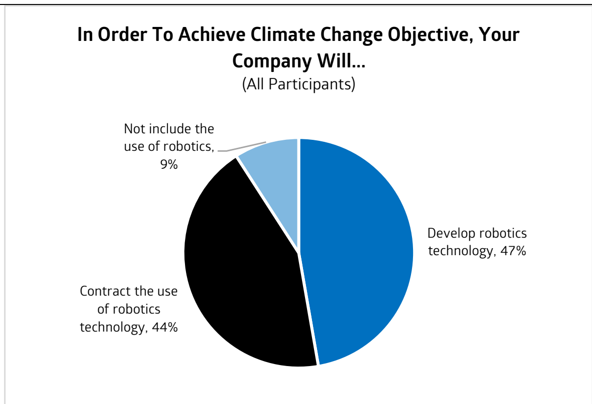
2) Robotic end-users are much further along in terms of committing to climate targets than robot manufacturers, and climate has become a standard part of the end-user pitch to customers (not yet the case for robot manufacturers).

3) Respondents tend to view their climate plans as highly formalized, which contradicts our anecdotal discussions with users and providers.

4) Manufacturers and users are fairly well aligned on capabilities they are looking to deploy / develop.

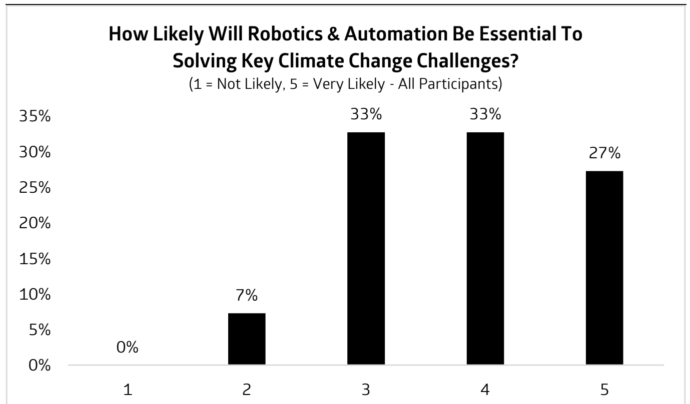
5) GHG reduction is the clear focus in terms of climate agendas.

Figure 4 The Vast Majority Of Participants Plan To Use Or Develop Robot Technologies To Achieve Climate Change Objectives



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

Figure 5 While 93% Believe Robotics And Automation Are Likely To Be Essential To Solving Key Climate Change Challenges



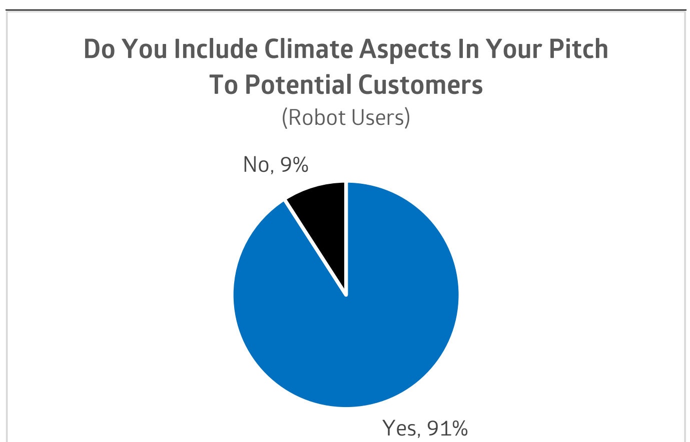
The idea of robotics as tools for climate change appears to be well understood, though still early stage in terms of usage. <u>Over 90% of all respondents expect to use robotics or develop robotics to achieve climate change related objectives. However, only 44% have deployed to date, suggesting much of the opportunity lies ahead.</u> 93% believe that robotics and automation are likely to be an essential tool in solving key climate change challenges.

When asked if they expected current or potential partners to discuss climate related topics in conversations with them, all robotic end users responded "yes" and that answer was consistent with the response when asked if they are actively using climate in their pitches to potential customers.

Figure 6 All Robot End-Users Expect To Discuss Climate With Customers…

Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

Figure 7 …And Almost All Are Including Climate In Sales Pitches



Interestingly, despite 2/3 of robot manufacturers expecting to discuss climate topics with customers, only about half that amount are actively using climate in their sales pitches.

Figure 8 Two Thirds Of Robot Manufacturers Expect to Discuss Climate With Customers…

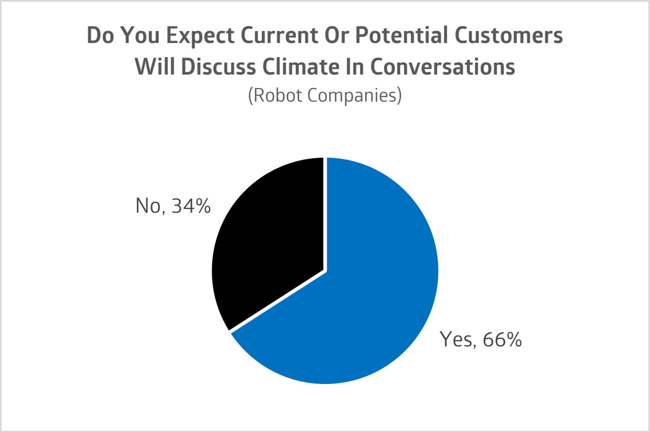
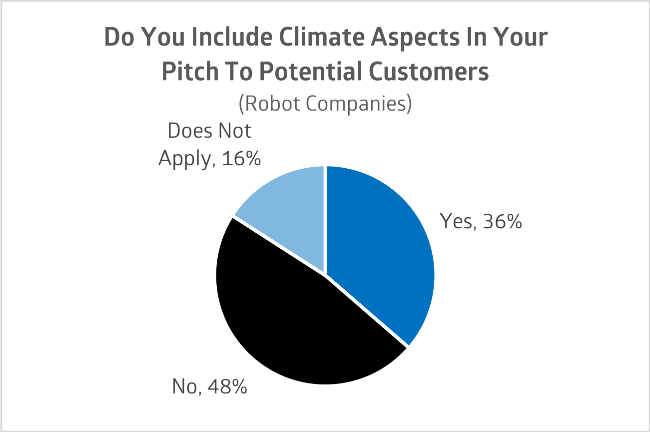


Figure 9 …But Only About Half As Many Are Using It In Pitches



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

As expected, significantly more robot end-users have already communicated, or plan to this year, objectives related to climate change. Only 9% of end-users do not have plans, whereas over 40% of robot manufacturers (typically smaller, earlier stage companies) do not have plans yet to do so.

Figure 10 Over 90% of End-Users Have Already Communicated Climate Objectives Or Will In 2022…

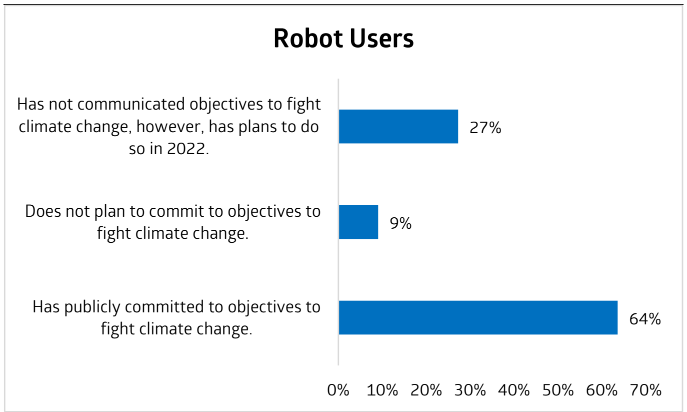
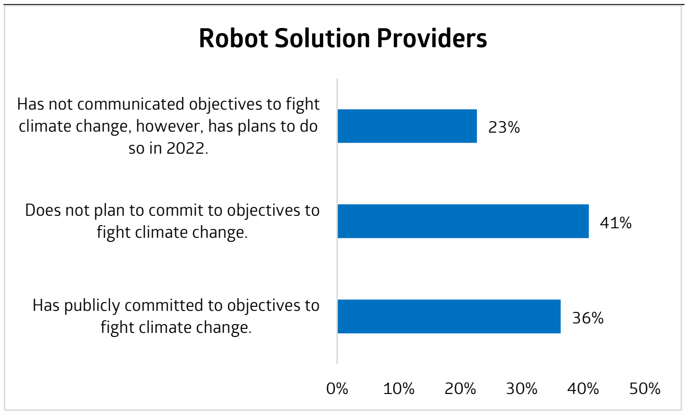


Figure 11 …Vs. Under 60% of Robot Manufacturers



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

One element of our survey where we question the responses concerns the level of formality of communicated climate objectives. Both end-users and manufacturers generally see their plans as fairly well formalized (end users more so). Our discussions anecdotally suggest that the plans to achieve stated objectives are still somewhat vague. There is likely some bias here depending on who from the company answered the question – respondents with an ESG centric role tend to view their plans as more formalized than more operational respondents.

Figure 12 End-Users See Their Climate Plans As Well Formalized (5 = Most Formalized) …

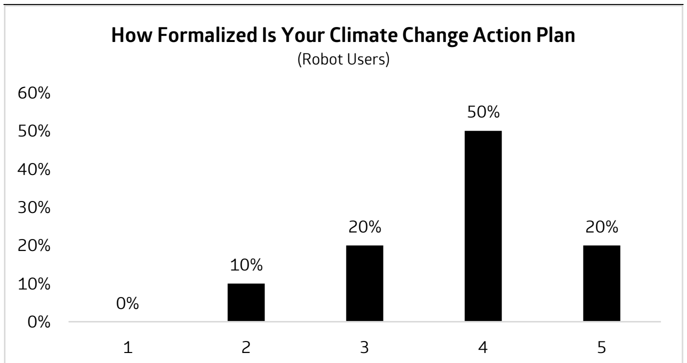
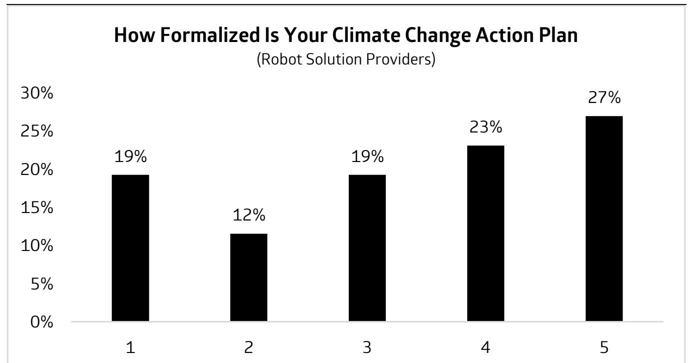


Figure 13 …As Do Manufacturers, But To A Lesser Extent



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

About half of survey participants are actively working with climate crisis solutions providers (73% of end users and 45% of manufacturers), though the interest level is significantly higher so that level will likely increase. Technologies / solutions targeting GHG reduction is the overwhelming desire among participants.

Figure 14 Collaboration Right Now Is Mixed…

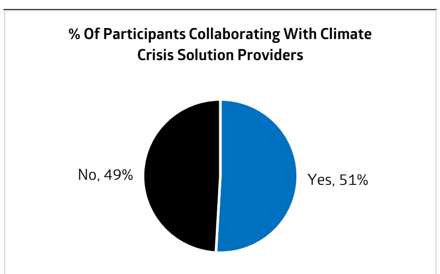


Figure 15 …But Interest Is High

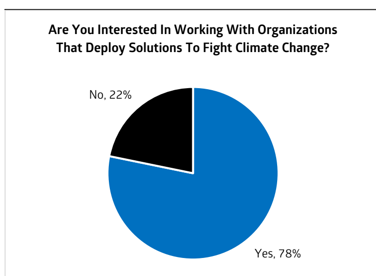
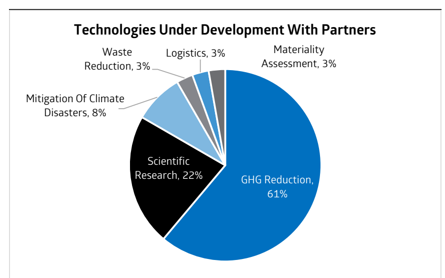


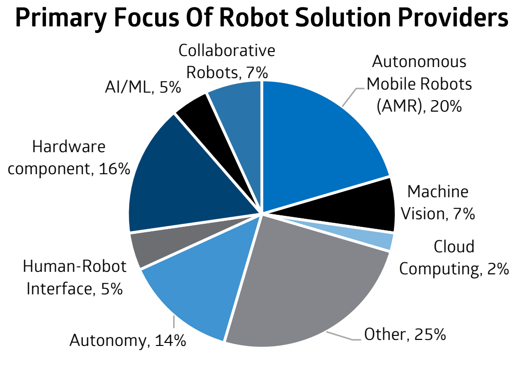
Figure 16 GHG Reduction The Clear Target



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

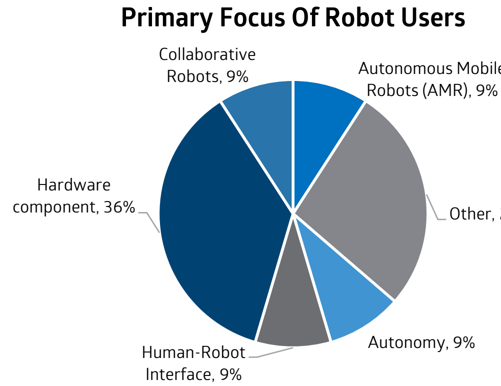
Key technologies that users and manufacturers of robots are focused on deploying and developing are fairly well aligned. The top categories for each include AMRs, hardware components, human-robot interfaces, collaborative robotics, and autonomy.

Figure 17 Robotics Companies Are Focused On AMRs, Components, Autonomy, And Collaborative Robotics ....



Source: MassRobotics and Cowen and Company Robotic Survey March 2022, n=55

Figure 18 .... Which Aligns With Robot Users



A Framework For Evaluating Potential Impact Of Robotic Solutions

At peak impact (2046/47), full scale US deployment of a Locus type solution could save in 1 year:

- Over 45MM nonrenewable commuting miles
- Over 5MM delivery van loads from returns
- Over 18MM metric tons of CO2 at customers – for scale, total 2020 CO2 output at UPS was ~38MM and ~60MM at Amazon

The go to market strategy of most robotics companies does not currently have a climate focus and is generally centered around productivity gains, payback period, and more recently the ability to maximize output with a labor constraint. This is largely appropriate considering the near-term climate priorities of large organizations with public commitments are on power, planes, trucks, etc.- the largest contributors to overall GHG within the companies. Those that we've spoken with acknowledge that robotics will have a role to play (and our survey work previously discussed certainly supports that view), but the actual impacts have not been calculated and/or evaluated yet internally at most companies.

We held discussions with Locus Robotics and one of their primary customers, DHL, on this topic and based on our takeaways developed a carbon-based model that can be used as a framework to evaluate the environmental impacts deployment of these technologies could have at scale. The assumptions in the model are our own (not Locus's or DHL's), but the logic behind it is consistent with our discussions.

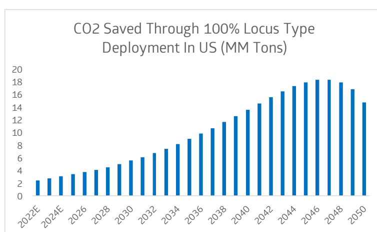
The key drivers to our model are ecommerce growth, the amount of warehouse/ fulfillment square footage needed to support incremental volume, the productivity increases gained (less labor required) and the commutes saved as a result, and the benefits of fewer errors (less returns and corresponding shipments, etc.). The transition to EV transportation complicates matters, though we do attempt to adjust for it over time in our commutes saved calculation by considering EV penetration (assuming 65% in US by 2050) and clean energy penetration into the grid (assuming 100% by 2050).

The Locus solution we explored is a test case simply to show how powerful robotic technologies can be in terms of achieving climate targets even if the technologies themselves weren't specifically designed for that purpose. Labor constraints coupled with increasing demand almost require solutions like these to be deployed to grow – so climate benefits can be viewed as somewhat ancillary to a technology that likely has to be deployed anyway. But they are nonetheless material. **On average over 2022-2050, a Locus type solution just in the US (assuming full deployment into the TAM) could save emissions equal to over 25% of UPS's 2020 total and over 15% that of Amazon. At peak**

(2047 in our model), we estimate the benefit to be 75+% higher than that average – pretty impressive for a technology designed without this in mind. The framework we developed could be manipulated and applied to other technologies as well, and in most cases the impacts would be compounding in nature. Our analysis does not consider the environmental impact of Locus' operations on its own (though we do discuss this later in this report and the impacts even worst case would be minimal compared to customer savings) or the additional benefits from having less workers at customer sites (food, water, supplies, etc.).

Figure 19 CO2 Model Framework Using Locus As Test Case Application

Locus US CO2 Summary Model	2022	2030	2040	2050	Comments
Total Retail Sales Estimate (MM)	$6,380,273	$8,884,853	$13,214,623	$19,654,380	
Ecommerce Sales Estimate (MM)	$931,819	$2,173,157	$5,923,873	$14,745,376	
Ecommerce Related Warehouse Square Footage (MM sq ft)	1,118	2,608	7,109	17,694	1.2MM sq ft per $1B Ecommerce sales
Square Footage Applicable To Locus Type Solution (MM sq ft)	376	876	2,389	5,945	Roughly 70% of sq footage have pick and place applicabiilty and just under 50% of that applicable to Locus type solution
Bots Required	250,473	584,145	1,592,337	3,963,557	1 bot per 1500 sq feet of applicable space - Assumes 100% deployment
Total Emissions From Bot Charging Eliminated Via Sustainable Power (tons CO2)	**56,728**	**132,298**	**360,635**	**897,673**	Assumes 2 batteries per bot charged 2x daily
Total Warehouse Workers	1,439,758	3,357,755	9,153,004	22,783,149	
Total Commuting Miles	11,518,063,011	26,862,042,456	73,224,030,192	182,265,194,043	Ave commute of 32 miles and assumed 250 work days / year
Estimated EV Penetration	1%	4%	15%	65%	
Estimated % Of Grid On Sustainable Energy	21%	33%	57%	100%	
CO2 Generated From EV Charges From Non-Sustainable Sources	13,990	87,742	640,965	0	
CO2 Generated From ICE Engine Commutes	4,598,775	10,454,067	25,019,908	25,767,901	
Total Commuting Emissions Avoided (tons CO2)	**2,306,383**	**5,270,904**	**12,830,436**	**12,883,950**	Loucs type solution enables 50% workforce reduction at given level of volume
Package Return Trips Avoided Through Higher Accuracy	67,668,587	157,814,422	430,190,967	1,070,807,491	Standard error rate of ~3% and Locus provides ~25% improvement
Total Emissions Saved Through Few Return Related Logistics (cargo planes, trailers, vans - tons CO2)	**59,708**	**139,249**	**379,583**	**944,837**	
Total CO2 Emissions Saved (tons CO2)	**2,422,818**	**5,542,451**	**13,570,654**	**14,726,460**	



Source: US Census Bureau, Bureau of Transportation Statistics, EIA, Statista, Reuters, Company reports, Cowen and Company

Climate Impact Reduction Initiatives At Logistics Leaders DHL and Amazon

DHL 2030 Carbon Reduction And Neutrality By 2050 Initiatives

DHL is accelerating sustainability efforts between now and 2030 – initial goals are to reduce carbon emissions from 33MT in 2020 to <29MT by 2030 and this is despite expectations of increased growth in global logistics operations. DHL will invest €7B on green technologies – this spend will help meet various 2030 environmental goals, including:

- Electrify 60% of last-mile delivery fleet.
- Increase the use of sustainable fuel sources in line haul to >30%.
- Increase sustainable aviation fuel usage, >30% of all fuel used will be mixed with sustainable blend.
- All new buildings will be designed to be 100% carbon neutral.

- Offer green alternative products for 100% of their offering of products and solutions.

The company will implement ESG-related targets in the Board's annual bonus – these targets will account for 30% of the Board's performance measurement. The path to a more sustainable DHL started in 2003 with the company's first environmental report, and continued from there. In 2017 the company set 2050 targets for zero-emissions logistics, and it released a Sustainability Roadmap in 2021.

While this report focuses on the "E" pillar and climate change, we'd also note that DHL has extensive frameworks, goals, and benchmarks in the Social and Governance pillars. Within social, they will focus on sustaining high employee engagement, safety/accident reduction, diversity and inclusion (increase share of woman in upper and middle management to 30% and protect human rights for all workers). Within the Governance pillar, they will focus on compliance management, providing ESG KPIs that will be implemented in internal and external communications and reporting, and managing supplier relationships and provide partners with clear ESG related expectations.

Amazon Sustainability Initiatives Within Fulfillment Operations

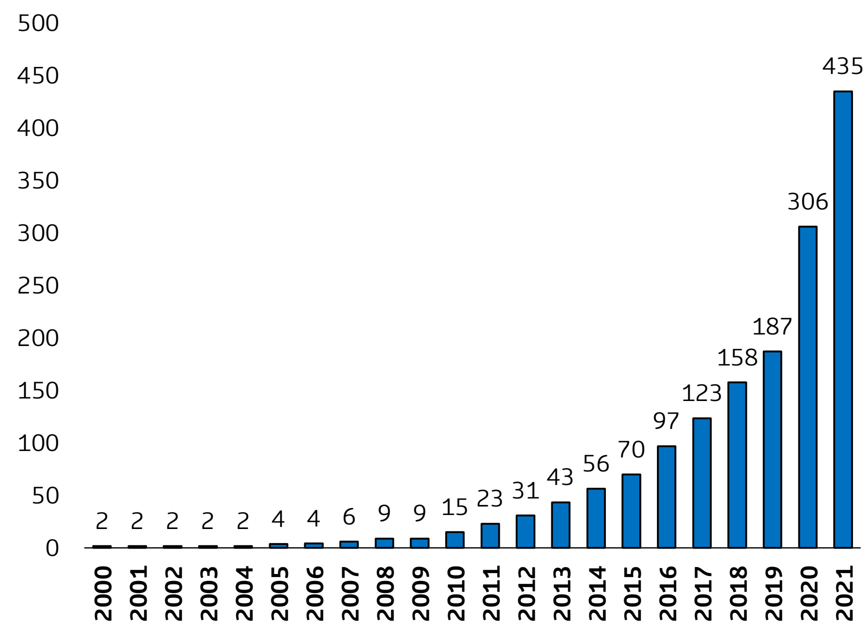
Amazon operations facilities are working to reduce carbon emissions in several ways. In 2020, Amazon opened 300 operating facilities – more than the previous four years combined. New facilities use cutting-edge technologies and are designed to be more efficient. They are expanding building control systems technology and the use of real-time data analytics to help optimize HVAC usage (one of the largest sources of energy consumption inside commercial buildings). The use of onsite solar panels has expanded, and as of June 2021, >90 fulfillment facilities have rooftop solar installations globally. These installations can generate up to 80% of annual electrical needs and the initiative is being expanded. AMZN is leveraging robotics and innovative conveyor systems to minimize energy usage and maximize facility throughput. Employees that work alongside robots in fulfillment operations are provided with intelligent vests that utilize short-range radio frequencies that alert the robots when a human is nearby and the bot needs to slow down, stop, or change course.

The company is also working to reduce delivery distances by constructing delivery operations close to large customer populations. Given that AMZN is the leader in fulfillment consistency and has been leveraging robotics and other innovative technologies for >10 years, we'd expect other 3PLs and logistics providers, where possible, to follow this initiative – building smaller operations close to concentrated customer areas. Building a higher number of smaller fulfillment centers in urban areas will require a smaller footprint, higher inventory turns, lower total inventory levels, and leverage efficiency maximization tools (like robotics, AI/ML, data analytics etc.), to establish successful operations.

AMZN US Fulfillment & Logistics Network Has More than Doubled Since '19 – John Blackledge

Amazon's investments in its US fulfillment network have ramped dramatically in '20 and '21 as their retail capex spend over the 2-year period totaled $78BN vs. just $58BN in the prior 5 years combined. The investment reflects AMZN's efforts to i) Strengthen their fulfillment capacity to meet heightened demand driven in part by the pandemic and ii) Build out Delivery Stations to handle Last Mile for its own burgeoning AMZN delivery network as it increasingly focuses on Prime 1-day and same-day delivery. We remain confident that the company (with the help from independent partners) can continue to handle more of its own shipping volumes and drive the availability of same-day delivery. Based on data from MWPVL, Amazon's US network has more than doubled in size since 2019, ending 2021 with ~435MM square feet vs. just ~187MM at the end of 2019, up ~53% annually over the 2-year period.

Figure 20 Estimated Square Footage of Amazon's Network '00-'21 (MM)

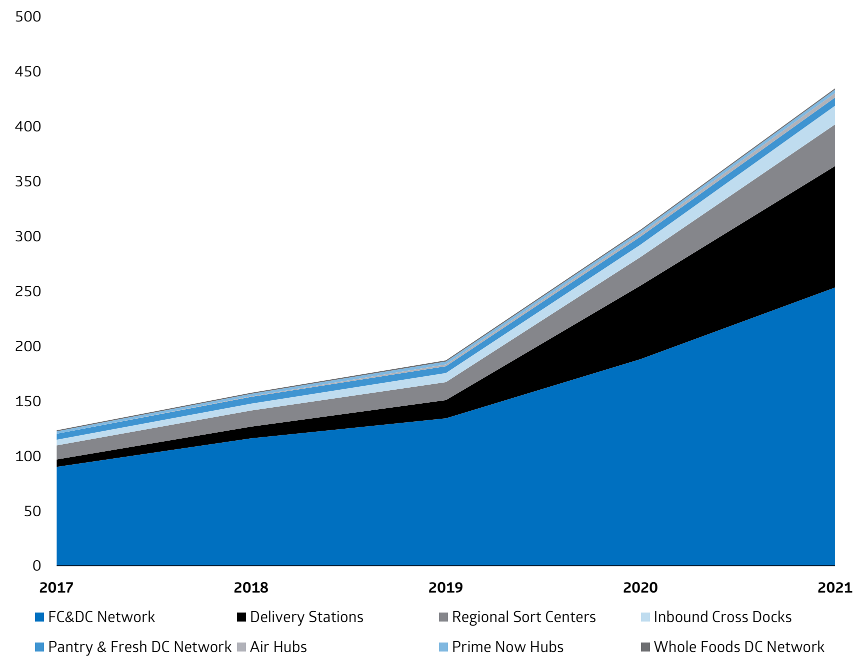


Source: Cowen and Company; MWPVL International.

Sort Centers and Delivery Stations Key to Amazon's Strategy

Outside of growing the absolute number of fulfillment centers (Amazon's traditional facility for fulfilling eCommerce orders) in its network, Amazon is sharply ramping its Sortation and Delivery facilities, largely aimed to help the company control more of its outbound shipping and be less dependent on the large national carriers. Regional sort centers, for example, sit between FCs and last mile and sort packages by zip code in order to deliver the packages to the appropriate delivery agent (typically either USPS or Amazon's own delivery network) who then completes the last mile delivery. Amazon delivery stations serve a similar role, with the key difference being that they are typically within large cities. Amazon ended 2021 with 781 sort centers and delivery stations in the US up from just 221 in 2019 and 1 in 2009. Sort centers and Delivery Stations are a key component of Amazon's strategy to control more of its own last mile delivery.

Figure 21 Estimated Square Footage of Amazon's Network by Facility Type '17-'21 (MM)



Source: Cowen and Company; MWPVL International.

Amazon Building Out National Shipment Capabilities Through Air Hub Expansion

In recent years, Amazon has ramped investment behind their Air Gateway Centers to further take control of outbound national shipping and enable Prime 1- and 2-day delivery. These facilities, located near regional airports, collect packages to be flown to Amazon's central Air Hub, where they are sorted and flown to their respective shipping destinations. Amazon ended 2021 with 18 Air Hubs, up from just 4 in 2018. Going forward, we expect this to be a continued area of focus for AMZN.

Figure 22 Estimated US Facilities '00-'21

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
# of US Facilities																						
FC&DC Network	3	3	3	3	3	7	9	11	15	15	22	32	41	51	60	72	97	119	156	185	265	367
Delivery Stations	0	0	0	0	0	0	0	1	1	1	1	1	1	9	10	26	48	77	123	174	442	682
Prime Now Hubs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32	49	55	56	63	69	74
Regional Sort Centers	0	0	0	0	0	0	0	0	0	0	1	1	1	4	19	24	28	38	43	47	68	99
Pantry & Fresh DC Network	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	8	14	21	23	23	23	23
Whole Foods DC Network	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	10	10	11
Inbound Cross Docks	0	0	0	0	0	0	0	1	2	2	2	2	2	2	3	6	8	9	11	14	19	30
Air Hubs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	10	18
Total US Facilities	**3**	**3**	**3**	**3**	**3**	**7**	**9**	**13**	**18**	**18**	**26**	**36**	**45**	**69**	**100**	**168**	**244**	**328**	**425**	**523**	**906**	**1,304**
Net Additions																						
FC&DC Network	1	0	0	0	0	4	2	2	4	0	7	10	9	10	9	12	25	22	37	29	80	102
Delivery Stations	0	0	0	0	0	0	0	1	0	0	0	0	0	8	1	16	22	29	46	51	268	240
Prime Now Hubs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	30	17	6	1	7	6	5
Regional Sort Centers	0	0	0	0	0	0	0	0	0	0	1	0	0	3	15	5	4	10	5	4	21	31
Pantry & Fresh DC Network	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	6	7	2	0	0	0
Whole Foods DC Network	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	1	0	1
Inbound Cross Docks	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	3	2	1	2	3	5	11
Air Hubs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	3	8
Total US Facilities	**1**	**0**	**0**	**0**	**0**	**4**	**2**	**4**	**5**	**0**	**8**	**10**	**9**	**24**	**31**	**68**	**76**	**84**	**97**	**98**	**383**	**398**
Y/Y % Change																						
FC&DC Network	50.0%	0.0%	0.0%	0.0%	0.0%	133.3%	28.6%	22.2%	36.4%	0.0%	46.7%	45.5%	28.1%	24.4%	17.6%	20.0%	34.7%	22.7%	31.1%	18.6%	43.2%	38.5%
Delivery Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.1%	160.0%	84.6%	60.4%	59.7%	41.5%	154.0%	54.3%
Prime Now Hubs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1500.0%	53.1%	12.2%	1.8%	12.5%	9.5%	7.2%
Regional Sort Centers	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	300.0%	375.0%	26.3%	16.7%	35.7%	13.2%	9.3%	44.7%	45.6%
Pantry & Fresh DC Network	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.0%	33.3%	75.0%	50.0%	9.5%	0.0%	0.0%	0.0%
Whole Foods DC Network	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	11.1%	0.0%	10.0%
Inbound Cross Docks	-	-	-	-	-	-	-	-	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	100.0%	33.3%	12.5%	22.2%	27.3%	35.7%	57.9%
Air Hubs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75.0%	42.9%	80.0%
Total US Facilities	**50.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**133.3%**	**28.6%**	**44.4%**	**38.5%**	**0.0%**	**44.4%**	**38.5%**	**25.0%**	**53.3%**	**44.9%**	**68.0%**	**45.2%**	**34.4%**	**29.6%**	**23.1%**	**73.2%**	**43.9%**

Source: Cowen and Company; MWPVL International.

How Robotics Can Help Companies Reach ESG / Climate Goals Within The Warehouse – Joe Giordano

It is estimated that 50-60% of warehouses have minimal automation and rely largely on manual operation. Some element of conveyors / sortation is historically an entry into automation and more advanced players like Amazon / WMT engage with more fully automated solutions. The ultimate end-game is a fully automated supply chain. We have identified four key attributes where automation can help operators achieve ESG goals in the warehouse/distribution center arena.

Efficiency of facilities – higher throughput, doing more/processing more with less inefficient or redundant movements

Probably the most recognizable impact of incorporating robotics/automation solutions in a warehouse setting are the efficiency gains relating to energy, time, and space. We have written extensively about these themes previously and highlight a few key thoughts below.

Energy costs represent roughly 5-10% of all warehouse operations (climate-controlled locations closer to 15-20%), while studies suggest up to 50% of energy costs could be eliminated with more efficient use of resources. Clearworld suggests a 20% cut in energy can represent the same bottom-line benefit as a 5% increase in sales. Increases in throughput can result in greater profitability on a GMS/Kwh basis, and less carbon density. Notably, half of Amazon's carbon intensity improvement is a result of investment in operational efficiency. Second order effects are also prevalent, as increases in productivity can potentially result in fewer employees on the floor, with benefits from fewer commutes and a reduction in on-site support.

Time with various manual processes can also be greatly reduced, particularly around material handling, increasing throughput. Solutions such as Exotec's "skypods" or Bionic Hive's "squids" climb racks vertically or transversely, thereby automating the most arduous tasks of SKU retrieval. Berkshire Grey has a wide portfolio of eCommerce fulfillment capabilities and Locus's AMRs can greatly reduce time spent moving SKU's throughout warehouse facilities, just to name a few. Currently, ~50% of the total picking time is associated with intra-facility travel. Thus, hardware and software solutions aimed here have the power to significantly increase efficiency.

Pressure on **space** in warehouses and distribution centers is not expected to ease in the short term, increasing operators' focus on more efficient processes. Automated storage & retrieval systems (ASRS) are among solutions that aim to optimize palletizing/racking, thereby increasing footprint yield and reducing operators' carbon/financial goals by meeting demand without the need to increase footprint. Ocado was a pioneer in this market. More recently companies like AutoStore have emerged and there are multiple players specifically targeting urban / vertical applications.

Fewer mistakes / returned packages – return shipments and the associated travel by incorrect product shipments can increase carbon intensity

Shipping delays, write-offs, cycle counting, and pallet hunting are all pain points associated with less automated warehouses. These manual processes are currently human intensive, and redundant processing can create a larger carbon footprint.

If mistakes are reduced or eliminated, so will related transportation/return related carbon emissions. Currently, inventory errors of 1-3% are seen as "acceptable failures" for operators. However, solutions which aim to close that gap can not only have a significant impact on customer relationships and profitability, but also on carbon emissions. Verity, a drone developer for warehouse inventory tracking/inspection, calculated a 2% decrease in fulfillment errors for a 1 million sq ft facility translates to taking 5k cars off the road per year.

Worker safety/satisfaction – increased safety of workers and less strain can improve worker satisfaction, and quality of work

In our last robot report in 2021, we discussed injury-related productivity loss and impact to the economy – here. Robotics and automation solutions provide clear and well documented improvements to dull and dangerous tasks and free up human capital for other applications.

A 2019 Harvard study identified safety as the most important factor contributing to employee happiness within the warehouse sector. This is most pronounced on in the reduction of "wear-and-tear" on the body. For instance, repetitive strain injuries, or accidents from heavy unwieldy loads can be reduced, decreasing absences and worker scheduling headaches. A typical 50k sqm facility with 40ft clearance heights (last decade average heights increased 25%) may have as many as 55k pallets stored above floor level.

Higher quality/ fulfilling work is also a priority for labor, as repetitive tasks more apt for automation can reduce work errors and increase throughput. For instance, inventory tracking is seen as a nearly universally unpopular task among warehouse personnel, and as employee satisfaction drops, process compliance suffers. Now, employees may only be engaged when there is a technical problem, which increases work complexity (in a good way) and novelty and ultimately employee satisfaction.

Renewable energy for warehouses/fulfillment centers – forms of clean energy brought on-site can offer advantages to operators

IPCC estimated between 10-13% of global GHG missions are caused by logistics activity in supply chains – roughly 15% of which is related to warehouse/sortation facilities. This is a significant contributor to a company's overall carbon footprint and provides an opportunity for improvement.

Importantly, the economics of power generation are subject to economies of scale and are a balance between capital costs, fuel, and life-time operating calculations. Often a combination of off-site wind/solar through green tariffs and on-site solar installations can work in unison to accomplish carbon reductions. Amazon's fulfillment capabilities showcase this strategy. As of June 2021, 90 facilities were powered by solar installations providing nearly 80% of the facilities' energy needs.

Commercial rooftops, such as those provided in a warehouse setting, make obvious sense for solar panel installation but often older buildings have corrugated roofs that can't support the weight of the installation and would need to be fortified (though the ROI still likely makes sense, and we'd expect to see this proliferate). For those who are hesitant to take on upfront capital costs, power purchase agreements are an option. Here, an installer pays for all upfront/service costs (design, installation, maintenance), leases the roof from the warehouse operator, and sells electricity to the owner (could be up to 20% less than the grid). Contracts vary can in length between 5-30 years. The robotic solutions we discuss in this report can be deployed using 100% renewable energy often generated on site.

The Tools Also Need To Mirror The Message – How Locus Is Approaching Sustainability Internally

Our report focuses on how robotic tools can be utilized to help end-users achieve climate goals (among other benefits), but as these technologies are deployed, there will likely be an increasing focus on the ESG frameworks employed at the providers themselves. Given that many of these companies are small and private, sustainability frameworks are generally less formalized and not seen as an immediate priority. Our survey results support that with over 40% of robotic solutions providers having no plans in place to establish publicized climate goals, vs. only 9% of robotic end-users. It's understandable that the immediate focus of these organizations is to scale the business and put the company on the path to future success, but we do believe that those that are able to do so while consciously maintaining a sustainability profile that potential customers can see will have an advantage as Scope 3 emissions are considered.

Locus Sustainability Playbook – Mature For An Emerging Growth Company

Locus is committed to recycling nearly 100% of robot components at the end of useful life. While still in the early stages of its business journey, Locus Robotics has a strategy and framework on how to manage its carbon footprint internally – something not all companies at that stage can highlight. The fact that the company is attempting to quantify and evaluate its operations in that light likely resonates with customers, and correspondingly becomes a differentiator vs. companies at similar levels of maturity. There is more to be done, but this is a clear gesture that shows where the values of the firm lie.

Refurbishment Of LocusBots

LocusBots have a useful life of five to seven years, but with refurbishment they can last significantly longer. The company's Robots as a Service (Raas) model – which they helped pioneer – allows Locus to control the entire lifecycle of LocusBots and enables the company to refurbish, repurpose, or redeploy robots to new facilities or geographic regions. The company has established a dedicated refurbishment center at its European HQ in Amsterdam. This enables local refurbishment and eliminates the need for excess shipping/travel that would be required if this center was located in the U.S. As the company matures and first generation LocusBots are fully amortized, they intend to retrofit, refurbish, and redeploy bots to lower income geographic regions that would not otherwise be able to justify the deployment cost of robotic solutions and would typically use human labor that would be cheaper (but less productive). From a Locus standpoint, they can offer these bots at lower prices because they are fully depreciated, and still make acceptable returns while providing a service these customers otherwise wouldn't receive.

Remote Deployment And Service

Remote deployment and service of LocusBot fleets is a key attribute – fully remote deployment significantly reduces travel required for Locus personnel. An added benefit is higher level of customer service (real-time) that can be accessed anywhere at any time. Locus only needs to send personnel to customer locations for specific technical issues or replacement of parts. Over time, customers will be trained to enable in-house engineers to replace basic serviceable parts on location without the need for a Locus representative.

Recycling

LocusBots are composed of four major components – ABS plastic, metal casings, batteries, and printed circuit boards / related electronics. Each component's useful life varies; therefore, Locus focuses on refurbishment and repair first and only resorts to recycling when components must be replaced. Below is an outline of how each major component is recycled:

- *ABS Plastic* – Acrylonitrile Butadiene Styrene is a thermoplastic used for several components in the LocusBot. Useful life is extended by wrapping it with vinyl. When the component cannot be extended any more using vinyl, 99% of the ABS plastic can be recycled – recycled ABS can be combined with virgin ABS to produce new products.

- *Metal Casing* – Locus decided to switch from steel to aluminum as the primary component of each chassis, helping to reduce robot weight and increasing the ability to recycle parts at the end of useful life. Aluminum is 100% recyclable and is the most sustainable metal; using recycled aluminum is 92% more energy efficient than producing virgin aluminum (also reduces pollution) and saves natural resources (every ton of recycled aluminum saves four tons of bauxite ore) – all three important attributes that drove the decision to make the switch.

- *Lithium Iron Phosphate Batteries ($LiFePO_4$)* – LocusBots each have two $LiFePO_4$ batteries. While this type of battery has a lower energy density than other alternatives (like Lithium-ion), it offers excellent lifetime supply (potentially 10x more cycles than Lithium-ion), good power density, and is safe (more thermal and chemically stable). At the end of useful lives, Locus uses specialized vendors and recycling techniques. The recycling process is simple - outer casing is disassembled, internal components are melted and crushed, while various componentry is sorted, cleaned, and returned into new product material streams.

- *Printed Circuit Boards (PCBs)* – Recycling of PCBs is as important as other materials like plastic and reduces waste to landfill. Several PCBs are used in each LocusBots – recycling helps recover precious metal scrap, electronic components, and connectors. At the end of PCB's useful life, the company is working with a leading US-based PCB recycling provider.

Airlines And Carbon Reduction Initiatives – Helane Becker

Airlines are committed to reducing their carbon footprint to net zero by 2040 or 2050. The easiest way to reach the goal is through the increased use of Sustainable Aviation Fuel and more direct routings into airports. Airlines have a young, fuel-efficient fleet, especially post-pandemic given most airlines retired older aircraft. American Airlines, for example, went from eight aircraft and model types to four. Its regional airline providers did the same thing, increasing fuel efficiency and reducing their carbon footprint.

United Airlines has 70% of the world's SAF commitments and continues to focus on reducing its carbon footprint through agreements with Heart Aerospace, one point five, Boom Aerospace and others. The two major issues with SAF are cost and scale. Right now, SAF cannot be scaled and as a result, it's too costly. Right now, SAF is ~$10 / gallon and compares unfavorably to jet fuel, which although double year ago levels, and down ~10% from recent peaks, is still at $2.90 / gallon.

Airlines are being proactive in their plans to lower their carbon footprint, including agreeing to acquire eVTOL aircraft as they become available. The following chart summarizes what the major US airlines are doing on the climate side. There isn't a significant amount of opportunity for automation until the US Federal Aviation Administration approves either one pilot in the cockpit and one on the ground or complete autonomy. We do not believe we will see autonomous flight in passenger airline service until the 2030s. We should see autonomous flight in cargo service in the second half of this decade.

Figure 23 Climate Targets And Details By Airline

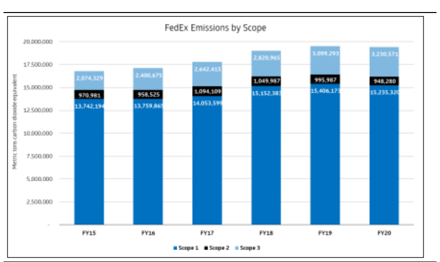
Airline	Overall goal	Fleet Decision	SAF Commitment
Alaska Air Group	Net-zero carbon emissions by 2040	737 MAX	Yes: Signed agreement w/ SkyNRG; Set up Alaska Star Ventures to invest in ESG projects
Allegiant	Net-zero carbon emissions by 2050	New A320s; New MAX	Not yet
American Airlines	Net zero carbon emissions by 2050; Ordered up to 250 Vertical Aerospace eVTOL aircraft	737 MAX, A320neo, Vertical Aerospace order	Yes: to use 9 MM gallons by 2023
Delta Air Lines	Net-zero carbon emissions by 2050	A350s	Yes: to use 10% SAF by 2030
Frontier	Net-zero carbon emissions by 2050	A320neos	Yes
Hawaiian	Net-zero carbon emissions by 2050	787s; A330s	Not yet; talking w/ various providers
JetBlue	Net-zero carbon emissions by 2040; Invested in Joby Aviatior	E190s; A321neos	Yes: to be at 10% of fuel used by 2030
Mesa	Investing in Archer Aviation, Elroy Air and Heart Aerospace	Regional jets	Participation in carbon offset programs
Southwest	Net-zero carbon emissions by 2050	737 MAX	Yes: Partnering w/ Red Rock Biofuels & the US DOE's NREL to support SAF development & production; Signed 15-year agreement w/ Velosys for 215 MM gallons of SAF
Spirit Airlines	Net-zero carbon emissions by 2050	A320neos / A321neos	
United Airlines	Investing in Archer Aviation and Heart Aerospace; net zero carbon emissions by 2050	737 MAX, A320neo, 787	Yes: to buy 15 MM gallons of biofuel from AltAir over 3 years; partnering w/ Fulcrum BioEnergy to convert waste and household trash into SAF

Source: Company Reports, Cowen and Company

Air Freight

FedEx and UPS aggressively focus on using robotics in their facilities to reduce the need for human capital. All new facilities are fully automated except for intake and outtake. Both companies use people to offload trucks and put the packages into the network, and then the same people reload containers and trucks once the packages go through the sort facility. Neither company is building the large "sun-blocking" buildings anymore, preferring to lease or build smaller facilities closer to the end user. This further reduces their carbon footprint. FedEx has been testing Roxo in Memphis, a last mile delivery robot based on the same principal as the Segway.

Figure 24 FedEx Emissions By Scope



Source: Company reports, Cowen and Company

Figure 25 Direct And Indirect Emissions

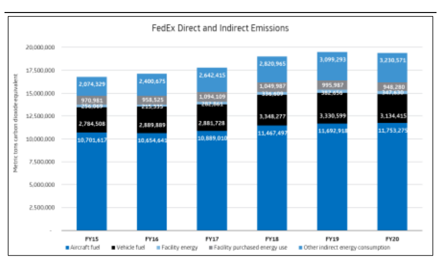


Figure 26 Scope 1 Emission % Contribution

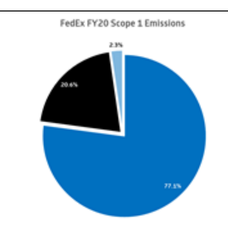
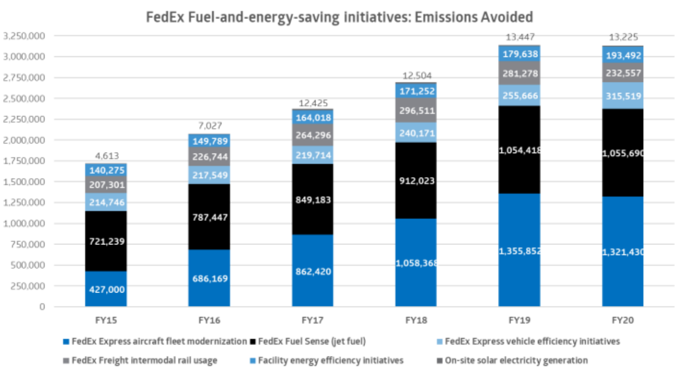


Figure 27 FedEx Emissions Avoided By Source



Source: Company reports, Cowen and Company

Figure 28 FedEx Emissions Avoided By Source % Contribution

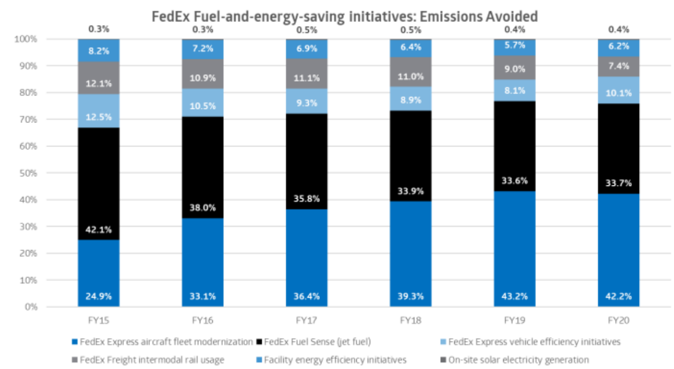


Figure 29 UPS Emissions By Scope

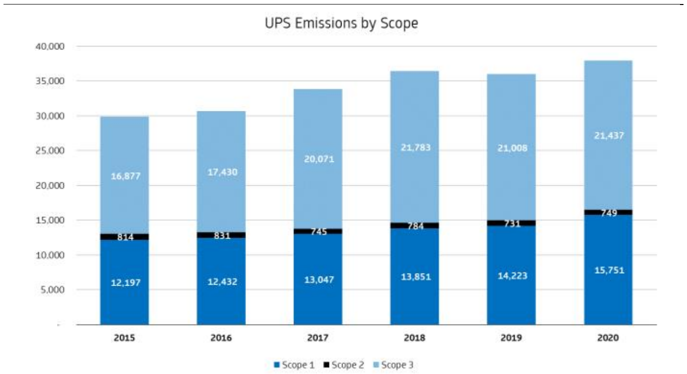
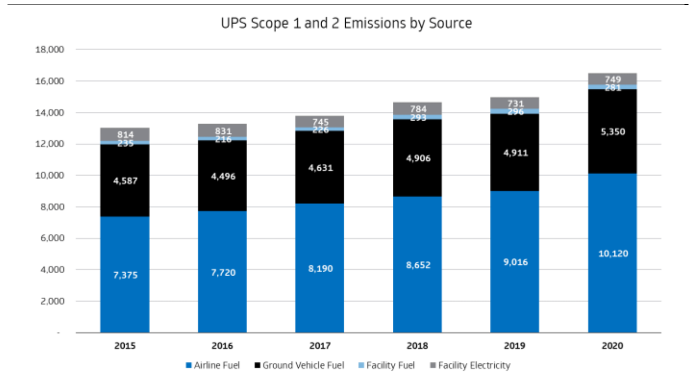


Figure 30 UPS Scope 1 and 2 Emissions By Source



Source: Company reports, Cowen and Company

Both companies are also working aggressively to reduce their carbon footprint via delivery drones. UPS has an order for 10 of Beta Technologies' Alia-250 eVTOLs pending certification from the US Federal Aviation Administration. These aircraft would be delivered in 2024 and will be used to deliver packages in mostly rural areas to replace automobiles. UPS also has an order for 10,000 purpose built electric vehicles for Arrival which will be rolled out between 2020 and 2024. The company has the option to order a further 10,000.

Figure 31 FedEx Robotics Initiatives

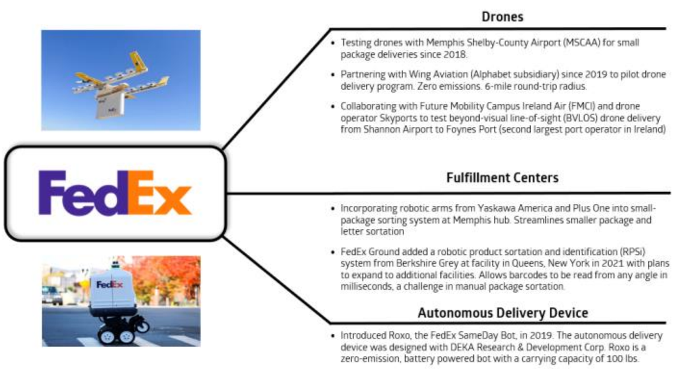
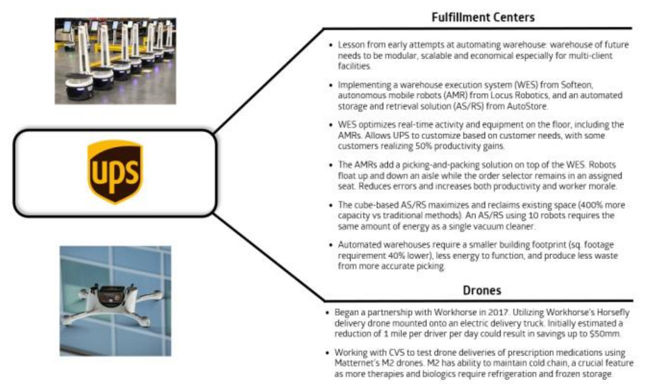


Figure 32 UPS Robotics Initiatives



Source: Company reports, Cowen and Company

Finally, both companies have been replacing older aircraft with new, more fuel-efficient aircraft ordered directly from Boeing. At FedEx, and at current fuel prices, every B767 that replaces an MD11 saves the company ~$10 MM. The MD11F and the B767-300F have similar volume specs, but the MD11F can handle heavier payloads, as seen in the chart below. The MD11F is more of an intercontinental aircraft while the B767-300F is more of a regional aircraft.

Figure 33 Air Freight Comparison – Every MD11F Replaced With 767-300F Saves FDX ~$10MM

Air Freighter Specs		
	MD-11F	767-300F
Maximum payload, lbs	191,461	116,200
Maximum takeoff weight, lbs	602,500	408,000
Total Volume, ft^3	15,530	15,469

Source: Boeing, Cowen and Company

How Consumer Brands Are Utilizing Robotics - Oliver Chen

WMT Leaning Into Electric Vehicles, Partnering With Leading Private Companies & Other Automation To Achieve Sustainability Goals

WMT is focused on reaching zero emissions across global operations by 2040, without relying on carbon offsets. To reach this goal, the retailer will need to lean into robotics and automation to drive efficiencies, and sustainably grow the business. WMT recently announced (link) plans to build out a fleet of 100% all-electric delivery vans to support its quickly growing InHome delivery service. The implementation of EV vehicles is helping support the retailer's goal of operating a zero-emissions logistics fleet by 2040. Additionally, the fleet is supported by WMT's growing infrastructure of ~1,400 EV charging stations at stores and Sam's Clubs across 41 states. Furthermore, in support of WMT's sustainable goals, WMT aims to be supplied by 100% renewable energy by 2035 across its global operations, electrify and zero out emissions from all its vehicles by 2040, and transition to low-impact refrigerants for its facilities by 2040. Ahead, we expect increased investments in robotics and automation as last September WMT closed its inaugural $2bn green bond offering. Projects that will be allocated toward a portfolio of eligible green investments include: renewable energy, high performance buildings, sustainable transport, zero waste and circular economy, quality and efficient water stewardship, and others.

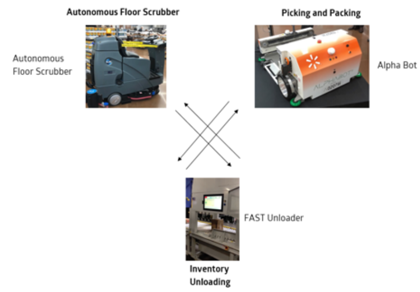
WMT also recently participated in Plenty Unlimited's latest financing round, helping the company raise $400mm Series E funding. Plenty Unlimited is an indoor vertical farming company that uses less space and fewer resources to grow flavorful, healthy, fresh, and clean produce year-round. WMT's investment is part of the retailer's broader strategic partnership to utilize Plenty's indoor vertical farming technology platform to deliver fresh produce to its stores. Plenty's proprietary tech meaningfully improves on traditional agriculture's use of water and land, and by building farms closer to the consumer, helps reduce transportation and food waste, keeping items fresher for longer in 100% recyclable product packaging.

Furthermore, WMT is leaning into automation and building micro fulfillment centers to improve online grocery throughput to help fulfill demand given the success of online grocery curbside pickup. Automation has allowed WMT to significantly increase fulfillment volume and accommodate order flow. WMT is also investing and testing drone delivery which have lower emissions and are able to deliver small orders to shoppers in as quickly as 30 minutes. WMT made a strategic investment and is partnering with DoneUp on a network of drone delivery hubs. The first hub is in Farmington, Arkansas, with plans for two additional ones near Walmart stores in Rogers and Bentonville.

Figure 34 WMT & TGT Leaning Into Robotics & Innovation To Reach Sustainability Targets

WMT

- Developing a fleet of 100% all-electric delivery vans – supported by WMT's growing infrastructure of 1,400 charging stations
- Partnering with Plenty Unlimited, an indoor vertical farming company which will help reduce transportation and food waste and spoilage
- Testing drone delivery for small orders which lowers emissions



TGT

- Investing in robotics across distribution centers to improve efficiency and throughput
- Leveraging automation to drive greater volume through stores which lowers emissions and last mile expenses
- Investing in large-scale renewable energy projects which will help reach goal of sourcing 100% of electricity from renewable resources by 2030

Source: Cowen and Company

TGT's Automation Investment Across Its Supply Chain Supports Sustainability Targets

By putting stores at the center of its distribution strategy, TGT is able to significantly reduce emissions by lowering last mile expense costs. Over 95% of TGT's sales are fulfilled through its stores (physical sales + majority of e-comm orders) as the retailer has transformed its stores into mini omni hubs by leaning into technology to drive efficiencies. Further, TGT is scaling its sortation center pilot to help stores handle greater volume. Sortation centers are local hubs that receive and sort packages from a large group of surrounding stores multiple times per day, which allows for more optimized granular sortation. Sortation centers help remove the sorting process from stores' backrooms, which saves time and space to fulfill additional orders as the technology pre-sorts and arranges packages for easy pickup. Furthermore, TGT is investing in robotics in their distribution centers to make store replenishment more efficient, increase throughput, and drive greater volumes.

Additionally, TGT now has at least three large-scale renewable energy projects which, when operational, alongside its existing partnerships, will result in the retailer purchasing nearly 50% of its electricity from renewable resources as management continues to make strides towards its goal to source 100% of its electricity from renewable resources by 2030. Projects include a renewable power purchase agreement for two solar projects in Texas, including the Golden Buckle Power Project with Savion, and the Haystack Wind Project (in Nebraska). Management noted that together these projects will generate the equivalent electricity required to power over 100k homes and will pace the retailer ahead of schedule in meeting its goals. Separately, TGT also now has at least 542 stores with solar rooftops.

Sure Sort: Creating Efficiency And Speed In Supply Chain

Retailers are increasingly investing in automation in the supply chain, and OPEX Sure Sort provides a highly scalable, cost-effective system that facilitates handling multi-line ecommerce orders, parcel sorting, and reverse logistics. The Sure Sort solution is differentiated with fewer touches, and, with the six-sided scan tunnel, all barcodes can be read easily. Key benefits of using Sure Sort include (1) fast and accurate sorting of up to 2,400 items per hour with only three operators, (2) easily scalable and customizable, (3) integrates easily with existing WMS systems, and (4) ROI is as little as two years.

Restaurant Robotics Moving From Science Fiction To Reality – Andrew Charles

We are optimistic advancements in kitchen robotics ordering will drive broader industry adoption as soon as 2023. This is driven by a combo of: 1) the tightest labor market in industry history, 2) improved technology & price points making automation more realistic; & 3) greater industry open-mindedness to automation given digital inroads amid COVID-19. We outline the potential applications for automation technologies at our coverage universe that also have ESG benefits, particularly minimizing food waste. We also illustrate the potential change in unit economics from automation.

Spyce (Owned by sweetgreen)

One differentiated aspect of the sweetgreen story is the September 2021 acquisition of Spyce, a two-store concept in Boston powered by kitchen robotics technology. sweetgreen believes Spyce's technology is scalable to the flagship concept's digital assembly lines to prepare orders. In the coming years, sweetgreen will begin to experiment with adding Spyce technology at existing stores. Our sweetgreen model embeds $8-$10 million of annual Spyce R&D costs within 2022-25E G&A and a CapEx ramp from $2 million in 2022E to $28 million in 2025E. As shown in the figure below, this could be game-changing for unit economics. sweetgreen's labor expense is ~30% of sales and is evenly split between prep and assembly. If we assume half of prep labor, or 7.5% of sales is added back to restaurant level margins, it is accretive to cash on cash returns up to an incremental investment of $575,000. We use an estimated $250k in build-out cost, though given the early-stage nature of the tech, we do not have certainty on the pro forma costs.

Figure 35 sweetgreen Current Unit Economics (millions)

		Memo:
AUVs	$2,900	$2.8-$3M Range
RLM	19%	18%-20% Range
Restaurant Profit	$551	
Investment Cost	$1,200	
Pre-opening	$240	
Cash on Cash	**38%**	

Source: Cowen and Company, Company Documents

Figure 36 sweetgreen Potential Unit Economics (millions)

		Memo:
AUVs	$2,900	$2.8-$3M Range
RLM	27%	Current + 7.5%
Restaurant Profit	$769	
Investment Cost	$1,450	Current + $250k
Pre-opening	$240	
Cash on Cash	**45%**	

Source: Cowen and Company, Company Documents

RLM assumes midpoint of the company's 18-20% range plus 7.5%, or 25% labor savings … Assumes $250K incremental investment cost for Spyce technology. The investment would be accretive to cash on cash returns at a per store cost of up to $0.575M assuming a 7.5% benefit to RLM

We View Wingstop As Positioned to See The Greatest Benefit from Miso Robotics

Miso Robotics has a product known as "Flippy 2" that assists with frying operations and alleviates labor needs at the store level. The company estimates that the technology can remove 165 labor hours per restaurant per month, or 1,980 labor hours per restaurant per year. Flippy's lease cost begins at $3,000/month.

We believe Wingstop is uniquely positioned to utilize this technology given the brand's streamlined operations, and see an inflection point once Flippy is able to cross 2,400 hours of savings per year. At that point, not only will the breakeven make sense, but this could also enhance Wingstop's franchisee unit economics. Importantly, a lower reliance on in-store labor with improved unit economics only has positive ramifications for accelerated store development.

Figure 37 Wingstop Corporate Store Potential Labor Savings From Implementing "Flippy" (millions)

	Inputs
Assumed Labor Rate/Hr	$15.0
Annual Flippy Cost (M)	$36,000
Flippy Breakeven Hours Replaced/Year	**2,400**

Source: Cowen and Company, Company Documents

We highlight the following benefits for both sweetgreen and Wingstop:

1) **Minimizing Food Waste** – In addition to improving consistency (i.e. each order has the same amount of each ingredient/is prepared the same way) automation can eliminate human error that would cause food to be discarded (i.e. wrong dressing mixed in or stayed in the fryer too long). Not only is this a cost benefit, but it also would lower the COGS requirements on a per-restaurant basis. Given food production and distribution's contribution to carbon emissions, this has environmental benefits as well.

2) **Labor Savings** –The automation could remove significant costs from the company's income statement (though some amount would be reinvested in the guest experience/oversight). For Wingstop, assuming $15/hr labor cost per employee, we

can see that Flippy is very close to becoming breakeven at the restaurant level. Additionally, with fewer employees needed per restaurant, we believe this would significantly reduce any potential staffing constraints in opening restaurants.

3) **Unique/Theatrical Customer Experience** – Robots making your food? Seems like a show! We believe that the unique customer experience could be a top-line driver, while speed of service benefits will allow restaurants to fulfill more orders during peak hours.

Machinery and Transportation OEMs – Matt Elkott

We see the integration of autonomy and electrification as a key growth area in industrial equipment. This is particularly true in closed environments such as mining and, to a somewhat lesser extent, in open but highly controlled environments like construction and rail. Caterpillar is developing autonomous technologies for all three markets, helping customers to inch closer to carbon reduction goals and improve workplace safety. For example, Rio Tinto on September 14 announced an agreement with CAT for 35 new 793 zero-emission trucks which will also be autonomous. We would expect more such deals that combine autonomy and electrification in the coming years.

Mining Equipment

We place the ESG-related advantages of autonomy in mining into two categories: 1. Safety. 2. Productivity and Efficiency. Both yield human, environmental, and economic benefits.

i. Safety: It is estimated that the heavy machinery industry has delivered 5Bn tons of material autonomously with zero fatal accidents.

ii. Productivity and Efficiency: Fully autonomous trucks in mining operations can be 15-25% more productive than human run counterparts, as autonomous trucks can run close to 24 hours a day, seven days a week, eliminating the need for three human in-truck operators ($500K per year of comp). This could yield north of 800 extra hours of operation per year, which would result in $2-4MM in cost savings. Even three human operators may not be able to run a full 24 hours of operation per day due to labor safety regulations. Furthermore, autonomous trucks can run more efficiently, reducing idle time, improving synchronization with other equipment such as loaders, and subsequently resulting in lower energy consumption.

We estimate the global mining equipment market to be ~$130Bn. We are projecting a 9% CAGR in the 2021-25 five-year period broken out as follows: 3% general price inflation not specifically tied to autonomy; 3% volume growth; and 3% related to autonomy and automation. This last piece would yield a revenue opportunity of $21Bn for the industry related to autonomy over the 5-year period ending in 2025. For the ensuing 5-year period, we are projecting a 7% CAGR for global mining equipment revenues broken out as follows: 1% general price inflation not specifically tied to autonomy; 1% volume growth; and 5% related to autonomy and automation. This last piece would yield a revenue opportunity of $55Bn for the industry related to autonomy over the 5-year period ending in 2030. This puts our total estimated revenue opportunity for the next 10 years at $76Bn for the industry.

Beyond this 10-year period, we fully expect autonomy to be the standard and prevalent method in mining given its advantages and likely gradual improvements in cost competitiveness, not just on a total-cost-of-ownership basis, but upfront cost as well.

Construction Equipment

In construction, productivity and efficiency have historically lagged many other industries. Autonomy could go a long way to change that. In the case of road rehabilitation, for instance, savings well above 15% are likely attainable.

We estimate the global construction equipment market to be around $120 Bn. We are projecting a 5% CAGR in the 2021-25 five-year period broken out as follows: 3% general price inflation not specifically tied to autonomy; largely flat volumes (as growth in NA and India should be offset by a China cyclical decline); and 2% related to autonomy and automation. This last piece would yield a revenue opportunity of $13Bn for the industry related to autonomy over the 5-year period ending in 2025. For the ensuing 5-year period, we are projecting an 8% CAGR for global construction equipment revenues broken out as follows: 2% general price inflation not specifically tied to autonomy; 2% volume growth; and 4% related to autonomy and automation. This last piece would yield a revenue opportunity of over $32Bn for the industry related to autonomy over the 5-year period ending in 2030. This puts our total estimated revenue opportunity for the next ten years at $46Bn for the industry.

Rail Equipment

Automation—with or without no-person trains—could be a game changer for rail. It could allow trains to run closer together and enable the rails to de-emphasize longer trains when warranted and increase the number of shorter trains to compete for a bigger portion of highway traffic (rail is 3-5x more energy efficient than truck). While a move to one-person crews or full autonomy would reduce costs, automation, even with the current system of two-person crews, would likely boost rail capacity and create new opportunities for traffic growth (see our March 2019 deep dive <u>Rail Automation Is Coming, With or Without Autonomy - Ahead of the Curve Series</u>). The Class Is have thus far made neither autonomy nor transformative network automation key focus areas, at least not publicly. One reason is that they have not had to. Over the last several years, the carriers have had a compelling story that has produced great results and won shareholders' approval. It is the story of operating ratio (OR) improvement primarily through PSR and resilient pricing power, while traffic remained largely flat. The good news is that most Class Is are in the advanced innings of the OR improvement game. But that's also the bad news. What will the story be after that? We doubt that the rails or their shareholders are quite ready to be content with a transition into becoming mainly income investments. That's where dramatic network automation could come in as a significant traffic growth opportunity, and one-person crews/no-person trains could be the next driver of margin improvement.

That said, full autonomy's march into ubiquitous commercial application should happen much faster in the mining industry than in road and rail transportation. This is in large part because of the closed environments of many mining operations. This can also be true, but to a lesser extent, in the construction industry. Indeed, mining embraced autonomy before transportation and many other industries. For example, CAT had its first big autonomous project around 2008.

We expect the incremental revenue opportunity for CAT from autonomy and automation to be ~$35Bn over the next 10 years. This would be back-end loaded, with steady increases over the period. The company's Mining Resources segment would be the biggest beneficiary, followed by Construction Industries and Energy & Transportation.

We would put these revenues broadly into five buckets:

i. CAT's portion of revenues generated from retrofitting existing equipment.

ii. Outright replacement of traditional equipment with autonomous or highly automated machines.

iii. Incremental revenues associated with the premium pricing of newly built autonomous products and related services as compared to such products being conventional.

iv. Potential market share gain in autonomy driven by the company's scale, resources, leading market position, and possible acquisitions in automation.

v. We believe it is plausible that autonomy could also help to create new demand for mining projects that wouldn't otherwise exist, as the benefits of autonomy could yield more favorable outcomes to feasibility studies. However, we do not see this as a particularly significant opportunity and are baking it modestly into our outlook.

Truck Equipment

The conventional truck OEMs' interest in new technologies has been on the rise over the last several years, and we expect this to accelerate further. But between their legacy products, autonomy, and a multitude of new energy technologies, it's unlikely that any single OEM can forge a pioneering presence in all areas. This leaves room for pure play companies, such as TuSimple, to help shape nascent markets, such as Level 4 autonomous trucking.

Longer term, as the commercial market for autonomous truck operations grows, and as driver recruitment challenges in conventional trucking intensify further, large, well-capitalized OEMs could eye outright acquisitions of disruptors in autonomy. Thus far, some of these OEMs have opted for a combination of in-house research and development, third-party suppliers, and strategic partnerships, such as PACCAR's deal with Aurora, announced in January 2021. The two companies signed a strategic agreement to develop, test and commercialize autonomous Peterbilt and Kenworth trucks. The collaboration is designed in part to integrate PACCAR's autonomous vehicle platform with the Aurora Driver to enhance the safety and operational efficiency for PACCAR's customers.

Today, most conventional heavy and medium-duty trucks in the North American market come either pre-equipped with autonomous features, or with such options offered to the customer upon ordering. Many of these features are in the Level 1 and Level 2 autonomy categories. Knorr-Bremse and Daimler, both Germany-based companies, are the two primary providers of driver assistance and collision mitigation technologies for conventional trucks. Daimler's product is Detroit Assurance and is installed on the company's trucks, Freightliner and Western Star. Knorr-Bremse's Bindex Wingman Fusion product is installed on most other truck makes.

Robotics and Automation – Cybersecurity Implications – Shaul Eyal

Robotics, Internet of Things (IoT) devices, and operational manufacturing (OT) are all data dependent, which means this data is mission critical and sensitive, hence, addressing a critical need to be protected and secured. While this report focuses on robotics/automation in the context of climate changes, we believe security solutions are agnostic to the end market or use case and have broad-based implications for all market segments and/or use cases.

Overview

Robotics, operational manufacturing, IoT devices and technologies are gradually changing not only the enterprise arena but also the consumer landscape. We see a high correlation between the ongoing adoption of such technologies with cyber security solutions and services addressing both the enterprise and consumer arenas. Robotics, IoT, and OT could become an additional tailwind to support ongoing growth within the security landscape.

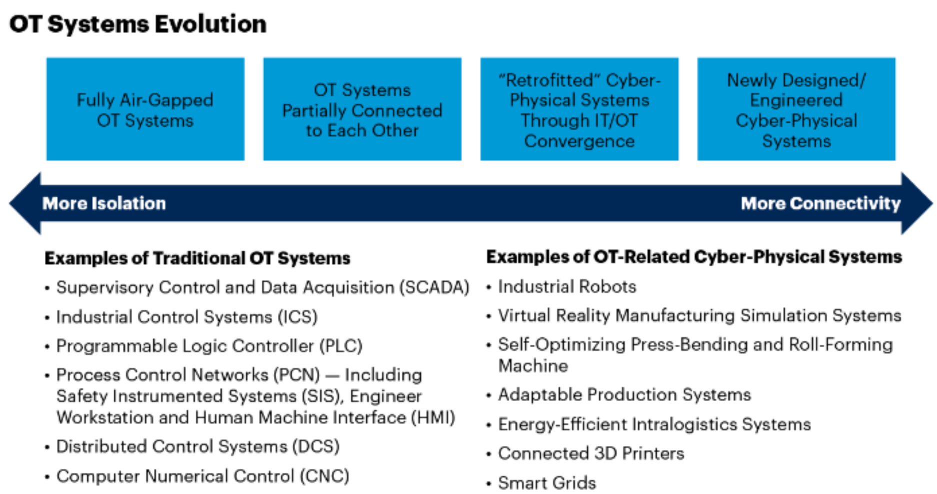
Cybersecurity Market: Estimates & Definitions

Cybersecurity & Information Security generate $161B in annual revenue, growing at 10%, on pace to reach $194B by 2024E. By 2025, per Gartner, 75% of OT security solutions will be delivered through multifunction platforms interoperable with IT security solutions. Gartner views operational technology as “Hardware and Software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in asset-centric enterprises, particularly in production and operations.” (Gartner, “Market Guide for Operational Technology Security”, 1/13/21, Katell Thielemann et al.). OT security is defined as “the practices and technologies used to protect people, assets, and information involved in the monitoring and/or control of physical devices, processes and events in asset-centric enterprises, particularly in production, and operations.”

All Things Autonomous

Be it robots, cars, connected 3D printers or unmanned aircraft, autonomous things are physical devices that can function with no need for human direction. The proliferation of autonomous technology is elevating the need for cyber-related solutions. In early 2020, as COVID-19 was spreading globally, a string of ransomware attacks named Ekans was targeting industrial control systems (ICS) with the ability to inflict harm and cease operations at hospitals, factories, and additional mission critical systems.

Figure 38 Operational Technology Systems Evolution



Source: Gartner, Market Guide for OT Security, 1/13/21, Katell Thielemann Et. al; Cowen and Company

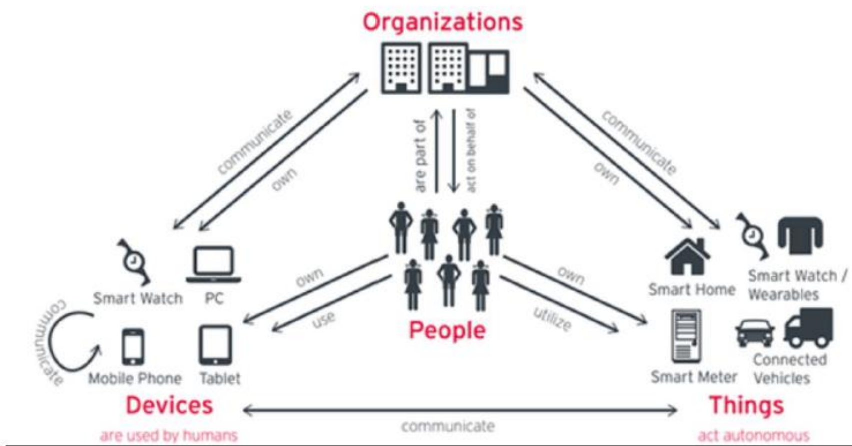
Potential Losses In The Billions Of Dollars

In January 2022, as reported by bloomberglaw.com (news.bloomberglaw.com, "Merck's $1.4 Billion Insurance Win Splits Cyber From 'Act of War'", January 19, 2022) Merck & Co. won $1.4 billion in insurance compensation for its estimated losses from the June 2017 NotPetya attack. The NotPetya attack, which impacted thousands of companies globally, destroyed data on more than 40,000 Merck computers. Loss categories included production outages, equipment replacement, and the hiring of IT experts. It took the company months to recover. We use the Merck case as an example of the scope and magnitude of cyber attacks and their extensive impact on companies and many of their vendors. The problem is a multi-dimensional issue.

Focus on IoT Opportunity

While still nascent in nature, companies have increased focus on this quickly emerging category. IoT devices, per Crowdstrike, include anything from industrial machinery, automation tools, smart grids, and essentially anything that gathers and transmits data over the internet. From an Identity perspective, ForgeRock views the total addressable market (TAM) as a $3B longer term opportunity. Research firm IoT Analytics believes that IoT connections encompassing anything from connected cars, industrial equipment to smart home devices exceeded traditional connected devices such as computers and laptops for the first time in 2020, representing 54% of the overall 21.7B connected devices. IoT Analytics believes that by FY25, there will be more than 30B IoT connections, representing on average approximately four IoT devices per person.

Figure 39 Ecosystems Are Becoming Increasingly Connected & Complex



Source: ForgeRock; Cowen and Company

It is difficult to estimate the total financial drag of cybercrime on global or national economies, but the costs are high and rising. BCG estimates that losses due to cybercrime reached $2 trillion by the end of 2021, up from $400 billion in 2015. These losses include direct costs (e.g., technical remediation, fines, lawsuits) as well as indirect costs (e.g., reduced productivity, misappropriated IP, and lost customers).

Figure 40 Cybersecurity: An Increasingly Pressing Issue

Source: BCG Ensuring Online Security in a Quantum Future (March 2021), Worldometer, CNBC, World Economic Forum, Cybersecurity Ventures, Ponemon Institute, press search, BCG analysis of 50 major data breaches (2021), BCG analysis.

Robotics: An Emerging Front in US-China Trade Narrative – Chris Krueger, Cowen Washington Research Group

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Semis and 5G remain the tip of the spear in the US-China trade/tech war, though robotics is in the queue of sectors likely to become the public face of this conflict in the years and decades to come. The trade/tech war has shifted under the Biden Administration from the Trump Administration with export controls largely replacing tariffs as the new tools (though tariffs remain in the toolbox); soybeans have been replaced by semis. The sectors that line up in the Venn Diagram between Made in China

2025 and the Administration's focus on supply chains will be the battlefronts of the future, with robotics squarely in the middle.

We expect that a new Section 301 investigation aimed at China's industrial policy subsidization (national champions from Made in China 2025 initiative & Belt and Road Initiative) will be announced before May 31. Policy action is likely a year away, though is likely to feature some combination of tariffs, export controls and investment restrictions.

For further background and analysis, see our March 17, 2022, report **China, Cat, Sunflower: Section 301 Tariff Review Timeline & New Investigation.**

Robotics and Automation for Solar and Wind - Jeff Osborne

For the purposes of this report, we highlight the robotics and automation opportunity for operations & maintenance (O&M) of the solar and wind industries, though note there are other energy-related applications.

Overview

Robotics and autonomous systems are set to play a key role in the efficiency, safety and cost reduction for photovoltaic (PV) plants and wind farms. Together, there is potential to increase performance and reduce installation/maintenance costs, while lowering the levelized cost of electricity. Solar and wind capacity growth will involve more remote locations (particularly for offshore wind) that increase safety risk for manual operations. Through predictive maintenance, potential failures can be addressed, prolonging the lifetime of components and reducing operating expense.

Solar PV O&M Market

Solar PV plants are complex and commissioned with a lifetime of 25-30 years, making operation and maintenance (O&M) critical for optimizing performance. O&M strategies remain in an infant stage. Digitization and the development of data driven models will allow lifetime predictions, which then feed data-driven O&M strategies.

In a 2020 report, Wood Mackenzie forecasted solar power systems nearing inverter end of life will account for 16% of the global PV market by 2025, up from 5% in 2020. The global non-residential PV O&M market is expected to reach $9.4B by 2025, led by repowering opportunities related to aging systems - inverters need to be replaced roughly every 10 years - and advanced analytics for new projects. Wood Mackenzie also estimates 36 GW_{DC} of solar assets experiencing premature failure in 2025, up from 4.2 GW_{DC} in 2020.

Annual solar installations are projected to average 135 GW_{DC} over 2022-2025, creating an attractive O&M opportunity for service providers. NREL has identified 15%-20% of residential and commercial solar projects missing expected energy production by at least 10%, resulting in reduced revenue, high O&M costs, and higher financing costs on future projects. Cost effectively scaling O&M services is a key strategy to address challenges, with automated solutions and advanced analytics gaining traction. Advanced sensors, drones and robots are being used for data acquisition in conjunction with analytics to predict and optimize asset performance. The use of technologies is expected to lower the levelized cost of energy (LCOE) through lower opex. Aided by more efficient operations, IEA expects the LCOE for solar PV in the US to decline to $50/MWh in 2020 and $30/MWh in 2030.

Exponential growth also creates labor-related challenges which can be eased through automation. In 2020, the U.S. solar industry employed ~230,000 workers according to the annual National Solar Jobs Census, which was published by The Solar Foundation, the Solar Energy Industries Association, and the Interstate Renewable Energy Council (IREC). Ramping solar sector employment by >3x could prove difficult. U.S. solar workers needed by 2030 to reach the 100% clean energy goal by 2035 has been estimated at 900,000, with employment in solar installation from 2020-2030 expected to grow 52%.

As the solar industry matures, data can be leveraged to support return expectations from investors. In its 2021 Solar Generation Index Report, kWh Analytics, an aggregator of renewable energy performance data, compared estimated average production, or P50s, to actual production to understand project performance by collaborating with 15 of the 20 largest U.S. asset owners. The report found solar PV projects underperformed their average (P50) production estimates by 5%-13% over 2011-2020, with performance deteriorating over time. Over the last 5 years, the average level has been 92% (no change expected without additional investment), below the 100% of the P50 level expected over the life of the asset. Performance at levels below 100% of the P50 level are likely to have significant impact on equity returns. In a hypothetical 100MW solar project in CA with a PPA of $35/MWh, kWh Analytics estimates performance at 92% of P50 on average over a 10-year period results in 8% lower revenue for the project vs initial estimates and 60% lower cash flow to equity based on the equity investor position in the example. Lower realized cash yields can result in investors reevaluating expectations. Factors contributing to solar asset underperformance include overly optimistic irradiance assumptions, higher-than-expected degradation, terrain and soiling mis-modeling, poor modeling of sub-hourly inverter clipping (occurs when solar panels provide more power than an inverter can handle) and higher-than expected equipment downtime.

PV O&M Technology

Based on a BloombergNEF survey of O&M providers, aerial inspection is the most popular technology used (94%), followed by anti-reflective coating (41%), I-V tracing embedded in inverters (41%), and predictive maintenance (35%). Predictive maintenance, using data analysis to identify expected failures and providing an opportunity to remediate before failure occurs, remains in an early adoption stage. While companies typically do not include predictive maintenance in their asset management plans, they are expanding digital talent to strengthen capabilities. Aerial inspection is widely used as it helps reduce manual inspection and lower cost. However, companies noted that manual inspection has not yet been eliminated from their service. I-V tracing allows inverters to identify abnormalities. I-V tracing is relatively inexpensive. Traditionally, physical PV site inspections have been performed by an I-V curve trace to determine whether a string or module is broken and whether the system is degrading. I-V trace is not considered a sustainable solution as it is expensive and labor intensive in addition to exposing technicians to high voltage DC components, creating an arc-flash hazard.

Large scale power plants have brought increased demand for inspection and monitoring improvements. Drones are well suited for solar inspection due to inspection and monitoring capabilities. Using sensors, drones can obtain data for analysis, reducing time and improving accuracy. In addition, drones offer enhanced security for solar parks via imaging and built-in alarm systems.

Over a 25-30-year warranty period, PV module manufacturers typically guarantee a power reduction of less than 20%. Drones and analytical software have the potential to provide early detection of potential induced degradation (PID), caused by design faults from module producers, which can reduce retrofitting costs. As the decade progresses, solar production from the boom period of 2011-2017 is particularly exposed to PID risk.

In the last few years, drones have gained increased adoption for inspecting solar PV plants given clear advantages over manual module inspections. Robotics, combined with AI, are being used to develop a drone that can make real-time adjustments to capture the condition of PV modules more accurately. Unmanned aerial vehicles (UAVs) equipped with sensors (cameras, lidar) combined with AI address time, labor, and cost challenges associated with human manual inspection. Drones equipped with cameras and lidar have also started to be used to manage solar plant construction projects. A cloud-based platform provides insight on progress of construction to track with targeted milestones.

Using data across the lifecycle of a project can provide investors greater visibility on production forecasts while more effectively managing operations and maintenance. AI has the potential to transform solar O&M by helping explain module performance and degradation over the PV plant lifecycle. For solar, AI can be defined as software using analytics to help asset owners obtain insights from data sets that can be incorporated into operations. Analyzing individual modules can identify which modules are underperforming and alert operators when maintenance is needed. Aerial images of solar parks provided by drones coupled with analytics software can predict maintenance issues in modules. Guidehouse, a market research firm, estimated the market for unmanned aerial systems and drones for energy infrastructure to be $1.4B in 2021. AI systems will also more accurately predict plant production. We expect asset owners to buy software from companies who maintain the data sets or outsource AI operations to service providers.

Predictive maintenance software based on robust data sets helps improve returns for investors through optimized output/reduced downtime and extended project lifespans. Module degradation maintenance and energy yields are expected to be improved by artificial intelligence and predictive analytics.

Market research firm Guidehouse Insights projects the market for unmanned aerial systems and drones for energy infrastructure will grow at a CAGR of 25% to $10.6B by 2030 from $1.4B in 2021. For solar, a drone located on a solar project in a protective box ('drone in a box') with the ability to take and land as well as charge wirelessly is expected to be ubiquitous. Using lidar and infrared, these drones are designed to be deployed regularly to examine module performance across a solar park. To address maintenance under modules, robot dogs are expected to monitor at ground level. Current hurdles to utilizing the technology include high cost and regulation, expected to be resolved in the coming years.

Wood Mackenzie has found solar assets are underperforming by 6.3% compared to financed performance expectations. The underperformance has led asset owners to identify operational improvement strategies and protect returns with production insurance. Preventative maintenance, corrective maintenance, and inverter replacement combined account for 60% of PV O&M cost. All three areas are positioned to benefit from digital solutions with analytics platforms, aerial thermography, and autonomous drone inspections being key solutions.

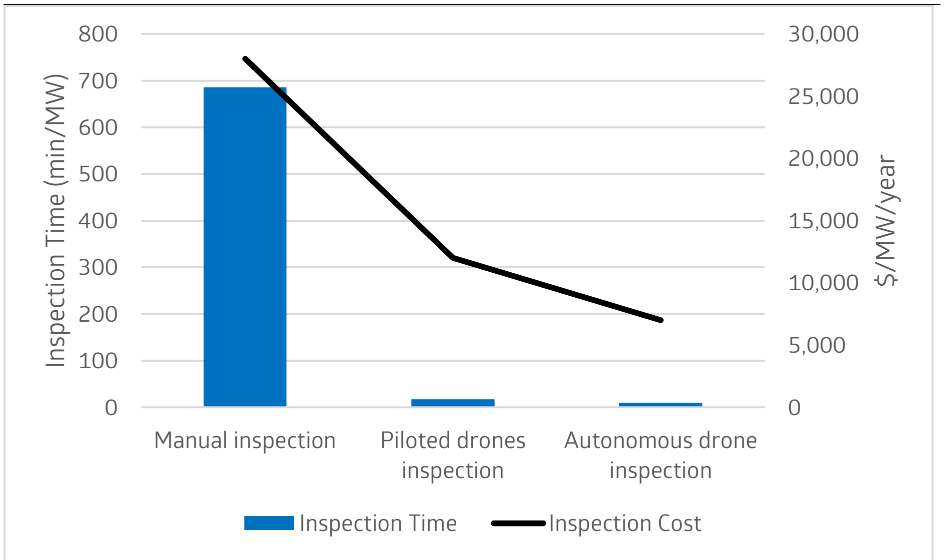
Figure 41 – 60% of PV O&M Value Chain Poised to Benefit from Digital Disruption

Segment	% of O&M annual cost	Category	Digital Solutions	Benefits
Operation & Adminstration	17%	Maintenance & repair	Centralized asset management platform	-Overall system efficiency -Access to accurate data -Actionable insights
Module cleaning	12%	Operations	Autonomous module washing	-Increased water efficiency -Reduced man-hour cost
Vegetation management	11%	Operations	Robotic lawnmowers	-Improve process efficiency -Reduced labor cost
Preventative maintenance	28%	Maintenance & repair/operations	-Analytics platforms -Aerial thermography -Autonomous drone inspections	-Maintenance schedule optimization -Reduction of frequency and execution time of on-site inspections -Reduction of hazardous man-hours -Reduce labor costs
Corrective maintenance	17%	Maintenance & repair/operations	-Analytics platforms -Aerial thermography -Autonomous drone inspections	-Maintenance schedule optimization -Reduction of hazardous man-hours -Reduce labor costs
Inverter replacement	16%	Maintenance & repair/operations	-Analytics platforms -Aerial thermography -Autonomous drone inspections	-Avoid plant's downtime -Pinpoint of required serviceable area in advance -Premature failure prediction

Source: Wood Mackenzie, Cowen and Company

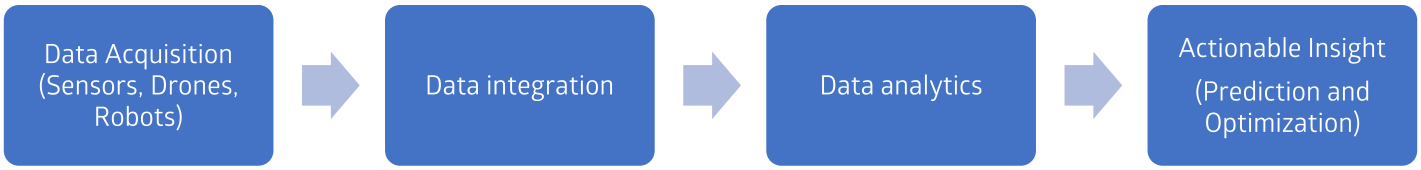
Autonomous inspection coupled with data analytics provide clear efficiency advantages over manual and piloted inspections. Drone inspection and aerial thermography (method of using aerial systems and specialized infrared cameras) are widely used to lower O&M expense. Adoption has been slow as operators figure out how to deploy digital solutions, leverage benefits, and remain profitable. The revenue risk for digital vendors is misaligned with operational risk assumed by asset managers, which are seeking a business model focused on outcome-based payments rather than fixed fees. This stems from the operational flexibility model, where some operational risk is kept in house by asset owners rather than fully outsourced to a third party.

Figure 42 – Time and Cost for Different Inspection Methods



Source: Wood Mackenzie, Percepto, Cowen and Company

Figure 43 – Big Data Approach for Solar PV O&M



Source: Clean Power Research, Cowen and Company

Recent Company Developments by Technology

Robotic panel cleaning. Module washing is required to prevent soiling from negatively impacting PV plant performance. According to IRENA, soiling causes a 2% power loss in rainy environments and up to 11% in non-rainy environments. Robotic panel cleaning addresses the soiling, with robots moving along the array of panels. Robotic cleaning is largely utilized in the Middle East and North Africa given the need for frequent cleaning.

Erthos, an Arizona-based solar company, recently closed a $17.5M Series B financing round which will be used to double headcount and support product development for robotic cleaning, system analytics, and modeling software. The company raised $7.4M in a Series A financing in 2019 to help launch the company. Erthos developed Earth Mount Solar™ PV, a method of building utility scale solar plants where modules are placed directly on the ground, which results in less capital cost, 1/2 the time to build with 1/3 land needed. The company provides complete O&M cleaning through the Erthos cleaning robot, which is deployed nightly to fully clean the array for <1% annual soiling over the life of the facility. The cleaning robot also captures module-level DC health data.

Airtouch Solar (ARTS IT) has developed an autonomous, water-free robotic PV panel cleaning solution for utility-scale PV installations. Based in Israel, the company sees its water-free robotic cleaning solution as a logical solution for sunny, dry areas that face challenges from dust and water shortages. In March 2022, the company completed an IPO and began trading on the Tel Aviv Stock Exchange. The water-free solution targets large scale solar sites in dry areas with a lack of water resources, which are challenged by excessive soiling.

The solution is designed to collect data managed by a cloud-based solar panel cleaning solution. The next step is adding to data gathered from the system that will provide insight for site owners. Robust data collection will enable more precise prediction, which can be achieved by utilizing drones for additional sensors on the site. The value proposition is levering data to present the ROI to the site owner.

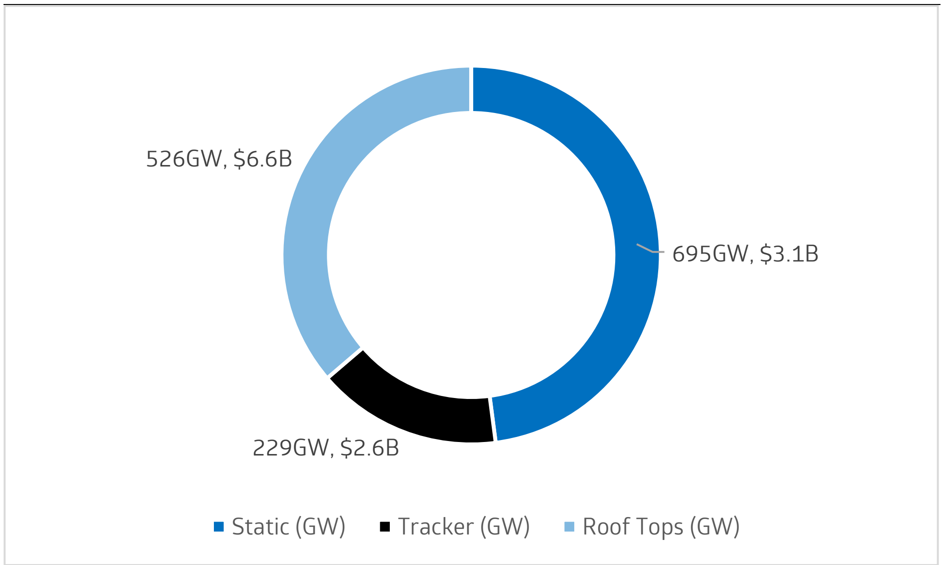
Figure 44 – Case Study – Sales of Robotic Cleaning Systems + Annual Maintenance Under a 25-30 Year Agreement

100MWp PV Field	Manual Cleaning ($ in thousands)	Robotic Cleaning ($ in thousands)	Assumption	Incremental CF ($ in thousands)
Capex	60,000	61,000	$10,000, MWp system	1,000
Loan payment (80%, 17 years, 3% interest)	-3,646	-3,706		-61
Annual yield (1650 SH, 0.18 INS/kwh)	8,580	8,837	3% additional yield	257
O&M+A&M ex Cleaning	-3,200	-3,200		0
Cleaning	-357	-90	9% robotic capex	267
Operational Cash Flow	**5,023**	**5,547**		**524**
Developer Cash Flow	**1,378**	**1,841**		**463**
Net Cash Flow Growth				34%
Develop Equity IRR	9%	13%		
IRR Growth				53%

Source: Airtouch, Cowen and Company

The company forecasts the robotic cleaning solutions market to roughly double to >$11B by 2024. The largest opportunity is expected from rooftops followed by fixed panels and trackers. Currently, 95% of the market is without a robotic cleaning solution. The current solution of manual cleaning using water is expensive and requires infrastructure from the developer. The company has completed 2 successful pilots. There are a number of competitors in the space including Ecoppia, Boson Robotics, Solbright, and NOMADD.

Figure 45 – Target Market for Solar Robotic Cleaning Solutions – 2024E



Source: Airtouch, Cowen and Company

Airtouch's IPO followed the December 2020 IPO of Ecoppia (ECPA IT), which is also listed on the Tel Aviv Stock Exchange. Ecoppia also offers a water-free, cloud-based solution. Ecoppia products include E4 robotic cleaner (for fixed-tilt installation) and T4 (for single-axis trackers). The company's project portfolio is 3.1GW across >30 large scale sites with 5.4B panels cleaned. Ecoppia is a water-free robotic cleaning solution provider for PV offering a cloud-based platform and a suite of fully autonomous robots to help maximize the performance of utility scale PV plants. The E4 and T4 clean panels use soft microfiber cloth and controlled air flow and are remotely managed. Products are designed to lower O&M costs and improve solar park productivity, while saving water in locations where it is scarce. Ecoppia's E4 fully automated and water free solution has been installed at a number of locations, including Bikaner solar park in India, which is surrounded by the Thar Desert and faces soiling, which can reduce panel energy 17%-25%. The E4 eliminates the need to perform manual wet cleaning, saving billions of liters of water annually and maximizing productivity through reduced soiling losses, lowering the LCOE. The Ecoppia AI platform is cloud-based, collecting data points related to cleaning and weather conditions to help optimize performance.

Ecoppia translates data received from the PV site into insights provided to the client through dashboards that use cloud-based servers. Ecoppia provides predictive maintenance by monitoring the robot to prevent potential disruptions and malfunctions in the service provided. Ecoppia offers an all-inclusive 25-year warranty for its installations, which include a wide range of services over the lifetime of the project.

Azure Power, an independent power producer in India, recently awarded Ecoppia a robotic cleaning services contract for 400MW of solar PV. Ecoppia will provide robotic cleaning equipment for a hybrid project of 400MW. Deployment is expected to begin in 1H22 and will include Ecoppia's E4, T4 and H4, which channel dust and dirt down without accumulation by moving horizontally while cleaning vertically.

Figure 46 – Ecoppia Services

Service	Description
Optimization (Planning)	Optimizing site design to minimize investment
Collaboration (Planning)	Tight interaction with developers, EPC's and structure provider's teams
Deployment (Commissioning)	Configurations and installation of all robots on site
Training (Commissioning)	SCADA traning for system monitoring and service analysis
Acceptance Test (Commissioning)	Final QA cycle on site
Predictive Maintenance (Maintenance)	Pre-scheduled maintenance windows and advanced predictive maintenance ensure constant availability
System Performance (Monitoring and Analysis)	Monitoring of system components
Weather Intelligence (Monitoring and Analysis)	Collection and evaluation of forecasted and real time weather
Machine Learning (Monitoring and Analysis)	Constant service enhancement using sophisticated algorithms
Reports and Analytics (Monitoring and Analysis)	Analytics via dedicated interface

Source: Ecoppia, Cowen and Company

Figure 47 – Companies Offering Robotic Solar Panel Cleaning Solutions

Skilancer Solar	Indisolar
Heliotex	Integra Global Co.
Ecoppia	Aegeus
Sunbotics	Airtouch Solar
Kambay Robotic	B.P. Metalmeccanica
Solabot	

Source: Cowen and Company

Solar installation. BloombergNEF has estimated that 455 GW of new solar facilities are required annually (3x capacity installed in 2020) through 2030 to meet net-zero emissions targets. In December 2021, AES, producer and distributor of electric power, launched a first of its kind solar installation robot called Atlas. Designed by AES and built with Cavalry Robotics and other third parties, the Atlas robot will help scale new solar capacity faster by automating construction in addition to providing a safer work environment and lowering overall energy costs. Atlas addresses installation labor constraints though will complement AES' skilled workforce by performing the heavy lifting and attachment of solar modules while adding new high-tech jobs. AES estimates 70% of solar construction can be automated while 25% of O&M services are suitable for automation. AES' other initiatives related to solar energy technology include deploying solar robots from Ecoppia to automate the cleaning of panels to optimize performance.

Figure 48 – Atlas – A Solar Construction Robot Designed By AES

Source: AES

Robot dogs for PV plant monitoring. Boston Dynamics has developed a mobile robot called Spot®, designed for sensing and inspection across multiple industries. Spot® can be deployed for inspection of remote facilities like wind and solar farms to help detect hazards before they escalate. The robot has a built-in thermal vision system that generates thermographic reports on PV plant components.

Acciona (ANA SM), a renewable energy developer, is using Spot® to monitor the performance of a utility scale solar plant it operates in northern Chile. The mobile robot can carry and power up to 14kg of inspection equipment, compared to ~5kg of payload by a drone. While drones can move faster than Spot®, their batteries usually only last up to 30 minutes vs the 90 minutes of operation for Spot®. Acciona added the robot to its operations in 2019.

Figure 49 - Spot® from Boston Dynamics

Source: Boston Dynamics, Cowen and Company

Aerial inspection. In January 2022, NovaSource, a solar O&M provider, acquired aerial inspections and site data service provider Heliolytics. Heliolytics primarily uses aircraft for its image capture instead of drones, citing a more accurate, faster, cheaper and repeatable process. Heliolytics attributes the improved quality to the ability to use the best available sensors for solar PV inspection as opposed to sensors that fit on a drone. Operating on an aircraft with a higher resolution, Heliolytics notes it can inspect at a rate of up to 150MW/hr at high resolution, compared to 2.5MW/hr for a drone inspection, with longer inspection times potentially impacting data quality. To be flexible with customers, the company also offers drone aerial inspections providing flight parameters, flight training and advanced analytics. In 2020, Heliolytics inspected over 25GW of projects in a year across three continents.

Given aerial imaging and AI are complementary, companies offering both capabilities appear better positioned to meet demand. In December 2021, DroneBase, an aerial imaging company, acquired AirProbe, an India-based AI analytics provider. The deal brought DroneBase's wind and solar assets under inspection to >59GW. AirProbe's AI will reduce time required to analyze aerial inspection data for solar projects, enabling more timely and efficient maintenance. DroneBase closed a $12.5M funding round in June 2021 and raised another $20M in October 2021 to support its global expansion.

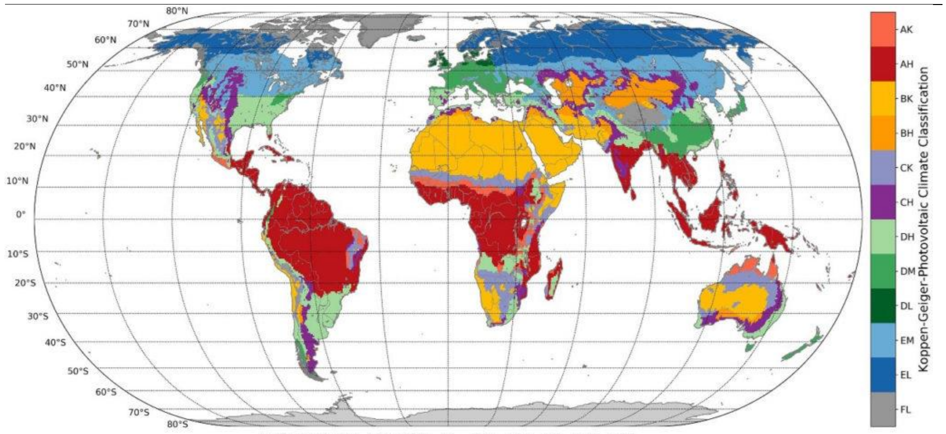
Climate and PV Plants

Climate influences performance as temperature, humidity, rain, and wind can each impact materials. Various climates indicate the need for PV plant operators to offer O&M services that address requirements for a specific plant. In addition, climate change has caused an increased frequency of extreme weather events, making weather monitoring an important consideration.

A paper by Ulrike Jahn, VDE Renewables, Germany and Dr. Bert Herteleer, KU Leuven, Belgium, provides guidance for setting up a customized O&M practice for PV plants in three different climate zones: 1) moderate, 2) hot & dry, and 3) flood-prone (monsoon). For moderate climates, automated cleaning solutions with dry brushing is ideal for large facilities in regions with high risk of soiling. In hot and dry climates when vegetation is present, the use of cleaning robots has been limited due to remote location and relatively low pollution losses. Soiling losses are typically higher in hot and dry climates without vegetation, with dry automated module solutions preferred.

The Koppen-Geiger PV map below is a climate classification map dividing the globe into 12 zones with respect to temperature, precipitation, and irradiation. The map is used to analyze long-term performance and reliability of PV modules and to compensate for a lack of standardization in climate zones.

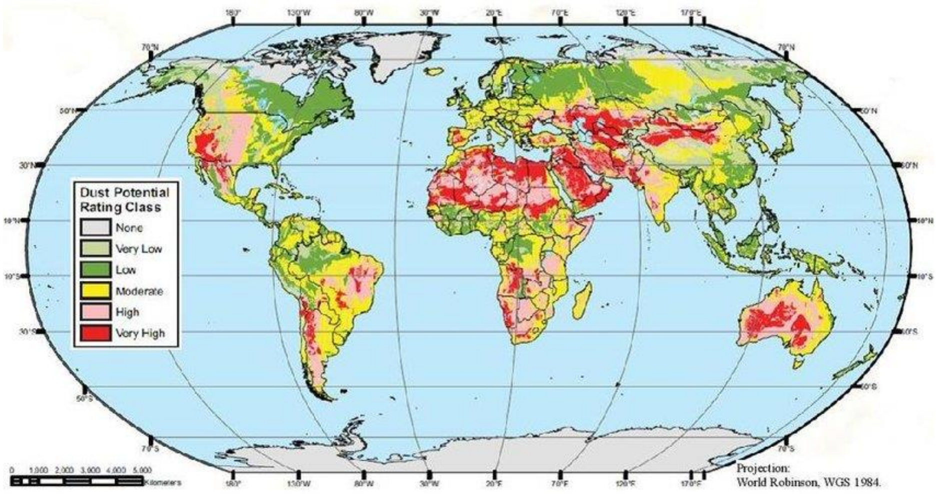
Figure 50 – Koppen-Geiger PV Map



Source: Beck, H.E.; Zimmermann, N.E. T.R.; Vergopolan, N.; Berg, A.; & Wood, E. F.

India is an attractive opportunity for robotic cleaning for solar. India added 10GW of solar PV in 2021, including 8.5GW of utility-scale solar, reaching cumulative installed solar capacity of 49GW. Solar PV represented 62% of new power capacity additions and accounted for ~12% of India's installed power capacity at the end of 2021. Research firm Bridge to India expects 16GW of solar PV to be installed in 2022, bringing cumulative installed capacity to 65GW.

Figure 51 - Global Dust Potential



Source: DTF (2013)

PV O&M Contracts

O&M contract prices are the most significant factor for solar asset owners, with falling prices reflecting a reduction in scope. Flexible O&M contracts include operations & administration and preventative maintenance. Vegetation management, module cleaning, and corrective maintenance are typically excluded from standard service agreements but are critical to keeping a solar plant operating. O&M costs are facing significant inflation risk related to equipment cost increases, rising labor wages, and increased failure rate, resulting in an increased need for operational efficiency.

PV O&M contract prices have been falling as competition among service providers increases and asset owners improve technical capabilities to narrow scope and negotiate lower prices. The figure below shows the main components of an O&M contract. Periodic maintenance costs have fallen due to the adoption of aerial imaging with infrared cameras, which identifies faults and drives down manual inspection costs. Robotic cleaning is a less widely used application within panel cleaning and requires additional advancement to reduce cleaning costs for the industry. Asset management (excluded in the figure below) is increasingly being brought in-house by asset owners to be closer to performance data to ensure O&M is optimized.

In the U.S., prices for PV O&M contracts range from $4,500/MW/year to $5,680/MW/year, with pricing for larger contracts lower per MW. Contracts typically last 5 years and include monitoring, periodic maintenance, and corrective maintenance. O&M pricing is expected to be roughly stable near term following a sharp decline in recent years due to competition, with more potential for price reduction in less mature markets as large O&M providers enter.

Figure 52 - Summary of U.S. PV O&M Contracts

Scope	Mounting	Capacity	Price ($/MW/year)
Monitoring, periodic maintenance, spare parts management, cleaning, vegetation control	Single-axis tracking	<5MW	5,680
Periodic maintenance, corrective maintenance, spare parts management	Fixed-axis	>5MW and <50MW	4,500
Monitoring, periodic maintenance, corrective maintenance, spare parts management	Fixed-axis	>5MW and <50MW	5,050

Source: BloombergNEF, Cowen and Company

PV Manufacturers Exiting O&M

Across our coverage universe, First Solar and SunPower have effectively exited O&M services due to increased competition and low margins. First Solar sold it North American operations in March 2021 and expects to sell its O&M services business in Japan in the near term. SunPower largely exited its O&M business in 2020 though retained O&M services to its residential customers. SMA has faced headwinds from a purchased legacy O&M contract in the U.S. due to defects in some SMA-maintained solar parks. On January 12, the company cut its guidance from €50-65 million to €20-30 million. To shield the company from greater damage given the subpar asset performance, SMA aimed for an early dissolution of the contract. In early March, 4Q21 guidance was lowered again as the company noted increased provisions for the contract, which resulted in EBITDA for 2021 coming in at ~€9 million.

Wind O&M Market

There is a significant robotics opportunity for wind. For offshore, applications include site survey and consenting, installation, O&M and decommissioning. Wind power producers have begun to depend on predictive maintenance to increase scalability and cost-effectiveness of wind power. Wind turbines have a lifespan of 20-40 years, making a predictive maintenance program critical for optimizing performance and lifespan.

Due to high equipment and O&M costs along with difficulties of onsite inspection, predictive maintenance can provide significant cost reduction on wind farm maintenance. We note offshore wind typically has 4x the O&M costs of onshore wind, largely attributed to complex marine logistics. Turbine manufacturers GE, Siemens, and Envision offer wind predictive maintenance.

Offshore O&M Presents Challenges

The global market for onshore and offshore O&M is expected to reach $37B by 2029. Onshore global O&M is expected to reach $25B by 2029, representing a 5% CAGR over 2019-2029. Unplanned repair costs for onshore wind turbines are expected to reach $17B by 2029 based on a CAGR of 5.9% over 2019-2029. Global O&M offshore market is expected to grow at a 16% CAGR, reaching €10.4B by 2029 from €2.8B in 2020. Turbine O&M represents the largest share of spend at 59%, followed by BOP O&M and operational support.

The O&M industry needs to scale quickly to meet global offshore wind capacity growth (expected to increase to 185GW by 2029 from 33 GW in 2020) while the age of offshore wind projects >10 years will increase at a faster rate. The offshore industry does not have significant experience in long-term O&M issues and failures as only 1.8GW of installed offshore capacity has been operating for over a decade. This figure is expected to increase to ~20GW by 2030. The remaining 90% of the offshore fleet will be <10 years old by 2029. We note large next-generation turbine models and model design of transmission systems for remote assets are expected to be significantly more complex than the wind farms currently operating. Therefore, failure rates and common issues related to long-term operations remain unknown.

Operators will need to set up an O&M plan to address the rapid expected ramp, including building a workforce to maintain this fleet. Remote O&M strategies are required for increasing project capacity and longer distances to shore. Remote operations come with logistical challenges, making technologies like drone and monitoring systems necessary for enhancing proactive maintenance and preventing major failures, while lowering overall cost.

A final challenge will stem from >34GW of global capacity no longer receiving subsidies in the 2030s. For the UK, Wood Mackenzie expects the offshore wind capture price to decline gradually to ~€25/MWh, reaching a 47% discount to the average UK power price by 2050. This will pressure project profitability and increase investment risk.

Drones, cameras, robotics, and new digital technologies are expected to drive global average opex down 20% for offshore wind between 2020 and 2029. As of the end of 2020, turbine OEMs and operators accounted for 27% and 40% of O&M solutions, respectively, to the operational fleet. Siemens Gamesa dominates the turbine solution market, providing solutions for a 12GW offshore wind fleet, followed by Vestas.

Figure 53 – New Technologies Across the Offshore Wind O&M Value Chain

O&M Value Chain	Asset management & remote support	Supply chain and marine coordination	Turbine maintenance and repair	Blowout Preventer (BOP) maintenance and repair
New Technologies	-Big Data and AI -Digital twin	-Marine operation planning software -Supply chain management software	-Drone inspection -Robot blade crawlers	-Drone inspection -Unmanned aerial vehicle or hybrid ROV -Unmanned surface vehihcle
Applications	-Turbine failure prediction -AI-based plant management -Increased production/revenues	-Optimized spare part inventory levels -Automated logistics management	-Blade and tower inspections -Minor blade repairs -Major component repairs -Goods transfer	-Cable and foundation visual inspections and minor repairs -Environmental monitoring -Goods transfer
Total yearly market potential in €M (2020E)	150	520	Inspections: 25 Minor repairs: 74	Cable inspections: 6 Foundation inspections: 45

Source: Wood Mackenzie, Cowen and Company

Wind O&M Technologies

We see robotics and autonomous systems playing an increasingly important role as offshore wind capacity growth accelerates, as wind farms will become increasingly located in remote areas. Drones carrying cameras or multiple sensors are also applicable to wind turbine blades as well as conducting surveys of environmental conditions at potential offshore wind sites.

Predictive maintenance can increase utilization and safety while reducing machine failures, capex for equipment replacement, and inspection service replacement. Predictive maintenance involves implementing methods to identify recurring system failures and reduce associated costs through early detection, which can significantly reduce downtime. Leveraging AI-based predictive analytics, predictive maintenance systems can analyze real-time data and identify underperformance along with failures. Rotating components like gearboxes and blades are monitored most closely by predictive maintenance as they are expensive to fix, and failures result in significant plant downtime.

Figure 54 – Component failures costs: equipment damage and downtime

Component	Gearbox	Blade	Nacelle	Generator	Tower
Equipment damage	$0.4M	$0.7M	$1.3M	$0.1M	$0.9M
Days of downtime per failure	6.3	4.0	6.0	5.8	4.0

Note: Costs apply to 2.5MW onshore wind turbines

Source: BloombergNEF, Institut für Solare Energieversorgungstechnik (ISET), Cowen and Company

Figure 55 – Predictive maintenance application in wind turbines

Key component	Sensor data required	Fault type	Predictive Maintenance Companies	Value Brought Predictive Maintenance Companies
Gearbox, blade, nacelle, tower, yaw system	Temperature, vibration, lubrication, wind speed	Mechanical	-Sentinent Science -Envision	Preserving high cost equipment, minimizing costs of O&M and downtime

Source: BloombergNEF, Cowen and Company

Robotic systems and blade reliability. Aerial inspections are suitable for wind turbines as they are the largest single piece of composite structure in the world and are often located in remote areas. While aerial inspections can detect visible damage, inspections supported by robotics can detect subsurface damage. Through the DOE Sandia National Laboratories' Blade Reliability Collaborative, Sandia has teamed with International Climbing Machines, whose suction robot can climb on any surface including wind turbine blades, and dolphitech (developers of advanced ultrasound cameras for two-dimensional and three-dimensional inspection of materials) to build a robot to conduct automated, full-penetration inspections of wind turbine blades. The robot is controlled by an operator, the Assessment Robot for Resilient Optimized Wind energy, or ARROW. Onboard cameras provide real-time image to detect surface damage while phase array ultrasonic imaging finds any nonvisible, subsurface damage. The next step is to deploy the robots to assess viability to inspect all aspects of wind turbine blades.

We see the industry shifting toward wind plants with one or more drones to inspect wind turbines daily and then return for data to be uploaded. An autonomous inspection system that identifies changes in the blades based on prior inspections would then trigger a robot to be deployed and get a more detailed view to address any required repair.

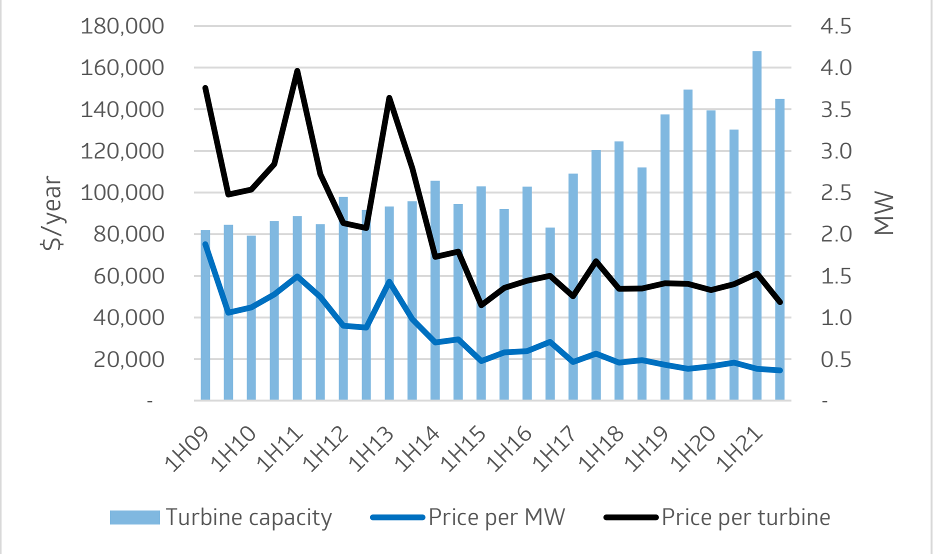
Figure 56 – Suction Robot from International Climbing Machines

Source: International Climbing Machines

Wind O&M Contracts

Onshore wind for initial O&M prices hit a record low in 2021, attributed to more powerful turbines as service cost is based on turbine visits rather than a per MW cost. Over the last few years, price per turbine has been stable while price per MW has been on a downward trend. Digital technologies (inspection drones and predictive maintenance) have lowered initial prices and driven high margins for turbine makers. Participants in BloombergNEF's O&M Price Index expect prices to increase 15% by 2026 from 2021. The increase is expected to be driven by major competitors maintaining each other's turbines, creating pricing pressure.

Figure 57 – Service Contract Pricing and Average Turbine Capacity (Initial Contract for Turbines >1MW)



Includes labor, routine, and unscheduled maintenance, and component replacements.
Source: BloombergNEF, Cowen and Company

Renewal contracts are usually more expensive than initial contracts given less reliability for older turbines. Renewal contract pricing has been on an upward trend and was nearly double the price of initial contracts in 2021. The cost of services is dependent on the number of turbines instead of the number of megawatts; therefore, increased turbine capacity can reduce O&M prices. Larger projects with more powerful turbines provide greater O&M savings as service providers can divide per-turbine pricing over a larger number of megawatts.

BNEF has quantified the economic benefit of asset performance management (using data to improve asset reliability, lower labor costs, increase safety, and extend asset lifetime). Most wind projects installed over the last 10 years have digital monitoring systems that enable asset performance management (APM). BNEF estimates APM improves onshore wind farm LCOE by 7.6% to $36.66-$39.67/MWh for a 50 MW onshore wind farm by generating capacity improvements through efficiency optimization. The improvement relates to lower operational costs and improved capacity factors. APM can identify turbine misalignment and optimize air flow between turbines in a wind farm while minimizing downtime, which all contribute to lower O&M costs. GE, Vestas and Siemens Gamesa are among turbine OEMs that have developed digital monitoring capabilities to complement their turbine and industrial hardware businesses by integrating APM applications into their cloud platform.

Greater insight on asset performance can be achieved through integration of data sets ranging from maintenance records, supervisory control and data acquisition (SCADA), and real-time monitoring. APM can incorporate data captured by sensors with analytics capabilities enabled by cloud computing.

Figure 58 – Capabilities of asset performance management (APM)

APM sophistication	Data stream correlated	Analysis enabled
Basic APM	-SCADA systems -Digital maintenance records -Legacy historian data -Manual asset observation data	-Anomoly recognition -Trend analysis -Regression analysis
Intermediate APM	-Real-time condition monitoring -Business operation data -Failure mode libraries for diagnostics	-Relative comparison between machines -Maintenance, repair, and operations workflow automation
Advanced APM	-Addition of sensor hardware -Real-time streaming data analytics -Edge optimization and control	-Predictive maintenance -Advanced diagnostics -Reliability forecasting -Digital twin comparisons

Source: BloombergNEF, Cowen and Company

Army Robotics Remain Promising But A Work In Progress – Roman Schweizer – Cowen Washington Research Group

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After several years of increased funding, experimentation and commitments, we get the sense the DoD's commitment to unmanned and robotic systems is steady but with uneven results. DoD continues to purchase mature systems and has a handful ready to move through development and into production. Many of most ambitious and ground-breaking programs, however, remain under study or in experimentation. For the time being, it appears that forecasts of significant growth have yet to pan out and that concepts and needs are changing, particularly as the department thinks about future warfighting needs for China and attempts to field commercial tech-based solutions.

At the time of this writing, the details of DoD's FY23 budget and its five-year spending forecast have not been released so it's impossible to make a long-term projection or gauge how prior plans have changed. We do not believe DoD is turning away from robotics and unmanned systems but sense it is more cautious about the speed of introduction, particularly as it adopts crucial "enabling" technologies such as artificial intelligence/ machine learning, advanced processors, increased communications bandwidth, better batteries and other subsystems.

Many programs remain in varying stages of maturity within the departments of the Army, Air Force and Navy/Marine Corps. They span several different categories (air, sea and ground); different systems (vehicles, robots, and cobots); and different missions (combat, maintenance and logistics). Over the last several decades, unmanned aerial systems or drones have played import roles in U.S. airpower in the form of intelligence collection, reconnaissance and even weapon strikes. A newer generation of airborne drones is taking shape today. Ambitious and more capable ground and maritime drones and robotics have lagged (with some exceptions, of course). The Army and Navy had appeared committed to spending more money on developing and fielding these systems. For now, those plans seem paused or at least delayed as both concepts and technologies are further explored. The Army is experimenting with prototype "Robotic Combat Vehicles" that come in a variety of sizes. Field testing is underway to develop operations concepts and to set requirements for full-fledged acquisition programs but those may not begin fielding until the mid- to late-2020s. The Navy is experimenting with its first generations of unmanned ships and submarines that will operate independently for days or months on end and have ranges of thousands of miles. The Navy had ambitious plans to spend billions over the next five years to buy swarms of them, but it appears those plans have also been scaled back and system may not be in the fleet until the late '20s.

Like our prior report, we have decided to exclude the DoD's unmanned aerial systems and the Navy's unmanned ships and submarines because they are military specific and will have limited crossover benefit to and from commercial systems being developed. We have focused on the Army's unmanned and ground robotics programs. The Army will be the biggest market for ground unmanned & robotics in DoD, and its plans and requirements will play an important role in developing and shaping the market. We also expect there will be some shared benefit from commercial systems (such as artificial intelligence, vehicle operations and vehicle technology & components). While the Army still appears to be serious about fielding various types of robotic vehicles, we get the sense that spending plans may be more modest as concepts are fleshed out, technologies matured and different systems compete for Army spending.

Army Unmanned and Robotic Systems

In our opinion, the Army should have the biggest impact long term on the adoption of robotic ground vehicles and humanoid robotic systems. In the near term, it is focused on unmanned ground vehicles, ranging from large tank-sized vehicles down to small backpack-sized vehicles that can perform different roles and missions on the battlefield. We expect the linkage between commercial technology development and adoption will go both ways and benefit both markets (civilian and military).

Over the last several years, the Army has put a significant effort into concept experimentation and field testing available technology in real-world situations. The ongoing Project Convergence series by Army Futures Command is the centerpiece of this effort and we expect it will continue to inform the service's plans. The Army does have an array of programs either beginning or under development. It is planning a new infantry fighting vehicle called the Optionally Manned Fighting Vehicle, which will replace its current Bradley Fighting Vehicles. There are currently five industry teams competing for three further development contracts, leading to selection of a single manufacturer to field the first vehicles in 2028. The service is also experiment with light- and medium-sized Robotic Combat Vehicles that could start procurement in the mid-'20s. It has also started studying a future Optionally Manned Tank that could one day replace the M1 Abrams main battle tank. We expect this effort will be studied significantly but will not pan out to a replacement for some time, if ever. Over the last several decades, the Army has fielded small robotic systems that help with reconnaissance and ordnance disposal. Those systems are going through generational upgrades and improvements, and even expanding their mission sets.

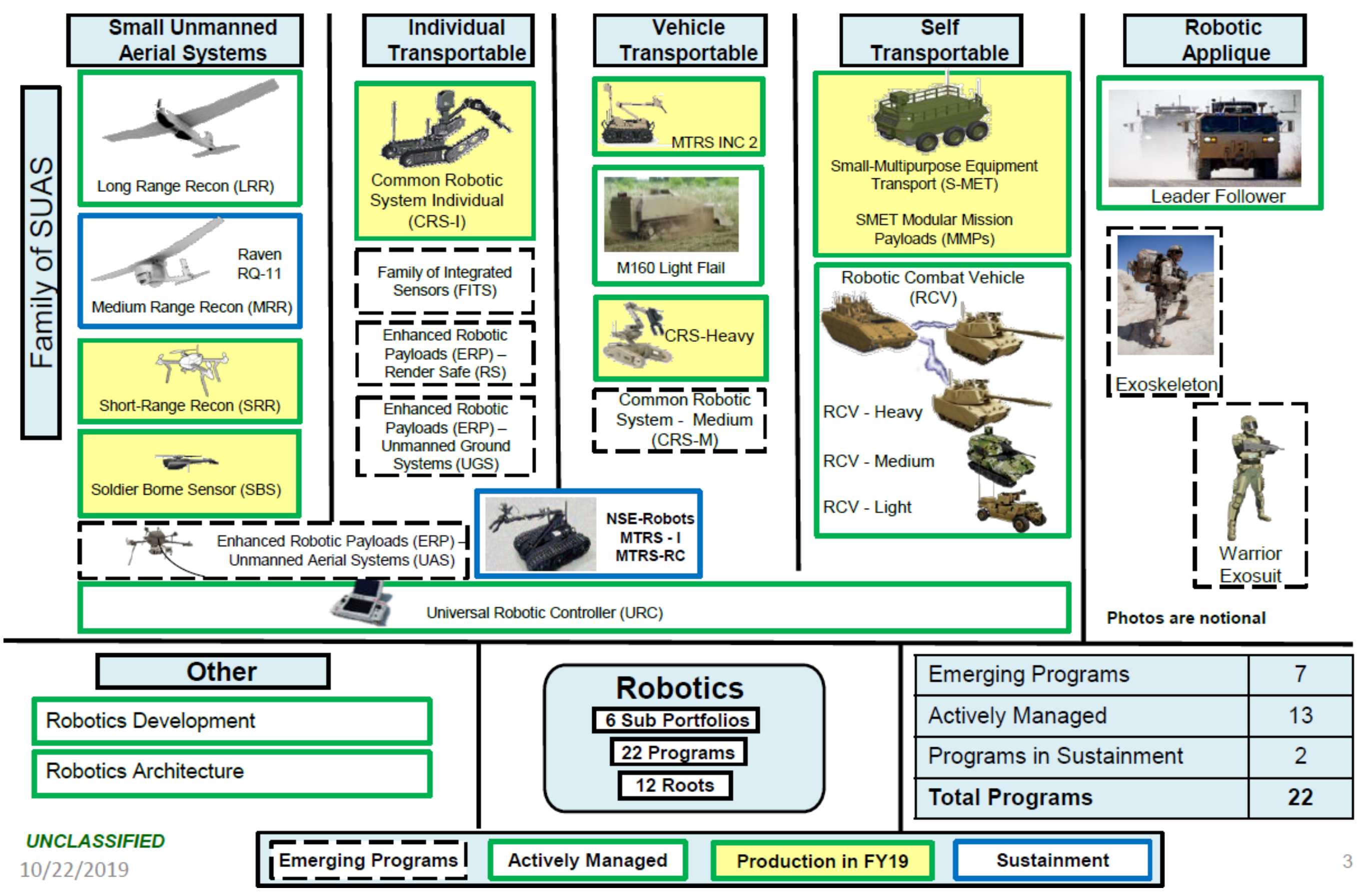
According to previous Army projections, robotics funding just five years ago was about $20M/yr. but was planned to grow significantly. Army procurement for small robotic systems was expected to grow from about $35M in GFY19 to $255M in GFY25. For GFY21, the service asked Congress for $180M to buy 2,380 robotic systems and small drones. In GFY22, that number declined to $124M to buy 1,942 robotic systems and small drones. At the time of this report, the details of the Army's GFY23 budget have not been released. We'll provide an update once the new plans are released.

Figure 59 Army Ground Robotics and Applique Systems Funding (FY20-FY22)

		FY20		FY21		FY22	
Program	**Company**	**#**	**$M**	**#**	**$M**	**#**	**$M**
CRS-I	QinetiQ	960	32.7	1,056	53.6	330	13.7
MTRS Inc II	Teledyne	230	36.2	474	63.9	459	62.3
CRS-H	Teledyne	47	23.1	70	36.6	-	-
SMET	GD	24	8.8	203	28.5	148	29.4
Total		1,261	100.8	1,803	182.6	937	105.4

Source: U.S. Army budget

Figure 60 U.S. Army Robotics Portfolio Overview



Source: U.S. Army

R&D Programs

Robotic Combat Vehicles Light & Medium

The Army's main development effort right now in the unmanned vehicle category is centered around several platforms designed to carry supplies and weapons and support combat operations. The Army is using a methodical development and experimentation process, and it could be some time before significant amounts of money are spent on acquiring these systems and they are fielded in large numbers. Based on Army funding documents, it appears the earliest formal procurement program for either the RCV-M or RCV-L may not occur until FY24.

Robotic Combat Vehicle – Light (QinetiQ)

The U.K.-firm **QinetiQ** is the prime along with Pratt Miller (since acquired by **Oshkosh**), and it has built prototypes and delivered them to the Army for testing and potential procurement. The first RCV-L was delivered to the Army in November 2020. The agreement includes the delivery and support of four RCV-L platforms with procurement options for up to 16 additional RCV-L systems.

Figure 61 Robotic Combat Vehicle – Light (QinetiQ/Oshkosh-Pratt Miller)

Source: QinetiQ

Robotic Combat Vehicle – Medium (Textron)

Textron has developed a prototype small light tank with a 30mm cannon. The company has produced and delivered four prototypes to the Army for tests and experiments. These systems will be used to develop requirements for a follow-on system to be acquired through another full-and-open competition to be held at a later date. Based on Textron's designs and videos of its "Ripsaw" concept, which utilizes not only ground vehicles but carries integrated smaller ground vehicles and unmanned air vehicles like a mothership, there could be a quite formidable use case for this kind of system. R&D spending in the RCV has accelerated quickly in recent years, going from $70M in FY19 to $121M in FY21. Spending is expected to increase to about ~$145M per year between FY22-FY25.

Figure 62 Robotic Combat Vehicle – Medium (Textron)

Source: U.S. Army / Textron

Small Multipurpose Equipment Transporter (General Dynamics)

The Army has moved relatively quickly to develop and buy S-MET. General Dynamics is the developer and builder. S-MET is an unarmored support vehicle for infantry squads, essentially a robotic "mule" that will carry equipment, ammunition, and other supplies for infantry squads. S-MET is designed to be unmanned or optionally manned, carry up to 1,000 pounds, operate 60+ miles for 72 hours and generate power to charge equipment and batteries. The Army plans to spend $250M to buy 624 of the six-wheeled vehicles through 2H2024.

Figure 63 SMET - Multipurpose Equipment Transport (General Dynamics)

Source: U.S. Army

Production Programs

While the Army is proceeding cautiously with RCVs, it has used smaller robotic vehicles in important ways since Afghanistan and Iraq for support missions such as reconnaissance and explosive ordnance disposal. These small robots have articulating arms and cameras for remote operation to inspect tunnels, disarm/activate roadside bombs, and provide reconnaissance.

Common Robotic System – Individual (QinetiQ)

The Common Robotic System – Individual (CRS-I) enables ground forces to conduct reconnaissance and weighs less than 25 pounds. It is designed to be highly mobile and carries payloads, advanced sensors, and mission modules for dismounted forces. The system also has a Universal Controller (UC) that will have the ability to control airborne drones (such as Puma and Raven) and other ground robots (Man Transportable Robot System Increment 2 and Common Robotic System – Heavy).

Figure 64 Common Robotic System – Individual (QinetiQ North America)

Source: U.S. Army

Man Transportable Robotic System Increment II (Teledyne-FLIR)

The Man Transportable Robotic System Increment II (MTRS Inc II) is a remotely operated, medium-sized robotic system that provides capability to detect and dispose of hazards. MTRS Inc II has a standard chassis and modular mission payloads in support of current and future missions. According to Army information, MTRS Inc II was planned to be fielded in FY21 but the service was able to accelerate fielding by more than a year.

Figure 65 Man Transportable Robotic System Inc II (FLIR Systems)

Source: U.S. Army

Common Robotic System – Heavy (Teledyne-FLIR)

The Common Robotic System – Heavy (CRS-H) is the U.S. Army's large vehicle-transportable robot capable of using various payloads. It allows soldiers to find and dispose of explosive ordnance and improvised explosive devices (IEDs). The Army's Acquisition Objective is 248 CRS-Hs. Based on Army budget information, it appears the Army has purchased all of the CRS-Hs it needed and has not requested money for additional robots.

Figure 66 Common Robotic System – Heavy (FLIR Systems)

Source: U.S. Army

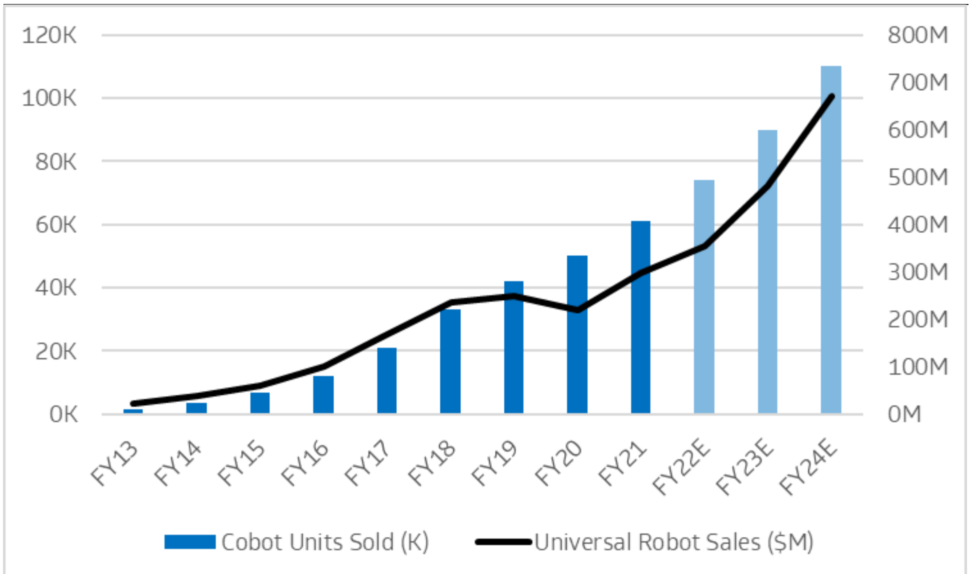
Teradyne Cobot Growth Potential – Krish Sankar

Industrial Automation Drives Teradyne Growth: Following the acquisition of Universal Robots in 2015, Teradyne has grown its Industrial Automation business from ~$100M in annual sales to upwards of an estimated $500M+ CY22 through a mix of cobot sales growth (sales network & customer expansion; new products and software tools, etc.) and tack-on acquisitions including Energid (CY18), Mir (CY18) and AutoGuide (CY19). We model UR sales of $350M in CY22 (+13% Y/Y). We estimate IA sales could reach >$1B annually by CY25 driven primarily by cobot sales (~70% of IA) with prudent tuck-in M&A targeting new areas of product growth/integration.

Universal Robots estimates that the company's market share is ~50%, which is broadly consistent with the 45% to 55% range over the past several years. We think UR's simple teach-to-program UI and fast deployment time remain industry benchmarks. Additional software innovations that also make its new ActiNav Bin Picking solution easy to deploy could further raise the bar and help it maintain 40%+ market share in the coming years. Cobots are well suited for smaller scale (ROI, ease-of-use) operations such as bin/part picking in the industrial market and as a “manual labor” replacement in the automotive industry in areas prioritizing flexibility & precision such as screwdriving. Most importantly, cobots can be deployed quickly, easily, and safely in work areas alongside humans.

Universal Robots’ sales grew at a >60% CAGR from CY15 until C2H19 before a cooling off/digestion period in late CY19 and CY20. We believe the cause was more macro related rather than competition/MS loss and that LT growth expectations for the business have been reset. While we conservatively model low-teens Y/Y growth in CY22 due to supply-related headwinds and component shortages in the industry, we expect a return to a LT CAGR of ~30% to 35% as current headwinds alleviate. Hitting a record 400 UR cobots manufactured in a week (C4Q21), we believe Teradyne has the capacity to meet demand over the mid-term without the need for significant capacity expansion. Net, net we believe Teradyne is well positioned to defend its current cobot market share and, using UR sales as a proxy, expect a Cobot TAM >$1B in CY23/24 (& >100K UR cobot milestone).

Figure 67 Cumulative Cobot Units Sold (K) vs. Annual UR Sales ($M)



Source: Teradyne Company Disclosures, Cowen and Company

Future Potential Universal Robots Growth Drivers:

1) Disruption to the Manufacturing Status Quo Could Benefit UR: Given the ongoing US China trade tensions and the disruption of supply chains due to COVID-19, we believe new attitudes could emerge from manufacturers regarding the re-shoring of manufacturing, especially in the US, as well as strategies to mitigate labor shortages and improve operational and cost efficiencies. In many of the case studies shown, the ROI across several light manufacturing applications was often less than 12 months. In addition to labor cost savings, the increase in manufacturing productivity from being able to add more work shifts and/or lower operating costs add further to the value proposition.

2) ActiNav Autonomous Bin Picking Could Be Disruptive: We continue to believe bin picking can be a disruptive application for cobots in the coming years. A key question is how total cobot solution pricing including the vision and autonomous software subsystems compares to current blended ASPs that are sub-$20K. We think UR's Autonomous Motion Module (AMM) that helps the cobot determine how to navigate into the bin to pick, move through the environment, and place the item into the destination machine could be a competitive advantage at this juncture given the level of abstraction it provides to allow easy programming by end users (no expertise needed). An ActiNav application would only require 6 lines of software code for controlling the cobot whereas traditional programming-based methods could require 240-360 lines of code.

3) Potential Services Revenue Stream from Service360 Extended Warranties: UR is increasingly offering an end-to-end experience for its cobots including a standard 12-month warranty, free software updates by application, regional support, UR Academy for end user training, and myUR for case/asset management tracking for online support.

Post warranty, UR offers the Service360 Basic plan that adds an additional year of coverage and the Service360 Advanced plan that improves on the Basic by including remote and onsite diagnostics as well as free 2-week cobot loaners to mitigate any downtime. Pricing is based on number of cobots and type of model deployed by the customer. As the installed base grows, we think this could offer an interesting recurring revenue stream for UR.

Figure 68 Universal Robots The Industry Standard & Future Market Trends

	Universal Robots Competitive Moat		Future Industry Trends
Software			
	Ease of Programing	UR academy; virtual training	AI & Vision Recognition
	Flexibility	Application builder, Tool Kits	Precise Grippers; 3D Modeling
	Motion Control	simple teach-to-program	Higher Payload, Articulation and Balance
Ecosystem			
	Distributors	700+	New Market Entrants
	Developers/Integrators	400+ Devs, 245+ Certified Parts	Commoditization of Hardware
ROI			
	Low Cost, Quick-to-Market		ASP Pressure, Leasing Programs
Sales Model			
	Cobot Unit Sales (ASPs $15K+) and UR Service360		Recurring Rev. Model (charge-per-productivity)

Source: Cowen and Company

Figure 69 Universal Robots Sales ($M) vs. Y/Y Growth

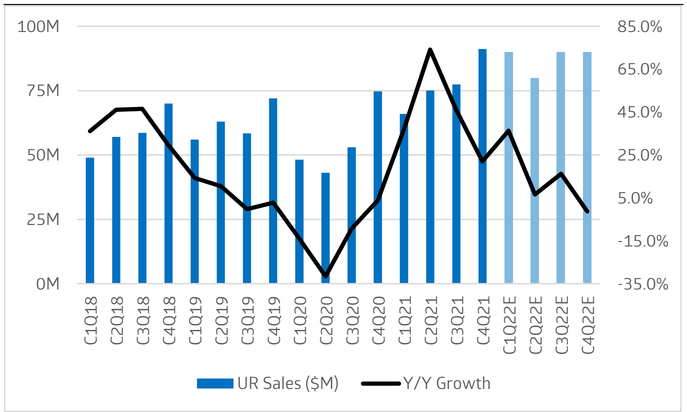
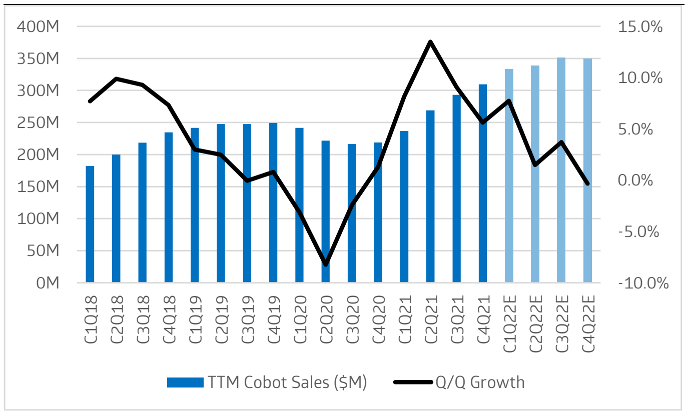


Figure 70 Trailing 12-Month UR Sales ($M) vs. Q/Q Growth



Source: Company Disclosures, Cowen and Company

ESG Impact: Cobots are often deployed in small batch numbers at small-medium size companies in applications where tasks can be either repetitive and/or dangerous over time. Teradyne has remarked that through its distributor network many customers are first time buyers who emphasize ease of use and ROI during their decision making. Over time we expect new product offerings, such as higher payloads in the recent UR-16 and 10e upgrade, integrated peripheral components (ActiNav sensors, grippers, actuators etc.), as well as software innovation to open new applications & addressable markets, such as those in auto/industrial applications — where heavy machinery is the incumbent technology — or electronics manufacturing (widening the ESG impact). Furthermore, customers can reduce energy consumption through the remote monitoring and access of 24/7 cobot deployments. Some UR case studies include:

Food & Beverage:

Atria Scandinavia's three cobots used in packaging, labelling and palletizing of goods reduced packaging waste by 25% and <1Y ROI

Auto:

Stellantis installed 11 UR cobots at its Mirafiori plant in Turin, Italy for use in Fiat 500 electric manufacturing (5 UR10e, 4 UR10 and 2 UR5 cobots).

Craft and Technik, an auto parts supplier, deployed UR cobots for automatic inspection processes and CNC machining, which led to an estimated 15%-20% increase in production and increased material efficiency.

Auto Industry has deployed 40+ UR cobots to date in conveyor pick-and-place, cleaning, testing and other repetitive manufacturing steps, which has not only reduced labor costs to stay competitive but also has reduced defects and production line downtime.

Electronics:

Benchmark Electronics improved operational efficiency by 25% (and saved 10% floor space) through the use of UR cobots in handling, assembly and testing applications.

RUPES, a manufacturer of power tools, found the precision of UR cobots enabled "zero defects" in its production process and the programmability/ flexibility to adjust manufacturing tasks reduced waste.

Industrial:

RCM Industries found cobots could perform high-precision, repetitive tasks in its Illinois based die-casting factory and not only reduce labor costs but also increase output.

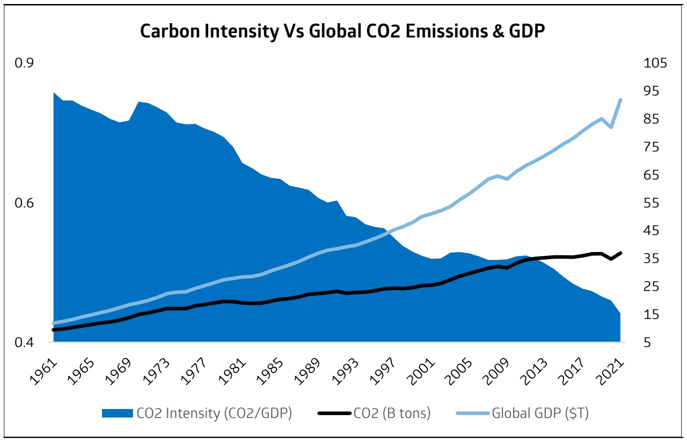
Primer – The Climate Conundrum – Joe Giordano

In this reference section we explore some of the critical challenges related to the climate crisis, applicable policy, and some background on how we got here.

Carbon Intensity Has Improved – But Gross CO_2 Has Continued To Rise And Significant Thresholds Are Approaching

Carbon intensity, measured as total CO_2 emissions divided by global GDP, has improved since 1961. Many factors like productivity & efficiency improvements, emissions regulation, and renewable energy proliferation contributed to lowering carbon intensity over time. Despite the improvement, gross emissions have continued to rise – since 2000 the average yearly gross increase in CO_2 is 45% above the yearly average increase from 1961 to 2000. On average, gross emissions have increased >2% annually since 1960, or 0.5 $GtCO_2$.

Figure 71 Carbon *Intensity* Has Declined Steadily Since 1961 …



Source: Our World In Data, World Bank, Cowen and Company

Figure 72 …But Gross CO_2 Emissions Are Rising At A Quicker Pace – '00-'20 >50% Above The 1961-2000 Average

Carbon Intensity By Decade	CO2 MM Mt / $1B GDP	% chg
1960s	0.77	
1970s	0.75	-3%
1980s	0.65	-14%
1990s	0.56	-13%
2000s	0.50	-10%
2010s	0.47	-6%
Total	**0.61**	

Avg CO2 Gross Increase By Decade	CO2 Increase
1960s	0.49
1970s	0.58
1980s	0.28
1990s	0.21
2000s	0.71
2010s	0.51
Total	**0.45**

The Global Carbon Budget (GCB) 2021 report provided an update to the global carbon budget – the amount of total CO_2 emissions over a period of time to keep global warming within a certain temperature threshold. According to GCB 2021 report, in order to limit global warming (with a 50% probability) to 1.5°C, 1.7°C, and 2°C, the remaining carbon budget is 420, 770, and 1270 $GtCO_2$, respectively. If CO_2 emissions were to continue at 2021 levels, we would reach the carbon budget threshold for a 1.5°C surface temperature increase before 2032.

Figure 73 Demand Is Expected To Nearly Double, Where Will Carbon Emissions Trend?

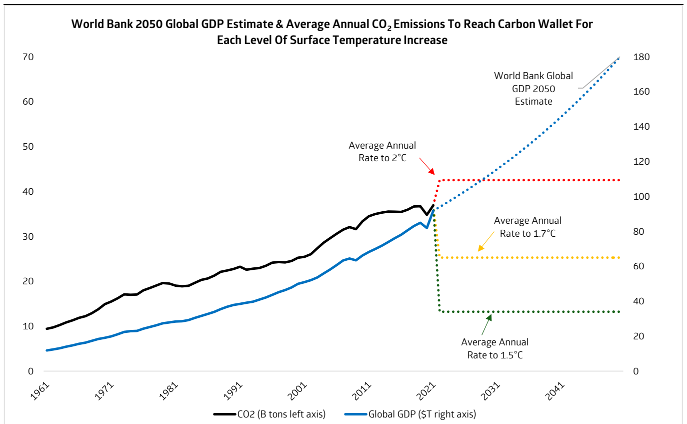
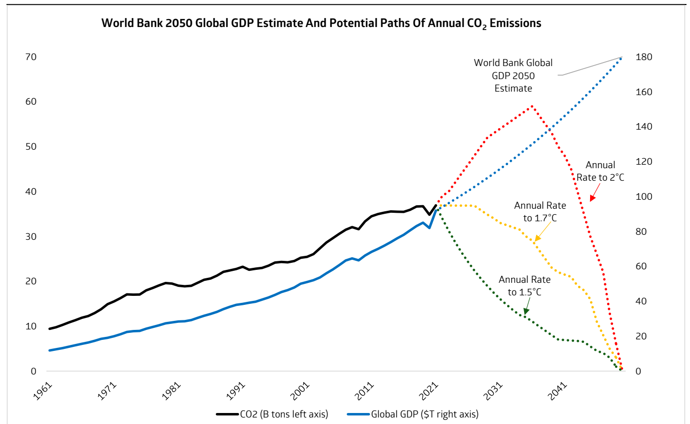


Figure 74 Potential Paths To Reaching Carbon Wallet Caps That With High Likelihood Lock In Surface Temperature Increases …



Source: Our World In Data, World Bank, Global Carbon Budget 2021, Cowen and Company

Importantly, in the charts above the averages shown and the potential glidepaths assume that carbon output in year 2050 is net neutral and that the total available budget is exhausted in that year. On its own, assuming neutrality from where we are today is a leap. Clearly an urgent situation if those wallets are accurate given our current trajectory.

Relationship Between Energy Use, Consumption, And Global Surface Temperatures

We acknowledge that climate change and the increase in surface temperature are extremely complex and stretch well beyond the sources we highlight in our report. Our aim is not to cover each facet, but rather to understand the largest contributors and some emerging tools available that corporations are likely to leverage as they achieve long-term carbon emission reduction targets.

According to the Intergovernmental Panel on Climate Change (IPCC), each successive decade over the last 40 years has experienced warmer temperatures compared to any preceding decade since 1850.

Figure 75 IPCC Simulation Of Natural Force Impact On Global Surface Temperatures …

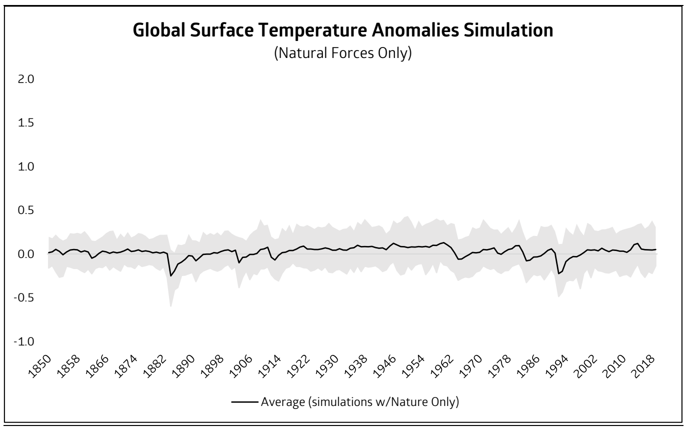
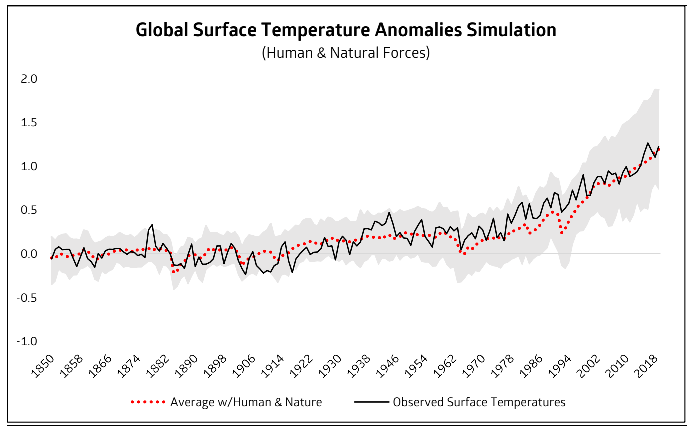


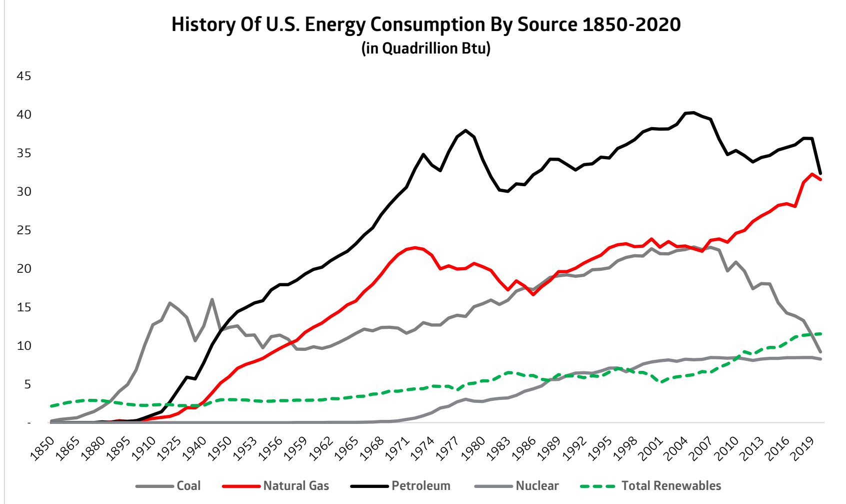
Figure 76 … Human Forces Have Driven The Rise In Observed GSTA Relative To 1850-1900 Levels



Source: IPCC, Cowen and Company

To better understand the drivers of surface temperature increases, we looked at energy consumption (both US and Globally), and personal consumption as measured by U.S PCE (gross dollars, not inflation) as a proxy for global consumption increase over time. We focused our analysis on the consumption of fossil fuels, both globally and in the U.S., given they are the highest contributing fuel source to carbon dioxide emissions (at ~85% or 65% of all GHG emissions).

Figure 77 Uptick In Surface Temperatures Coincides With Petroleum & Coal Consumption Increases

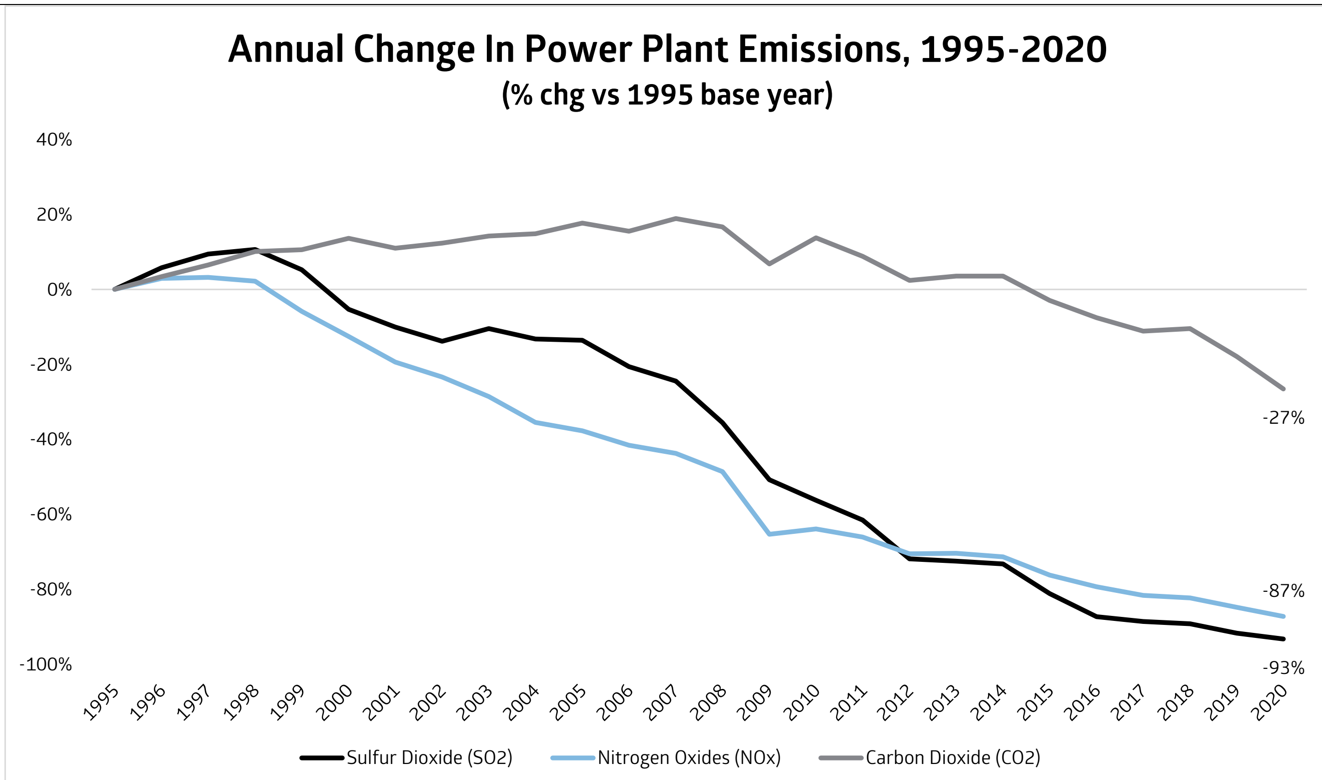


Source: U.S. EIA, Monthly Energy Review, Cowen and Company

Interestingly, while the rapid rise in temperatures has corresponded to a global increase in fossil fuel energy consumption, US usage has trended mostly flat for an extended period despite a parabolic rise in demand. Many initiatives were undertaken by the U.S. government agencies to reduce GHG emissions across various sectors of the economy – since 1970, when the EPA was established, emission reduction goals have been accomplished, fuel/gasoline has become cleaner (removal of lead, oxygenated gasoline in highly polluted areas, etc.), and fuel efficiency standards set and improved upon. We discuss many of these initiatives later in our Primer.

Despite electricity production accounting for 1/3 of US carbon dioxide emissions, the EPA was not cleared to set limitations on power generators until a 2007 Supreme Court ruling, while the final rule to limit GHG on new power plants was not released until August 2015. Previously unregulated, other emissions like sulfur and nitrogen oxides declined steeply since 1995, while CO_2 emission only started to turn negative vs the 1995 base year in 2015.

Figure 78 Emissions For SO_2 And NOx Have Declined Steadily Since The Early 2000s, While CO_2 Only Began To Decline In 2015



Source: US EPA, Cowen and Company

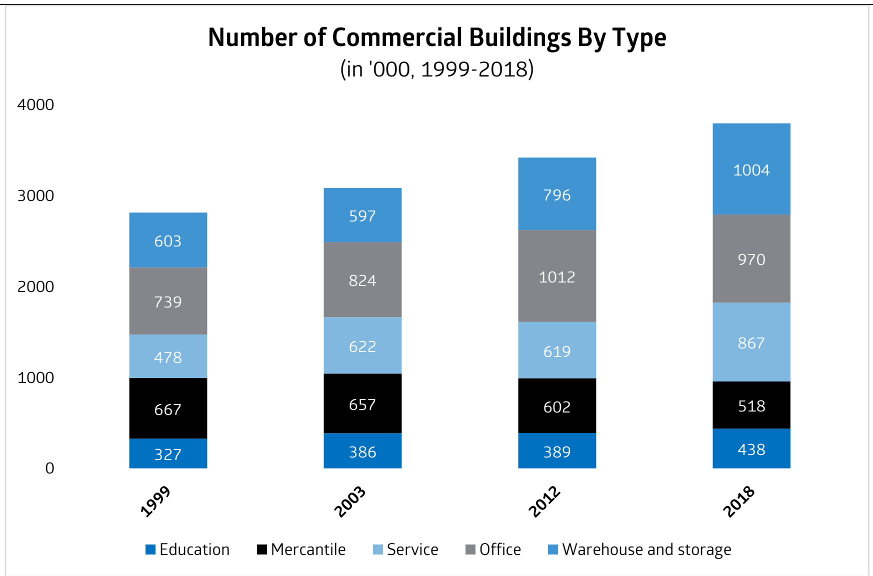
Politics (at least in the U.S.) remains somewhat of a headwind to climate change initiatives. We'd note there is a pending U.S. Supreme Court case against the EPA (*West Virginia v. Environmental Protection Agency*) – this case is a consolidation of three other cases against the EPA involving coal companies (North American Coal Corporation and Westmoreland Mining Holdings), and the state of North Dakota. The case will decide if the Constitution gives Congress the power to delegate regulatory power on GHG emissions to the EPA. The outcome is unclear, but legislation that limits the authority of the EPA to enforce GHG emissions would be a clear step back for climate change initiatives in the U.S.

Commercial Buildings - Warehouse Operations' Carbon Footprint

In the United States, the commercial building sector accounts for nearly 16% of all US CO_2 emissions (compared to the global figure of ~28% of direct CO_2 emissions). In 2018, according to data from the EIA, warehouse and storage-related commercial buildings totaled ~1MM ,or 17% of all 5.9MM commercial buildings. Of the warehouse and storage buildings, there were 167k distribution / shipping center warehouses (~2.8% of all commercial buildings).

The footprint of US warehouses increased to 1MM in 2018 from ~600k in 1999 (66% increase), while total commercial buildings increased to 5.9MM from 4.6MM (27% increase) – over this time, warehouse builds accounted for 31% of all new builds. More recently, warehouse builds have accelerated and accounted for ~58% of total commercial building growth between 2012-18. In 2018, warehouses surpassed office buildings to become the most common type of commercial building on both total number of buildings and square footage.

Figure 79 Warehouses Surpassed Office Buildings As The Most Common Type Of Commercial Building



Source: U.S. Energy Information Administration, CBECS, Cowen and Company

Despite accounting for 14% of all commercial buildings in 2012, warehouses accounted for only ~7% of total U.S. commercial building energy consumption – the 6th largest energy consumer – but on per-square foot basis, was #12 out of 14. **If we extrapolate this figure, it suggests that storage/warehouses (proxy for e-commerce) account for 1.1% of total US CO_2 emissions and ~3% of global emissions.**

Figure 80 Warehouses Are the 6th Largest Energy Consumer ….

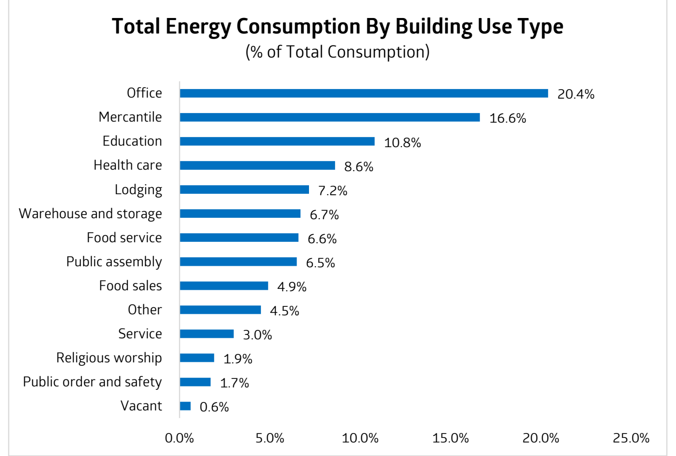
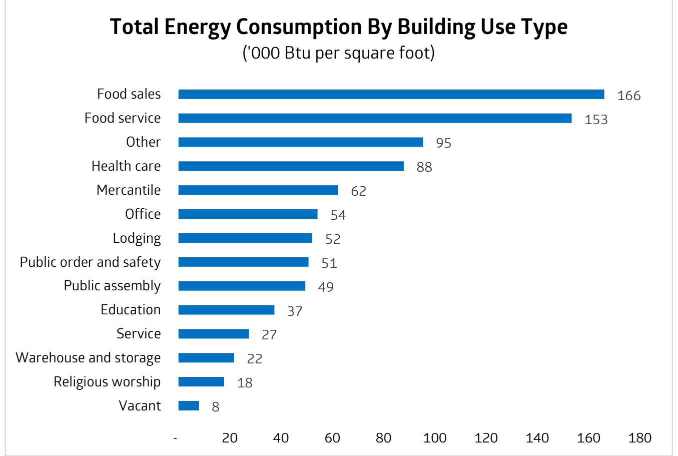


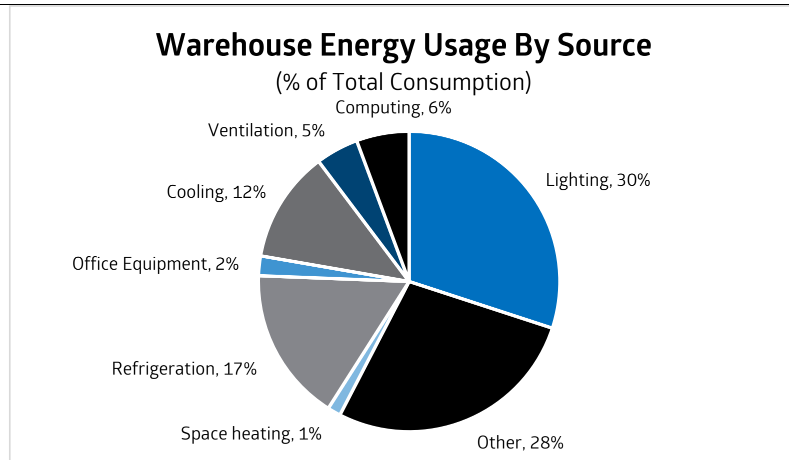
Figure 81 … But Per Square Foot Energy Consumption Is Very Low



Source: U.S. Energy Information Administration, CBECS, Cowen and Company

Energy consumption within warehouses is concentrated in three areas: Lighting (30%), Refrigeration (17%), and Cooling (12%) – while 28% of total energy consumption does not fall into a traditional category and is labeled as "Other". While the EIA does not explicitly identify what "other" energy usage encompasses, we suspect this includes energy consumption from stock movements/storage and retrieval, primarily fixed material handling equipment (FMHE) and mobile material handling equipment (MMHE).

Figure 82 Warehouse Energy Usage By Source – Lighting, Refrigeration And Cooling Top The List



Source: U.S. Energy Information Administration, CBECS, Cowen and Company

Given the high level of energy consumption that stems from FMHE and MMHE, there is a big opportunity for automation and robotics to play a role in reducing the carbon intensity from these important tools. FMHE includes fixed infrastructure such as conveyor belts, elevators, and lifts, while MMHE includes pallet trucks, forklifts, tuggers, and trucks (typically combustion engines). In our report, we explore how emerging technologies such as autonomous guide vehicles (AGVs) and autonomous mobile robots (AMRs), will help play a role within warehouse/logistic operations' goal to lower, and potential reach, carbon neutrality.

Scaling Climate Change Figures, Global Policy, GHG 101, And Terminology

Climate Change Scaling

The size of the numbers we reference throughout the report is difficult to visualize and comprehend. We describe CO_2 emissions in gigatons (Gt) – a gigaton is 1B tons or 2.2 trillion pounds. Still doesn't really help, does it? How about this - 1GCt is the equivalent of 147MM elephants (avg weight of 6.8 tons), >6MM blue whales, 1.9MM fully loaded Antonov 225s, ~10k U.S. aircraft carriers, or ~2.7k Empire State Buildings. If that doesn't help, let's take NYC's Central Park (2.5 miles by 0.5 miles) - according to NASA, 1 Gt of ice would create a block the length and width of the park that extends 1,119 feet in the air.

Figure 83 Putting 1 Gigaton Into Perspective Helps Give Context To Climate Change Numbers – The Scale Is Remarkable

1 Gigaton = 1,000,000,000 Tons

~1.9MM Fully Loaded Antonov 225's

~10k U.S. Navy Nimitz-Class Aircraft Carriers

~2.7k Empire State Buildings

Source: Kamil Paradowski, U.S. Navy, Jeenah Moon/Bloomberg News, Cowen and Company

COVID-19 Lockdowns Provided A Brief Glimpse Of Carbon Reduction Benefits

During the early days of the lockdowns in 2020, pictures circulated on major news outlets and websites, and highlighted the positive benefit lockdowns had on air quality within metropolitan areas. While the benefits were short-lived, it served as irrefutable evidence of how emission reduction can and will positively benefit the planet and society.

Figure 84 Aerial View Of Central New Delhi Prior To COVID-19

Figure 85 The Same View During COVID-19 Lockdowns

Source: Anushree Fadnavis, Adnan Abidi, Reuters

Sources Of GHG Emission

The IPCC and EPA break down GHG emissions by economic sector - industry, electricity/heat production, and agriculture industries account for ~70% of GHG emissions, with each similar in contribution. Carbon dioxide (CO_2) accounts for ~75% of all GHG emissions globally.

Figure 86 Electricity Generation, Industry, And Agriculture Account For 70% Of All GHG Emissions

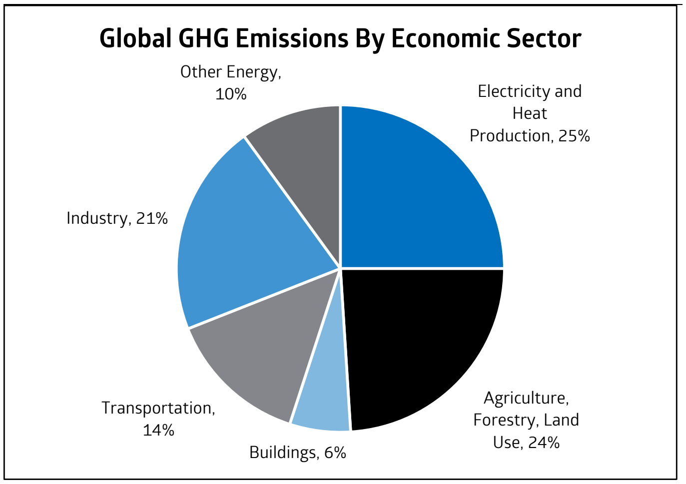
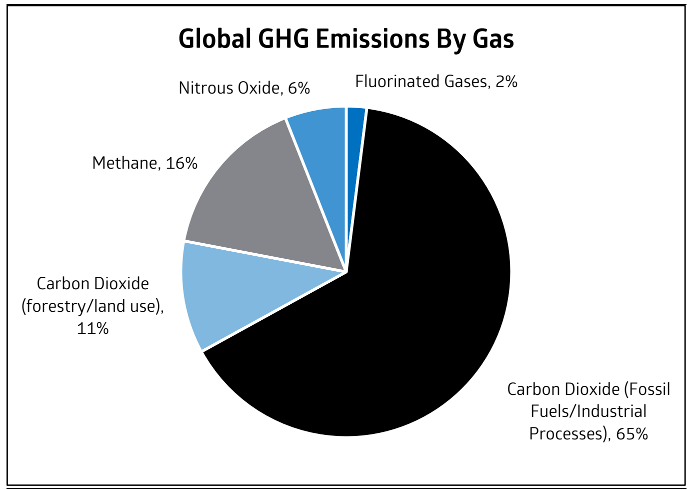


Figure 87 … At ~75% Of Total Emissions By Gas, Carbon Dioxide Is By Far The Most Commonly Emitted Gas



Source: IPCC, EIA, Cowen and Company

- ***Carbon Dioxide (CO_2)*** – The primary GHG by gas type, accounting for a combined 76% of total emissions according to the IPCC 2014 report. Emissions can arise from human impact like land clearing for agriculture/deforestation, but the primary source is from fossil fuel related emissions.

- ***Methane (CH_4)*** – Agricultural activities, livestock, waste management, and biomass burning are all sources of methane emission.

- ***Nitrous Oxide (N_2O)*** – Fertilizer use is a primary source of N_2O, while fossil fuel combustion is also a contributor.

- ***Fluorinated Gases (f-gases)*** – Industrial processes, refrigeration, and other consumer products contribute to the emission of fluorinated gases (or f-Gases).

GHG Protocol and Emission Scopes Explained

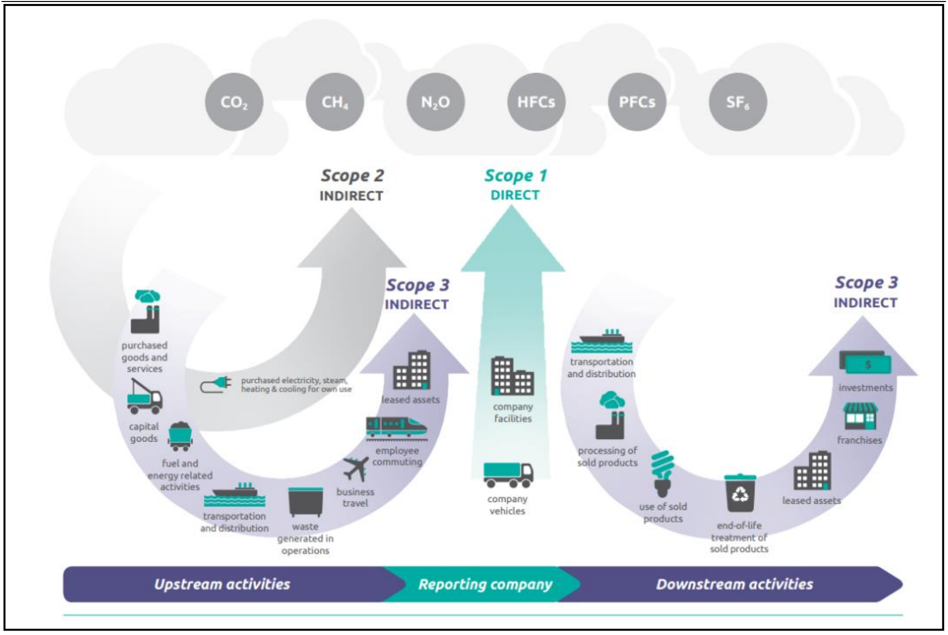
GHG Protocol (GHGP) establishes global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from companies/operations. The organization works with governments, industry associations, NGOs, and businesses. GHGP also provides accounting and reporting standards, sector guidance, and calculation tools for businesses and governments.

Scope 1 – GHGs that are directly emitted by facilities owned by a company. This includes emissions from company vehicles, buildings, warehouses, manufacturing facilities, etc.

Scope 2 – indirect emissions generated by purchased or acquired electricity, steam, heating, or cooling used by a company.

Scope 3 – Essentially covers all other indirection emissions that arise from upstream and downstream activities. Upstream activities include the purchase of goods/services, fuel/energy related activities, transportation and distribution, waste, business travel, employee commuting, and leased assets. Downstream activities include transportation/distribution, processing of sold products, use of sold products, end-of-life, leased assets, franchise, and investments.

Figure 88 Overview Of Scope 1, 2, and 3 Emissions



Source: Greenhouse Gas Protocol

United Nations Framework Convention On Climate Change (UNFCCC)

During the early 1990s, the **U.N. Conference on Environment and Development** sought an international coalition regarding sustainability issues in the post-Cold War era. Among the topics addressed, alternative energy sources to replace fossil fuels and effects on climate change were at the forefront. As a response, member states established the **UNFCCC**. This multilateral agreement, and later U.N. Secretariat by this name, aims to guide annual meetings and policy agreements designed to combat global climate change. Members typically congregate on a yearly basis at the Conference of the Parties (COP) to devise new resolutions, and several landmark treaties have been enacted – namely the Kyoto Protocol and Paris Agreement (Accord).

The **Kyoto Protocol** was adopted in 1997 and was the first large scale agreement among nations to adopt policies to limit GHGs and provide accountability through periodic reporting. The first commitment period was 2008-2012 and a modified agreement, the **Doha Amendment**, provided another commitment period between 2012-2020. A salient feature of the agreement was a tri-tiered classification system (Annex I, Annex II, and Non-Annex I) that divided countries on various commitments. The complexities associated with tiering and related outcomes are outside the focus of this report; however the Kyoto Protocol is notable for establishing the first international standard for emissions permits (international emissions trading, clean development mechanism, joint implementation) and rigorous monitoring systems.

The **Paris Agreement** was adopted in 2015 and sought to improve upon the Kyoto Protocol. Namely, the resolution focused on temperature (limit below 2ºC compared to pre-industrial levels) rather than GHG benchmarking and doesn't discriminate standards by national economic status (develop vs. developing). To achieve the objective, nations would aim to peak GHG emissions as soon as possible with the goal to undertake reductions, thereafter, culminating in a universal climate neutral environment by 2050. This could be possible with the appropriate balance between emission activities (fossil fuels burning, etc.) and GHG removal from sinks (forests, oceans, soil and technologies to sequester GHG). The Agreement did not include any formal funding mechanisms, but developed a framework for developed countries to aid less developed nations. To date, 194 nations have signed the Agreement, representing 98% of global greenhouse gas emissions.

Figure 89 Kyoto Protocol vs. Paris Agreement

	Kyoto Protocol	Paris Agreement
Scope	Mitigation	Mitigation, adaptation, finance
Intent	Decrease overally emissions by 5% from 1990 levels	Overally goal to limit global temperatures to 1.5-2.0 degrees celsius above pre-industrial levels
Duration	Phase 1: 2008-2012 Phase 2: 2012-2020	Indefinite, revisions every five years
Application	Only developed countries have emission targets	All parties must take (nationally determined) mitigation measures
Coverage of global emissions	14% in phase 2	98% of globally
Mechanisms	emissions targets for developed countries, market-based mechanisms	nationally determined contributions, voluntary cooperation between parties
Compliance	Legally binding agreement to decrease GHG	Not legally binding commitment to reduce emissions, increases accountability
Tranparency	Different reporting requirement between developed and developing countries	Similar reporting requirements between for all parties

Source: Care about Climate, Cowen and Company

Science-Based Targets Initiative (SBTi)

In response to the Paris Agreement, SBTi was founded in 2015 to provide a framework and guidance for the private sector towards reducing GHG emissions. The initiative is a partnership between CDP, the U.N. Global Compact, World Resources Institute (WRI), and Worldwide Fund for Nature (WWF), and receives funding from a diverse group of companies and organizations. Currently, ~1.1k companies have implemented science-based targets for net-zero carbon emissions, which is nearly 20% of total global companies according to market cap.

The initiative is based on the four key themes:

- Promote emissions reductions and net-zero targets to halve emissions by 2030 and achieve net-zero emission before 2050.
- Provide science-based target setting methods and guidance to companies.
- Provide companies with independent assessment and validation of targets.
- Be the lead business partner for the coalition of UN agencies to set net-zero based target in line with the 1.5°C goal (based on IPCC).

Figure 90 SBTi's Initial Recommendations for Corporate Net-Zero Target Setting

	Recommendations
Boundary	A company's net-zero target should cover all material sources of GHG emissions within its value chain
Abatement	companies aim to eliminate sources of emissions at pace and scale consistent with mitigation pathways that limit warming to 1.5 degrees, includes emissions not feasible to be eliminated, neutralized with equivalent measure of CO2 removals
Accountability	Long-term net-zero targets should be supported by interim science-based emission reduction targets in-line with Paris Agreement mitigation levels
Timeframe	No later than 2050, while a more ambitious timeframe should not come at expense of level of abatement
Mitigation hierarchy	Companies should follow a strategy that prioritizes eliminating sources of emissions within the value chain vs. compensation or neutralization measures, and land-based climate strategies vs. preserving existing terrestrial carbon stocks
Environmental and social safeguards	Mitigation strategies should adhere to robust social and environmental principles: protection/restoration of naturally occurring ecosystems, social safeguards, protection of biodiversity etc.

Source: SBTi, Cowen and Company

Among the various criteria considered by the SBTi, standards currently apply to Scope 1 and 2 emissions, as defined by the GHG Protocol corporate standard. However, if a company's Scope 3 emissions are more than 40% of total output, a Scope 3 target is required.

Sustainability Accounting Standards Board (SASB)

There has been a considerable focus on the establishment of accounting standards tied to ESG-related themes, with investors such as President and CEO of State Street, Cyrus Taraporevala, stating in a 2020 letter to board members that "we believe a company's ESG score will soon effectively be as important as its credit rating." Founded in 2011, the SASB seeks to standardize ESG performance factors and is currently utilized by nearly 1.3K companies globally.

Currently, SASB provides standards for 77 industries; below we provide sustainability disclosure and accounting metrics which correspond with our current coverage: Electrical & Electronic Equipment (detail here) and Industrial Capital Goods (detail here).

IPCC

In 1988, the IPCC was created by the U.N. Environment Programme and the World Meteorological Organization (WMO) in a concerted effort to promote scientific collaboration on climate research. Through regular assessments, thousands of scientist volunteers identified relevant scientific research to develop a consensus reading, and areas for further inquiry. The IPCC does not conduct its own research, however, aims to formulate reports that are neutral in stance, and are "policy-relevant rather than policy-prescriptive." These findings play a key role for the UNFCC and other inter-governmental/sovereign bodies as it relates to issues regarding climate change. The organization currently has 195 nation members and is primarily funded by a trust seeded by the U.S., Australia, Belgium, Germany, Italy, Japan and UNFCCC.

IPCC is divided into three working groups and a separate task force. Working Group I deals with the physical science basis of climate change, Working Group II with climate change impacts, and Working Group III with mitigation considerations. While the Task Force on National Greenhouse Gas Inventories advances methodologies for reporting GHG and removal.

The organization has published five comprehensive assessment reports (will be releasing a sixth later this year) and frequently publishes “Special Reports” on specific topics. Since these reports are numerous and extensive, we have highlighted a few key findings below:

First Assessment (1990) (**Link**) – established GHG from human activities resulted in the potential for additional warming of the Earth’s surface. Scientists calculated CO_2 accounted for ~50% of the greenhouse gas effect.

Second Assessment (1995) (**Link**) – established a more discernable difference between human and natural forces on climate; stated there are many uncertainties relating to estimation of future emissions, representation of climate processes in models, regional variability.

Third Assessment (2001) (**Link**) – projected global average surface temperature and sea levels to increase under all IPCC emission scenarios; asserted “inertia” is an inherent characteristics of climate-related issues where some human forces may be slow to become apparent, while some areas may be irreversible after certain thresholds are met; adaptation measures have potential to reduce adverse effects of climate change but will not prevent all damages.

Fourth Assessment (2007) (**Link**) - established unequivocally human influence has warmed the Earth; projected 0.2°C in warming per decade even if concentrations of all GHGs and aerosols kept constant from 2000 level; provided more specific information on the future impact to ecosystems, food, coasts, industry, health, geographic regions; stated with high confidence that neither adaption nor mitigation alone can avoid all climate impacts; offered emission trajectories for stabilization.

Fifth Assessment (2014) (**Link**) – highlighted current GHG concentrations were unprecedented in the last 800,000 years; offers several mitigation pathways that are likely to limit warming below 2°C and specifics around each GHG; introduces climate cognizant finance themes.

Special Report on Global Warming of 1.5°C (2018) (**Link**) – highlighted climate consequences from previous 1°C of global warming (extreme weather, rising seas levels, diminishing Arctic ice. etc.); compared the difference in impact from 1.5°C vs. 2°C of warming (sea levels would be 10cm lower, coral reefs would only decline 70% vs. nearly 100%); established a 45% decline in CO_2 from 2010 levels by 2030 and reaching “net zero” around 2050, as the antidote for a 1.5°C target.

Sixth Assessment (2021, Part 1) (**Link**) – under scenarios with increasing human CO_2 emissions, natural carbon sinks could become less effective; continued warming is projected to intensify the global water cycle; every region can increasingly experience multiple changes in climatic “impact-drivers”.

Climate Targets And Terms Deciphered

With so many buzzwords and jargon being used, we thought it would be helpful to define some of the most used phrases as companies aim to be better stalwarts of the environment and planet.

- *Greenhouse Gases (GHG)* – any gas in the atmosphere that can absorb infrared radiation (heat energy) and reflect back to the Earth's surface (ex. Water Vapor, Carbon Dioxide, Methane, Ozone, Nitrous Oxides and Fluorinated Gases).

- *Decarbonization* – refers to the ratio of GHG emission to sequestration either during energy production or industrial processes. Frequently this is accompanied by a timeframe and rate/scale.

- *Carbon Neutrality* – is when a company makes no net release of CO_2 to the atmosphere or has zero carbon footprint – this can be accomplished through offsetting emissions by planting trees, for example. This term does not encompass all greenhouse gases. Synonymous with Net Zero, Net Zero Emissions.

- *Climate Neutral* – refers to targets that mitigate emission of all greenhouse gases, emitting GHG at a rate equal to offsetting activities that remove GHGs from the atmosphere. It is an order of magnitude higher than carbon neutrality as it reaches beyond Carbon Neutral/Neutrality.

- *Climate Positive* – activity or targets that go beyond achieving net-zero emissions and aim to remove more carbon dioxide from the atmosphere than is emitted. The term is synonymous with *Carbon Negative.*

- *Carbon Budget* – amount of CO_2 the world can emit while still having a likely chance of limiting warming to the target range in °C.

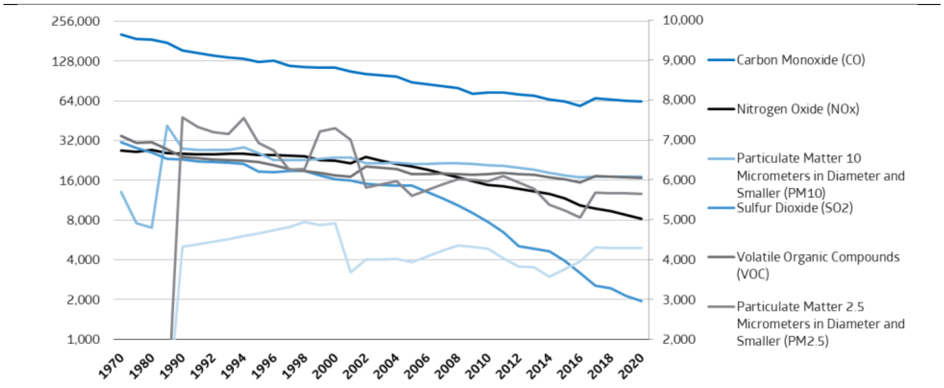
- *Carbon Credit* – an emissions unit that is part of a crediting program and represents the removal/reduction of GHG emissions. These credits are part of an electronic registry.

- *Insetting* – the processes of a company offsetting emissions or other environmental impacts of a company within its own supply chain

- *Nationally Determined Contributions (NDCs)* – mitigation and adaptation targets set by countries as part of the Paris Agreement (COP21 in 2015). Required each country to outline its own plan by 2020.

EPA Timeline And Notable Initiatives On Emissions Reduction Of Vehicles/Engines

Figure 91 National Emissions Totals (thousands of tons) From 1970 To 2020



Source: EPA, Cowen and Company

*PM2.5 and Ammonia value are tracked on right vertical axis

This flattening/decrease coincides with initiatives from the US EPA that started in the 1970s:

- **1970-71** – U.S. Congress passed the first major Clean Air Act that required a 90% reduction in emissions from new automobiles by 1975. The EPA was also established by President Nixon this year as the agency responsible for the regulation of motor pollution. The agency was directed to set health-based National Ambient Air Quality Standards for six pollutants. Fuel economy testing began on cars, trucks, and other vehicles in 1971 to inform customers on gas mileage metrics.

- **1975** – Congress passed the Energy Policy Conservation Act – setting the first fuel economy goals. The Corporate Average Fuel Economy (CAFE) program started a phase-in of more strict fuel efficiency standards starting with 1975 models.

- **1981-83** – New cars meet the amended Clean Air Act standards for the first time. During 1983, Inspection and Maintenance programs were established requiring passenger vehicle emission control systems to be tested periodically.

- **1990** – The Clean Air Act was amended to require further reductions in HC, CO, NOx, and PM emissions – the EPA was also given authority to regulate emissions from nonroad engines and vehicles for the first time. Oxygenated and reformulated gasoline was required to be sold in areas of the U.S. that did not meet air quality standards for CO and "air toxics" emissions.

- **1996-2000** – Lead is banned from gasoline as of January 1, 1996, completing the EPA's 25-year mission to eliminate lead from gasoline. During 1998, more stringent emissions standards were issued by the EPA for diesel engines used for non-road construction, agriculture, industrial equipment, and certain marine applications. In 2000, rules were released to reduce HC and NOx emissions by 70% for handheld engines (chainsaws/cutters, etc.).

- **2004-05** – The EPA launched the SmartWay Transport Program, a collaboration between the EPA, logistics companies, carriers/shippers and other stakeholders to reduce GHG, air pollution, and improve fuel efficiency within the transportation supply chain industry. In 2005, the EPA matched emissions standards from the United Nations International Civil Aviation Organization for new commercial aircraft engine NOx emissions.

- **2006** – New test methods for measuring fuel efficiency were introduced to bring MPG (miles per gallon) estimates closer to actual fuel economy. Heavier vehicles up to 10,000lbs were required to display fuel economy metrics on window labels of vehicles.

- **2008** – More stringent standards were adopted by the EPA to reduce emissions of diesel PM and NOx from locomotives and marine engines. $50MM in grant funding was made available under the Diesel Emissions Reduction Program, aimed at reducing emissions from existing diesel engines.

- **2010-2012** – The EPA and NHTSA established a national program to reduce GHG emission and improve fuel economy of new light-duty vehicles for model years 2012-16. In 2012, the national program was extended for model years 2017-25 – over the lifetime of these model year standards, the program was projected to save ~4B barrels of oil and 2B metric tons of GHG emissions. Net benefits were estimated to be up to $451B.

Links to interactive charts in this report:

Percentage Of Robot Users That Have Or Plan To Communicate Climate Objectives In 2022

Percentage Of Robot Solution Providers That Have Or Plan To Communicate Climate Objectives In 2022

Percentage Of Robot Solution Providers That Include Climate Aspects In Customer Sales Conversations

Expectations For Climate Change To Be Discussed With Potential And Existing Customers

Figure 92 Companies Mentioned In This Report

ABBN.SW (Outperform, CHF28.19)
AMZN (Outperform, $2176.98)
CAT (Outperform, $206.29)
CGNX (Outperform, $49.14)
CMG (Outperform, $1276.57)
FDX (Outperform, $208.27)
FORG (Outperform, $15.79)
FSLR (Outperform, $68.33)
PCAR (Market Perform, $85.3)
S92.GY (Market Perform, €36)
SG (Outperform, $20.35)
SPWR (Market Perform, $15.36)
TER (Outperform, $100.28)
TSP (Market Perform, $7.855)
UPS (Market Perform, $181.43)
WING (Outperform, $80.82)
WMT (Outperform, $151.31)

Source: Refinitiv, Cowen and Company

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