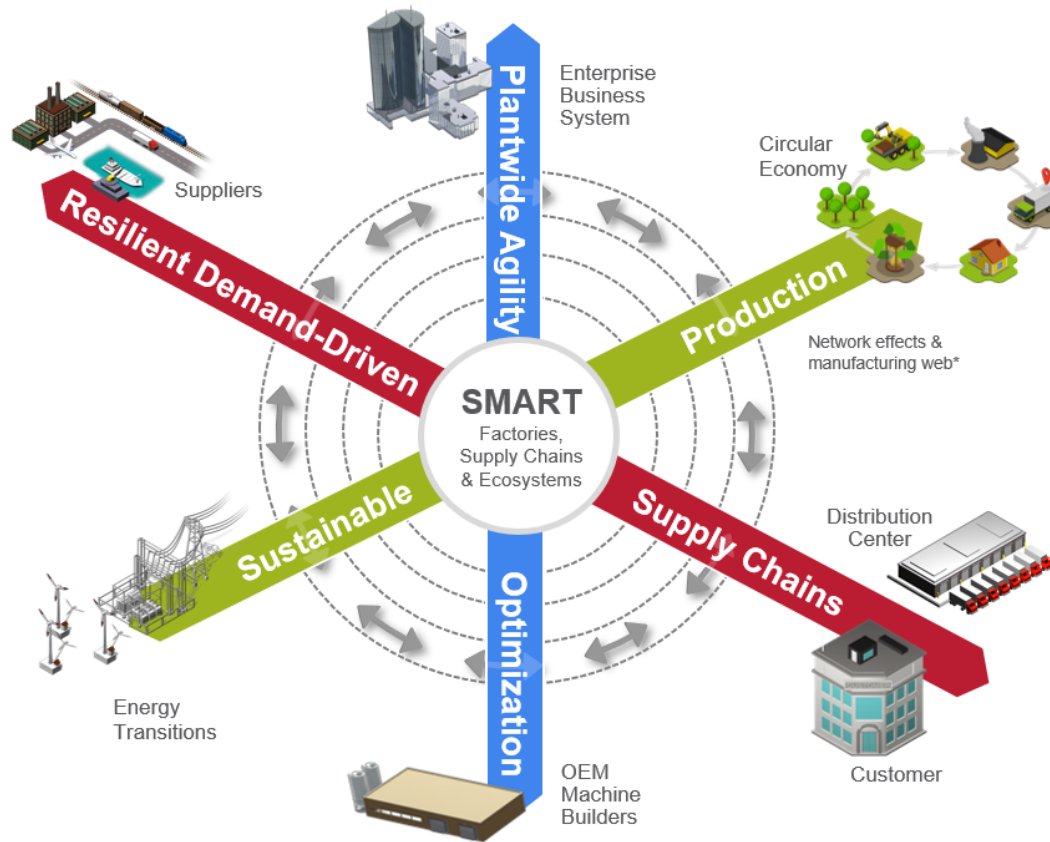# Options for a National Plan for Smart Manufacturing

Learn more and download the report:
nap.nationalacademies.org/27260

Smart manufacturing has the potential to transform the U.S. manufacturing sector


Smart manufacturing uses next-generation technologies such as artificial intelligence (AI) and machine learning, high-speed connectivity, advanced data analytics, and hard and soft automation to augment human beings in the workforce.

Implementing these technologies could:

- **Improve productivity, efficiency, and sustainability** for the manufacturing workforce, factories, and supply chains.

- Provide opportunities to **expand and develop the smart manufacturing workforce**

- Increase **U.S. economic competitiveness and resilience**.

About the Study

Options for a National Plan for Smart Manufacturing

Consensus Study Report
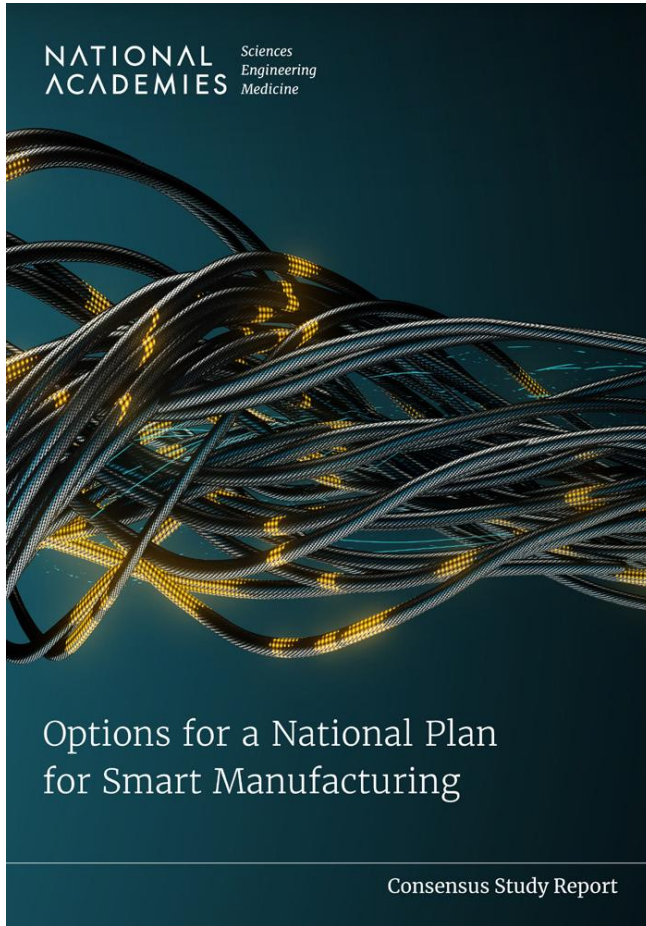
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DOE turned to the National Academies to convene a consensus study committee to explore and recommend options for a national plan for smart manufacturing.

A committee of leading experts in advanced and smart manufacturing was assembled from across academia, industry, and trade and technology associations to:

- **examine** the state of the smart manufacturing industry;
- **explore** technology, workforce and education, social and environmental, and economic challenges and opportunities;
- and **recommend** critical elements and considerations for DOE's national plan for smart manufacturing.

Committee Roster

Thomas Kurfess, NAE, *Chair*
Georgia Tech

Billy Bardin
Dow, Inc.

Richard Braatz, NAE
MIT

Jian Cao, NAE
Northwestern University

Krystel Castillo
Cybersecurity Manufacturing Innovation Institute, UTSA

Lili Cheng, NAE
Microsoft Corporation

James Davis
Clean Smart Manufacturing Innovation Institute

Robert Gao
Case Western Reserve University

S.K. Gupta
Center for Advanced Manufacturing

Susan Houseman
Upjohn Institute

Jeanine Kunz
Society of Manufacturing Engineers

Stuart Lawrence
Titan Robotics

Blake Moret
Rockwell Automation

Chinedum Okwudire
University of Michigan

Melissa Orme
The Boeing Company

William Spriggs
Howard University & AFLCIO

John Sutherland, NAE
Purdue University

Karen Thole
Penn State University

Study Staff:
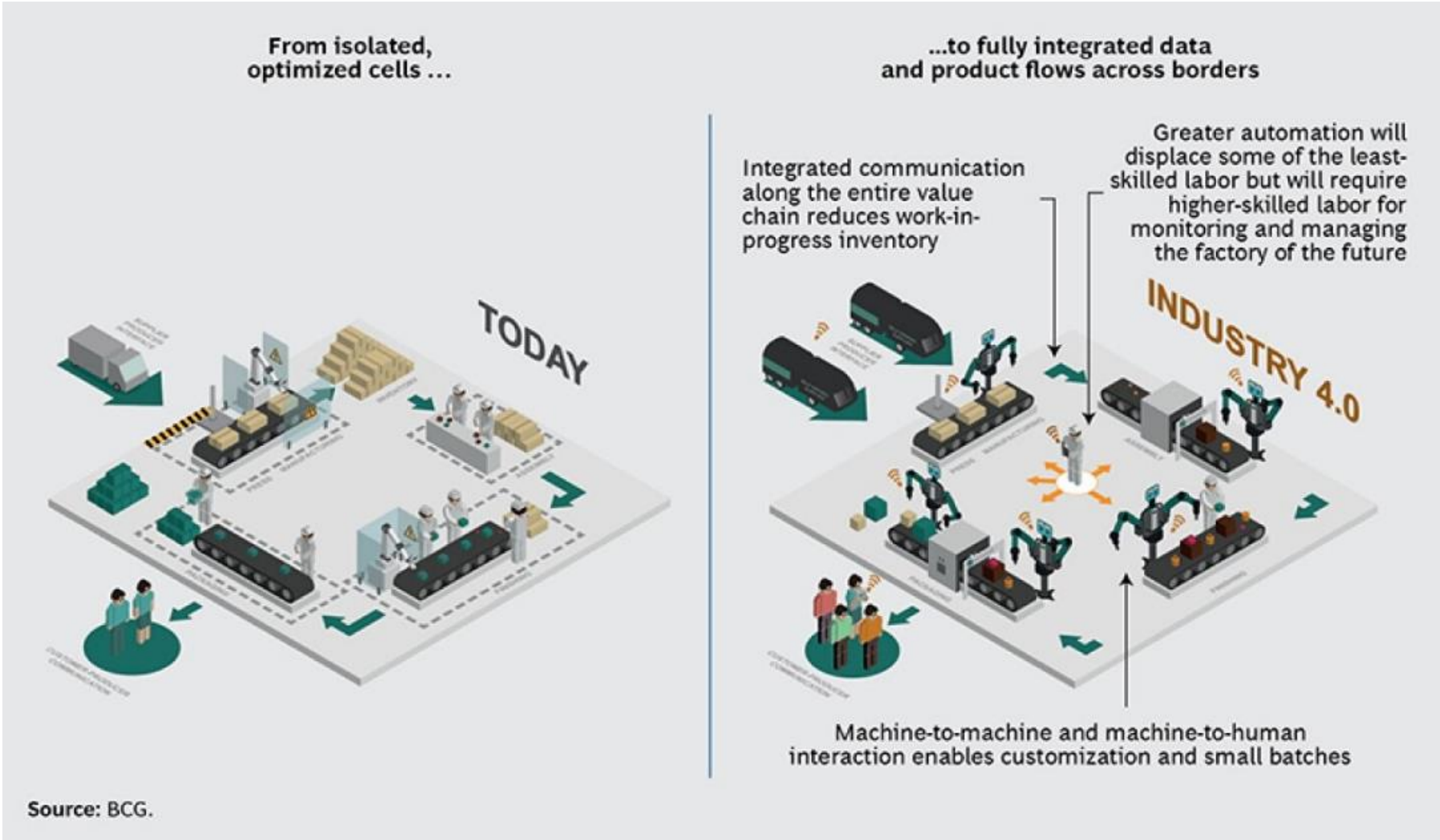**Michelle Schwalbe**, NMMB Director
Erick Svedberg, Study Director
Steven Darbes, Program Officer
Amisha Jinandra, Associate Program Officer
**Joe Palmer**, Senior Project Assistant

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4

A Vision for the Future of Manufacturing in the United States

From isolated, optimized cells …

…to fully integrated data and product flows across borders

TODAY

Integrated communication along the entire value chain reduces work-in-progress inventory

Greater automation will displace some of the least-skilled labor but will require higher-skilled labor for monitoring and managing the factory of the future

INDUSTRY 4.0

Machine-to-machine and machine-to-human interaction enables customization and small batches
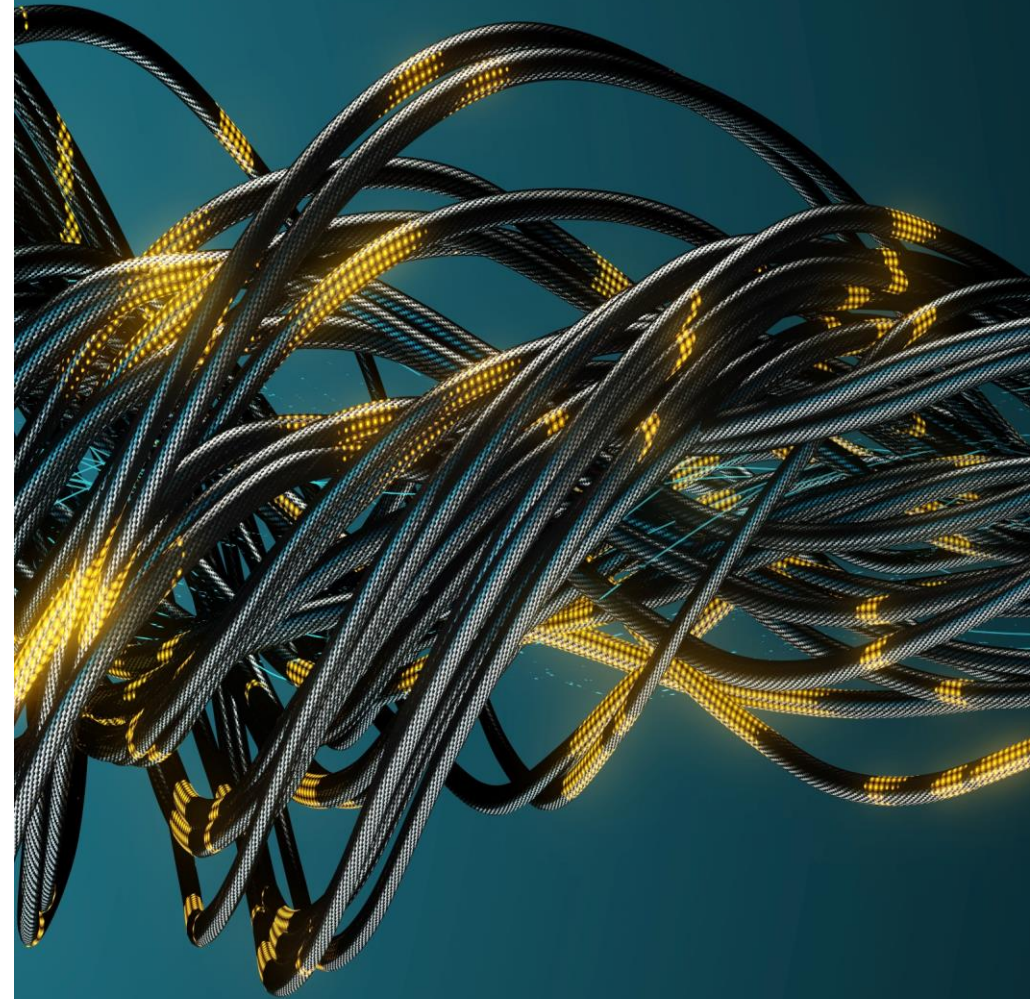
Source: BCG.

Main Messages

The federal government can accelerate and promote the implementation of smart manufacturing in the United States by:

- Supporting **new education and training programs** for the next-generation smart manufacturing workforce

- Providing cross-industry **data sharing infrastructure and capabilities**

- Improving **coordination across federal agencies and industry** around key technology areas

- Quantifying how advances in smart manufacturing could **contribute to sustainability**

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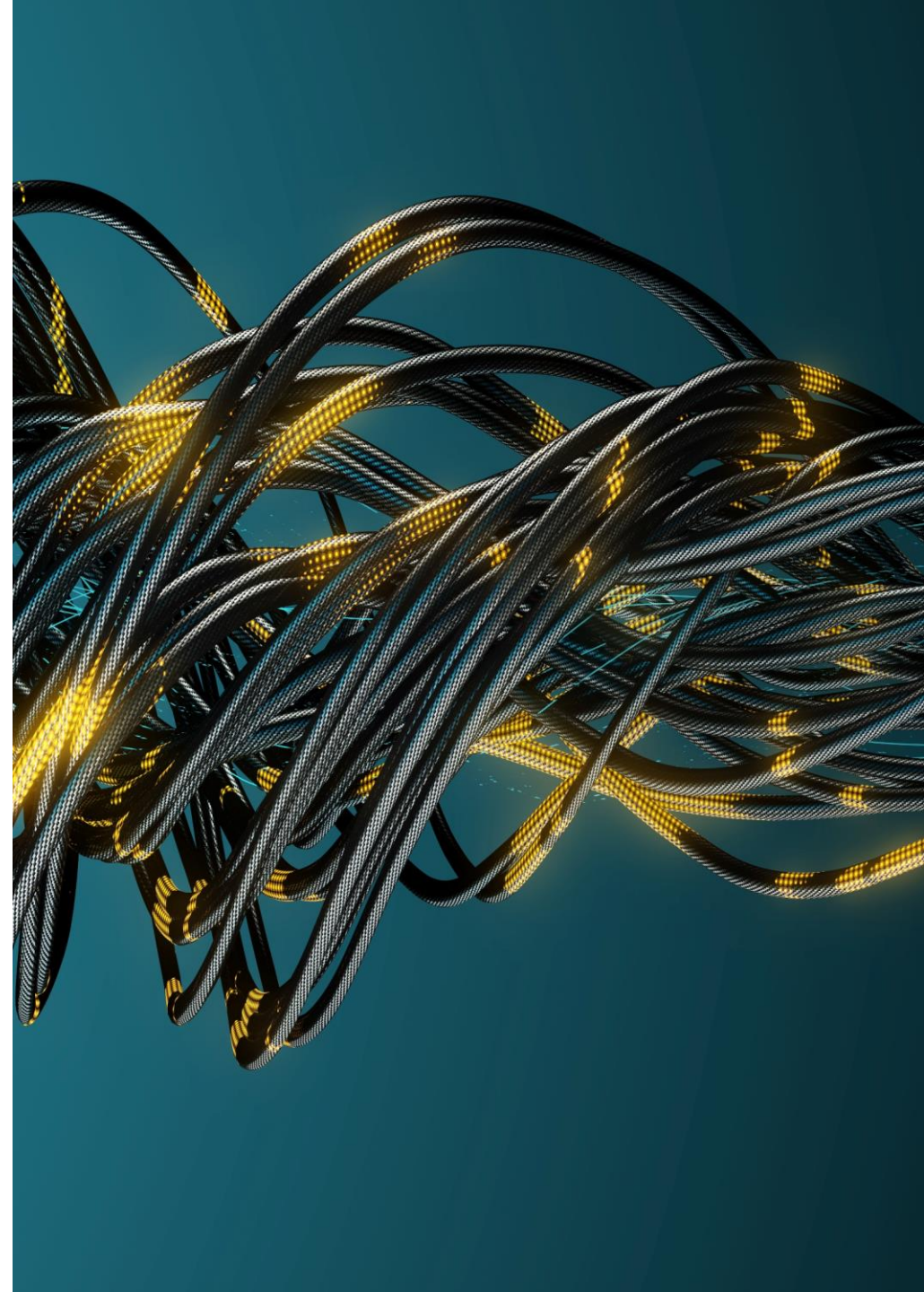
Report Structure

- **Chapter 1**: Value of SM and its critical role in the future of the U.S. economy and environment

- **Chapter 2**: Workforce and education challenges facing the SM industry with a focus on new and continuing education support and reform

- **Chapter 3**: Technology challenges and data sharing needs for the SM industry

- **Chapter 4**: Challenges and opportunities of realizing the broader impacts of secure SM

- **The conclusion:** Implementation details, methods, and timelines for report recommendations

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Key Recommendations

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Key Recommendation: Nation-wide Academy for SM Education and Training

A national plan for smart manufacturing should **offer a holistic, boldly orchestrated national approach** to solve workforce challenges and **support existing workforce development infrastructures**, investments, and systems.

An effective initiative could take the form of **an independent nongovernmental institute or organization**, such as a smart manufacturing education and training academy, that is chartered to drive workforce-related initiatives and support smart manufacturing education and training in the United States.

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Key Recommendation: The Cyber Interstate

A national plan for smart manufacturing should urgently support the establishment of national transformative data infrastructure, tools, and mechanisms to assist with:

(1) **cultivating, selectively sharing, and securing the use of data** in real time and at scale; and

(2) sharing best practices to **promote industry-wide technical data standards**.

Such infrastructure could take the form of a **secure digital network that facilitates the flow of data with controlled and credentialed access**, such as a Cyber Interstate.

It should be planned and coordinated with companies, government agencies, associations and consortia, and academic stakeholders.

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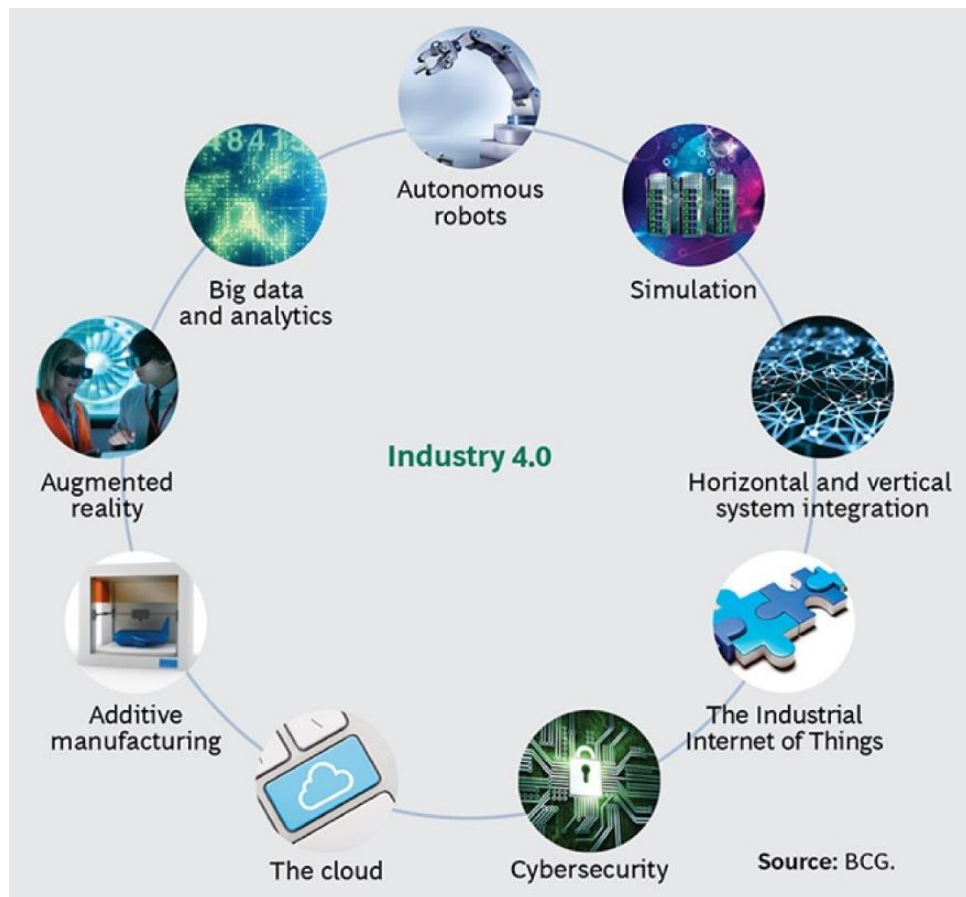*Sciences*
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Key Recommendation: CASE Data Banks

The Department of Energy in partnership with the National Institute of Standards and Technology, the Department of Defense, and manufacturing institutes should **establish manufacturing CASE (Calibration, Autonomy, Security, Evaluation) Data Banks** with the next generation of secure manufacturing architectures.

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Key Recommendation: Technology Development

Industry 4.0 diagram showing: Autonomous robots, Simulation, Horizontal and vertical system integration, The Industrial Internet of Things, Cybersecurity, The cloud, Additive manufacturing, Augmented reality, Big data and analytics. Source: BCG.

Smart manufacturing is multifaceted, and technologies developed in one specialty area most likely will not be suited for other applications.

The Department of Energy and other federal agencies should **fund programs and consortia** that develop technologies at:

- the intersections of **critical technologies** (e.g., human–AI co-piloting, sensing, AI/machine learning, platform technologies, digital twins, uncertainty quantification)

- **unit manufacturing processes** (e.g., casting, forming, molding, subtractive, additive, and joining)

- **industry sectors** (e.g., semiconductor, aerospace, automotive, biomedical, and agriculture)

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Key Recommendation: Measurable Sustainability

Funded by the Department of Energy, in consultation with other relevant federal departments and agencies, a **framework should be developed to quantify the broader sustainability benefits** of implementing secure smart manufacturing (considering three pillars: environment, economy, and society) as well as industry-wide sustainability metrics.

Report Recommendations

Assess and Invest in Education

Given the fast-moving nature of the smart manufacturing field, it is critical to ensure that the current and future manufacturing workforce in the United States is relevant, robust, competitive, and adaptable. However, existing efforts to train and educate the manufacturing workforce are fragmented and insufficient.

The report recommends:

– **Assessing all existing smart manufacturing education activities** for their capacity to engage with stakeholder groups

– Financial and other **incentives for instructors** to help them keep abreast of new developments in smart manufacturing

– Significant resources and investment in **new initiatives to address skill shortages and build an internationally competitive manufacturing workforce**, from entry-level positions to Ph.D.-level engineers.

– **Rigorous, planned evaluation** to determine the effectiveness of each program.

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Support Workforce Development

To address workforce training and education challenges and increase the number of qualified workers with credentials in smart manufacturing, the report presents several options, including:

- **Financing sabbaticals for instructors** at the high school, community college, and university level for training in the latest developments in smart manufacturing.

- **Providing need-based financial support** for both new and returning students enrolled in smart manufacturing credentialing and upskilling programs.

- Providing grants to high schools and community colleges for **smart manufacturing training laboratories**.

- Developing a **national repository of learning materials and curricula** for industry, high school, community college, university, adult education, and independent training in smart manufacturing.

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Career Support

In order to provide direct investment and support for smart manufacturing skills development, the national plan for smart manufacturing could adopt one or more of the following initiatives:

- **Option**: **Set up fellowship programs, traineeships, or E-corps** in smart manufacturing for individuals and invest in much needed infrastructure to train the workforce of the future.

- **Option**: **Improve and modify existing continuing education programs** to provide funding for microcourses and microcredentialing opportunities, allowing subsidized access to the evolving world of educational offerings.

- **Option**: **Create a career exploration requirement** in middle school with a federal mandate that covers it; the content delivered should be flexible in terms of career pathways.

- **Option**: **Offer tax incentives** for corporations and grants for small and medium-sized businesses to fund job training and education.

- **Option**: **Support wraparound services for students and workers** with mentoring and implementation services to assist those pursuing entry-level positions, including the requisite support systems (e.g., childcare, travel, connections for scholarships).

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New Smart Manufacturing Programs

Programs are needed to ensure that smart manufacturing is integrated not only into large multinational companies, but also into the small and medium-sized manufacturers (SMMs). The report recommends that:

- Industry associations and consortia should **fund pilot programs for data sharing** and intellectual property retention and protection to be used by small and medium-sized enterprises with nascent efforts in smart manufacturing.

- Federal agencies should **support new programs to provide funding and resources for small-to-medium manufacturers** to update and secure their current operations and equipment by deploying smart manufacturing technologies.

- Federal agencies, in collaboration with universities and consortia with interests in smart manufacturing should **support the development of new programs to provide easy access to expertise and facilities** and to aid in the design and development of prototype systems and processes.

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Stakeholder Coordination

Several of the recommendations in this report are national in scale and are simply not possible without strategic coordination among federal agencies together with joint agreements on implementation. The report recommends:

- **Forming a subcommittee of the federal agencies** to coordinate cross-agency smart manufacturing efforts at the strategic, financial, and administrative levels.

- The Manufacturing Extension Partnership program, the Industrial Assessment Centers, and the Manufacturing USA institutes should be **empowered and funded to work together on smart manufacturing capabilities for small-to-medium manufacturers (SMMs).**

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Conclusions

Conclusion

- Smart Manufacturing is horizontal, crosscutting, and will require both industry and government driven strategies to help companies to transition from traditional vertically integrated processes and facilities.

- Public-private partnerships are critical to ensuring the future of smart manufacturing in the United States.

- There is a significant opportunity to empower the Manufacturing USA institutes to help integrate the long term cultural, business, and market changes necessary for the advancement of the smart manufacturing industry.

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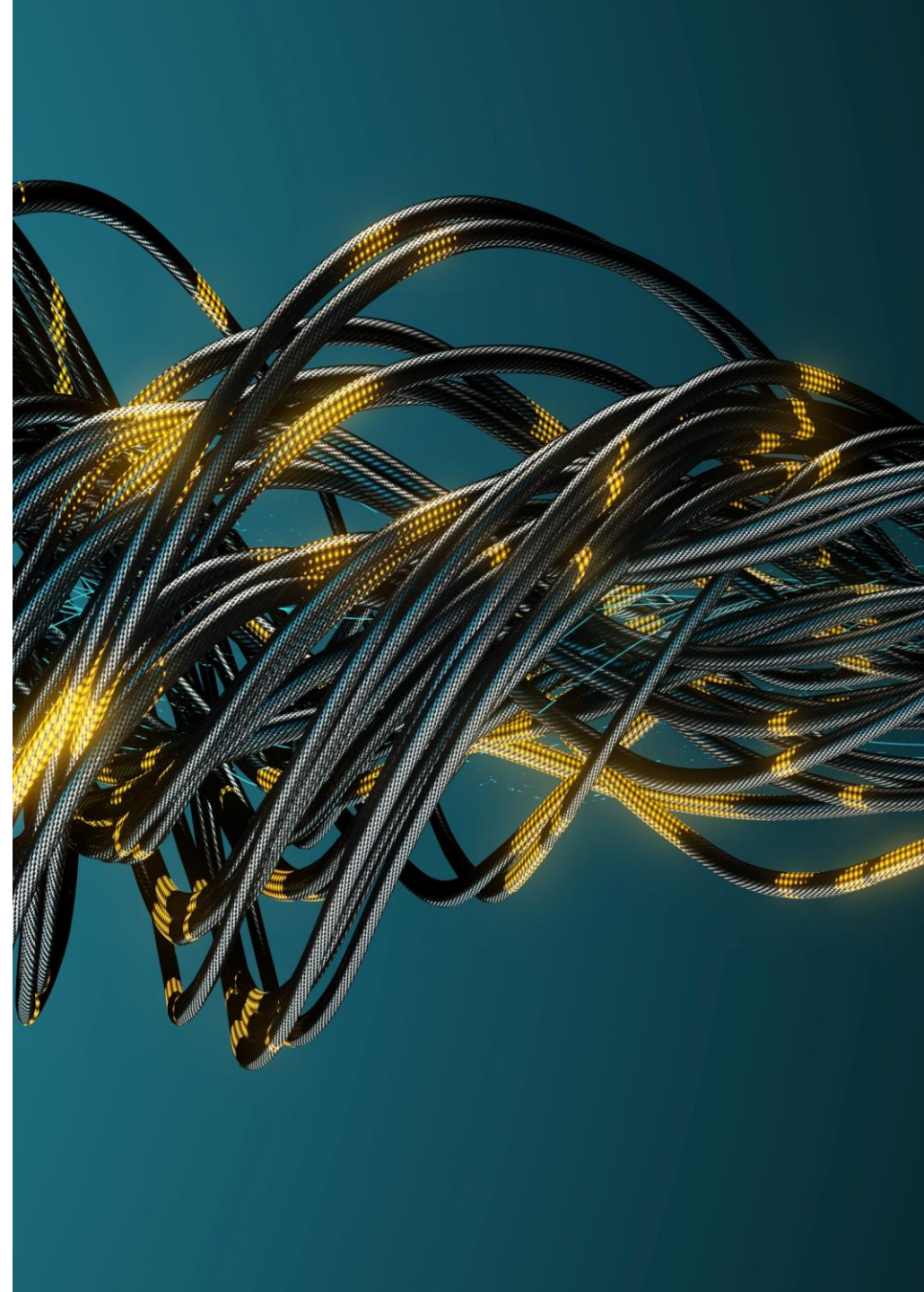
Conclusion

- The execution of the national plan for smart manufacturing needs to inspire change that disrupts current industry practice, stimulates new market drivers, motivates new ways of thinking about data, and drives more rapid approaches to addressing environment stability.

- The report recommendations are built around three primary levers for disruption:

  - Build a cyber-ready, data savvy workforce
  - Build the digital and physical infrastructure for cross-industry tools, platforms, connectedness, best practices, and the managed exchange of data
  - Commitment to smart manufacturing as a national priority

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Conclusion

- Upgrading our manufacturing workforce and ecosystem will provide next-generation capabilities in manufacturing.

- Investments in smart manufacturing, including the workforce, technology deployment, and cyber security infrastructure, will ensure the United States can deploy state-of-the-art capabilities in all manufacturing sectors and remain at the forefront of the industry in all areas critical to the nation's economy and security.

- The proposed solutions in this report focus on how technology can be deployed to the U.S. Industrial base, and highlights the importance of integrating smart manufacturing into both large and small companies.

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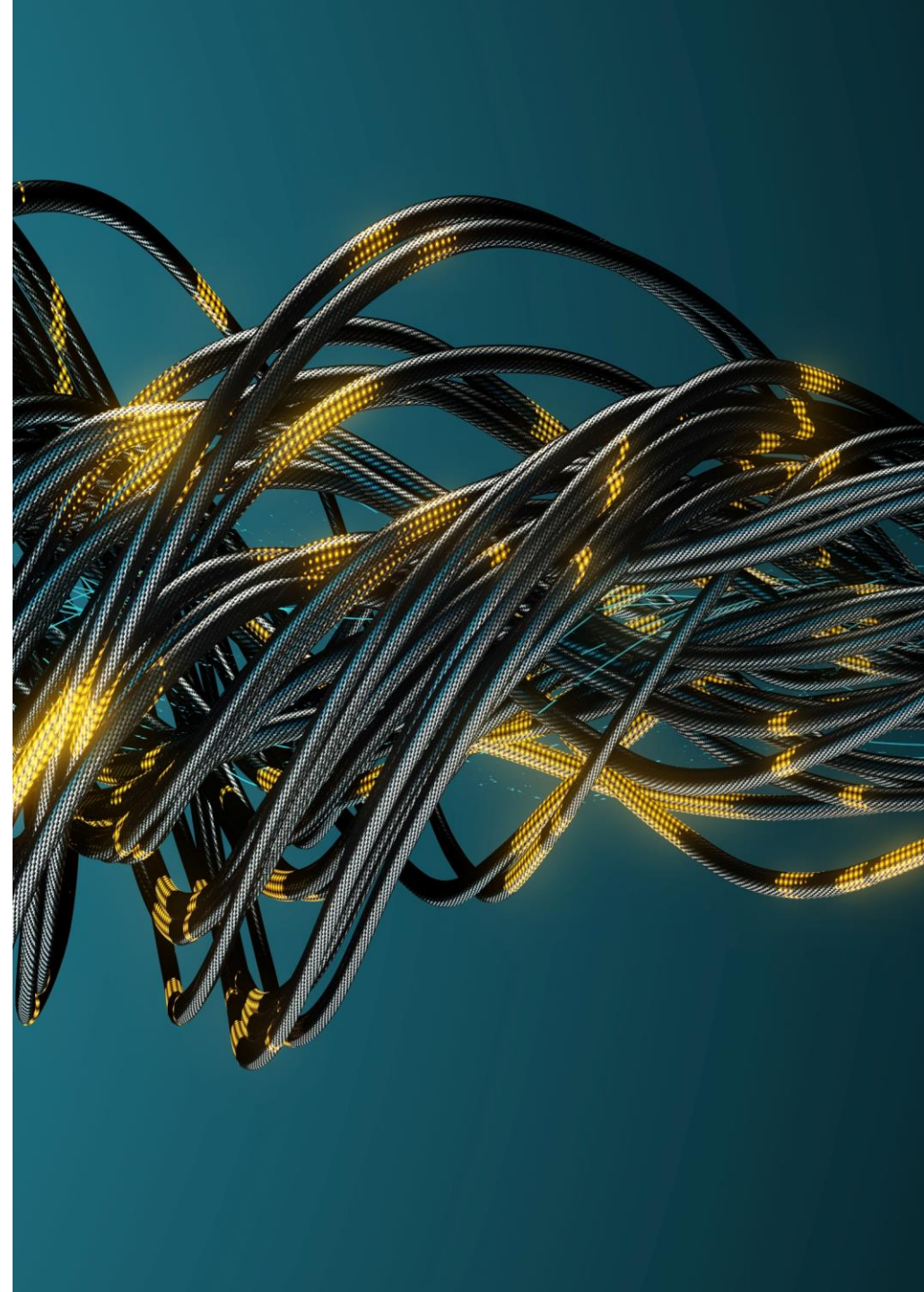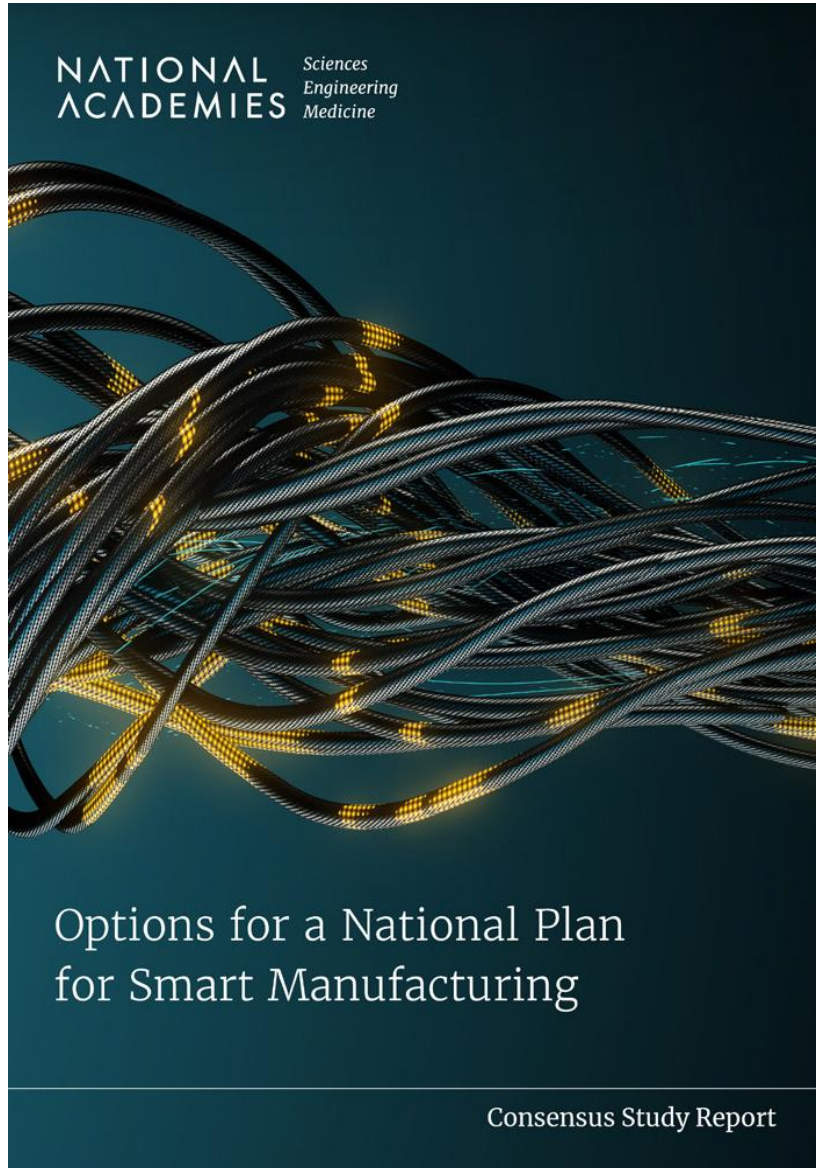
Questions?

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