SIEMENS

Designing a better world

5 steps to create more sustainable products in your Digital Enterprise

Executive summary

Companies around the world are rushing to integrate sustainability goals into their businesses, for a variety of reasons – for ESG investment opportunities, meeting customer demands, and adhering to emissions regulations. For each and every reason, the solution is rooted in the design of products and services. Much of a product's overall carbon emissions are determined during the design phase and integrating the requirements for sustainability successfully relies on a digital transformation that starts in early concept design.

This paper will examine five common stages of design and how your Digital Enterprise will help you accelerate your transition to sustainable design. You will also hear about how some businesses are deploying these technologies and methodologies today and thus become sustainable Digital Enterprises. And we will delve into how your business can plan for success with sustainable design.

siemens.com/sustainable-industries

To overcome resource scarcity, meet emissions targets, and exceed customer expectations, industrial businesses are steadily increasing their environmental consciousness. And those set to succeed are doing so holistically and from the very start of their development processes.

> 80 percent of a product's sustainability impact is determined in its design phase" - European Commission Proposal for Directive on Eco-design requirements for Energy-Using products.

That makes design a critical step to reevaluate when updating the metrics for a successful sustainable business. The design decisions and process changes made to the start of the development cycle lay the groundwork for future optimized processes across design, manufacturing, logistics, maintenance, and eventually the complete enterprise.

With such a massive dependence on design, thinking about the environmental impact of a product as early as possible is critical to understand the impact alongside cost, quality, and time. Digitalization and automation are key to meeting these challenges and to their continuous improvement, allowing industrial businesses to move away from silo-based knowledge towards collective intelligence to make better design decisions. Combining the real and digital worlds makes it possible to seamlessly integrate and digitalize the entire value chain, from design and production to maintenance and recycling.

From there, designers get access to the comprehensive digital twin, informed by simulation results, production data, material information, supplier carbon footprint data, product carbon footprint data, and much more, allowing designers to make smarter decisions when designing sustainable products. And to understand just how great the impact of the digital enterprise is to sustainable design practices, we will cover five general phases to design a product – the conceptual design, the supplier network, detailed design work, validation steps, and continuous design improvement.

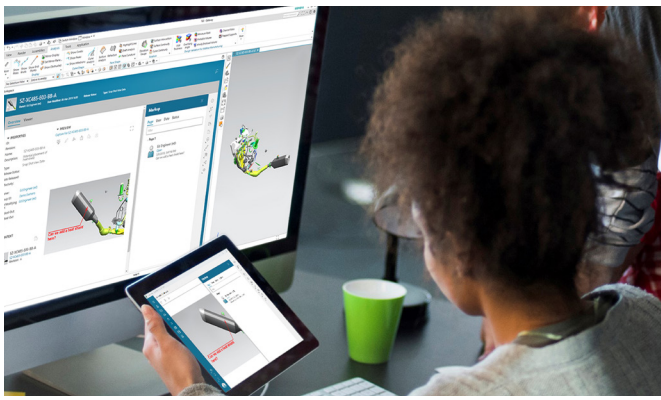
Conceptual design

In addition to traditional requirements such as performance, durability, useability and cost, designing for sustainability will create an additional set of requirements.

It is critical to capture these requirements from the very beginning of development and define the relevant sustainability key performance indicators (KPIs) for proper monitoring of the design process. In a traditional design process, this stage is to calculate product costs from the bottom up throughout the entire value chain to analyze cost saving scenarios. Companies often struggle to make trade-offs between driving down their carbon footprint while reducing cost, so it is critical to link cost and CO2 emissions early in the development phase to identify the most important levers in a design. By establishing this connection early on many more comparisons can be made. For example, what is the impact of a swapped material on cost and carbon emissions vs. thinning a component and the manufacturing implications that brings?

By expanding the view beyond isolated optimization, a business is better positioned to tap into the potential of balancing cost and carbon intensity. This capability can be implemented today, with Teamcenter® product cost management solution. Businesses can make informed decisions to drive down carbon emissions, reduce product costs and address customer value demands early on and continuously through the design and development process.

Engineers on the shop floor evaluating a prismatic battery cell on the production line



Validating design requirements is made easier with digital tools earlier in design

A great example of these early design criteria is seen in the battery manufacturing market – for electric vehicles, grid storage, and personal electronics. There is a finite supply of the key materials for production, so it is important to set targets on material efficiency and scrap rates to ensure as much of the material gets into the products as possible. This would also include the phases where a company would outline the goals for recycled materials. In many cases, using recycled materials requires different processes to be cleaned or refined than virgin materials.

The battery industry also has a very direct example of the influence of government incentives and regulations on development decisions – the money allocated for battery growth under the Inflation Reduction Act requires that much of the manufacturing be done nationally. This is incentivizing businesses to develop new supply chains locally to the markets being served. Aside from the economic effects of the program, it is also helping reduce the environmental impact of supply chain logistics.

Suppliers

With a conceptual understanding of the product and requirements created in the digital twin, the next step is to source materials and components.

Reichhart Logistik's use of digital logistic solutions has made shipments more efficient

Few businesses will design, let alone build, every component that goes into their product, and this important step determines which parts will be made in-house and what will be purchased from trusted suppliers. Leveraging product lifecycle management (PLM) systems helps source and compare potential suppliers based on sustainability RFP (request for proposal) requirements.

As this information becomes available in the Digital Enterprise, through new relationships or existing knowledge, a business can simulate hundreds of supplier logistics network variations to optimize carbon emissions and ensure they achieve the best environmental performance from logistics. It will help answer many of the big questions of logistics. Where are the suppliers located? How do the shipments get to the right locations? And what mode of transportation will be used? All of the answers to these questions have very distinct impacts on cost and carbon emissions, but understanding the dynamic relationships is where digitalization with Siemens Supply Chain Suite is key.

Automating these kinds of processes will be extremely important because of the breadth of data being collected and handled. After selecting the suppliers that best comply with product requirements, compliance results can be rolled up into the KPIs. This also creates transparency in the environmental performance of the product and suppliers and can further incentivize a supplier network to seek carbon-conscious production methods.

For logistics companies, making services more efficient incentivizes more businesses to partner. Moving material more efficiently reduces the overall emissions due to transportation while also reducing operational costs from lowered energy consumption. Together, these advantages make logistics partners an important decision in designing sustainable supply chains. Our customer, Reichhart Logistik uses digital logistic solutions to simulate scenarios and optimize transport networks to move the same volume of cargo with fewer vehicles. Their work resulted in 22 percent emissions savings and a 10 percent efficiency increase.

InDesA's Pandora electric vehicle:

InDesA wanted to design decarbonized, energy efficient, flexible and resource efficient products and extend their useful lifetime.

Their solution was leveraging a comprehensive digital twin for a system of systems approach and greater design space exploration.

They were able to place their parts into an assembly and the complete product to consider how it would perform in different environmental scenarios.

The team was able to develop advanced thermal and electrical systems for optimized vehicle performance in the Pandora EV.

Copyright: InDesA GmbH

CFD simulations help engineers and designers understand their product earlier, providing more time for sustainability optimizations

Detailed design

Next, we move into the detailed design phase. At this stage, business will leverage their digital models to select the right part materials based on material properties and the associated sustainability scores from the supplier network directly within the design tools.

Fluid simulations help mold makers design molds to more efficiently inject plastics, reducing waste

One material may be applied to a part, resulting in a lowered carbon emission rating within manufacturing because it is more easily recycled while another material option might be more durable and extend product life. With this kind of information available to the designer, in their tools, they can do rapid design iterations and get sustainability impact scores on the spot to understand the effect of design decisions. Making these decisions with overall sustainability in mind fully characterizes the dynamic relationships between product performance, manufacturability, energy efficiency, carbon emissions, profit, and much more.

A business can then design and optimize for things such as weight, flexibility, modularity, and reliability. They can simulate and optimize the product and related production systems without investing in physical prototypes and assets. This is tremendously valuable to the designer because it allows for almost unlimited design variations, unleashing innovation and pushing the boundaries of what is achievable, without the associated cost, energy, and resources of physical iteration. This opens the door to consider new technologies and drive materials innovation. New manufacturing methods such as additive manufacturing can be considered – it has become a compelling option for its sustainability benefits under the right circumstances. Iterating in the virtual world is really changing the way companies innovate and can deliver huge efficiency gains.

Simulation provides an environment to test different scenarios before consuming the resources to physically build the product, enabling bolder approaches and ideas while adapting and pivoting faster than ever. Once the design is more clearly understood, it is important to simulate the lifecycle impacts, including end of life, from design changes to make sure the design is still on track to meet sustainability KPIs.

All the work prior to this step establishes the ability to conduct performance engineering with a system of systems understanding. How does one design change in an individual part impact the larger assembly? These insights are critical for designers looking to optimize their products and it is important to understand that validating requirements should be a continuous process. That is why a digital-native and data-accessible design methodology is so important, to help automate some of these checks and reduce the barrier to expanding the design space.

Detailed design is crucial to creating more sustainable products, because of the performance and efficiency gaps that can be closed through simulation. DNV, an international certification and classification body for the marine industry used computational fluid dynamics (CFD) simulations in Simcenter™ STAR-CCM+™ software.

As a result of the CFD optimization process, the ships can carry as many containers as before and are 36 percent more energy efficient."

Shai U. Thayil
Director APL

Validation

Once detailed designs are developed, it is time to validate the prototype's performance. Validation covers many different workflows and domains to ensure the material properties and overall product work as expected.

New materials or geometries for a component might require more thorough testing to characterize performance. That testing data can then be used to further inform and refine the digital twin.

But validation also covers the simulations themselves – are the models accurately reflecting the physical world? Were the assumptions made in design reasonable approximations to real-world physics? Feeding results from the physical test back into the simulation is important to better characterize the real world. But this data analysis can also be used to eliminate redundant testing from development. If data can be collected on multiple phenomena in a single test, it can streamline what is often a lengthy process. Additionally, these results can be used to train specialized AI algorithms in the form of reduced order models (ROMs) capable of accurately inferring simulation results in close to real time. By augmenting parts of the validation process with ROMs, sufficient accuracy can be reached to fill out the design space with AI inferences rather than full simulations for every test. These ROMs can be continuously improved as more information is gleaned on the relationship between the digital and real worlds, further increasing accuracy and speed.

Validation even extends into the field as products are used to determine the long-term reliability of models and even update understanding as novel situations are uncovered. Leveraging the Digital Enterprise helps gather information and monitor the compliance to sustainability KPIs. An offshore wind system, monitored with IoT sensors, might provide novel information on the environmental conditions where it was deployed. This kind of data collection can stream back to inform the digital twin of the product. Real time information could be used to better collect wind energy from the system by pitching blades or rotating the structure to better face prevailing winds. Longer-term data could also help define the maintenance procedures for the turbines with more frequent cleanings or different component materials if the salty air is corroding vital systems faster than expected.

Off-shore wind farms need to communicate with on-shore facilities to better understand their operation in inclement weather and for long-term trends

Design **improvement**

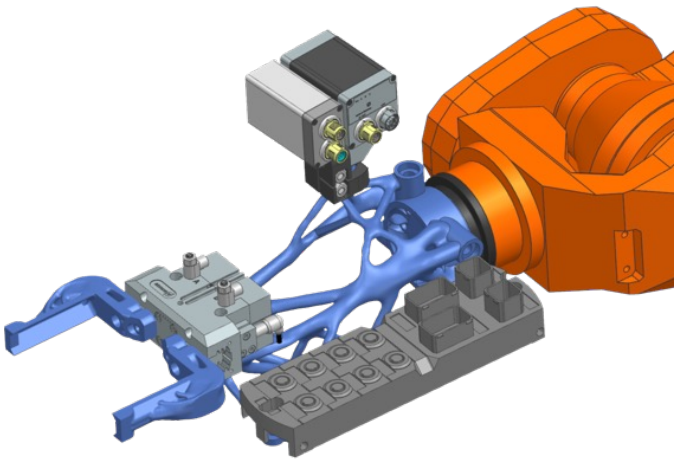
Improving a product is not just a final step in a design process, but rather a continuous journey that extends beyond design. Integrating sustainability goals into product design is making that a reality for every company.

With the simulation data, testing results, and a more realistic digital twin as a part of the Digital Enterprise, uncovering any performance gaps, reliability issues, and refurbishment and upgrade paths for products becomes easier.

There are many product segments that rely on iterative release cycles, and the information gained from a wealth of data on energy utilization, material costs, and shortened logistical networks will help make each subsequent release more sustainable than the last. Some companies are even iterating on products during a single release cycle and using robust PLM solutions to track the different versions for maintenance requirements and software updates. A product could have been overengineered for a wide range of operating conditions, but as information comes in about how they are functioning, small tweaks could be made to make it more efficient in 95% of usage conditions.

But there are other products that rely on service contracts rather than direct ownership, which can create even more value through sustainable design improvements. Heavy equipment is one of the most common industries for this practice. Rather than selling a multimillion-dollar machine, a capacity over time is written into a lease contract. If the company fulfilling the contract can do so using fewer resources, it is a win-win for their bottom line and sustainability goals. This highlights the need for companies to understand and define sustainability goals as an integrated part of their business strategy, because sustainability improvements can also be profit drivers.

Design improvement is not limited to new products either, in fact it is a valuable component to existing manufacturing equipment. One of our customers sought to simplify the end-effectors for their robotic arms. Their goal was to reduce weight and assembly complexity without sacrificing strength or performance. By designing with topology optimization and additive manufacturing in NX™ software, they consolidated the assembly while retaining manufacturability requirements and long-term durability. In the end, each assembly required 80% fewer screws, weighed 64% less, contained 85% fewer parts overall, and reduced assembly time by 80%. For an individual robot, these metrics may not have an enormous impact on an enterprise but conducting these types of optimizations across the whole business has a major impact in designing for sustainability.



3D printed gripper assembly to reduce product complexity, material use, and energy consumption during operation

Designing for improvement **beyond design**

Each of these concepts is extremely important to facilitate sustainable design, but they do not stop outside of the design workflow.

The impacts from design decisions ripple out to every part of a business. This is why the Digital Enterprise is so important in making a product sustainably. Material selection for a component and its geometry determine what manufacturing processes are required to make it in the physical world. This in turn has an associated sustainability and profitability impact – a part manufactured with 3D printing can be far more efficient in certain applications, but the overall sustainability is balancing the manufacturing impacts, the usage impacts, and the end-of-life costs.

Collecting the data to make these large decisions relies on easily accessible data and will continue to push the necessity of IoT sensors for automatically sampling the complete enterprise. One machine at a manufacturer might be less efficient than expected for certain operations. Having that kind of data on hand could prompt maintenance action, or if it is within expected operating conditions, a change to the design to better suit the manufacturing process.

Becoming a Digital Enterprise also links the supply chain to design decisions. Some products only have a handful of suppliers that can meet the product specifications, so it is important to understand the performance gains of working with one supplier against the possible emissions savings of another supplier who is geographically closer to the production and end users.

The future of sustainable design

Each of the design processes we've outlined above provides a tangible value to developing sustainable products and services. And together they can provide a streamlined development process for businesses as they adopt new sustainability practices.

The sustainability impact of decisions made in design is too great not to change the development process from the earliest stages. For designs to be successful long-term, there should be a focus on sustainability alongside more traditional metrics of cost, performance, utility, and attractiveness. Integrating sustainability in early conceptual design necessitates a digital twin to best inform supplier networks and the detailed design of the product. Meanwhile IoT systems provide data collection throughout development to simplify validation processes and ensure design requirements are met. By constantly improving products in the digital world, designers are guided along the innovation cycle. However a business begins the sustainability journey, the digital enterprise is ready to support sustainable outcomes for their products, processes, and services. For more information on the Digital Enterprise and how Siemens is paving the way for the future of sustainable design today, check out our website or reach out directly.

Siemens Digital Industries (DI) is an innovation leader in automation and digitalization. Closely collaborating with partners and customers, DI drives the digital transformation in the process and discrete industries. With its Digital Enterprise portfolio, DI provides companies of all sizes with an end-to-end set of products, solutions, and services to integrate and digitalize the entire value chain. Optimized for the specific needs of each industry, DI's unique portfolio supports customers to achieve greater productivity and flexibility. DI is constantly adding innovations to its portfolio to integrate cutting-edge future technologies. Siemens Digital Industries has its global headquarters in Nuremberg, Germany, and has employed around 72,000 people internationally.

Siemens AG (Berlin and Munich) is a leading technology company focused on industry, infrastructure, transport, and healthcare. From more resource-efficient factories, resilient supply chains, and smarter buildings and grids, to cleaner and more comfortable transportation as well as advanced healthcare, the company creates technology with purpose adding real value for customers. By combining the real and the digital worlds, Siemens empowers its customers to transform their industries and markets, helping them to transform the everyday for billions of people. Siemens also owns a majority stake in the publicly listed company Siemens Healthineers, a globally leading medical technology provider shaping the future of healthcare.

In fiscal 2023, which ended on September 30, 2023, the Siemens Group generated revenue of €77.8 billion and net income of €8.5 billion. As of September 30, 2023, the company employed around 320,000 people worldwide. Further information is available on the Internet at www.siemens.com

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