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How Generative AI is transforming the semiconductor industry

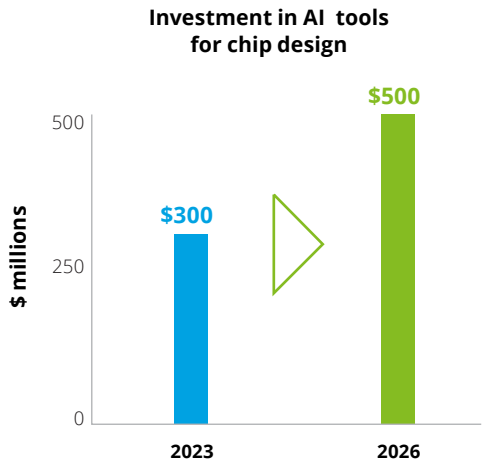
What's inside

Transformative opportunities for smart manufacturing

Semiconductors power every conceivable electronic device—putting chip design at the core of technological innovation. Under constant pressure to develop faster, cheaper, higher-capacity chips, manufacturers have pushed traditional design, manufacturing, and verification to new levels. Meanwhile, the industry's appetite for innovation shows few signs of slowing.

Enter GenAI is used to supercharge different aspects of how semiconductors are created, with transformative effects on nearly everything from iterating to prototyping to manufacturing. The technology is especially adept at adding intelligence to large, complex data models and accelerating the planning, development, and execution of chip design and manufacturing.

The industry knows an opportunity when it sees it: Semiconductor giants invested approximately $300 million in AI tools for chip design in 2023, a total expected to rise to $500 million by 2026.[1] And 72% of the semiconductor professionals Deloitte polled in 2023 believe that GenAI's impact on the industry will be "high to transformative."[2] AI is a lot more than just a new tool; it can be a foundational element with the power to open up entirely new opportunities.



A GenAI decoder

Generative models have existed for centuries, in forms from Naïve Bayes classifiers to hidden Markov models. But it's only with recent leaps in data availability, computing performance, and model complexity that GenAI has become truly valuable in a business context.[3]

The recent proliferation of GenAI models and approaches following the introduction of ChatGPT has ignited tremendous interest in all industries. Within the semiconductor sector, there is dramatic and transformative potential at all stages in the value chain.

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Common semiconductor industry applications

GenAI can be used to accelerate and differentiate product designs, improve operations, and proliferate leading practices throughout the semiconductor industry value chain, especially in these areas of the business:

Supply chain forecasting. Generate more accurate schedules and forecasts while optimizing process flows.

Research augmentation. Use custom mixed-language models to help develop knowledge bases, notes, and communication records. All are fully searchable, facilitating sharing of leading practices and discovery of reference designs and customer intellectual property.

Design generation. Rapidly iterate to improve existing designs or discover entirely new ones. Optimize performance based on criteria including power consumption, performance, location, and manufacturability, saving both time and money.

Anomaly and defect detection. Generate synthetic data for use in downstream defect detection algorithms. Automatically identify rare failure modes and quantify them more accurately.

Process simulation. Use training data from sensors, process logs, and other sources to generate digital twins that can simulate sorting, assembly, testing, and other complex manufacturing processes. Build capacity models and flows that can maximize productivity and optimize equipment and resource use.

Streamline legal contract review. Verify important legal clauses in contracts, highlight issues, suggest changes, and revise contract language. Extract critical information pertinent to individual contracts or intellectual property. Automatically pull critical dates (payments, deadlines, renewals), populate calendars, and send notifications when action is required.

Product selection and search. Assist semiconductor field application engineers with product selection, search, part explanation, and citation for customers. Help design engineers find the optimal engineering part or SKU for end circuit design.

Top opportunities in chip manufacturing

While GenAI is relatively new to the industry, our survey respondents saw high potential for its use throughout the semiconductor business; this reflects the interest for GenAI across the semiconductor value chain with slightly heavier expectations of value lying within core engineering chip design and manufacturing, operations, and maintenance.

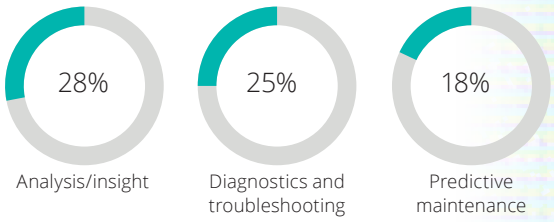
Survey respondents: Areas of the business where GenAI shows the highest potential

Source: Deloitte and SEMI, 2023 Smart Manufacturing: GenAI for Semiconductors Survey

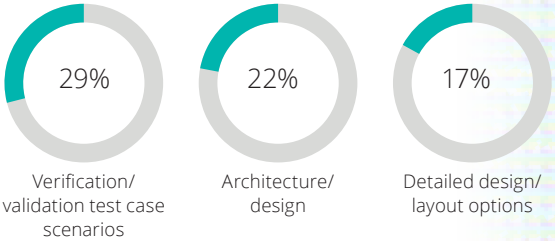
Within the manufacturing, operations, and maintenance function, respondents saw the highest potential value for GenAI in three areas: analysis of/insight into processes and equipment (28%), diagnostics and troubleshooting of processes and equipment (25%), and predictive maintenance (18%).[4]

For GenAI in engineering, respondents saw the most potential in verification and validation test case development (29%), architecture and design scenarios (22%), and detailed physical design and layout options (17%).[5] One example: context aware GenAI tools that use conversational intelligence and natural language prompts to eliminate much of the grunt work of RTL generation and verification.[6]

Potential value of GenAI in manufacturing, operations, and maintenance function



Potential value of GenAI in engineering



Source: Deloitte and SEMI, 2023 Smart Manufacturing: GenAI for Semiconductors Survey

The future of GenAI in semiconductor manufacturing

Today there are many GenAI-enabled productivity and efficiency improvements that can help designers, researchers, and developers accelerate low-risk workflows while keeping human specialists in the loop. Beyond this low-hanging fruit, more and more automation is possible, reducing costly human involvement while increasing the deployment risks. For example, GenAI could be used to generate scanning electron microscope (SEM) images of rare defect modes immediately. These generated images can then be used to train downstream defect detection algorithms. Longer-term opportunities will likely flow from systemwide workflow changes such as material design, circuit path finding, fab simulation, operational optimization, and dynamic pricing via simulated agents, which require significant domain expertise and major investment; such heavy investment allows for significantly larger market leading opportunities with higher possible return on investment (ROI).

Of all GenAI use cases, text generation, summarization, translation, and classification are the most developed, followed by applications such as time-series forecasting and signal processing.

This table summarizes Deloitte's analysis of the complexity and ROI potential of near-, short-, and long-term GenAI applications across the value chain. There is significant expected ROI across the value chain, with many different GenAI solutions that augment current workflows (e.g. easily simulating logistics scenarios for optimization), extend traditional AI opportunities (e.g. rare defect detection), and open new possible areas of innovation (e.g. fully personalized marketing and customer relationship management that was hitherto cost prohibitive).

	Current		Six months		Long term	
	Complexity	**ROI**	**Complexity**	**ROI**	**Complexity**	**ROI**
Planning						
Supply chain forecasting	Medium	Medium				
Logistics optimization			Medium	Medium		
Scenario modeling and simulation					High	High
R&D						
Digital twins	High	Medium				
Documentation summarization and research acceleration	Low	Medium				
Content drafting	Low	Medium				
Layout design			High	High		
Material science					Very high	Very high
Design						
Document parsing for extraction/summarizing	Low	Medium				
Design generation			Very high	High		
Route test generation			Medium	Medium		
Manufacturing						
Anomaly detection	Medium	Medium				
Yield forecasting	Medium	High				
Code development	Low	Low				
Test suite generation			Medium	Medium		
Defect detection			Medium	Medium		
Operations						
Document review	Low	Medium				
Report first-draft generation	Low	Low				
Procurement document (RFP, PO) generation and supplier evaluation			Low	Low		
HR management (recruitment, training creation)			Low	Low		
Schedule planning					High	High
Intelligent routing					High	High
Operations						
Customer analytics, support, and chatbots	Medium	Low				
QA services	Low	Low				
Demand forecasting	Medium	Medium				
Marketing and sales content, including text/images generation	Medium	Low				
Chatbots			Medium	Low		
Relationship management			Medium	Low		
Dynamic pricing					High	High

Source: Deloitte analysis.

Low Medium High Very high

Measuring the value of GenAI in the semiconductor industry

The value created from GenAI is significant and has wide reaching implications to the semiconductor industry. Across use cases, GenAI is expected to improve efficiencies and create value, some of the business KPIs that will likely be impacted from GenAI include:

Area	Key performance indicator
Planning	• Freight costs • Inventory levels
R&D	• Time to market
Design	• Power, performance, and area (PPA) • Sustainability
Manufacturing	• Downtime • Yield improvement • Defect density • Work-in-progress turns • Cost of goods sold
Operations	• RFP build time • Time to onboard • Contract review
Sales and Marketing	• Per-unit profit • Customer satisfaction score

Source: Deloitte and SEMI, 2023 Smart Manufacturing: GenAI for Semiconductors Survey

Examples of GenAI at work

Manufacturing and defect detection

Using GenAI to automate defect detection during manufacturing offers clear and measurable benefits. Historically, engineers have had to manually analyze in- and end-of-line signals to determine root causes of failure—a process that's slow, expensive, and tremendously human-intensive. Until recently, this knowledge was passed between core teams as new defect modes and signals were identified. Conventional AI has significantly sped up this process by identifying known issues; however, these models generally require significant data support to match signals to underlying root causes.

The newest iterations of GenAI can create synthetic data to train both human engineers and AI systems. A generative adversarial network (GAN)—or a diffusion model trained on patterns such as wafer maps, e-test signals, or statistical process control (SPC) measurements exhibited in a small set of identified wafers—can be used to generate realistic defect examples. The output—for example, realistic gross failure areas on wafers—can then be used to tune downstream processes, from SPC limits to other defect detection AI models. Compared to manual processes, a GenAI solution can classify defects more accurately and more quickly, at significant cost savings, with massive potential for scale.

Optimizing PPA

Chip design optimizes three variables—power, performance, and area (PPA)—to produce chips that maximize processing speed while minimizing size and energy use. Doing this with conventional electronic design automation (EDA) tools is slow and labor-intensive; weeks-long design iterations can yield only minute improvements.

With traditional methods, it can take years to design a chip; build a prototype; and evaluate, test, and simulate both design and implementation. In contrast, GenAI learns from each iteration, improving PPA to the greatest extent possible. It can test human designs, identifying placement errors that increase power consumption, impede performance, or use space inefficiently. Then it suggests, simulates, and tests improvements. But what's truly revolutionary is that it can do all of this autonomously guided by design principles and can generate PPAs that exceed those created by humans using EDA. And it can do it all in just hours with a single design engineer, rather than weeks or months with an entire engineering team. And this, at heart, exemplifies the transformative power of GenAI.

Emerging issues

GenAI has the potential to revolutionize the semiconductor industry—dramatically improving efficiency and accuracy, helping to maximize quality, speeding product development, and opening new areas of innovation. But before embarking on any GenAI journey, it's important to carefully consider the potential risks, including:

- **Cost:** Building custom models for generating circuit design, testing plans, and synthetic data can be expensive compared to manual execution. Ongoing costs for very large models can also outweigh the speed benefits of automation.
- **Accuracy:** Contrary to popular belief, GenAI may not always deliver outputs with the same quality and accuracy of humans using more traditional methods. Generative AI large language models can generate content with errors, inconsistencies, and hallucinations. The solution: Keep humans in the loop. Use GenAI to augment rather than replace human contributions—validating everything from designs and testing to code.
- **Bias and privacy:** Consider ethical issues when working with human-centered applications such as HR or sales and marketing. Mandatory human review can help ensure that all data is sanitized, personally identifiable information removed, guardrails installed, and results validated.

Read the Deloitte AI Institute report for more ideas on how to manage risk around using GenAI.

How Deloitte can help

In the semiconductor business, managing impossibility and navigating uncertainty are just part of the job. You need collaborators that understand the complexities and nuances of this unique industry—and their implications for your organization. Deloitte's multitalented, multidisciplinary tech pioneers and GenAI specialists can help you identify new ways to sustain growth, gain a competitive edge, and power a more promising future.

Learn more about Deloitte's take on GenAI in the semiconductor industry.

Methodology

The *2023 Smart Manufacturing: GenAI for Semiconductors Survey* was conducted by SEMI and Deloitte's Semiconductor practice following Semicon West 2023. The survey solicited feedback from 53 semiconductor executives knowledgeable about GenAI in August of 2023.

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Endnotes

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