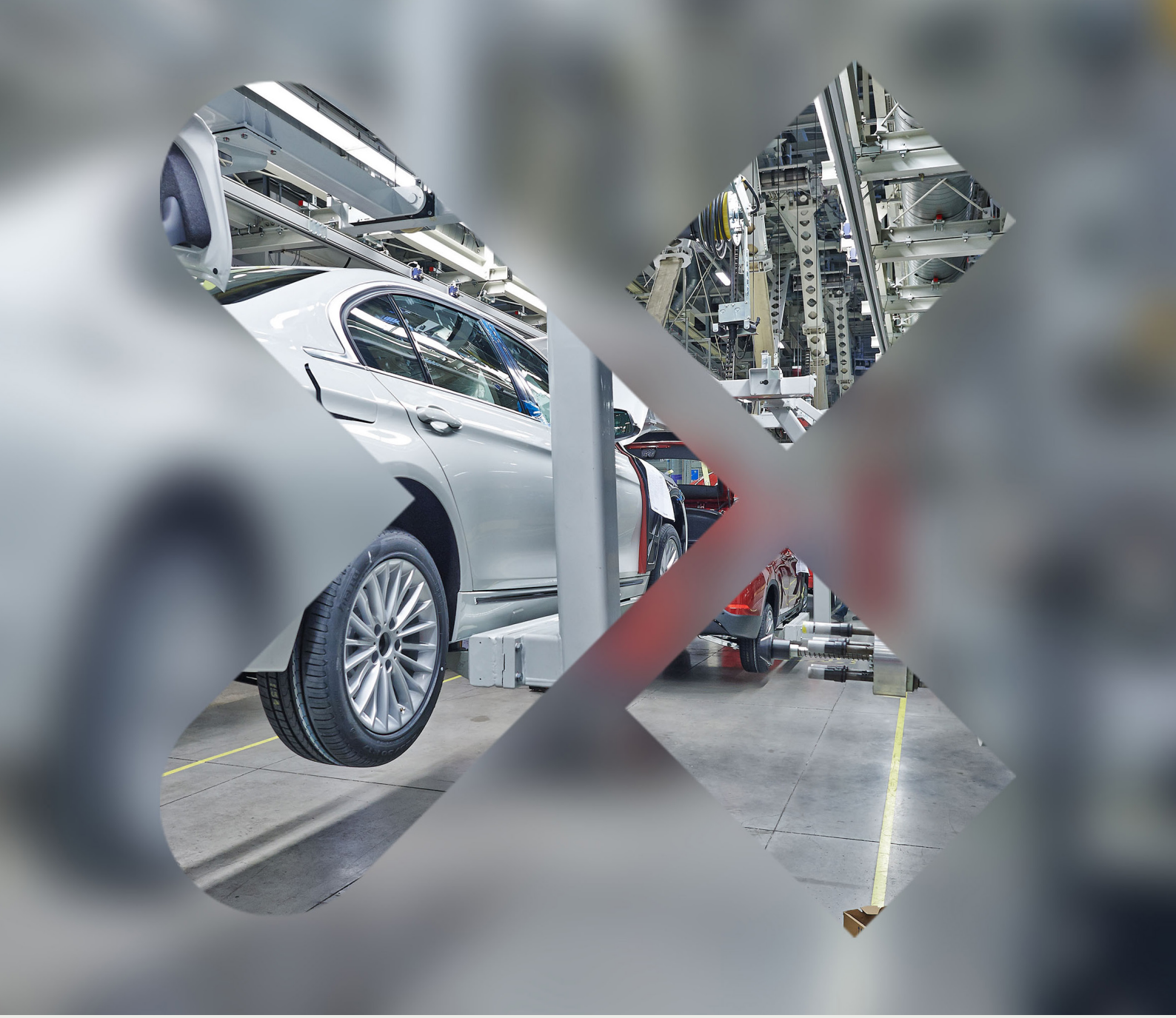

Decarbonizing practices in the global automotive industry

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Index

1 Foreword

This whitepaper examines the current state and trajectory of decarbonization within the global automotive industry. By examining and establishing a baseline on industry action, early- mid- and long-term initiatives can be highlighted to help inform manufacturers and producers how they can engage and push themselves further towards full decarbonization. This effort also highlights the challenges and complexities in the path towards decarbonization, which is complex and layered. Industrial producers should be looking outwards to determine how to take best steps from within.

The white paper is a joint effort of Siemens AG and Frost and Sullivan.

2 Executive Summary

The global automotive industry has taken leading steps in commitments to decarbonize. Early initiatives have brought great benefit in reducing energy consumption, optimizing plant operations, and boosting the use of renewable energy. There remains, however, a great capacity and need for these organizations to do more in order to meet their aggressive targets. Through the development of a decarbonization roadmap, the global automotive industry can take comprehensive steps in energy consumption optimization, energy infrastructure and supply modernization, and pushing forward service-based business models that will help each facility to deliver on its mandate to deliver a global mandate for a sustainable future.

3 Facing the energy transition

The world faces an ever-widening gap between current levels of greenhouse gas emissions and the reduction in levels that must be met in order to mitigate the worst impacts of global climate change. As documented by the United Nation's Emissions Gap Report 2021, the world is currently on track to reach an average temperature rise of 2.7°C, well over the target of 1.5°C. In a globalized, predominantly capitalist economy, the incentives for sustainable growth and profit are often at odds with environmental sustainability.

Fundamentally, however, it is increasingly seen that sustainable economies are reliant on a sustainable environment; industries require raw materials, customers, workers, and transportation and logistics infrastructure that require sustainable and reliable physical and natural environments. The importance of industrial decarbonization to long-term sustainability is well established and leading organizations are taking bold approaches to improving and reimagining business practices.

Sustainabiity, digitalization, health & wellness and business models are the four underlying factors for future transformation. Influencing the four models will be the need to build resilience and lower the financial risk for customers.

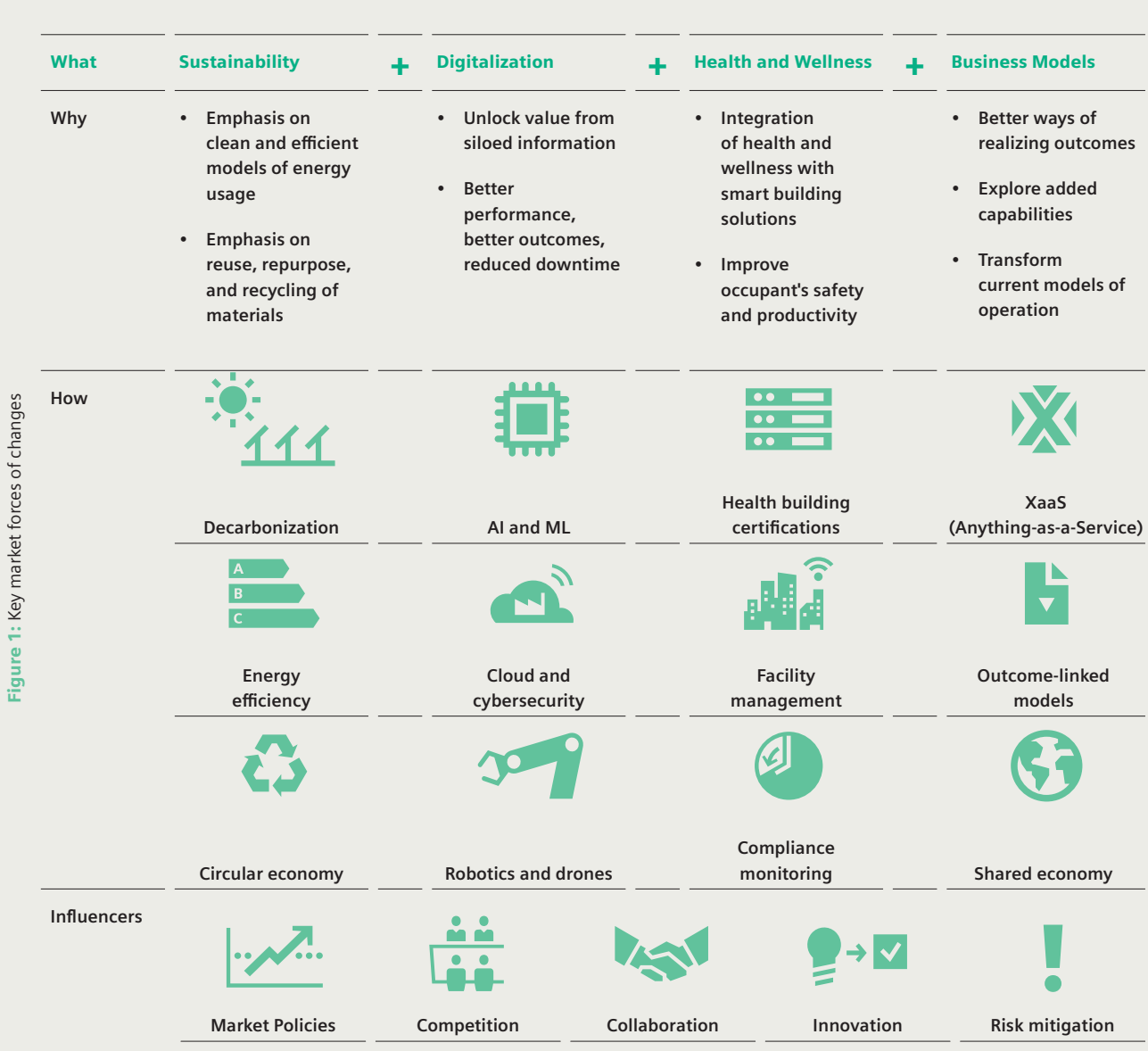


Figure 1: Key market forces of changes

Current status of decarbonization strategies

Decarbonization strategies within the global automotive industry remains at an early stage, overall. Much needs to be done in order to fully achieve decarbonization in regards to Scope 1, 2, and 3 emissions. The global automotive industry is the most advanced in decarbonization among other industrial verticals. A greater rate of adoption of renewable energy, IIoT and factory modernization, and the creation of circular economies has helped drive manufacturing facilities, especially those in North America and Europe, towards decarbonization. The industry benefits from greater levels of consolidation in the market, which can centralize efforts and deliver critical mass.

Key energy intensive areas in the vehicle manufacturing process: material transformation activities such as stamping, casting, and forging (among others) are the most energy intensive steps of vehicle manufacturing, followed by painting. In addition, facility related HVAC, lighting and heating are also significant energy consumers during manufacturing.

Actions to further and achieve industrial decarbonization can be summarized through four key initiatives:

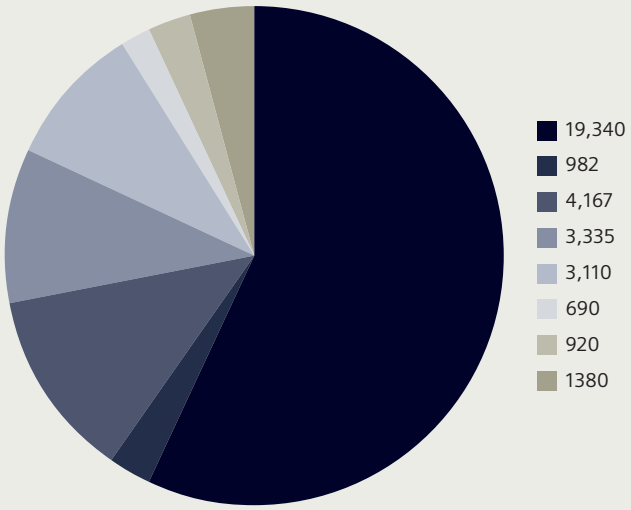
- **Decarbonization Roadmap**: foundational assessments and action
- **Resource Efficiency**: improve energy consumption efficiency and develop circular economies
- **Infrastructure Enhancement**: improve assets and infrastructure
- **Innovative Business Models:** advanced performance contracting

Every organization will need to adopt a range of measures within each initiative to deliver an effective, holistic means to achieve decarbonization. The specific set of activities, timeline of implementation, and means of verification will be unique; in many cases industrial organizations and facilities will benefit from third party assistance to ensure strategies are comprehensive and achievable.

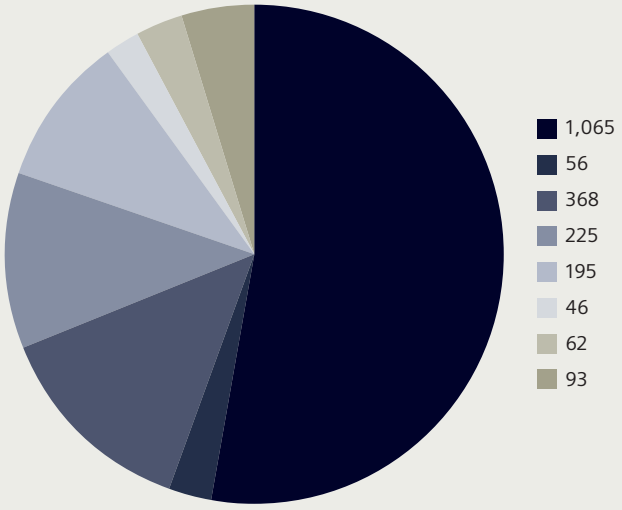
This whitepaper is a step towards understanding the current landscape of decarbonization to help speed understanding and action for all stakeholders.

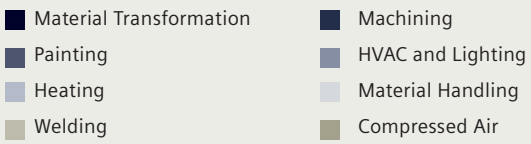
Vehicle manufacturing process – What are the energy intensive areas?

Energy (MJ)



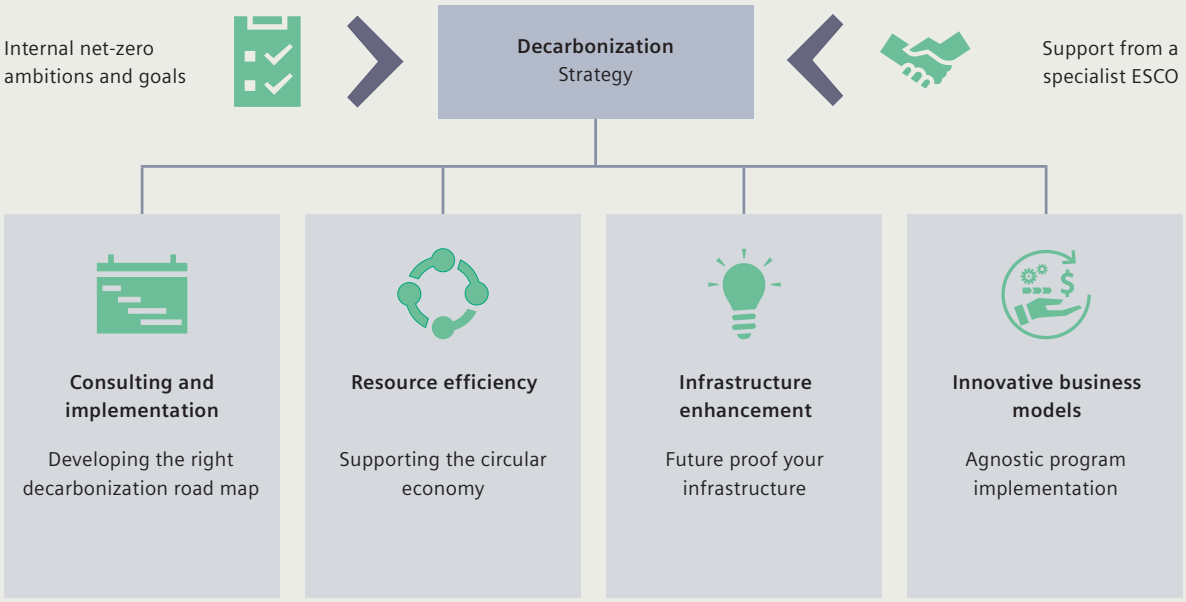
CO_2 (Kg)



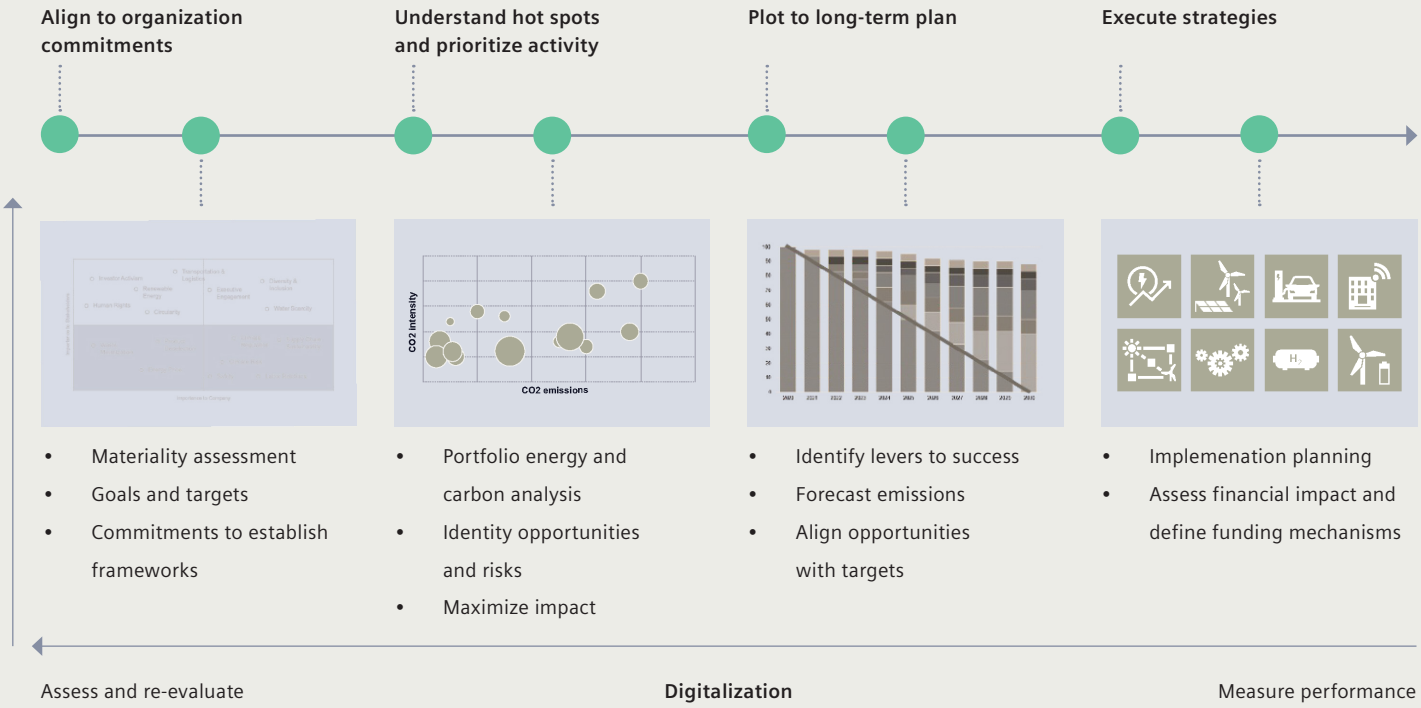


Estimated Energy Consumption (MJ) and CO2 Emissions (Kg) per Major Manufacturing Process for a Generic 1532Kg ICE Vehicle

Develop your decarbonization strategy



Developing the right action plan



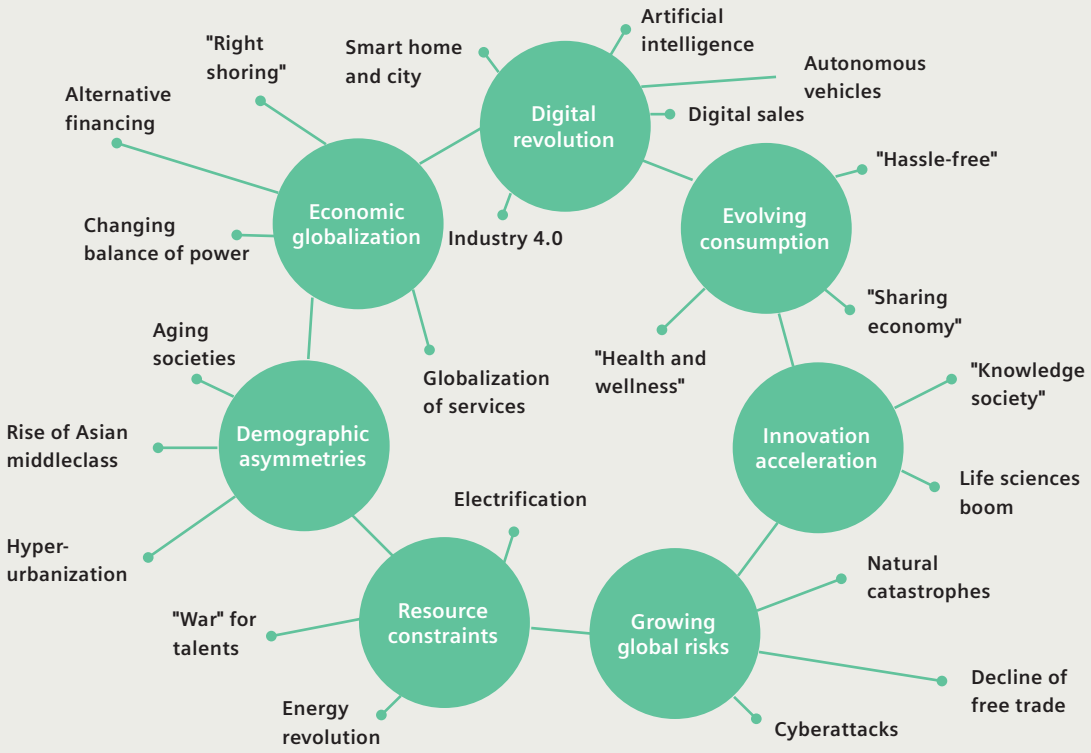
Decarbonization actions in the global automotive industry

The global transport sector is responsible for 14%, or 7 billion tons, of greenhouse gas emissions (Intergovernmental Panel on Climate Change, IPCC). As the world's governments, societies, and economies push towards decarbonization to mitigate the worst effects of climate change, the automotive industry must engage with this global mandate. Keys to this industry's current response are:

- **Power Purchase Agreements (PPAs)** – automobile manufacturers ensure the use of renewable energy through PPAs with their utilities.
- **Energy Reduction and Reuse** – industrial internet of things (IIoT) technologies help optimize operations to reduce energy use and loss and reduce downtime.

Leading global automotive manufacturers, including GM, Honda, Volkswagen, Ford, Toyota, and Nissan, have taken important steps towards PPAs and energy reduction and reuse. Successfully deploying initiatives towards decarbonization, however, requires an acknowledgement and embrace of complexities and challenges within the current state of the industry.

Automotive megatrends and challenges requiring transformative change



Automotive – A Major Actor in Global GHG Emissions

Today, according to IPCC, the transport sector accounts for approximately 14% (=7 Billion tons) of global greenhouse gas emissions, of which an estimated 45% comes from passenger vehicles, and nearly 30% from road freight.

As the use phase of Electric Vehicles (EV) significantly reduces carbon emissions, OEMs have significantly increased EV development programs and set sales targets to transition from Internal Combustion Engine (ICE) to EV.

OEMs are also increasingly turning toward digital solutions to improve energy usage and condition monitoring of their facilities, adopting renewable energy, and turning toward new innovations during manufacturing stages.

The implementation of sustainability in the automotive industry receives significant attention but initiatives are still fragmented

80%
of automotive respondents said that their company plans to transition to carbon-neutral operations.

56%
Out of 74% of automotive OEMs who have an electric vehicle strategy only 56% have it as part of their sustainability strategy.

3%
Yet only 3% of automotive executives and sustainability experts claim that they invest sufficiently above required needs.

52%
Some initiatives receive significant attention, but there is no consistent focus on the entire value chain. The most deployed is supporting a circular economy by 52% of the companies surveyed.

8%
In contrast, sustainability in IT is only being adopted by 8% of the organizations. Sustainable power procurement is also falling short.

45%
The KPIs required to establish accountability and measure progress are also lacking in several areas. For example, only 45% of automotive organizations have dedicated sustain-ability targets for key executivt

The Manufacturing Challenge

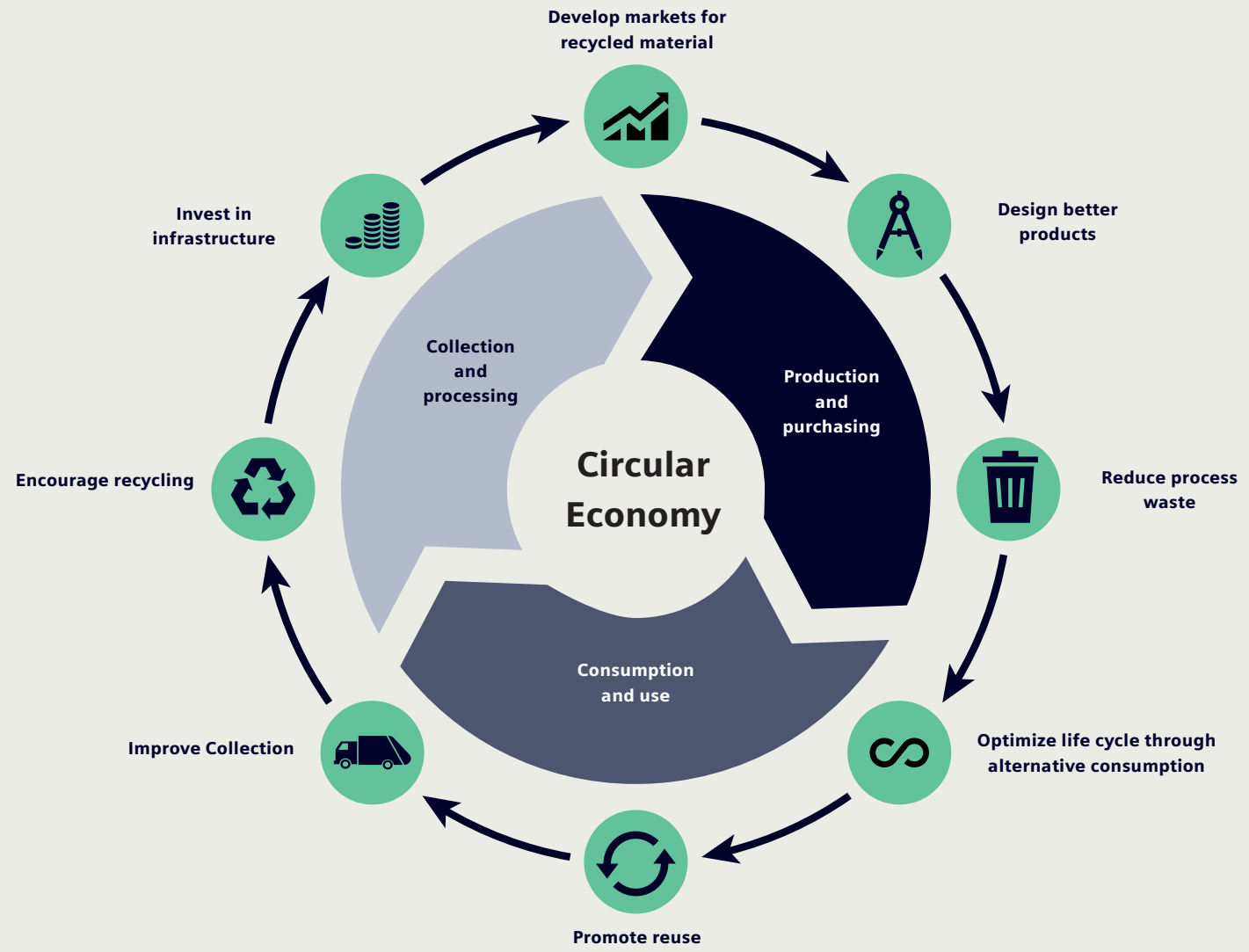
The world's 10 largest automobile manufacturers emitted 35.5 million ton of CO_2 through production activities in 2020. The millions of tons of CO_2 generated sets up the challenge of delivering on upcoming 100% renewable energy use targets: GM (2025), Volkswagen (2030), Ford (2035), and Toyota (2050). Achieving 100% renewable energy use as early as 2025 sets up some of the most ambitious targets compared to any industrial sector and nation state. Indeed, the global corporate mandates adopted by the automotive industry are set to outpace similar targets from the European Union (35% by 2030) and Canada, Mexico, and United States agreement through NAFTA (50% by 2025).

The rise of EV is leading to new challenges for Zero Carbon emission manufacturing facilities. The reason being that battery **EVs possess a significantly larger carbon footprint during their manufacturing stage compared to Internal Combustion Engine (ICE) Vehicles, raising new sets of challenges to the carbon footprint of manufacturing facilities.**

Primary reasons include the Li-ion battery, additional components such as traction motor and electronic controller, along with different vehicle material composition (e.g. more steel & aluminum used).

Key industry drivers for sustainability in automotive manufacturing, 2021
Most companies in the automotive industry are treating "sustainability" as the key objective in both their product strategy and operations in order to increase their global competitiveness.

- **Global Emission Reduction Targets**: The automotive industry has experienced stringent environmental pressures through stringent regulations to reduce emissions and waste throughout vehicle production. Along with this increasing global awareness, OEMs must complying with new environmental standards, while ensuring successful long-term performance.
- **Growing Adoption of Renewable Energy**: A key carbon-cutting strategy for OEMs is the use of renewable energy sources at vehicle production facilities. In addition to installing wind turbines and solar panels at facilities, OEMs are also purchasing large amounts of renewable energy from providers directly to power their plants, or to sell back to the grid to offset emissions from vehicle production.
- **Impact of Digital Transformation**: Due to long lifetimes, upgrading / replacing equipment & facilities to lower emissions requires long term planning & investment. Digital technologies & IIoT solutions have increasingly enabled the implementation of green services for OEMs, providing necessary solutions to monitor and control sustainability related initiatives with relatively lower cost and faster implementations.
- **EV Production to Overtake ICE by 2040**: EV Sales are expected to surpass ICE sales by 2030. With the rise of EVs, vehicle production facilities around the world will have to adapt and modernize in order to accommodate the greater volumes of EV production. In addition, the shift to EV production will lead to higher carbon emissions during vehicle production stage, resulting in increasing needs for facility decarbonization initiatives.
- **Influence of Gen Y & Z**: Sustainability has become a key strategy to meet increasing stakeholders' environmental commitment, strengthening corporate image, and increasing customer satisfaction. A new type of automobile consumer with a stronger interest in sustainability is appearing, and is willing to actively criticize unsustainable manufacturing practices.



Source: Sustainable Global Resources ltd. Recycling council of Ontario

The Rise of Circular Economy in automotive manufacturing

To reduce their carbon footprint, automotive OEMs and ecosystem players are increasingly turning toward decarbonizing energy use, creating circular material flows, extending product lifetime, and improving capacity utilization during usage:

1. Leveraging low-carbon resources, materials, and assembly, along with integration with the energy grid to achieve net-zero carbon emissions across the whole vehicle lifecycle
2. End-of-life disassembly, reverse logistics, battery and other materials recycling to enable resource recovery and close material loops
3. Adopting subscription based ownership, re-use and remanufacturing to increase the lifetime of the vehicles and components
4. Ensure efficient vehicle use over time and occupancy

Within the automotive sector players are increasingly adopting enhanced reuse, sharing, repair, remanufacturing and recycling practices across the entire value chains.

By investing more in design and improving end-of-life management, industry players are able to increase profits, while reducing environmental impact.

75%
Circular economy can help the automotive industry reduce the lifecycle carbon emissions per passenger km by up to 75% by 2030.

55%
As a result of circular economy initiatives, the Mega Tons of Oil Equivalent (MTOE) in the Transportation sector is expected to reduce by as much as 55%.

7M
End-of-life vehicles (ELVs) generate 7–8 million tons of waste every year, contributing to environmental pollution.

80%
Circular Economy strategies can reduce non-circular resource consumption by up to 80% per passenger kilometer for a battery electric vehicle by 2030.

Global CO_2 Emissions reduction targets impact on automotive manufacturing

The automotive industry has experienced strict environmental pressures through stringent regulations to reduce emissions and waste throughout vehicle production.

Along with this increasing global awareness, OEMs must complying with new environmental standards, while ensuring successful long-term performance.

Electrification is to be prioritized in the short and medium tern to meet GHG emission reduction targets. Evolution regarding CO2 regulation has been a key driver for change in the automotive industry, notably in vehicle technology (transition to EV). While the need for GHG neutral powertrains is and has been the key priority in the short to medium term, a change throughout the whole vehicle lifecycle will be necessary to achieve long term net zero commitment.

OEMs are committed to reduce GHG emissions from vehicle production. Multiple OEMs have pledged to reach net zero emissions for their operations by 2050.

Key initiatives include increased renewable energy uptake in their operations, shift to EV vehicles, implementation of innovative technologies throughout vehicle production steps, improved water usage and end-of-life material recycling strategy among others.

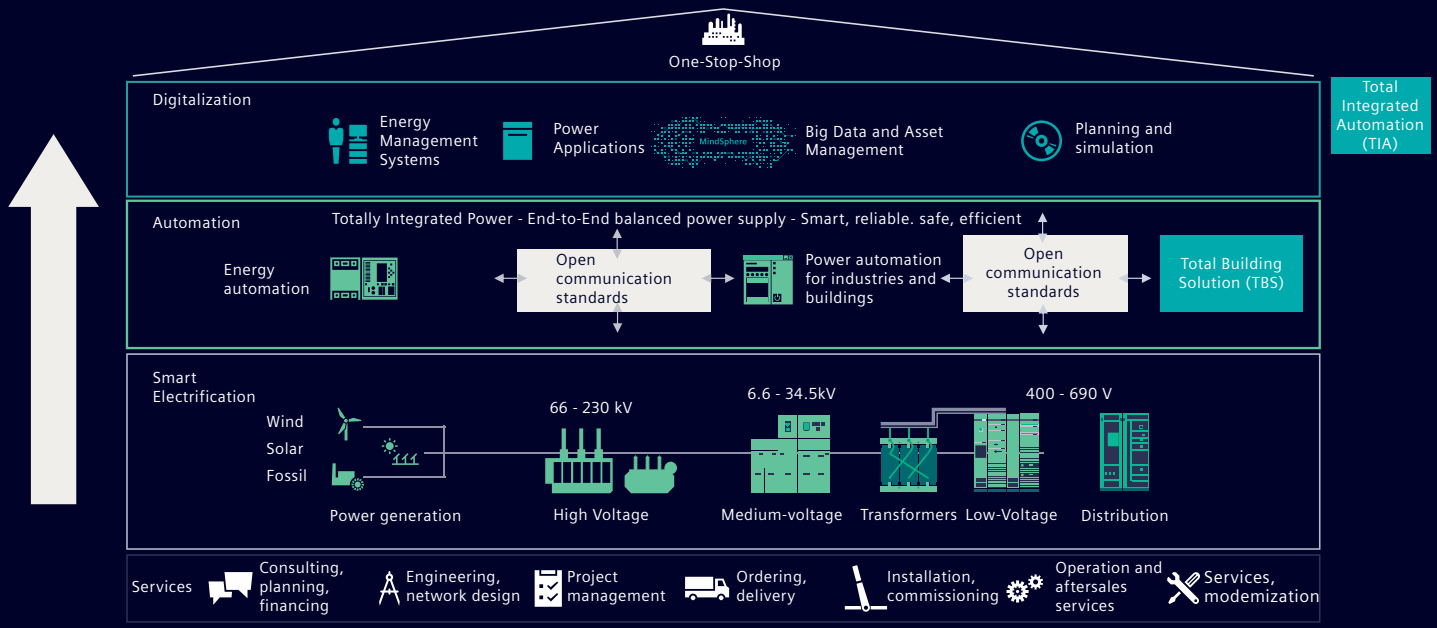


Figure 6: Integration of smart electrification to address the specific needs of automotive industry

Decarbonization in the automotive industry

Product Development
Vehicle design has been a key activity to address environmental concerns as it affects the entire product lifecycle. Initiatives vary from lightweight material, fuel efficiency, electrification, and reduction of materials of concerns for the environment.

Building & Facilities
Usage of green power with landfill gas, wind and solar energy to reduce dependency on traditional energy resources in automotive plants. Also includes building management systems to optimize buildings and facilitates energy consumption.

Manufacturing Operations
Environmental impacts of manufacturing are addressed through technology solutions. Energy and water conservation, greenhouse gas emissions reduction, waste management, and recycling are the main initiatives of focus in production.

End of Life
Following stricter End of Life Vehicle directives, manufacturers are increasingly focusing on design for recycling and dismantling, creating the path for an Automotive Circular Economy.

Supply Chain
Supply chain management has included environmental initiatives with three basic approaches: selection of suppliers, transfer of technology and more efficient logistics systems (e.g. packaging, reduction of empty container traveling, etc).

Critical processes and footprint to decarbonize

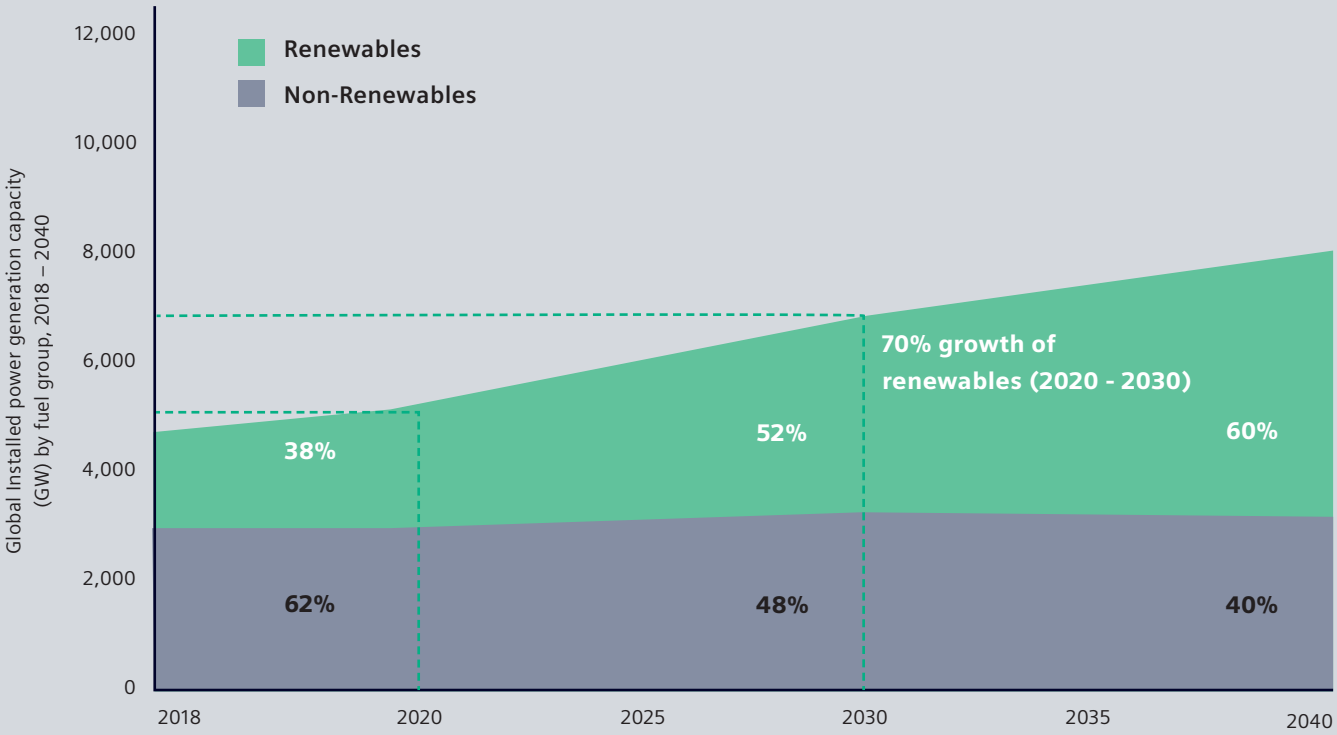
The global automotive industry has significant processes that deliver benefits through decarbonization. In product development, automotive manufacturers that incorporate lightweight materials, fuel efficiency, electrification, and material reductions in designs will reduce emissions and carbon footprint. In manufacturing buildings and facilities themselves, green power through the use of landfill gas, wind, and solar energy can displace conventional reliance on fossil fuels. Organizations can improve manufacturing operations through high efficiency equipment and processes that reduce waste and save energy, and focus on water conservation, emissions reduction, waste management, and recycling. Manufacturers are also increasingly proactive in designing vehicles with end of life disassembly with circular economies for materials and components. A much broader approach to decarbonization in supply chains can also be taken by manufacturers: the selection of suppliers, the transfer of technology and more efficient logistics systems to further decarbonize its footprint.

The four key initiative areas outlined in the previous section – decarbonization roadmapping, energy consumption optimization, energy infrastructure and supply modernization, and service-based business models – present a range of specific actions automotive manufacturers can employ to advance them from a current state in decarbonization towards a carbon neutral and net zero carbon future.

- **Decarbonization roadmapping:** risk management and hedging, energy audits, building performance optimization, EED compliance and ISO 50001 services, energy procurement and supply services.
- **Energy consumption optimization:** energy management and efficiency consulting, renewables and energy consulting, CO_2 emissions monitoring, energy transparency and forecasting.
- **Energy infrastructure and supply modernization:** grid consulting, microgrid storage integration, cogeneration optimization, smart campus supply design, efficient peak load management.
- **Service-based business models:** energy efficiency as a service, energy saving performance contracting, PPA green energy supply, positive cash flow energy transformation projects.

Global renewable power generation capacity to overtake non-renewable by 2030

As renewable power generation installations rapidly expand globally, the automotive manufacturing industry will increasingly adopt renewables as a way to offset CO_2 emissions from energy consumers at their facilities.



Case studies and regional initiatives

The ambitious targets of the global automotive industry are therefore vital goals that must be met to inspire the action of others, as opposed to serving as evidence that decarbonization is an intractable challenge. The gravity of the situation requires automobile manufacturers to craft robust, strategic roadmaps that outline actionable and verifiable steps to achieve their goals. Automobile manufacturers must ensure the most effective strategy is deployed at the corporate and facility level.

Snapshot examples presented below outline key steps organizations in Japan, the UK, and the US have taken to optimize operations and reduce energy consumption alongside PPAs to boost the use of renewable energy.

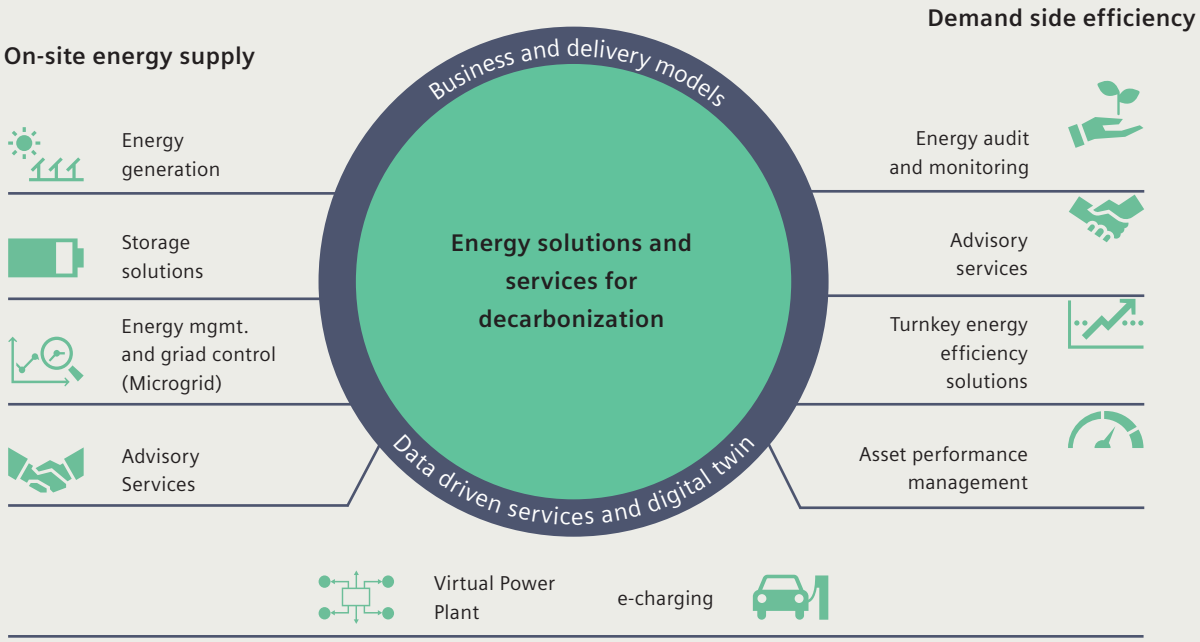
- **Toyota and IIJ (Japan)** – to obtain capabilities in predictive maintenance, usage forecasting, and components inspection to optimize operations, Toyota worked with Internet Initiative Japan to deploy an IoT platform for data visualization and analysis. The platform monitors roughly 370 production line machines, delivering 30,000 data points.
- **BMW and Spirax Sarco (UK)** – BMW's Plant Oxford steam-to-hot-water heating system was upgraded to gain efficiency and reduce costs. Spirax's EasiHeat™ heat exchange technology was installed with a PLC Energy Management System to permit more intelligent temperature control.
- **GM** – as early as 2017, GM set up a PPA to purchase 200MW from wind farms in Ohio and Illinois, followed by another 50MW in 2018, and the company continues to branch out into renewables through solar: by 2023 a total of 180MW will be developed in Arkansas and a further PPA agreement signed in Ohio 100MW of power was agreed in 2020.

4 Solutions and services that support decarbonization

The global automotive industry reviewed in this white paper has established important initiatives to reduce energy consumption, increase the use of renewable energy, and adopt greater rates of electrification.

Energy solutions and services delivering decarbonization are based on a strategic approach, utilizing value-stacking to exploit the full potential rather than execute isolated activities to optimize energy generation and sourcing, energy efficiency, supply security and reliability, or business and asset performance. This ensures the delivery of a positive impact right from the start and in the long-term for the entire organization.

Energy solutions and services for decarbonization
Delivering energy intelligence across the energy value chain



Demand side efficiency

Demand side efficiency is based on a thorough energy audit and performance data monitoring for complete transparency of the energy utilization and asset performance. In a first step energy efficiency solutions reduce the overall energy consumption and optimized energy efficiency of the entire facility.

In addition, asset performance management ensures the reliable and efficient performance of all business assets and advisory services support with the selection of the best suitable solution design and business model.

On-site energy supply

Local energy solutions are based on sustainable generation of power, heat and cooling with a maximized share of renewable energy sources.

In combination with powerful energy storage solutions, e.g. electrical storage or hydrogen storage, an on-site solution provides flexibility and allows for a maximum share of renewable energy.

Energy management and grid control tools ensure a reliable and efficient control of energy supply, usage and storage – and new profit streams by connecting the local energy solution to the energy market or managing it as part of a virtual power plant.

All the solutions are supported by advisory and consulting services from initial assessment and concept & design, to engineering, procurement and construction to operation, services and maintenance of the running system.

These are critical components in moving towards decarbonization. Power purchase agreements that deliver green, renewable energy support m activity and provide industrial customers with a faster-to-implement method of reducing carbon footprints. Additional efforts in capturing and using waste heat and the creation of circular economies are also core components of many strategies.

Comprehensive offerings to support our customer transferring to sustainable and digital enterprise

Smart grids Smart buildings Grid edge General

Business models and digital services

The technical implementation of solutions and services delivering decarbonization is supported by data-driven services and digital twin technologies.

Depending on the customer situation and goals the best suitable business model is selected:

- Customer financing of a project is based on milestone payments during the implementation and therefore cash negative. It requires capital investment and leaves the ownership of the asset and the performance responsibility with the customer.
- A deferred payment agreement is a performance contract, which optimizes CAPEX efficiency. It is based on a payment plan with positive cash-flow financed out of the project savings and requires no initial investment. The ownership of the asset remains with the customer, who can shift the responsibility for operation & maintenance and the solution performance to the solution provider with a respective agreement.
- X-as-a-Service models allow organizations to profit from project benefits regarding energy supply, equipment and facility maintenance for a service fee. They offer a greater value through their holistic nature and significantly reduce the time to profit from a system optimization – without capital investments and without taking over responsibility for new assets or systems.

These solutions enable our customers to take control of their energy supply and business performance.

Global manufacturers also look towards advanced equipment and process efficiencies to reduce carbon footprints of facilities. This includes LED lighting and new equipment with lower energy consumption. These actions should become a global standard in industrial facilities to deliver quick carbon reduction gains. These early successes should be reinforced and replicated among industry peers.

Siemens offerings across the entire automotive campus

Regional and local challenges in implementing the solutions and services for decarbonization

At a local level, however, there are regions that experience renewable energy supply challenges and higher economic costs in these initiatives. This is further complicated by a fragmented competitive landscape that is more greatly influenced by local conditions. As a result, regional and local landscapes can be highly variable.

Regions and localities may require structural assistance and incentives in order to help drive decarbonization activity. External third party support can also help manufacturers in these locations navigate these complexities to identify near-term opportunities as well as long-term initiatives that reflect changing local conditions to keep decarbonization initiatives running.

5 Conclusion and the way forward

Achieving economic change at the speed and completeness required to successfully respond to the world's decarbonization mandate requires focus and investment at a scale never seen before; this reinforces the need to act as a community and leverage partners to ensure critical success. The successes stemming from current initiative by global manufacturers need to be replicated globally. Increasing energy efficiency, driving renewable energy consumption, greater electrification, and facility improvements in efficient LED technology and energy efficient process equipment are all actions that must be embraced throughout industries.

1. Focus on Scope 3 emissions in addition to Scope 1 and Scope 2 emissions

In order to meet ambitious global targets, and to achieve sustainable industrial activity through decarbonization, a greater and deeper effort must be made in order to reach these goals. This requires industrial manufacturers to go deeper on Scope 1 and Scope 2 decarbonization initiatives while pushing into strategic Scope 3 emissions reductions.

Pushing into Scope 3 emissions reductions will require greater engagement with upstream and downstream partners, which is complex, but necessary in order to deliver sustainable industrial economies.

Tracking one of the most important KPI's: CO_2 emissions with Greenhouse Gas (GHG) Protocol Methodology

SCOPE 3: INDIRECT EMISSIONS Upstream Activities

- Purchased Good and Services
- Transport and Distribution
- Business Travel
- Employee commuting
- Leased Facilities
- Operational Waste

SCOPE 3: DIRECT EMISSIONS in facilities

- Energy / Heat Generation at Company Facilities
- Company Vehicles
- Fugitive Emissions

SCOPE 3: INDIRECT EMISSIONS in facilities

- Purchased electricity, stream, Heat and Cooling

SCOPE 3: INDIRECT EMISSIONS Downstream Activities

- Use of Sold Products
- Transport and Distribution
- End of Life for Products
- Processing of Sold products
- Investments

2. Focus and invest on technology developments

Thanks to available technologies such as renewable energy sources, energy storage, forecasting, data analytics, and building management services, it's possible to optimize operations, decrease energy usage and to create significant energy and resource savings. Energy management solutions incorporate this to deliver on the sustainability goals of the organization and at the same time support the financial side of the business and foster growth.

A holistic approach to sustainability measures ensures that measures are not implemented based only on individual payback time and ROI, but also based on their cross-synergies, allowing positive impacts to start earlier and also slower and less effective measures to be implemented, so that the highest total effectiveness can be achieved.

Technology developments around renewable systems

1. Storage
Reducing costs of battery storage

2. Digitalization
Digitalization increasing the viability of using green and distribution technologies, giving more control over customer energy use, and enabling the emergence of new business models and energy services

3. Electrification
The move towards electrification of heat and transport, adds further flexible electrical loads in the system

4. Hydrogen
Producing hydrogen using excess electrification from renewable energy resources is gaining increasingly more support in the decarbonization agenda

5. Demand flexibility
The emergence of grid interactive smart buildings that interact with smart grids to
1. Reduce overall consumption from fossil fuels
2. Provide grid stability through changing their energy loads via new technology
3. Generate revenue for selling energy demand of generation onsite that is flexible

6. Virtual power plant
Virtual power plants are platforms that act as intermediaries between consumers, who have flexible energy loads and network operators

3. Engage in the automotive community

Engaged automotive organizations exist throughout the world; their activities help form a blueprint for others to follow and from which to expand decarbonization activities. Engaging in the automotive community is critical to delivering success.

Further, looking outside of the automotive community for further strategy and innovation success is key; this includes bringing in third party partners to help evaluate facilities and organizations, to develop actionable strategies to push organizations towards decarbonization, and to monitor and confirm success.

Smart Infrastructure combines the real and digital worlds across energy systems, buildings and industries, enhancing the way people live and work and significantly improving efficiency and sustainability.

We work together with customers and partners to create an ecosystem that both intuitively responds to the needs of people and helps customers achieve their business goals.

It helps our customers to thrive, communities to progress and supports sustainable development to protect our planet for the next generation.

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For over six decades, Frost & Sullivan has helped build sustainable growth strategies for Fortune 1000 companies, governments, and investors. We apply actionable insights to navigate economic changes, identify disruptive technologies, and formulate new business models to create a stream of innovative growth opportunities that drive future success.

Our passionate commitment to growth starts with our Growth Pipeline Dialog, an all-hands approach that puts your management team in a room with our growth experts, addresses your top challenges, identifies areas of disruption, and develops tailored roadmaps and go-to-market strategies.

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Theilerstrasse 1a
6300 Zug
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Tel +41 58 724 24 24

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