ELLEN MACARTHUR FOUNDATION | OliverWyman

An innovation pathway to decarbonization:

circular economy solutions for policymakers and industry in the US

Contents

Executive summary

The US is at a critical moment in history—the nation faces mounting risks and pressures related to climate change, supply chain security, and economic competitiveness.

Circular economy solutions can deliver for the US on its most pressing political and corporate priorities such as:

The US government and businesses have an opportunity to embrace circular economy solutions to help address those priorities. Governments and businesses around the globe have done just that, as evidenced by the 70 national roadmaps in place globally and billions of dollars invested in companies contributing to, or benefiting from, the transition to a circular economy.

On climate in particular, the circular economy presents a critical opportunity. Efforts to date have focused on transitioning to renewable energy, complemented by work to increase energy efficiency, but those efforts can only address 55% of emissions globally.[1] The remaining 45% comes from how we produce and consume products—the circular economy can help to reduce these emissions by transforming the way we make and use products.

Research developed for this report shows a substantial economic and climate opportunity if the US were to have a more circular economy in three resource- and carbon-intensive industries selected for review—grid-scale and electric vehicle (EV) batteries, built environment and infrastructure, and electronic equipment. Of course, the opportunity is even larger if other industries are included.

US policymakers and businesses are increasingly recognizing the importance of circular economy solutions in achieving the US's climate and economic goals, among others. In the policy arena, laws like the Inflation Reduction Act (IRA), the Bipartisan Infrastructure Law (BIL), and the Creating Helpful Incentives to Produce Semiconductors and Science Act (CHIPS and Science Act), as well as executive action, have opened the door for circular economy solutions to benefit the US economy and decrease carbon emissions, in addition to driving industrial innovation and improving national security. However, we need to go further and faster to capture the full opportunity.

A cohesive, multi-industry policy strategy is needed, including an aligned set of policies and business actions to:

- Set the direction for travel
- Help understand and communicate the benefits of circular economy activities
- Remove barriers to circular economy activities
- Mandate circular economy solutions
- Continue to drive innovation

This report lays out near-term opportunities for policymakers and industry to move toward a more circular economy, capturing economic, climate, and other potential. Government and industry should work in concert to achieve progress toward a circular economy, ensuring the US maintains its position as a global leader in innovation and economic prosperity.

In the US, the circular economy can deliver on policy priorities such as climate, national security, economic performance, and industrial innovation.

The circular economy offers significant economic and climate opportunities across US industries, including EV and grid-scale batteries, built environment and infrastructure, and electronic equipment.

Grid-scale and EV batteries

Economic opportunity today:

~USD 6 to 24 billion

Climate opportunity today:

2 to 3 million tons of CO_2e

Built environment and infrastructure

Economic opportunity today:

~USD 575 billion to 1.1 trillion

Climate opportunity today:

295 to 538 million tons of CO_2e

Electronic equipment

Economic opportunity today:

~USD 301 to 388 billion

Climate opportunity today:

73 to 311 million tons of CO_2e

Total across three sectors reviewed

Economic opportunity today:

USD 883 billion to 1.5 trillion in economic value
(4% to 7% of US GDP)

Climate opportunity today:

370 to 852 million tons of CO_2e
(7% to 16% of total US GHG emissions)

The US policy landscape—particularly the IRA, BIL, and CHIPS and Science Act, as well as executive branch activities—has already made space for circular solutions to contribute to industrial decarbonization.

The US can build on progress to date and further unlock opportunity through strategic policy interventions. Government and industry can work together to achieve progress toward a circular economy, ensuring that the US maintains its position as a global leader in innovation and economic prosperity. To the right are recommendations for key near-term actions to drive progress:

- **Set the direction for travel with, for example, a national vision, goals, and whole-of-government approach to the circular economy**
- **Help understand the benefits of circular economy activities via the development of standards, research, and data collection; communicate that information across the value chain, with the public, and with the government**
- **Remove barriers to circular economy activities by making the economics work, addressing circular economy infrastructure needs, and facilitating the management of products after use**
- **Mandate circular economy solutions covering the design, production, use, and post-use phases**
- **Continue to drive innovation through ongoing and expanded investment**

Why move to a circular economy?

The circular economy offers solutions to some of today's most pressing challenges

The circular economy offers a vision of a future in which value creation no longer relies mostly on the consumption of finite resources—rather than being wasteful and polluting, the economic system is restorative by design. As an economic model that works within planetary boundaries, the circular economy can offer a long-term pathway for prosperity, security, and innovation that is not only nature-positive, but can also be designed to deliver on environmental justice objectives. It can help tackle resource scarcity and associated supply risks and regenerate, rather than deplete, nature.

The circular economy is a solutions framework based on three principles, all driven by design: eliminate waste and pollution, circulate products and materials, and regenerate nature. It runs on renewable energy and increasingly uses renewable materials.[2]

Applying principles of circularity can strengthen supply chains, create jobs across communities, reduce the environmental impacts of industries, and make the economy more resilient and competitive.[3] Moving toward a circular economy can support industrial resilience and competitiveness by strengthening domestic supply chains—including by securing the supply of the critical raw materials needed to drive the energy transition.[4] Circular business models can generate economic cost savings and reduce climate impacts as well as other negative externalities by designing out pollution and increasing resource productivity, and by ensuring that the value embedded within materials is captured, maintained, and circulated at every stage of the value chain.

The circular economy can advance US policy priorities on climate change and national security

> **"In order to meet our climate goals, we must build an increasingly circular economy—an economy that keeps materials and products in circulation for as long as possible, rather than throwing them away."**
>
> *White House Office of Science and Technology Policy*[5]

Circular economy strategies can help the US meet its emission reduction targets across sectors, including in the crucial area of industrial decarbonization.[6] In the case of greenhouse gas (GHG)-intensive materials—such as those used in EV and other large-scale batteries, building components, and electronic equipment—this means designing for multiple cycles of repair, reuse, refurbishment, and recycling. These strategies reduce demand for the raw materials needed to make new products, thereby decreasing emissions upfront.

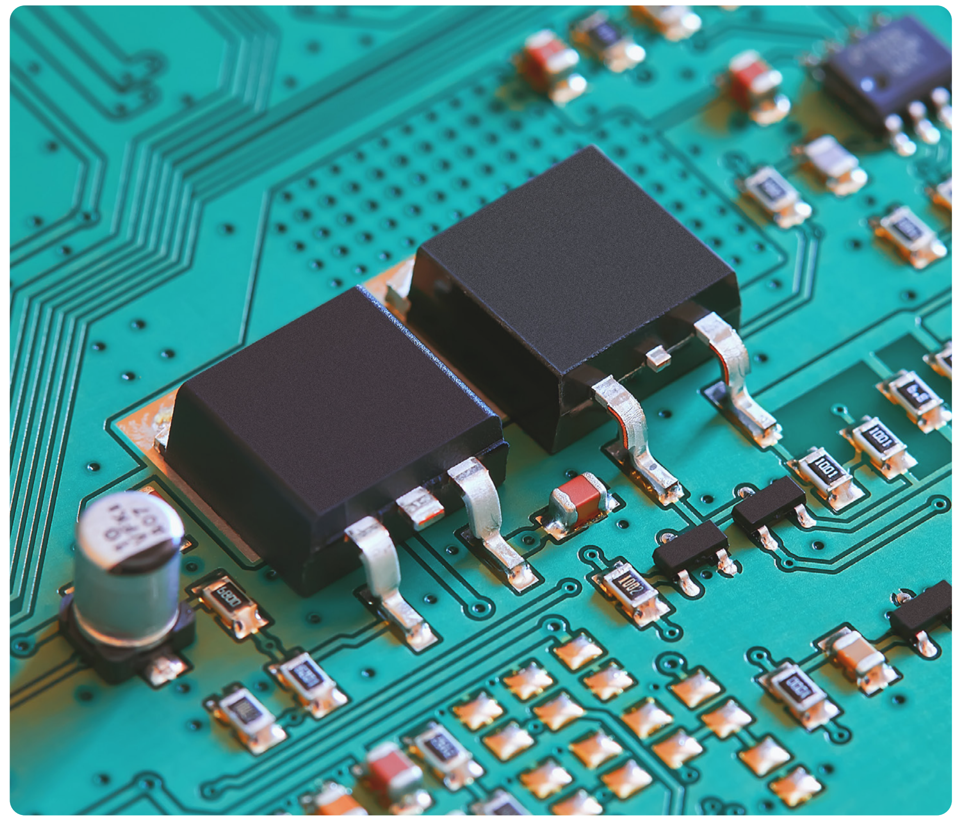
This reduction in demand for virgin materials can support US national security by reducing reliance on imported critical raw materials[7] and raw materials with supply risks, such as the metals needed in the build-out of renewable energy infrastructure.[8] As the penetration of these energy sources rises, independence from raw material imports increasingly enhances US energy security.

By keeping strategic materials within the US economy, the circular economy can also help insulate the US from volatile international commodity markets. This increase in supply chain resilience comes with substantial economic benefits to US companies and citizens.

The circular economy can improve economic performance and drive innovation

Circular economy strategies generate more value from a given amount of raw material than equivalent linear approaches since they do not let this material go to waste. The resulting reduction in net material costs[9] has the potential to benefit both producers and consumers by improving companies' bottom lines and making everyday goods and services more affordable for citizens over the long term. For the economy as a whole, these savings represent an increase in industrial performance driven by greater material productivity and a higher return on invested energy and labor. Additionally, circular economy strategies can help to guard against rising inflation, as shortage of raw materials is one of the key drivers in inflationary increases, so securing supply can stabilize prices and inflation rates. These improvements increase US industrial competitiveness and create domestic jobs and business opportunities in new areas such as reverse logistics, remanufacturing facilities,[10] and material banks.

The engine that drives these business opportunities is innovation—in product and systems design, material science, and business models. Circular economy strategies like developing novel materials, product-as-a-service models, and take-back systems all spur research and development (R&D) in physical and digital technologies across the economy. For instance, platforms that provide people with access to goods on demand and track materials around the economy can make use of technologies including artificial intelligence, biomanufacturing, the Internet of Things, and distributed ledgers. The US is well-placed to take a leading role on this new horizon of industrial innovation, driving the development of circular economy innovations that can be leveraged "to revitalize U.S. manufacturing, bolster national security, and enable a clean energy economy for all."[11]



The circular economy is critical to US industrial decarbonization

Industrial decarbonization is key to the US achieving its net-zero targets

The US has committed to a goal of net-zero GHG emissions by no later than 2050 and for net emissions to fall by 50% to 52% below 2005 levels by 2030.[12] Recent policy initiatives, like the IRA, have fast-tracked the energy transition, spurring high levels of investment in US renewable energy supply chains. US power and transport sector emissions are expected to fall steeply by 2035, partly as a result of this policy support, but emissions from industries such as cement, steel, and aluminum—critical for sectors across the economy—are expected to remain broadly flat.[13] This is consistent with how global efforts to tackle the climate crisis have focused on a transition to renewable energy, complemented by work to increase energy efficiency, which can address 55% of emissions globally.[14] However, the remaining 45% comes from how we produce and consume the products we use every day—the circular economy approach contributes to reducing these emissions by transforming the way we make and use products.[15]

Almost a quarter of total US GHG emissions come from industry, excluding its consumption of electricity,[16] and many industrial sectors like cement, iron, and steel manufacturing are considered "difficult-to-decarbonize."[17] These industries are often highly resource-intensive, and their emissions are largely generated by extracting and processing the finite virgin materials that make up the products and infrastructure they produce. While efforts to develop low- or zero-emission supplies of these materials are crucial, reducing demand for them in the first place plays an important role in reaching net-zero emissions targets. This is where the circular economy comes in. A circular economy can make more productive use of products and create markets that circulate them after use, for instance through design for disassembly, reuse business models, and product-as-a-service systems.

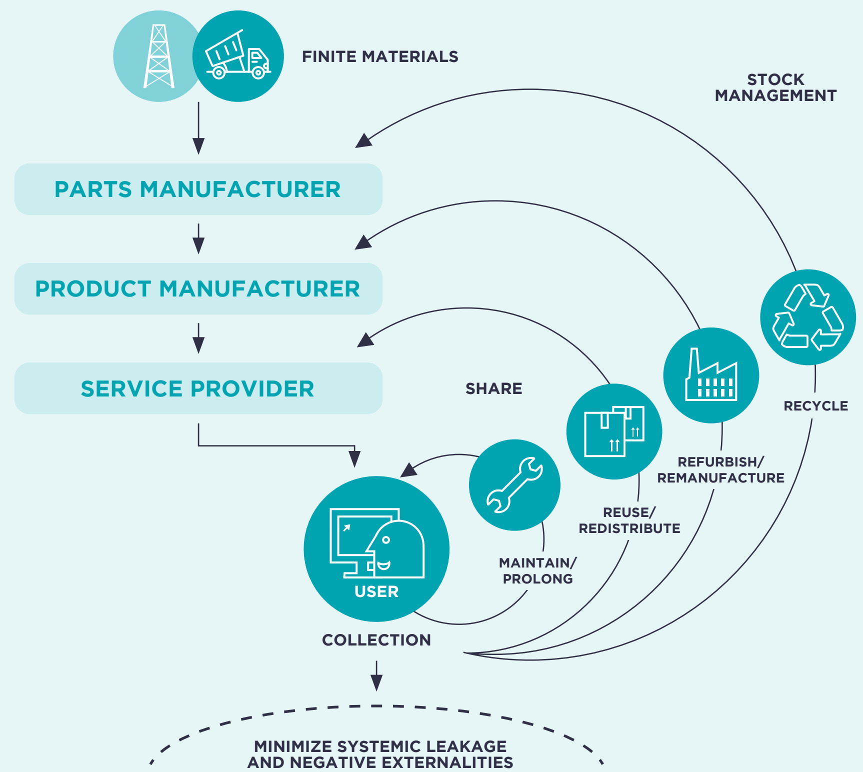
Circular economy strategies can play a crucial role in industrial decarbonization

Circular economy strategies help deliver the systemic transformations in production and consumption patterns needed to increase the value created from the energy, labor, and emissions invested in products and materials. In a circular economy, systems of maintenance, reuse, refurbishment, remanufacture, and recycling can provide people with access to high-quality products while reducing demand for virgin, GHG-intense materials. Business models such as product-as-a-service, in which customers pay for the use of a product and return it afterwards, can unlock these opportunities. The Department of Energy (DOE) recognizes that circular economy approaches could provide a crucial element of industrial decarbonization by 2050, since industrial electrification, low-carbon energy and feedstocks, and carbon capture will not be enough on their own.[18]

Research developed for this report shows there is a substantial economic and climate opportunity ready to be realized now if the US were to transition to a more circular economy in three resource- and carbon-intensive industries selected for review: grid-scale and EV batteries, built environment and infrastructure, and electronic equipment. These industries are heavy users of carbon-intensive and economically critical materials like steel, concrete, aluminum, plastic, and battery metals such as lithium, cobalt, and nickel. Making these three key industries more circular, and thereby reducing raw material inputs, could unlock USD 883 billion to 1.5 trillion in economic value (4% to 7% of US GDP) and reduce annual GHG emissions by 370 to 852 million tons of CO_2e (7% to 16% of total US GHG emissions).[19]

There is significant opportunity outside of these industries as well, such as within industries including agriculture, textiles, automotive, and consumer packaged goods, which are not included in the estimates developed for this report.

A circular economy for industrial decarbonization



How can the circular economy contribute to industrial decarbonization?

Circular economy principles offer solutions across a variety of stages in the value chain:

ENERGY TRANSITION

Circular economy strategies can facilitate the energy transition by expanding the availability of some critical energy infrastructure and related materials. For instance, they can ensure that we maximize the lifetimes of clean energy infrastructure through repair and maintenance, and they can ensure that batteries are repurposed and eventually recycled to increase the availability of critical raw materials for new batteries.

DESIGN AND PRODUCTION

During the design and production phase, circular economy strategies can drive down carbon emissions for products. For instance, companies can increase recycled content in building materials to avoid carbon emissions associated with production of virgin materials, and adopt designs that incentivize disassembly and repair.

USE

As products are put into use, circular economy principles can continue helping to decarbonize. For instance, electronic equipment can be provided as a service or repaired and remanufactured in order to extend its useful life.

END OF USE

Once a product has reached the end of its useful life (after repair, reuse, etc.), circular economy practices like recycling and deconstruction can ensure that the product's embodied carbon, labor, and materials remain in the economy at their highest value.

There is real opportunity for circular economy solutions to decarbonize major sectors today

Transitioning to a circular economy could help to decarbonize industries across the US economy.

In this paper, we take three sector examples, each crucial to US industrial decarbonization, and outline their circular economy potential: grid-scale and EV batteries, built environment and infrastructure, and electronic equipment. These examples heavily utilize the carbon-intensive materials of steel, cement, aluminum, plastic, and battery metals, and they present a substantial competitiveness and decarbonization opportunity if transitioned to a circular economy. Unlocking these benefits will require understanding the unique opportunities and barriers in each industry, crafting responsive policies, and investing in innovation.[20,21]

Embracing the circular economy will create value for businesses that leverage circular economy products and business models to unlock new revenue streams and lower costs. Some companies have already begun capitalizing on the opportunity presented by a circular economy, including to achieve their climate commitments.

Model and methodology

The model that Oliver Wyman developed for this paper estimates the scale of the opportunity if the focus industries were already more circular today. The model demonstrates the significant economic and climate opportunity a circular economy offers for the US—USD 883 billion to 1.5 trillion and 370 to 852 million tons of CO_2e annually.

For the economic value, the model begins with an estimated size of the market for each industry in 2023, which is then adjusted to isolate the size of the markets for materials used in the industry. Several researched assumptions are applied to capture the potential benefits of a more circular economy (derived from circular business models and reduced material consumption). For instance, the model uses a researched assumption that 40% to 60% of US construction material value can be reused. Finally, the model incorporates the impact of enabling factors—innovation, finance, digital technology, and reverse logistics. For instance, the model uses a researched assumption that the impact of digital technology could create 10% to 20% in economic value on average.

For the climate value, the process is the same, starting with the estimated GHG emissions from the industry in 2023 and then adjusting from there.

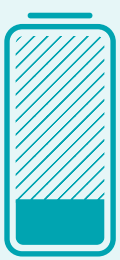
A full list of the assumptions used can be found on page 44. Each assumption has a high and low estimate, reflecting the wide range of values uncovered in research.

Future modeling could go further to assess the opportunity over time as specific new policies come online, the economy grows and shifts, and the carbon intensity and circularity of the industries evolve.

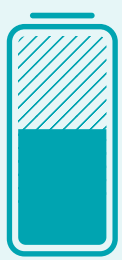
	Economic opportunity today: 4% to 7% of US GDP	Climate opportunity today: 7% to 16% of total US GHG emissions
Grid-scale and EV batteries	~USD 6 to 24 billion	2 to 3 million tons of CO_2e
Built environment and infrastructure	~USD 575 billion to 1.1 trillion	295 to 538 million tons of CO_2e
Electronic equipment	~USD 301 to 388 billion	73 to 311 million tons of CO_2e
Total across three sectors reviewed	USD 883 billion to 1.5 trillion in economic value (4% to 7% of US GDP)	370 to 852 million tons of CO_2e (7% to 16% of total US GHG emissions)

Grid-scale and EV batteries

Renewable power build-out—particularly energy storage assets—and widespread adoption of EVs require large quantities of critical raw materials.[22] The US EV battery and grid-scale battery markets are estimated to be around USD 22 billion[23] today but are projected to grow ~2.5x to nearly USD 56 billion[24] by 2030.[25] The global supply of critical materials for battery production is limited and complicated,[26] and the US lithium-ion battery production capacity is forecasted to be less than half of demand.[27] Those projections are coupled with the reality that raw material costs account for a greater share of battery costs than they did even five years ago.[28] As technology learning and economies of scale drive down overall production costs, the unavoidable material costs take on increased significance.[29]



The US EV battery and grid-scale battery markets are estimated to be around **USD 22 billion** today...



...and are projected to grow ~2.5x to nearly **USD 56 billion** by 2030.

With such high supply chain vulnerabilities for the materials involved, the grid-scale and EV battery industries are ripe for circular solutions that keep these valuable materials circulating within the US economy. A circular economy for grid-scale and EV batteries could include, for example: batteries designed for reuse, disassembly, repair, and remanufacturing; alternative business models like product-as-a-service systems for batteries and manufacturer take-back programs; and, efficient and effective recycling infrastructure for when the batteries can no longer be repurposed. These opportunities are promising because projections show that retired batteries could supply between 10% and 60%[30] of certain battery metals globally by 2040, even though just 1% of lithium is recycled today.[31]

Applying circular solutions to the large-scale battery industry can push down material costs,[32] reduce GHG emissions and improve environmental outcomes,[33] lower toxicity, and protect national security. Our analysis suggests that more circular practices within the US battery industry can generate ~USD 6 to 24 billion[12] in economic value and reduce GHG emissions by 2 to 3 million[12] tons of CO_2e. The economic value is primarily driven by cost savings stemming from the reuse of raw materials and the incorporation of new industrial technologies. The GHG emissions reduction would be driven by, for instance, reduced extraction and production emissions due to extended lifecycles. Furthermore, a circular economy for large-scale batteries can make an important contribution to tackling hard-to-abate emissions associated with the production of other products and infrastructure, including by offering a crucial enabler to the energy transition. Achieving net-zero emissions for the industrial sector will require a fully decarbonized power grid, supported by a strong battery storage network, which can be enabled and enhanced by a more circular economy for large-scale batteries.

Businesses in the EV battery and grid-scale battery space face barriers to capturing the opportunity. The primary barriers revolve around unclear and inconsistent definitions, the absence of key operational and logistical providers, and a lack of product standardization. Without standardized definitions or measurement frameworks, it can be challenging to demonstrate to customers that their solution has lower embodied carbon. Next, there is a need for expanded operations to manage batteries once they are used—reverse logistics, storage facilities, testing capacity, processing facilities, etc. Connected to that need are regulatory and cost challenges around classifying and transporting used batteries. Furthermore, as batteries are an evolving industry, each original equipment manufacturer has a fundamentally different manufacturing scheme for the battery, occasionally changing year over year, which complicates remanufacturing.

Business case – BBB Industries

Founded in 1987 as an automotive parts remanufacturer, BBB Industries (BBB) discovered early on that offering high-quality remanufactured parts was just as competitive as producing new parts with virgin materials.

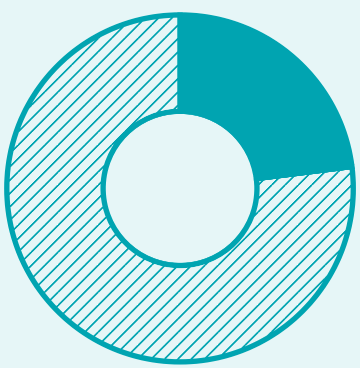
> **"We have about 1/10th the waste, half the energy consumption, and less than 30% of the production emissions compared to a typical manufacturer—we're making waves across different industries throughout the US and the world. Every business has the ability to do what we're doing at some level."**
>
> *Theo Lamperis, Sustainability Analyst, BBB Industries*

Automotive electrification opened new revenue pathways for BBB, starting with remanufactured electric steering systems and evolving to EVs and grid-scale batteries for stationary storage.[34] TERREPOWER is the division of BBB Industries that services the EV and renewable energy sectors. When BBB receives an EV battery core, the company performs diagnostic tests with its proprietary tools to determine if the battery is a candidate for remanufacturing or e-mobility applications, or if it might need to go to stationary storage. If deemed a candidate for one of those outcomes, the battery is disassembled, the components are validated or replaced, and the battery pack is re-assembled. It then undergoes full performance testing before being sent back to a customer.

By giving another lease on life to EV batteries that would otherwise be destined for scrapyards, BBB dramatically reduces raw material costs and can offer its customers a significantly more cost-effective product. BBB also leverages a core charge (a refundable deposit to encourage return of the battery for remanufacturing), another circular business model, to indicate to its customers that it sees value in the products it sells, even when the customer no longer does. Furthermore, the reuse and remanufacturing of batteries keeps critical materials within domestic holdings. "We want to ensure that the critical materials to create solar panels and EVs are kept in America, which then ensures we have the materials to meet our goals," says Maria Caballero, President, TERREPOWER.[35]

Built environment and infrastructure

The US economy spends nearly USD 2 trillion on construction annually, and this spend is projected to grow to USD 2.7 trillion by 2030.[36] Around half of this is spent on materials, including carbon-intensive steel, concrete, and glass.[37] It's estimated that between 11%[38] and 14%[39] of US GHG emissions come from the manufacturing of construction materials.[40] Construction and demolition (C&D) waste makes up 23% of the US waste stream.[41] The US's commercial building stock includes around 6 million buildings, nearly half of which are over 40 years old,[42] and the federal government alone has a portfolio of 2.8 billion square feet of buildings.[43]



23%

of the US waste stream is made up of construction and demolition waste

There is ample opportunity for circular solutions in the built environment space. The US typically uses 15% to 25%[44] more construction materials than structurally needed, and 40% to 60%[45] of construction materials used can be reused after their first life. A circular built environment can include, for example: making buildings more modular, flexible, and multi-purpose; designing for deconstruction and reuse; repurposing or renovating existing buildings instead of undertaking new construction; transitioning to lower-carbon or more durable materials (e.g. through alternative manufacturing processes or innovative new materials); using digital platforms to optimize design and increase use rates; utilizing digital tools that can help turn buildings into material banks; and, developing novel future ownership models. Through these strategies and others, the economic value generated from carbon-intensive materials can be maximized.[46]

Our analysis suggests that circular economy models within the US built environment can generate ~USD 575 billion to USD 1.1 trillion in economic value and reduce GHG emissions by 295 to 538 million tons of CO_2e. These significant opportunities are driven largely by the reduction of raw materials through design (which in turn avoids emissions associated with virgin production) and through the reuse of carbon-intensive materials like steel, and by keeping out of landfills materials that emit carbon at their end of life, like wood.

There are, however, several challenges to achieving a circular economy for the built environment and infrastructure. Most buildings are demolished after their first life rather than deconstructed, and even in the cases where buildings are disassembled, there are limited options for storing, transporting, recertifying, and reselling the components. There is a need for a skilled disassembly workforce. Additionally, many construction standards are material-based rather than performance-based, meaning that they incentivize the use of particular materials rather than the use of the lowest-carbon innovative materials or designs. Perhaps, underlying that challenge, there is also a lack of standardized, comprehensive, and cross-industry carbon measurement techniques. This results in inconsistent or unbalanced incentives, where there is insufficient information to compare different approaches. Furthermore, where reused components, or novel lower-carbon alternatives such as mass timber, are used, a building project is riskier in the eyes of investors and insurers because these more innovative approaches are less widely known and proven in today's linear economic system. This can make financing circular construction difficult.

Business case – Arup

Arup, founded in 1946, is a global collective of engineers, designers, advisors, and experts with a stated goal of “developing a truly sustainable built environment.” Arup optimizes the efficiency of material use through the building design phase and works in close collaboration with its clients and partners to shape a better world. Arup designs out embodied carbon where possible by reducing the materials needed, reusing components, specifying lower-carbon materials, and ensuring robust end-of-life planning for structures.[47] By leveraging reused materials, Arup can reduce raw material costs for its clients and provide some of the only end-to-end advisory services in the US for emerging sustainable materials and practices, such as working with mass timber. This creates unique circular revenue pathways for the global firm and its high-profile projects.

“Cost savings and carbon savings go hand-in-hand, at least today you can’t do one without the other.”

Lauren Wingo, Associate, Arup

To differentiate its services and better evaluate its impact, Arup committed to whole life-cycle carbon assessments for all buildings projects, which allows the company to quantify the benefits of a circular design approach. Arup’s assessment techniques encourage upstream circular actions like rethinking, reducing, and reusing, rather than downstream circular actions like recycling.

For example, Arup rethinks the materials used in a construction, questioning whether mass timber should be used instead of steel or concrete, and works to reduce the total number of materials needed, reusing existing components as much as possible. These circular actions can help reduce the embodied carbon within buildings by 30% to 50%[48] and send signals up the construction value chain to industrial manufacturers that there is demand for lower-carbon materials.

Electronic equipment

The US electronics industry is worth around USD 382 billion today,[49] with raw materials accounting for 47% to 55%[50] of the market. These materials include carbon-intensive steel, aluminum, and plastic. Many electronics also contain batteries. Many electronics are, on average, disposed of years before they are designed to be,[51] and many electronics are not recycled at the end of their lives.[52] Currently, over 60 million tons of electronics are discarded each year.[53] This is expected to grow to over 80 million tons per year by 2030.[54] In 2018, the US alone generated 2.7 million tons of consumer electronic waste,[55] in addition to 5.3 million tons of major appliances[56] and 2.2 million tons of small appliances.[57,58] In the US, less than 40% of consumer electronics were recycled; nearly 40% of major appliances were landfilled; and, about 94% of small appliances were landfilled or burned.[59]

In the US in 2018, over **60%** of consumer electronics and nearly **40%** of major appliances were landfilled; and, about **94%** of small appliances were landfilled or burned

Circular economy solutions can help transform the electronics space through product design and novel business models, leading to a range of positive business outcomes, including decarbonization. Designing products to be more easily repaired, disassembled, and recycled, and bringing end-of-life processing in-house can generate immense value for companies by limiting their need for new raw materials.[60] Businesses can incorporate design for disassembly, product take-back services, reverse logistics, and technology to reuse critical materials. Manufacturers can retain ownership and responsibility for the product, selling access to services that incorporate maintenance, upgrades, and product personalization enabled by closer relationships with customers.

Our analysis suggests that circular economy models within the US electronics industry can generate ~USD 301 to 388 billion in economic value and reduce GHG emissions by 73 to 311 million tons of CO_2e. This economic value is primarily driven by a reduction in raw material costs due to fewer materials needed and more strategic reuse of materials that would originally have been wasted, and the avoided extraction and production emissions.

For electronics companies, significant barriers include the availability of reusable or recycled materials and components, challenges with complex and potentially hazardous materials and components, and a lack of the corporate investment needed to make bold design bets, partly due to the challenges of calculating a return on investment on more circular design choices. Investments to capture, store, and recertify components could substantially improve market availability. Finally, a robust ecosystem of recyclers, either within the industry or external to it, could help ensure that the billions of dollars' worth of US electronic scrap is captured rather than sent to disposal facilities.

Case study – Philips

Philips (NYSE: PHG) is a manufacturing conglomerate with a focus on medical equipment and personal health products. Philips has established a set of goals for 2025 that include generating 25% of its revenue from products or services that contribute to the circular economy, closing the loop by offering take-back for all professional medical equipment, and committing to sending zero manufacturing waste to landfills. Philips is on track to reach these goals, with about 20% of its nearly USD 20 billion in revenue coming from products and services contributing to circularity today. These strategies largely rely on Philips maintaining a relationship with its large medical device customers, providing repairs, upgrades, and refurbishment throughout the product lifecycle, and ensuring that new materials are introduced only when needed.

> **"Instead of focusing on one-time sales of a certain product, you shift more to a solutions provider. Then, you're talking about multi-year XaaS deals, or take-back at end-of-use. You'll quickly find out that the ongoing relationship with the customer and the value potential of services and upgrades during the customer use phase is often bigger than the sales of individual equipment."**
>
> *Harald Tepper, Senior Director for Sustainability at Philips*

This strategy lowers Philips' carbon footprint and reduces the raw materials needed. It also allows Philips to leverage its industry and sustainability expertise to advise customers on their equipment footprint. For Philips, creating more value with less via circular business models makes long-term financial and climate sense.

Key insights from sector-specific reviews

Based on our review of the selected sectors and conversations with industry representatives, below are several areas where additional policy would be helpful in supporting the transition to a circular economy:

- Common definitions, language, and goals that can drive alignment, shared understanding, and progress for the transition to a circular economy. For example, clarifying what qualifies as waste versus non-waste (e.g. equipment for reuse) will be an important foundation for other policies
- Science-backed and standardized methodologies for evaluating and communicating the environmental benefits of circular products and services. This information can inform investments and enable businesses, governments, and individuals to better maintain and manage their assets
- Actions to create a level playing field in support of circular economy innovation and the circular economy transition. Because there is no level playing field today, there are some actions that businesses will not take (or at least not quickly) without government intervention. For example, investing in shared reuse infrastructure requires upfront costs that may be difficult for an individual business to justify in the absence of policy action
- More specialized circular economy infrastructure to ensure valuable materials are captured, stored, certified, and transported back into the economy rather than into a landfill. This could include material banks, reverse logistics providers, skilled disassemblers, recyclers, and material certification providers
- Circular economy innovation, supported by investment, to achieve industrial decarbonization. This could be innovation around new materials, new business models and ways of working, or new technologies, among other areas

The US has the opportunity to expand upon current policies to accelerate circular solutions and drive industrial decarbonization

As the US invests in new infrastructure, technology, and energy systems, it has an opportunity to design in circularity from the start to ensure an economically prosperous, resilient, and thriving future.

Policy can create the enabling conditions to capture this opportunity, while businesses can work in parallel toward the same outcome. Businesses and federal policymakers have made progress on this path, but the next step is creating a US policy environment that moves from making space for circular economy solutions to actively promoting and fostering them.

The current policy landscape makes space for circular solutions

Recent legislative and executive actions have catalyzed a step-change in industrial decarbonization, largely driven by three main laws: the Inflation Reduction Act (IRA), the Bipartisan Infrastructure Law (BIL) which is also known as the Infrastructure Investment and Jobs Act (IIJA), and the Creating Helpful Incentives to Produce Semiconductors and Science Act (CHIPS and Science Act). Combined, these three acts introduce around USD 2 trillion[61] in new federal spending over the next 10 years. In addition, executive agencies, such as the Environmental Protection Agency (EPA) and the White House Office of Science and Technology Policy (OSTP), have picked up on the momentum from these three laws to further decarbonization and circularity.

Recent US policy creates space for indutrial circular solutions, including:

BIL

Signed into law November 2021

Bipartisan Infrastructure Law

Most comprehensive investment in US domestic infrastructure since 1950s.

Supports circular economy solutions through sustainable infrastructure projects, grants for materials management, and funding for battery reuse and recycling.

USD 1.2 trillion

Allocated for power infrastructure, roads and bridges, public transit, waste and recycling infrastructure, and more.

CHIPS

Signed into law August 2022

CHIPS and Science Act

Largest sector-specific industrial policy act since the Cold War.

Requires a new national science and technology strategy to include circular solutions and supports other initiatives that could contribute to circular economy solutions.

USD 280 billion

Allocated to revitalize domestic semiconductor manufacturing and strengthen American microchip supply chains, scientific R&D, and commercialization.

IRA

Signed into law August 2022

Inflation Reduction Act

Largest ever investment from the US to address climate change.

Incorporates circular economy solutions into grant programs, federal procurement, and support for research and innovation, among other things.

USD 400 billion

Allocated toward climate funding, including clean energy infrastructure, EVs, and R&D, with support for domestic production and procurement.

The Inflation Reduction Act (IRA)

The IRA is the single largest investment in climate action in US history.[62] It allocates nearly USD 400 billion[63] toward substantially lowering the nation's carbon emissions by the end of this decade, by investing in American innovation and advancing the global clean energy economy. IRA investments can support circular economy solutions, including through the following examples:

- **Grant programs** – The IRA establishes the Climate Pollution Reduction Grants (CPRG) program, which provides USD 5 billion for cities, states, tribes, and territories to reduce GHG emissions and other harmful pollution. Covered projects include "[p]rograms and incentives to reduce or divert waste . . . through improved production practices, improved collection services, and increased reuse or recycling rates. . . ."[64] The IRA also provides USD 2.8 billion in financial assistance for the Environment and Climate Justice Program (ECJP) to support initiatives like local projects to divert electronics from landfills[65]
- **Federal Buy Clean Initiative** – The IRA provides USD 4.5 billion in funding for the General Services Administration (GSA), Department of Transportation (DOT), and Environmental Protection Agency (EPA) to designate and use construction materials and products that produce substantially lower levels of GHG emissions than "traditional" materials, potentially to include salvaged and reused materials/products and associated services.[66] Relatedly, EPA has announced USD 100 million in IRA-funded grants to help businesses develop robust environmental product declarations to disclose environmental impacts of their construction products[67]
- **National laboratories investment** – The IRA provides USD 1.5 billion to build and upgrade national laboratories and advance American leadership in science, research, and innovation.[68] That funding, and funding from other legislation, can be used to support initiatives by the White House and others to meet the country's GHG emission reduction targets, including through circular economy innovations
- **Domestic production** – The IRA also provides incentives for materials processed in the US, particularly when it comes to materials used in EV batteries.[69] In theory, this can increase the value of domestically held materials, rewarding circular economy solutions that keep materials in the domestic economy and reduce the need for cross-border virgin materials
- **Industrial facilities and clean energy manufacturing** – The IRA also provides DOE with billions for industrial facility retrofits and clean technology manufacturing,[70] including the USD 5.8 billion Advanced Industrial Facilities Deployment Program (AIFDP) which provides support for energy-intensive industrial facilities to complete transformational projects designed to reduce GHG emissions.[71] These projects can include the implementation of industrial processes that minimize negative environmental impacts of manufacturing by designing products that enable reuse, refurbishment, remanufacturing and recycling; by minimizing waste from industrial processes; or, by increasing resource efficiency[72]

The Bipartisan Infrastructure Law (BIL)

The BIL, also known as the Infrastructure Investment and Jobs Act (IIJA), authorizes USD 1.2 trillion in federal spending designed to significantly reframe the future of US infrastructure in order to build the infrastructure needed to deploy clean energy technologies at scale.[73] The BIL creates space for circular economy solutions to be employed in the development of sustainable and clean energy infrastructure, clean energy manufacturing, and grid modernization, among other areas. The BIL also allocates billions of dollars toward clean hydrogen and other technologies, as well as transmission infrastructure, that can set the stage for eliminating waste and pollution in line with the circular economy vision. A few examples of BIL programs that relate to supporting circular economy solutions are described below:

- **Sustainable infrastructure projects** – The Rebuilding American Infrastructure with Sustainability and Equity (RAISE) program provides USD 7.5 billion in grants for sustainable transportation infrastructure projects.[74] This program credits projects that incorporate lower-carbon construction materials and nature-based solutions and that restore and modernize the existing core infrastructure assets[75]
- **Solid waste infrastructure and education** – The BIL includes USD 375 million toward circular economy solutions through its solid waste and recycling provisions. This includes USD 275 million[76] in Solid Waste Infrastructure for Recycling (SWIFR) grants, which can be used to support, for example, material banks,[77] projects addressing construction and demolition waste,[78] sites collecting used electronics,[79] and other activities to provide or increase access to prevention, reuse, and mechanical recycling.[80] The remaining USD 100 million[81] focus on developing battery collection best practices and voluntary battery labeling programs, and more broadly supporting education and outreach about reducing, reusing, and recycling. Collectively, this funding supports circular economy programs that drive innovation and decarbonization
- **Battery recycling and reuse** – The BIL provides USD 3 billion for domestic battery manufacturing and recycling, alongside an additional USD 200 million for a battery design, recycling, and reuse program, and the over USD 100 million mentioned above used for best practices development[82]

The Creating Helpful Incentives to Produce Semiconductors and Science Act (CHIPS and Science Act)

The CHIPS and Science Act authorizes over USD 200 billion[83] toward boosting US semiconductor manufacturing and transforming the leading-edge technologies of today into industrial mainstays of tomorrow. The CHIPS and Science Act directly pushes progress on circular economy strategy and also opens the door to circular solutions that strengthen supply chains, support the development of climate technologies, and bolster US leadership in semiconductors. The appropriations, however, have not matched the authorizations, particularly for the science- and climate-related provisions, limiting the impact of this important law.[84]

The CHIPS and Science Act includes, among other provisions, the following:

- **National science and technology strategy** – The CHIPS and Science Act requires the Director of the Office of Science and Technology Policy to develop a comprehensive national science and technology strategy, including a description of "strategic objectives and research priorities necessary to maintain and advance . . . the leadership of the United States in technologies required to address societal and national challenges, including a transition to a circular economy. . . ."[85]
- **Climate-related provisions** – The CHIPS and Science Act has several climate-related provisions, including: establishing the Directorate of Technology to strengthen US competitiveness and grow the specialized, domestic science and technology workforce, among other things;[86] authorizing a new DOE program for low-emissions steel manufacturing focused on key areas like resource efficiency and alternative materials;[87] and, expanding the National Institute of Standards and Technology's (NIST's) GHG measurement program.[88] Each of these presents a potential opportunity to embrace circular economy solutions on the path to net zero
- **Manufacturing-related provisions** – The CHIPS and Science Act provides over USD 50 billion for American semiconductor research, development, manufacturing, and workforce development.[89] It also provides a 25% investment tax credit for manufacturing of semiconductors and related equipment, in part to secure domestic supply.[90] Relatedly, it provides support for critical minerals mining research and development to make better use of domestic resources and address supply chain resilience. This includes research on improving the manufacturing or recycling techniques and technologies that can decrease energy intensity, waste, potential environmental impact, and costs.[91] Circular economy activities could fit within these investments, bolstering the availability of semiconductors critical to clean energy infrastructure

Executive branch activities

Executive branch agencies are building on and going beyond the three laws described above to identify, invest in, and implement circular economy innovations contributing to industrial decarbonization. The federal executive branch has taken countless steps to move us toward a more competitive, resilient, circular, and decarbonized industrial economy, including:

- **Informal interagency group** – Circular economy champions across the federal government have been convening an informal, multi-agency working group of federal experts and policymakers to align federal work on the circular economy. They are coordinating across the whole of the government in order to capture the circular economy opportunities that exist in the US and move the US closer to the systems change required to secure long-term economic resilience and competitiveness
- **EPA's National Recycling Strategy** – EPA's National Recycling Strategy looks to improve the markets for recycled commodities, increase and upgrade US recycling capacity, reduce contamination, enhance policies, and standardize measurement.[92] While the National Recycling Strategy is focused on downstream solutions, it is the first in a series of circular economy strategies[93] that will center on upstream opportunities in specific industries, in part because "advancing [municipal solid waste] recycling alone will not achieve a circular economy for the United States. . . ."[94] EPA acknowledges throughout its National Recycling Strategy that waste management is responsible for significant carbon emissions and that transitioning to a circular economy can help to abate those emissions
- **White House work on circular economy** – Through its Net-Zero Game Changers Initiative and convening relevant groups,[95] the White House OSTP has opened a conversation about how a circular economy fits into industrial decarbonization and other workstreams. OSTP's Net-Zero Game Changers Initiative in particular includes "Industrial Products and Fuels for a Net-Zero, Circular Economy" as a priority area for early-stage research investments.[96] The White House Council on Environmental Quality (CEQ) also hosted a multi-governmental meeting where experts highlighted the opportunity to leverage circularity to help meet national climate commitments[97]

> **"Participants discussed how producing materials in a net-zero economy will require . . . developing new business models and policies that put a value on the benefits of a circular economy for the environment, economic prosperity, and national security."**
>
> *White House Office of Science and Technology Policy*[98]

- **DOE's Industrial Decarbonization Roadmap** – In 2022, DOE published its Industrial Decarbonization Roadmap, in which DOE identifies "circular economy approaches" as an important cross-cutting approach to industrial decarbonization.[99] The Roadmap notes the importance of circular economy approaches for decarbonizing industries like cement and chemicals, but it also underscores the need for additional research, development, and demonstration
- **DOE's Re-X Before Recycling Prize** – DOE has established a prize for "re-X" projects for established waste streams (including discarded electrical devices and building materials) and emerging waste streams (including clean energy technologies like batteries).[100] Areas of interest for the projects include: extension of battery lifetimes; recovery and repurposing of building materials; repurposing batteries for a second life in a different application; and, improved access to wastes and markets via improved data and analysis, logistics, and collection
- **DOE's Advanced Industrial Facilities Deployment Program** – Through the BIL and the IRA, DOE has over USD 5.8 billion in funding to support transformational GHG-reducing projects for energy-intensive industrial facilities.[101] With this program, DOE's priorities include minimizing "product-level GHG emissions to drive toward low- and zero-carbon solutions and accelerate the market for clean materials,"[102] and decarbonization approaches highlighted include smart manufacturing principles and reuse of waste streams in other industries[103]
- **Research partnerships** – The Reducing EMbodied-energy And Decreasing Emissions (REMADE) Institute is a public-private partnership (PPP) across industry, academia, and DOE, enabling R&D of technologies to reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing. To do that, REMADE focuses on technologies essential to reusing, remanufacturing, and recycling energy-intensive materials like metal, fibers, polymers, and electronic scrap.[104] DOE has also established the ReCell Center, led by the Argonne National Laboratory, and focused on fostering a battery recycling industry in the US[105]
- **NIST Circular Economy Program** – NIST has a Circular Economy Program working toward a circular economy by filling the gaps in the materials, data, and measurement science fields. NIST is actively researching and working to develop standards related to the circular economy, hosting workshops on these topics, and compiling a circular economy resource registry

Policy recommendations for accelerating industrial decarbonization by transitioning to a circular economy

> **"The circular economy is a journey. Sometimes you have to really understand why things aren't working the way they should, and then you change the incentives."**
>
> *Harald Tepper, Senior Director for Sustainability at Philips*

Existing US laws and federal initiatives have opened the door for circular economy solutions to contribute to industrial innovation and decarbonization, but more is needed to create a cohesive, multi-industry strategy that evolves beyond today's fragmented policy landscape. In order to expand the adoption of circular economy solutions to further decarbonize our economy, an aligned set of policies are needed to: **(1) set the direction for travel, (2) help understand and communicate the benefits of circular economy activities, (3) remove barriers to circular economy activities, (4) mandate circular economy solutions, and (5) continue to drive innovation.**[106]

These priorities should be accompanied by corporate commitments to and investments in decarbonization and circular economy solutions—both ambitious policy measures and accelerated business action will be crucial to unlocking progress. The fastest way forward is an "ambition loop" in which government policy and business action mutually reinforce and build off each other to grow ambition and progress toward a circular economy.[107] Furthermore, businesses are in a position to help ensure that policy facilitates (and does not hinder) the transition to a circular economy and the benefits it promises.

Set the direction for travel

To harness the potential of policy to scale the circular economy transition, a shared understanding of the systemic nature of the opportunity and a common direction for travel are needed. The government can set the US economy on the path toward the systemic shift required to build a circular economy and capture the industrial decarbonization opportunity.

A circular economy vision and aspirational goals should be backed by science and focus on topics like circular design, reuse business models and infrastructure, and systems for repair. A vision can establish a shared vocabulary around what to work toward and how to best achieve it. Goals can provide a springboard for context-specific policy development and can catalyze private sector innovation and the development of solutions that can be deployed and scaled rapidly around the world.

A coordinated, whole-of-government approach to the circular economy will also allow policymakers and economic actors at large to share information and to understand and highlight where circular economy solutions can and should contribute. A cross-government, interagency process can help connect and mainstream circular economy principles and their associated climate benefits for different policy portfolios, helping to deliver a transition where the policy signals align.

Where policymakers might start

- Formalize the existing informal interagency circular economy working group
- Ensure circular economy solutions are incorporated into the US's Nationally Determined Contribution (NDC) for climate and prioritized in the CPRG program
- Encourage federal agencies to continue incorporating circular economy principles across their work to begin to understand what a national circular economy roadmap could look like for the US

Help understand and communicate the benefits of circular economy activities

Policy is needed to help businesses and governments better understand the impacts of circular economy activities, particularly how they can contribute to decarbonization. This will require:

- **Standards, research, and data collection** – Agreed upon standards (including definitions) for measuring the climate, economic, social, and nature impacts of circular economy activities, accompanied by expanded research and data collection on such impacts

For businesses, building out data sets based on common standards is critical to ensuring high-quality measurement efforts which in turn support the business case for investing in circular economy initiatives and transitioning to circular business models to further industrial decarbonization. Similarly, as the government proceeds on a path toward industrial decarbonization, robust circular economy data and measurement frameworks will lead to improved comparability and better outcomes. This information can help to inform how the government invests its funds and resources, to identify where circular solutions may offer key contributions to national goals, and to evaluate the success of investments and the achievement of goals.

- **Communication and traceability** – Systems in place for communicating about businesses, their products, and their benefits more robustly across the value chain, with the public, and with the government

For customers (individuals, businesses, government, etc.), information on the characteristics and climate impacts of products and services could help to ensure that products are maintained, upgraded, repaired, recycled, and carefully managed. It could also inform purchasing decisions and encourage companies to compete on circularity in addition to quality and price. Information transfer can be improved through frameworks for reporting embodied carbon, measures for ensuring traceability across the supply chain like digital product passports, and public education programs for schools and other audiences. Additionally, carbon reporting frameworks can drive businesses to invest in measuring and reducing carbon emissions, including through circular economy solutions.

Where policymakers might start

- Convene stakeholders to assess the information gap and identify opportunities to develop new data and standards related to the impacts of circular economy solutions, including information relevant to awarding funds under the IRA, BIL, and CHIPS and Science Act
- Establish a taskforce or PPP to conduct a comprehensive needs assessment of existing measurement methodologies and standards, and develop recommendations
- Evaluate the opportunity for mandates like right-to-repair legislation,[108] digital product passports,[109] and public education campaigns to drive improved information sharing and environmental outcomes

How industry might support progress today

- Participate in third-party processes to develop and pilot standardized measurement frameworks or common standards
- Conduct assessments on the impacts of circular solutions and business models to inform internal decision-making processes; coordinate sharing of such data to encourage widespread understanding and, where appropriate, adoption
- Pilot digital product passports for key materials and products such as EV batteries

Remove barriers to circular economy activities

Policy can pave the way to a more circular economy by removing barriers that businesses face at a fundamental, existential level as well as at a practical, implementation-oriented level. There are three key ways that policy can and should smooth the path to a circular economy:

- **Making the economics work** – Leveling the playing field to enable circular economy solutions to become the norm, rather than the exception, thereby unlocking benefits at scale

Today, prevailing economic policies are hardwired for and by the linear economy. Resetting the playing field and making the economics work can help businesses to prioritize upstream solutions like circular design, reusability, and durability. Policies that can help make the economics work may include tax incentives, procurement policies, R&D tax credits, subsidies, and property tax abatements—all favoring circular economy solutions that contribute to industrial innovation and decarbonization.

- **Addressing circular economy infrastructure needs** – Buildout of shared circular economy infrastructure like material banks and reverse logistics platforms and facilities, in addition to expanded refurbishing, remanufacturing, recycling, and repair facilities

Expanded circular economy infrastructure is needed to help organizations collect, lease/sell, and rent/purchase components, materials, and products after their initial use. The upfront costs to set up and maintain the circular economy infrastructure needed to accelerate the transition may be too significant for individual organizations to take on alone, but the lack of infrastructure is a major barrier to acceleration. Policy intervention could address these challenges with tools like gap assessments to understand circular economy infrastructure needs, investment programs (including grants, matching funds, co-investing, etc.) to direct funding to respond to those needs, and programs establishing public-private partnerships.[110]

Where policymakers might start

- Assess and catalog procurement best practices for priority materials and industries; begin with a review of state-level buy clean initiatives[111] to understand how they account for embodied carbon, employ material- versus performance-based assessments, encourage reuse of components, etc.
- Evaluate existing subsidies and tariffs for opportunities to maintain a level playing field between domestic and foreign industry
- Conduct a gap assessment on the circular economy infrastructure available to support key industries transitioning to a circular economy; evaluate existing programs that could fill gaps
- Explicitly include and encourage circular economy-oriented projects under IRA and BIL grant programs (e.g. the CPRG program, the ECJP, the AIFDP, the RAISE program, and the SWIFR grants, all discussed above)
- Proceed with and expand upon efforts to classify or reclassify certain material streams in a way that makes them easier to manage in a circular economy[112]
- Ratify the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal

- **Facilitating the management of products after use** – Rethinking and simplifying how materials, product, and components are classified and transported after they have been repaired, remanufactured, or prepared for reuse

At present, businesses face uncertainties and difficulties when it comes to reusing materials and equipment—e.g. whether they are safe to use, whether they need to be managed as waste, how they can be moved across boundaries for repair. Resolving those challenges can keep materials in the economy and support a coordinated, scaled transition to a circular economy, which can in turn deliver industrial decarbonization benefits. To do that, there is a need for policies like material recertification standards; clear definitions of when something is no longer waste; direction on proper management of specific products and materials after use; work to ratify the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal; and, adjustments to occupancy, usage, and lifespan requirements for built environment.

Collectively, these policies would allow US industry to more easily store, recertify, redistribute, reuse, and recycle components and materials, thereby lowering costs and getting more economic value out of embodied carbon. These policies would also ensure that such activities are economically viable at scale.

How industry might support progress today

- Participate in PPPs for circular economy infrastructure buildout
- Coordinate industry education on availability of existing funding opportunities for circular economy projects
- Develop a mechanism to share industry-specific learnings on decarbonization and circularity
- Collaborate on third-party recertification standards for reusable components

Mandate circular economy solutions

Where an industry presents a particularly significant or urgent opportunity for decarbonization through circular economy, policy can mandate the adoption of circular economy solutions to accelerate and ease the transition. These mandates can require solutions across the product lifecycle, including:

- **Solutions for design and production phases** – Mandating changes in how products are designed and produced to make them more circular and carbon-efficient

Making materials and products more durable and more easily reused, repaired, and recycled should start at the design stage. To ensure industry adopts these changes, policies may include design standards and, for the built environment, building code changes, including embodied carbon requirements for new buildings.

- **Solutions for use and post-use phases** – Requiring reuse, repair, recycling, and other circular economy activities for products that have been used

In addition to upstream solutions, businesses need to undertake the measures necessary to drive circular management of products once they are used. Related policies could include Extended Producer Responsibility (EPR) programs, landfill bans, mandatory targets for reuse or recycling, and bans on the destruction of unsold goods. For the built environment specifically, this could also include deconstruction ordinances.

Policies focused on recycling and waste management should be designed to drive upstream changes to the greatest extent possible—e.g. including ecomodulation and reuse targets with EPR schemes, and investing in circular economy infrastructure alongside landfill bans. In order to reap the full benefits, they need to be integrated within a wider policy landscape driving the transition to a circular economy.

Where policymakers might start

- Collate best practices for design for circularity
- Evaluate the feasibility (and potential environmental benefits) of mandatory targets for reuse, recycling, and other circular solutions across key industries
- Collate best practices for cities and states implementing deconstruction ordinances[113] and disposal bans
- Assess opportunities to expand EPR programs to drive upstream changes and apply to new industries[114]

How industry might support progress today

- Develop software that can provide digital material inventories
- Feed into third-party design "templates" for how certain classes of products should be disassembled, such as standardized EV battery housing

Continue to drive innovation

The laws in place today have initiated progress toward circular economy innovation, but fully securing the benefits of a circular economy for future generations will require continued and expanded investment in innovation—innovation for new materials, new business models and ways of working, new technologies, etc. that will deliver on the industrial decarbonization agenda. Focal topics may include reducing the carbon intensity of materials, as well as product features and processes that enable circular economy approaches like product digitalization, product longevity, remanufacturing, disassembly techniques, and recycling.

Policies driving investments in circular economy science and technology, as well as supporting PPPs, could be instrumental in continuing to drive innovation and industrial decarbonization. Publicly funded research and innovation programs are essential for the transition to unlock new circular economy insights and drive long-term innovation.

Where policymakers might start

- Continue work on the Net-Zero Game Changers Initiative to provide targeted investment in research toward a net-zero, circular economy
- Evaluate existing R&D funding to ensure that awards capture the potential that circular economy solutions offer

Conclusion

In the US, the circular economy can deliver on policy priorities such as climate, national security, economic performance, and industrial innovation.

The circular economy offers significant economic and climate opportunities across US industries, including EV and grid-scale batteries, built environment and infrastructure, and electronic equipment.

Grid-scale and EV batteries

Economic opportunity today:

~USD 6 to 24 billion

Climate opportunity today:

2 to 3 million tons of CO_2e

Built environment and infrastructure

Economic opportunity today:

~USD 575 billion to 1.1 trillion

Climate opportunity today:

295 to 538 million tons of CO_2e

Electronic equipment

Economic opportunity today:

~USD 301 to 388 billion

Climate opportunity today:

73 to 311 million tons of CO_2e

Total across three sectors reviewed

Economic opportunity today:

USD 883 billion to 1.5 trillion in economic value
(4% to 7% of US GDP)

Climate opportunity today:

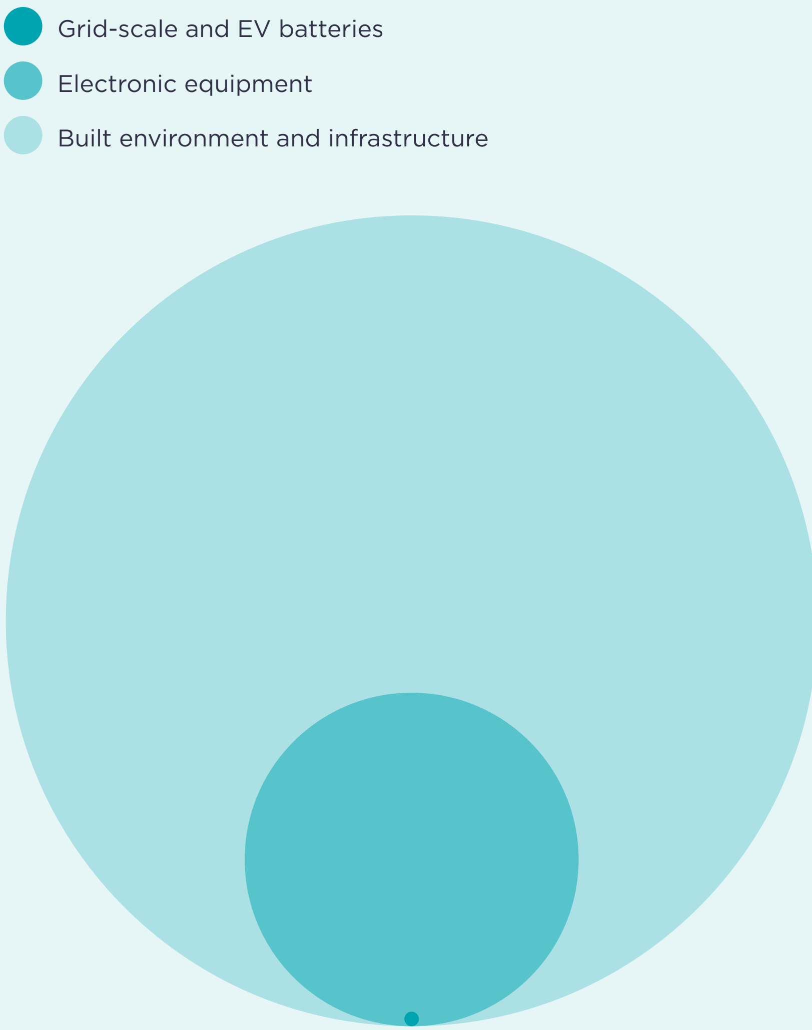
370 to 852 million tons of CO_2e
(7% to 16% of total US GHG emissions)

The US policy landscape—particularly the IRA, BIL, and CHIPS and Science Act, as well as executive branch activities—has already made space for circular solutions to contribute to industrial decarbonization.

The US can build on progress to date and further unlock opportunity through strategic policy interventions. Government and industry can work together to achieve progress toward a circular economy, ensuring that the US maintains its position as a global leader in innovation and economic prosperity. To the right are recommendations for key near-term actions to drive progress:

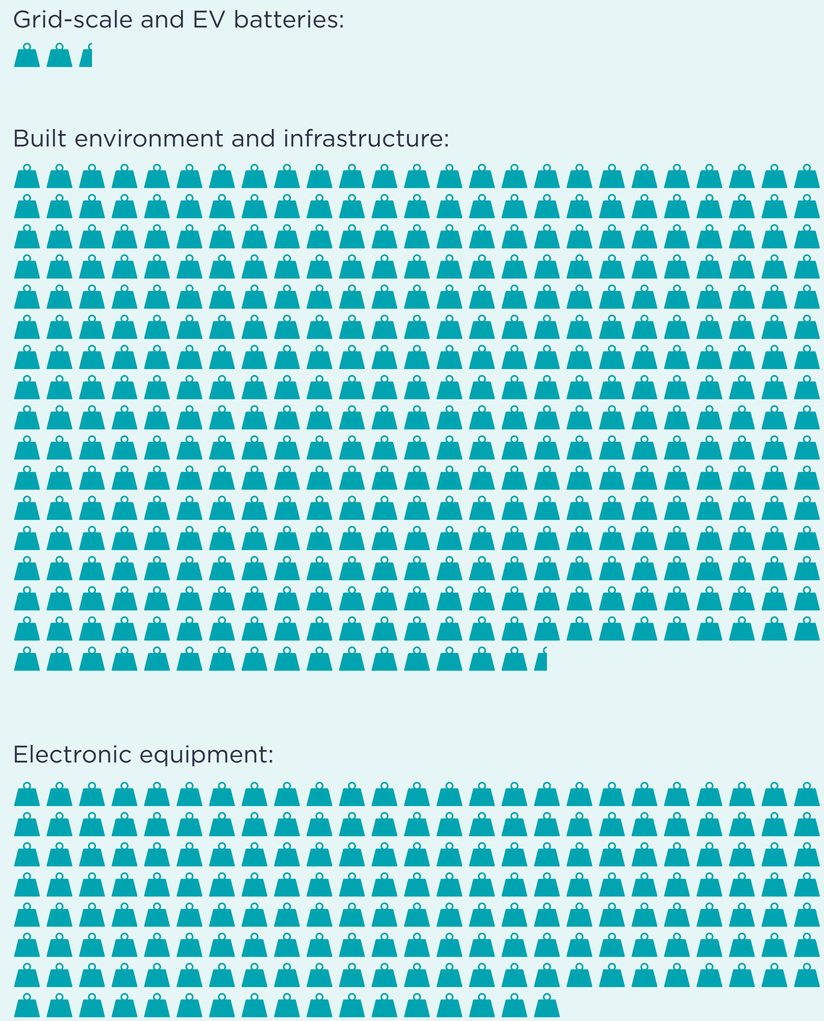
- **Set the direction for travel with, for example, a national vision, goals, and whole-of-government approach to the circular economy**
- **Help understand the benefits of circular economy activities via the development of standards, research, and data collection; communicate that information across the value chain, with the public, and with the government**
- **Remove barriers to circular economy activities by making the economics work, addressing circular economy infrastructure needs, and facilitating the management of products after use**
- **Mandate circular economy solutions covering the design, production, use, and post-use phases**
- **Continue to drive innovation through ongoing and expanded investment**

Economic opportunity today:*



*Averages taken for visualization

Climate opportunity today:*



*Averages taken for visualization

= 1 million tonnes of CO_2e

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About the Ellen MacArthur Foundation

The Ellen MacArthur Foundation is an international non-profit organization that develops and promotes the circular economy in order to tackle some of the biggest challenges of our time, such as climate change, biodiversity loss, waste, and pollution. We work with our network of private and public sector decision makers, as well as academia, to build capacity, explore collaborative opportunities, and design and develop circular economy initiatives and solutions. Increasingly based on renewable energy, a circular economy is driven by design to eliminate waste, circulate products and materials, and regenerate nature, to create resilience and prosperity for business, the environment, and society.

Further information: www.ellenmacarthurfoundation.org
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Technical Appendix: Oliver Wyman Circular Value Sizing Model

Overview

The Circular Value Sizing Model was assembled through Oliver Wyman's research and analysis. The purpose of the model is to estimate the US value potential for three key industries/material ecosystems upon advancement to a more circular economy. The three industries are 'Grid-scale and EV batteries,' 'Built environment and infrastructure,' and 'Electronic equipment.' 'Value potential' is primarily defined as the combination of new revenue dollars available for capture through novel business models and cost savings derived from better management of materials and 'waste.'[115] The model also includes estimates for the impact of four key enablers on the value potential—'Innovation,' 'Technology,' 'Finance,' and 'Reverse Logistics.' This model draws from a number of primary and secondary sources to derive both raw market values ('researched values') and projections of how changes to the market will have an impact on those values ('researched assumptions'). All sources and researched assumptions are documented below.

For the 'Grid-scale and EV batteries' section, researched values are built from the current US EV market and the US grid-scale battery market. Researched assumptions come from a variety of sources. For the 'Built environment and infrastructure' section, researched values are built from current US construction spending. Researched assumptions come from a variety of sources. For the 'Electronic equipment' section, researched values are built from the value of the current US electronics industry. Researched assumptions come from a variety of sources.

Process

Both the economic value and GHG emission numbers produced for this report were estimated through a bottoms-up, multivariable approach. For each of the three key industries, research was conducted to establish both the estimated size of the market and the estimated GHG emissions of the industry in 2023. Each 2023 market and GHG estimate was then adjusted by a high and low factor to isolate the portion of the estimate represented by materials. Each isolated material estimate was then subjected to a series of researched assumptions estimating the impact of more circular business models for that industry. These assumptions included the amount, value, and emission reduction potential of the materials that could be reused or reduced, and an estimate of the impact of new circular revenue opportunities. Finally, the impacts of enabling factors, such as innovation, finance, digital technology, and reverse logistics were also incorporated. Each of these enabling factors was represented again by a higher and lower researched assumption on impact. The impact of both the higher and lower estimates for enabling factors were applied to the value estimates for each industry, after the estimates had been subjected to the series of researched assumptions described above. The analysis does not assert a timeline for the transition to a more circular economy. A full list of assumptions utilized may be found below.

Disclaimer

This model leverages many disparate sources and a range of assumptions to drive possible outcomes. While this model is well-researched, logically sound, and fairly conservative in scope, it is intended to be a good faith estimate and should be caveated as such.

Assumptions

Below are the researched assumptions that were used in the model, along with the source for each value. These sources are also included in the complete source list further below.

Grid-scale and EV batteries		
Researched assumptions	**Assumption**	**Source**
Percent of large scale battery cost that is battery metals (high)	46%	Source
Percent of large scale battery cost that is battery metals (low)	12%	Source
Percent cost savings of using reused and recycled battery materials (high)	40%	Source
Percent cost savings of using reused and recycled battery materials (low)	30%	Source
Built environment and infrastructure		
Researched assumptions	**Assumption**	**Source**
Percent of US construction spending on materials (high)	50%	Source
Percent of US construction spending on materials (low)	40%	Source
Percent of US construction material value that can be reused (high)	60%	Source
Percent of US construction material value that can be reused (low)	40%	Source
Percent of US construction material value that can be reduced (high)	25%	Source
Percent of US construction material value that can be reduced (low)	15%	Source
Percent value of new revenue opportunities for construction using “Green Premium” as a proxy (high)	20.5%	Source
Percent value of new revenue opportunities for construction using “Green Premium” as a proxy (low)	13%	Source
Percent of US GHG emissions that are direct from building materials (high)	14%	Source
Percent of US GHG emissions that are direct from building materials (low)	11%	Source

Electronics		
Researched assumptions	**Assumption**	**Source**
Percent of US electronics spending on materials	60%	Bank of America Global Research (see below)
Adjustment for surplus of electronics goods produced (high)	48.5%	Source
Adjustment for surplus of electronics goods produced (low)	54%	Source
Percent value of new revenue opportunities for electronics using “Green Premium” as a proxy (high)	15%	Source
Percent value of new revenue opportunities for electronics using "Green Premium" as a proxy (low)	10%	Source
Cost reduction of reusing and recycling materials (high)	7.6%	Source
Cost reduction of reusing and recycling materials (low)	10%	Source
Percent of US GHG emissions from electronics (high)	5.9%	Source
Percent of US GHG emissions from electronics (low)	1.4%	Source
Enablement factors (assumed same for all industries)		
Enablement factor assumptions	**Assumption**	**Source**
Innovation and finance – ‘learning rate’ (high)	31%	Source
Innovation and finance – ‘learning rate’ (low)	22%	Source
Digital technology impact (high)	20%	Source
Digital technology impact (low)	10%	Source
Reverse logistics – built environment and infrastructure (high)	$28,262,016,932	Sub-model calculations
Reverse logistics – built environment and infrastructure (low)	$23,044,413,806	Sub-model calculations
Reverse logistics – electronic equipment (high)	$35,696,222,209	Sub-model calculations
Reverse logistics – electronic equipment (low)	$29,106,150,417	Sub-model calculations

Technical appendix sources

This is the complete list of sources used in building the model. The list here includes the sources for researched values and researched assumptions, including sources that were used in building sub-models.

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- McKinsey & Company, The race to decarbonize electric-vehicle batteries (23rd February 2023)
- US Energy Information Administration, Electricity explained: Energy storage for electricity generation (last updated 28th August 2023)
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- Accenture, Seeking responsible leadership (20th January 2020)
- Future Market Insights, Waste Recycling Services Market Outlook (July 2023)
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- US Geological Survey, National Minerals Information Center (last visited 2023)
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- Resource Recycling, Upward momentum continues in PET bale pricing (January 2023)
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- Mahajan, B., Recycled Concrete Aggregate: Crushed Concrete (last visited 2023)
- EPA, Construction and Demolition Debris: Material-Specific Data (last updated 22nd November 2023)

Endnotes

1 Ellen MacArthur Foundation, Completing the picture: How the circular economy tackles climate change (2019)

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11 White House, Industrial Innovation (last visited March 2024)

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14 Ellen MacArthur Foundation, Completing the picture: How the circular economy tackles climate change (2019). The report analyzes the global opportunity, so the breakdown in the US might vary based on US sources of GHG emissions.

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19 These estimates are based on 2023 economic indicators and represent the value of a circular economy in today's context. The research developed for this report does not assert a precise timeline for a full transition to a circular economy across these industries.

20 These industry-specific challenges and success stories were assembled through collaboration with the companies and practitioners at the forefront of the circular economy. In an effort to understand what has been preventing circular solutions from permeating these industries, we conducted multiple interviews with industry leaders and convened nearly 100 leading practitioners of circularity within the battery, buildings, and electronics industries during Climate Week NYC 2023.

21 Innovation is needed in technology, social science, business models, and policy. White House, Advancing a Circular Economy to Meet Our Climate, Energy, and Economic Goals (5th July 2023); see also Yang, M., Chen, L., Wang, J. et al., Circular economy strategies for combating climate change and other environmental issues (2023), ("All the circular economy measures require societal behavioural changes, capital investments, new business models and policies.")

22 To meet the goals of the Paris Agreement, critical mineral requirements for clean energy would quadruple by 2040. In particular, "mineral demand for use in EVs and battery storage [would be] a major force, growing at least thirty times to 2040. Lithium sees the fastest growth, with demand growing by over 40 times . . . by 2040, followed by graphite, cobalt and nickel (around 20-25 times)." International Energy Agency, The Role of Critical Minerals in Clean Energy Transitions (2021)

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24 GlobeNewswire, Grid-Scale Battery Market to Reach USD 30.95 Billion by 2029 at 21.9% CAGR; Advantages of Grid-scale Battery Adoption to Propel Market Growth: Fortune Business Insights (11th April 2023); Federal Consortium for Advanced Batteries, National Blueprint for Lithium Batteries (June 2021)

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31 International Resource Panel, Enabling the energy transition: Mitigating growth in material and energy needs, and building a sustainable mining sector (2023)

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33 See, e.g., Federal Consortium for Advanced Batteries, National Blueprint for Lithium Batteries (June 2021), ("Using recycled materials [assuming a direct recycling method] from spent batteries has potential to decrease: Costs by 40%[, e]nergy use by 82%[, w]ater use by 77%[, and] SOx emissions by 91%.") (citations omitted). For purposes of the model created for this paper, we have assumed that circular economy solutions can drive a 30% to 40% reduction in materials and, therefore, costs and carbon emissions.

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89 White House, Fact Sheet: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China (9th August 2022)

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93 Next in the series, EPA has published and received comments on its Draft National Strategy to Prevent Plastic Pollution and Draft National Strategy for Reducing Food Loss and Waste and Recycling Organics. We expect future strategies to focus on built environment, electronics and critical minerals, and textiles. In its strategies, EPA incorporates the definition of "circular economy" from the Save Our Seas 2.0 legislation.

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95 In February 2023, OSTP co-hosted a roundtable on circular economy innovation and industrial decarbonization with the Ellen MacArthur Foundation. The roundtable participants discussed the climate and economic benefits of the circular economy and highlighted the circular solutions businesses are already executing today. The roundtable also uncovered some of the barriers to circularity, including the need for standardization and measurement, more circular supply chains, and innovation in design and materials science. White House, Readout of the White House Circular Economy Innovation Roundtable (22nd February 2023); White House, Advancing a Circular Economy to Meet Our Climate, Energy, and Economic Goals (5th July 2023)

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103 Office of Clean Energy Demonstrations, DE-FOA-0002936: Industrial Decarbonization and Emissions Reduction Demonstration-to-Deployment Funding Opportunity Announcement (last visited March 2024)

104 Example REMADE projects underway include: a project on machine learning for hybrid and electric vehicle battery prognostics, with the goal of decreasing the time for battery reconditioning and remanufacturing; a project to develop a portable, fast test technology for EV battery health and reusability; a project to automate the disassembly of lithium-ion battery modules for remanufacturing; a project to improve the processing of electronic waste to extract metals; a project to evaluate logistics systems for collection, processing, and production of secondary feedstocks for e-waste; a project to improve recycling efficiency of portable electronics by automating battery disassembly; a project to automate elements of condition assessments for used electronics; a project to develop "design for remanufacturing" rules; a project to develop open access end-of-life databases for construction materials and a related process model. REMADE Institute, Projects (last visited March 2024)

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106 In addition to what is laid out in this report, the Ellen MacArthur Foundation has published Universal Circular Economy Policy Goals which can inform further thinking on goals for circular economy policy. That

report establishes a framework and explores the following circular economy policy goals: stimulating design for the circular economy; managing resources to preserve value; making the economics work; investing in innovation, infrastructure, and skills; and, collaborating for system change. Ellen MacArthur Foundation, Universal Circular Economy Policy Goals (2021)

107 Leading businesses can demonstrate what is possible and be vocally supportive of ambitious policy. Both signal to governments that industry is ready for a higher-level playing field. In turn, ambitious government policy raises the bar for everyone and enables industry leaders to go even further. Industry leaders are then positioned as frontrunners ahead of forthcoming legislation.

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109 Environmental product declarations, nutrition labels, and voluntary digital product passports can provide helpful examples of similar work ongoing today. It will be important to consider how digital product passports will operate across borders and throughout the full supply chain.

110 Similar policy tools can also be deployed to ensure that there is an adequate, trained workforce, including skilled disassemblers and recyclers, able to operate that infrastructure. In addition, we can begin building a skilled workforce by incorporating circular economy concepts in school curricula, in areas such as chemistry, legislation, business, behavioral science, and construction.

111 States with “buy clean” laws include: California, Colorado, New York, New Jersey, Oregon, and Maryland.

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Disclaimer

To quote this report, please use the following reference: Ellen MacArthur Foundation & Oliver Wyman, *An Innovation Pathway to Decarbonization: circular economy solutions for policymakers and industry in the US* (2024)

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