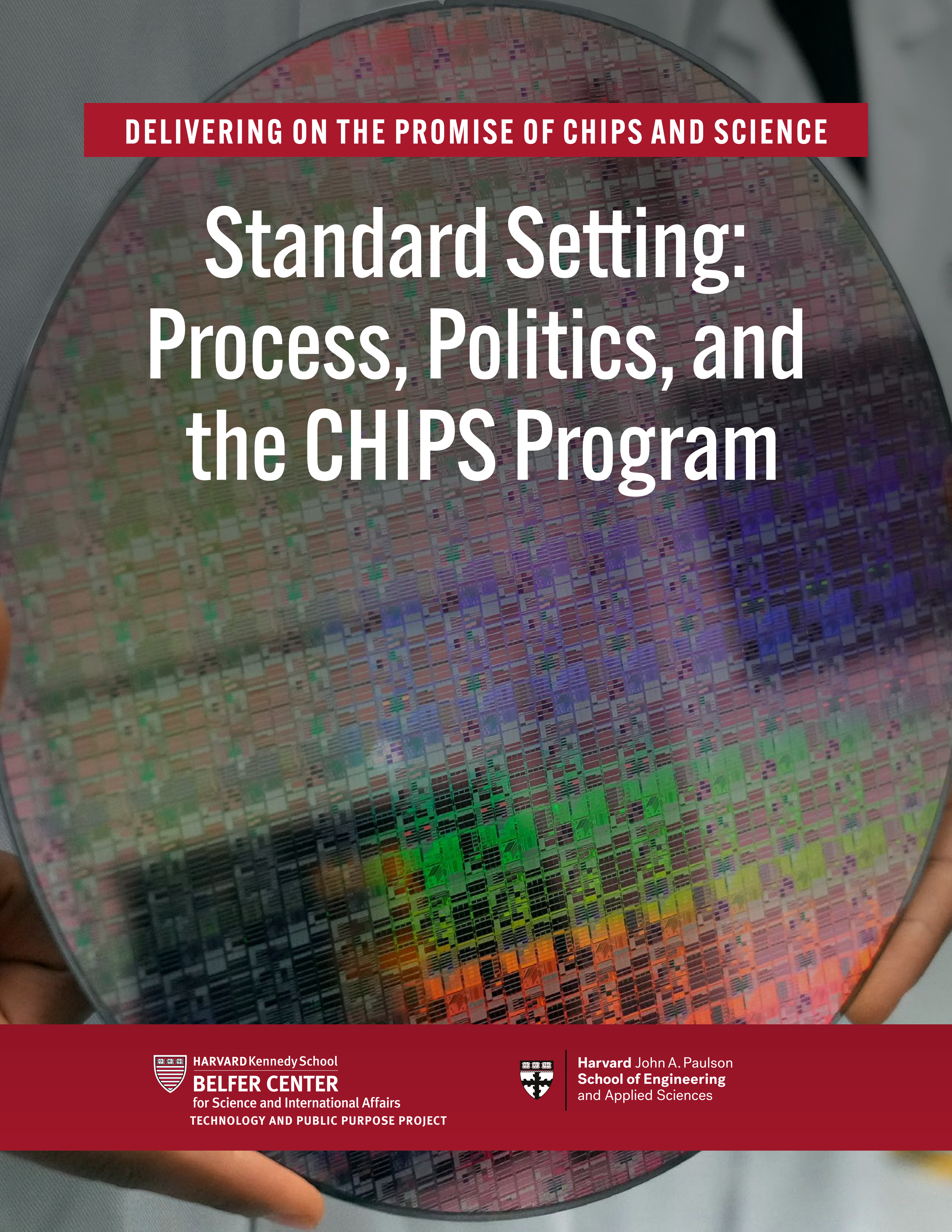

DELIVERING ON THE PROMISE OF CHIPS AND SCIENCE

Standard Setting: Process, Politics, and the CHIPS Program

HARVARD Kennedy School
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This paper series was designed to provide a brief overview of specific issues identified in the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022. These papers are not meant to be exhaustive.

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Contents

Delivering on the Promise of CHIPS and Science Report Series

This report is part of a four-part series of research primers produced by the Technology and Public Purpose (TAPP) Project focused on the implementation of the 2022 CHIPS and Science Act.

Report Topics

1. Lab-to-Market Translation at NSF's Technology, Innovation, and Partnerships (TIP) Directorate
2. Community Colleges and the Semiconductor Workforce
3. Standard Setting: Process, Politics, and the CHIPS Program
4. Catalyzing Semiconductor Innovation through a National Semiconductor Technology Center

Each report topic formed the basis of a discussion organized by the Boston Tech Hub Faculty Working Group.

About the Boston Tech Hub Faculty Working Group

The Boston Tech Hub Faculty Working Group (FWG) was founded by former Secretary of Defense and Belfer Center Director Ash Carter and Harvard John A. Paulson School of Engineering and Applied Sciences Dean Frank Doyle. From February to May 2023, the group held monthly discussion-based meetings with senior faculty across Harvard and MIT and practitioners/decision makers across the public and private sectors that sought to explore and answer the questions: “How do we execute on the promise of the CHIPS and Science Act in an effective way?” and “Where do we go from here?”

The report authors would like to thank the Boston Tech Hub Faculty Working Group speakers and attendees for their contributions to each session.

Session Topics

- “Advancing Strategic Translational Science at the newly authorized TIP Directorate.”
  Guest Speakers: Erwin Gianchandani, Stacey Dixon, Edlyn Levine, Steven Currall
- “Leveraging America’s Potential - Workforce Development for the Semiconductor Industry.”
  Guest Speakers: Sujai Shivakumar, Bo Machayo, Anastasia Urtz, Jared Ashcroft, John Katko
- “Standard Setting and CHIPS Legislation Implementation.”
  Guest Speakers: Naomi Wilson, Mary Saunders, Andrew Updegrove
- “Catalyzing Semiconductor Innovation through a National Semiconductor Technology Center.”
  Guest Speakers: Susie Armstrong, Jim Cable, Dev Shenoy, Gregg Bartlett

Executive Summary

The CHIPS & Science Act of 2022 outlines an expansive national strategy to preserve and bolster the United States' national security by ensuring a pathway for a resilient supply chain for semiconductors and other critical and emerging technologies. Targeted provisions in the CHIPS and Science Act aim to address U.S. leadership in domestic and international standards-setting processes.

Setting standards is the process by which a common set of guidelines, specifications, and/or characteristics are determined between relevant stakeholders for the design, manufacturing, or process implementation of technologies, products, and services. Fundamentally, a standards-setting process that enables inclusive participation between all relevant stakeholders and is open and transparent fosters technological innovation and interoperability. For implementers, balancing strategic national priorities related to critical and emerging technologies with the need to preserve an open, transparent, and inclusive standards-setting ecosystem is an important consideration. Upholding this model and encouraging multi-stakeholder standards-setting engagements within the United States thus becomes a critical priority under CHIPS legislation.

To reinforce the scope of standards-setting provisions within the CHIPS Act, this primer aims to identify and evaluate the critical characteristics, implications, and stakeholders of standards-setting processes, as well as forums where these activities take place. Further, it will identify critical aspects of standards-setting processes as they relate to design, production, and innovation of semiconductors and related to critical emerging technologies (i.e., information communication technologies). Finally, this primer will contextualize emerging challenges to the standards-setting ecosystem and offer potential recommendations in addressing these challenges.

For federal agencies such as the National Institute of Standards and Technology (NIST) contending with implementation of standards-related mandates within the CHIPS program presents a delicate balancing act between supporting emerging national priorities but preserving the existing industry-driven model for setting standards. Pragmatic implementation by federal agencies will require careful enactment of funding that aims to support industry-led processes by addressing gaps and existing market failures, without undermining the industry-led voluntary process. Key recommendations will strive to explain the specific actions NIST can incorporate ranging from workforce training support, visa streamline processes for international experts to engage in U.S.-hosted events, to stipulations that indicate recipients of federal funds incorporate standards engagement as a priority.

To conceptualize the process, politics and the implications, this primer is organized into the following sections:

Part 1 outlines how prioritizing standards can help the United States achieve semiconductor industry goals as outlined in the CHIPS and Science Act and the FY2021 NDAA CHIPS for America title. This section provides a brief overview of how the legislation empowers specific federal agencies toward achieving the objectives of ensuring industry-led consensus-based standards-setting processes.

Part 2 describes the standards-setting process and why they matter. This section identifies the broad stakeholders in the standards development ecosystem, evaluates the impact of standards in the global market, and touches upon the changes in standards development due to geopolitical factors.

Part 3 emphasizes the critical role of R&D in the standards development process and evaluates the role of small and medium enterprises in the development phases.

Part 4 explores implementation considerations, identifies challenges, redlines, and concludes with top recommendations for NIST as it seeks to implement the objectives set out by the legislation.

Part 1: The CHIPS and Science Act & Standard Setting

What Are Standards and Why Do They Matter?

Standards are a set of common guidelines, rules, or characteristics for design, construction, and/or implementation of a product or service. They are typically developed through a voluntary, consensus-driven process between stakeholders.

Standards play a critical role in the foundations of scientific research and technological progress by providing a common framework for innovation and implementation that encourages interoperability and promotes quality, safety, and efficiency in market operations. In so doing, standards foster collaboration, reduce complexity, and allow for the seamless integration of new technologies, ultimately driving innovation and progress across industries.

By establishing a shared foundation of best practices and requirements, standards enable researchers, engineers, and manufacturers to build on existing knowledge, push the boundaries of technology, and develop new and improved products and processes. This accelerates the pace of scientific discovery, technological advancements, and contributes to the common public good.[1]

Standards have the potential to facilitate crucial economic benefits and positive market dynamics. Ultimately, the adoption of standards widens choices, drives down prices, and leads to competition on value-added features and services, benefiting business and consumer purchasers.

How does standards-setting processes tie into the larger goals and objectives of CHIPS legislation?

In August 2022, the Biden administration signed into law the CHIPS and Science Act of 2022.[2] The CHIPS Act is a landmark measure among a series of recent bipartisan legislative efforts (i.e., FY2021 National Defense Authorization Act) focused on fortifying U.S. manufacturing, R&D, and promoting supply chain resiliency in semiconductor production and other critical, emerging technologies. The Act both created and continued several of the R&D priorities over five years across different federal agencies. The legislation elevated the rhetoric of of America's role , particularly in a heightened geopolitical environment and highlighted the standards development space as an important priority. Support for the development of technical standards exposes trade-off challenges of pursuing free market competition versus serving the greater public good through innovation.

Sections outlined within Division B of the CHIPS Act, explicitly address the role of NIST in the federal government and the relevant appropriations that allow NIST to pursue its objectives.[3]

Select CHIPS Legislation Provisions on Standards Leadership and Semiconductor Development

CHIPS and Science Act

Sec. 10245 – International Standards Development

NIST's role as a convener and federal coordinator in international setting of standards is codified. It further expands NIST's support for standards capacity building, which includes a pilot program establishing grants to small businesses, nonprofits, and universities to facilitate their participation in international standards-setting processes.

Sec. 10246 – Standard technical update.

Provides several technical and administrative updates to the NIST Act.[4]

In 1995 the passage of the National Technology Transfer and Advancement Act (P.L. 104-113, National Technology Transfer and Advancement Act [NTTAA]), directed federal agencies to "use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments," except where they are inconsistent with applicable law or impractical.

The standards provisions of the NTTAA and the Office of Management and Budget (OMB) Circular A-119 reflect the commitment to the industry-led, voluntary consensus standards system. OMB Circular A-119 changes the approval process of standards in that standards approval will no longer have to go through the OMB but by NIST itself.[5]

Potentially complementary to standards agenda

Sec. 106—Appropriations for wireless supply chain innovation.

$1.5 billion appropriated for open-architecture, software based wireless technologies, "leap ahead" technologies in the U.S. broadband market. This fund would be administered by the National Telecommunications and Information Administration with input provided by NIST & DHS and others.

Sec. 10251 Establishment of expansion awards pilot program as a part of the Hollings Manufacturing Extension Partnership.

The stipulated expansion establishes award possibilities for workforce development which could include technical experts and allow small and medium manufacturers expanded support for technological upgrades. Moreover, the awards can be used to facilitate research exchange between manufacturers, research institutions, public private partnerships, and other stakeholders. The award expansion also covers establishment of demonstration laboratories critical to the development of next-generation technologies which can be adopted by small and medium sized manufacturers.

CHIPS for America Title (FY2021 NDAA)

Sec. 9906(e) – Advanced Microelectronic Research and Development (R&D)
Authorizes the Director of NIST to conduct an R&D program to enable advances and breakthroughs in measurement science, standards, material characterization, instrumentation, testing, and manufacturing capabilities for next-generation microelectronics metrology, and to ensure U.S. competitiveness and leadership in microelectronics.

NIST, a Bureau within the Department of Commerce, seeks to boost U.S. innovation and competitiveness by advancing measurement science, standards, and technology. Its mission is to coordinate measurement standards rather than regulating industry, ensuring credibility of technologies. Building on NIST's long-standing reputation and relationship with private industries, the CHIPS for America Act expanded the Bureau's oversight creating two offices to oversee the implementation. The CHIPS Program Office incentivizes manufacturing, while the CHIPS R&D Office promotes basic research and industry exchanges for standards development.[6]

The R&D Program Office is responsible for managing the National Semiconductor Technology Center (NSTC), National Advanced Packaging Manufacturing Program, the Manufacturing USA Institute, and the NIST Metrology Program.[7] The NSTC will be a public private partnership office focused on facilitating R&D exchanges by being a platform for researchers, technical experts, industry, and consortia. The NSTC Vision and Strategy paper published in April 25, 2023, lays out the underpinning NSTC programs to include research on design innovation and manufacturing process improvements; its technical programs will facilitate coordination on the development of standards and more specifically standards for the microelectronic devices security.[8]

The implementation of CHIPS programming will be dynamic, depending on the appropriations outlined by Congress. The legislation has thus far appropriated the Department of Commerce with $50 billion dollars to promote U.S. competitiveness in the semiconductor ecosystem, from research, development, manufacturing, to investments in training technically sound workforce. A further breakdown stipulates $11 billion dollars for R&D purposes with the remaining $39 billion dollars to support incentives for manufacturing facilities.[9] Congressional appropriations for all segments remain in process, but once established, it will help propel increased levels of engagement and implementation as envisioned by the legislation.

White House Standard Strategy for Critical and Emerging Technology

In addition to legislative language outlined in the CHIPS and Science Act, the May 2023 standards strategy outlined by the White House provides specific clarity on the United States' commitment for engagement in the standards space for critical and emerging technologies (CET). The strategy reaffirms the United States' continued support for government supported R&D, promotes transparency, and mutual engagement of diverse stakeholders. The strategy outlines broad objectives that resemble the thematic narratives articulated by experts interviewed for the purpose of this primer. Specific lines of efforts are also provided to help obtain the objectives of the strategy.

Specific critical technologies are repeatedly highlighted as areas of crucial national interest for the United States. Among the considered CETs are microelectronics and semiconductor technologies. Four specific objectives are envisioned in the strategy, followed by four lines of effort to propel movement toward each of the objectives. The four objectives include: investment, participation, workforce, and integrity & inclusivity

NIST's measurement capability has always supported a diverse range of technologies designed to ensure U.S. competitive edge in innovation, measurement and standards. The CHIPs & Science Act has accentuated the range of NIST's capabilities; as such, this primer explores the importance of a dynamic, open, and consensus-driven standards-setting ecosystem. As additional appropriations become solidified, this primer strives to evaluate critical considerations for implementers seeking to enact nascent programs mandated via the CHIPS Act, in addition to other legislative mandates pertaining to standards.

Part 2: Standards Process, Stakeholders, and Impact

How Are Standards Developed?

Voluntary Consensus-based Standards-Setting (VCSS)

A collaborative and consensus-driven process is considered the cornerstone of the standards-setting ecosystem. The process involves industry stakeholders, manufacturers, consumer groups, government agencies, and other relevant parties working together to develop and agree upon common technical standards, guidelines, and best practices. Participants choose to engage and adopt consensus-driven standards even when there is no legal mandate to do so; this is due to the collective market competitive characteristics this type of engagement fosters (see section above).

Key Characteristics of the Voluntary Consensus-Based Standards Process[10]

1. **Participation:** Fundamentally, setting standards is a social process. Stakeholders from various sectors, such as private companies, government bodies, academic institutions, and nonprofit organizations, convene, develop, and refine technically grounded standards based on their collective expertise and interests.

2. **Consensus-based decision-making:** The voluntary system emphasizes the importance of reaching a consensus among participants. This means that decisions are made based on general agreement intended to ensure that all parties' concerns and perspectives are taken into consideration. When unable to achieve consensus, many such standards-setting organizations allow for a super majority vote to determine standards decisions.

3. **Transparency:** The process of voluntarily setting standards is typically open and transparent, with participants sharing information, research, and insights to facilitate informed decision-making. This transparency helps build trust among stakeholders and encourages broader adoption of the resulting standards.

4. **Flexibility:** Voluntary standards can be more easily updated and revised than legally mandated regulations, allowing for greater responsiveness to technological advancements and changing industry needs. This flexibility enables the standards to stay relevant and effective over time.

5. **Research & Development:** For high-end technologies, the standards-setting processes are intrinsically tied to R&D investments into critical pre-competitive basic research and proprietary

research that produce standards-essential patents and scaled adoption by implementers in complementary industries. The type of technology will motivate the level of information sharing and the type of R&D engagement among stakeholders, particularly concerning a public good versus critical technology where private firms have substantial investment prior to the development of new technologies. This trade-off for private companies will be an important consideration when it comes to sharing knowledge.

6. **Technical Integrity:** Nongovernmental standards processes place a strong emphasis on scientifically rooted rationale for negotiations of standards proposals before they are approved and codified. Prioritization of scientifically rooted rationale and industry-driven, pre-competitive R&D has been critical to preventing the politicization of the voluntary standards process.

7. **Implementation and compliance:** While the standards are voluntary, participants often choose to adopt and comply with them to demonstrate their commitment to quality, safety, and reliability. In some cases, voluntary standards may also serve as a basis for government regulations or industry certification programs, further encouraging compliance. In many cases, voluntary standards become de facto specifications through increased scale of adoption within industry. Such specifications converge with companies' interest in meeting consumer demand, gaining market access, and achieving cost competitiveness.[11]

Main Stakeholders of the Standards Ecosystem

Below is a non-exhaustive list of key stakeholders in the standards-setting process.

Industry: Companies and organizations in various industries contribute their expertise, resources, and knowledge to the development of standards. These entities have vested commercial interest in creating standards that create operational benchmarks for compatibility, interoperability, safety, and quality. Industry stakeholders often participate in working groups, provide input during public consultations, and adopt the standards once they are finalized.

In the semiconductor space, large hi-tech corporations such as Intel[12] and Qualcomm[13], contribute to standards processes through intensive pre-competitive R&D and participation in open-standards-based platforms, among other standards-setting organizations.

National Standards Bodies: Typically, nongovernmental organizations that represent the interests of domestic stakeholders, at a country level, in international forums such as the ISO. In the United States, the American National Standards Institute (ANSI) is the primary coordinator and facilitator, accrediting standards development organizations, ensuring that the process is transparent, consensus-based, and inclusive. ANSI also represents the United States in international standards-setting organizations, such as ISO and International Electrotechnical Commission (IEC).

Government: Governments play a role in the standards-setting process through a number of mechanisms. **(1)** Providing broader support for basic R&D from which private industries could springboard to spur innovation and standards. **(2)** Offering guidance on public purpose considerations that may impact independent standards-setting processes, such as safety, fair market access, and national security. **(3)** Government agencies may also adopt binding standards in public procurement processes within their jurisdiction, that in turn promote the use of standards in other forums.

In the United States, the NIST plays a critical role in setting standards for measurements (metrology), quality, safety, and industrial competitiveness. NIST fulfills this role through an expansive network of research labs and programs covering a broad range of scientific study. It is also a convener of stakeholders, facilitating basic and pre-competitive R&D available to private industries who further the technology on a competitive scale.

Academia: Academic institutions contribute to the standards-setting process by conducting research, providing technical expertise, and advocating for specific interests, such as environmental protection, consumer safety, or accessibility. In most countries, engineers and others employed by academic institutions - collaborate in public private partnerships, create joint working groups, offer public consultations, and/or facilitate research collaborations with industry and other stakeholders to help shape technological development and associated standards.

Key Forums for Standards-Setting Processes

At any given time, there are over 1,000 voluntary standards-setting organizations at the national and international level. These organizations provide a neutral platform for stakeholders to convene, develop, and maintain standards and promote their adoption across relevant industry players.

International Standards Bodies: Typically, international organizations that function as nongovernmental, nonprofit, or specialized agencies that convene country-level members for the purpose of setting standards. Whereas the scope of setting standards for some organizations is broad, while others are more specified. There are three traditional international standards-setting organizations. The three organizations frequently work together.

1. The **International Organization for Standardization (ISO**) convenes 168 national standards bodies and has a broad scope of standards-setting activities that are conducted to various technical committees and working groups.[14]

2. The **International Electrotechnical Commission (IEC)** convenes 89 members, who each represent a different country, to set consensus-drive standards, specifically on electronic technologies.[15]

3. The **International Telecommunications Union (ITU)** is a specialized UN agency focused on setting standards (among other activities) specifically for information communication technologies.[16]

Standards Development Organizations (SDOs): ANSI-accredited groups that are either nationally or internationally focused. SDOs are typically tasked with development of U.S. national standards that can be submitted to the ISO and IEC. There are 235 such ANSI-accredited SDOs in the United States for technical, process-based, and other standardization needs. Examples of U.S. SDOs include the American Society for Mechanical Engineers and the National Electrical Manufacturers Association.

Industry Consortia:[17] Non-accredited groups that are typically headquartered in the United States and predominantly address information and communication technologies. Consortia are also primarily global in membership. Examples of consortia include the World Wide Web Consortium (W3C) and the Internet Engineering Task Force.

An Example of How a Standard Could be Developed[18]

NOTE: Not all standards will follow this linear process and will depend on the specific technology and/or sector requirements.

Identifying the need for a standard

Taking the semiconductor industry as an example, imagine there's a need for a standard addressing energy efficiency and performance requirements for new chip designs. This need could be identified by industry players, consortia, or government agencies concerned about environmental impact and energy consumption.

↓

Initiating the standard development process

A group of companies focused on energy-efficient semiconductors identifies the need for development of a new standard. The group approaches a standards body, such as IEEE (Institute of Electrical and Electronics Engineers), to initiate the standard development process.

↓

Forming a working group

IEEE forms a working group comprising representatives from the industry (semiconductor manufacturers, designers, and suppliers), consortia, government agencies, academic institutions, and nonprofit organizations.

↓

Drafting the standard

The working group collaborates to draft the standard, utilizing input from all stakeholders. They review existing research, best practices, and related standards to develop energy efficiency and performance requirements that can be feasibly implemented and adopted by the industry.

↓

Public consultation and feedback

Once the working group completes a draft of the standard, it is made available for public review and comment. This allows for broader input and ensures that any overlooked issues or concerns are addressed. Based on the feedback received, the working group revises the draft accordingly.

↓

Consensus and finalization

After addressing the feedback, the working group reaches a consensus on the final version of the standard. IEEE then reviews and approves the standard for publication.

↓

Publication and adoption

The standard is published and made available to the semiconductor industry, consortia, and other interested parties. Manufacturers, designers, and suppliers adopt the standard to ensure their products meet the specified energy efficiency and performance requirements. Government agencies may incorporate the standard into regulations or procurement processes, while academic institutions and nonprofits may use it as a benchmark for research and evaluation.

The Semiconductor Industry and Standards

The Promoter-Adopter Model for Standardization

As the name suggests, the promoter-adopter model consists of two types of participants: (1) the promoters are companies that jointly create technical specifications required for the interoperability of a new product. Typically, these are firms with large portfolios of standards-essential patents. (2) Adopters are companies that are either competing or complementary firms that enter into an adopter agreement that grants them access to the implementation rights of the of the established technical specifications. The promoter-adopter model is typically an invitation-only system that allows stakeholders (particularly the promoters) close control over patent rights.[19] The semiconductor industry is a patent-heavy industry. As such, stakeholders in this field gravitate toward a promoter-adopter model for setting standards.

Promoter-Adopter Model Case Study
High Bandwidth Memory (HBM) Standard

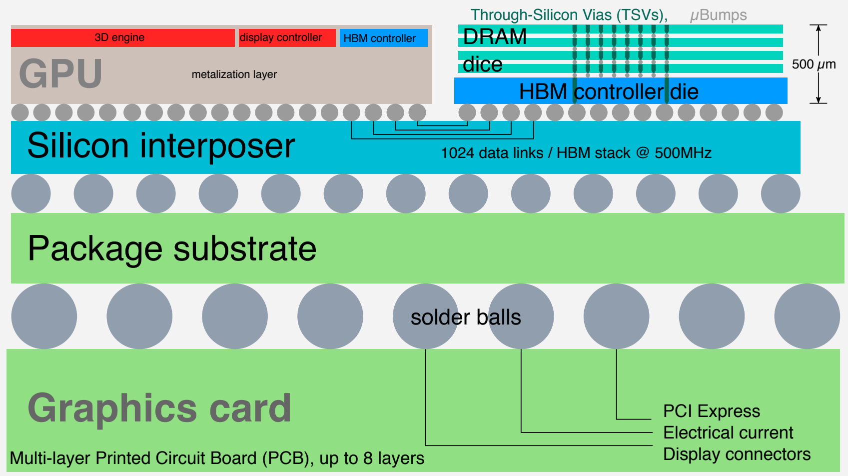


Figure 1. Schematic of High Bandwidth Memory[20]

The development and standardization of HBM in the semiconductor industry is a great example of the promoter-adopter model in action. HBM is a high-performance memory interface for 3D-stacked DRAM (dynamic random-access memory) that provides significant bandwidth improvements compared to older and traditional memory architectures.

In this case, **the promoters were semiconductor companies such as Advanced Micro Devices, Inc. (AMD), Samsung, SK Hynix, and Micron,** which played an instrumental role in developing the HBM technology and setting the technical specifications for the standard. These companies hold large portfolios of standards-essential patents, and their collaboration was crucial for the development and adoption of HBM.

The **adopters in this case were other competing or complementary firms in the semiconductor industry, such as Nvidia, Apple, and Qualcomm,** which entered into adopter agreements granting them access to the implementation rights of the HBM technical specifications. By adopting the HBM standard, these firms were able to enhance their products' performance and ensure interoperability with other devices and systems utilizing the HBM technology.

A potential pitfall of the promoter-adopter model arises when there is insufficient collaboration or consensus among key industry stakeholders. A lack of transparency or exclusion of important parties in the decision-making process can lead to fragmentation and the development of competing standards. This can result in a slower adoption process, increased costs for both manufacturers and consumers, and the potential for market confusion, as multiple, incompatible standards vie for dominance.

Promoter-Adopter Model Failure
Rambus Dynamic Random Access Memory (RDRAM)

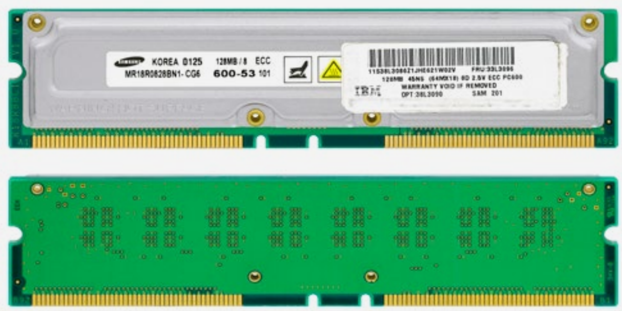


Figure 2. RDRAM[21]

RDRAM was a proprietary memory architecture developed by Rambus Inc. in the 1990s, initially positioned as the next-generation memory standard for personal computers and offered higher data transfer rates compared to the prevalent Synchronous Dynamic Random Access Memory (SDRAM) at the time. Intel, a major promoter of RDRAM, entered into a partnership with Rambus to develop and push the adoption of RDRAM in the industry but this eventually descended into a standards war (also known as a format war).

RDRAM faced several issues that hampered its success. The technology was more expensive than the alternatives, primarily due to the royalties and licensing fees associated with its proprietary nature. Other semiconductor manufacturers were also already working on improved memory standards, such as Double Data Rate (DDR) SDRAM, which provided better performance and cost efficiency. As a result, many manufacturers were reluctant to adopt RDRAM, and the industry eventually coalesced around DDR SDRAM as the dominant memory standard. RDRAM's failure to become the dominant standard can be attributed to its premature promotion, high costs, and the existence of more viable alternatives.

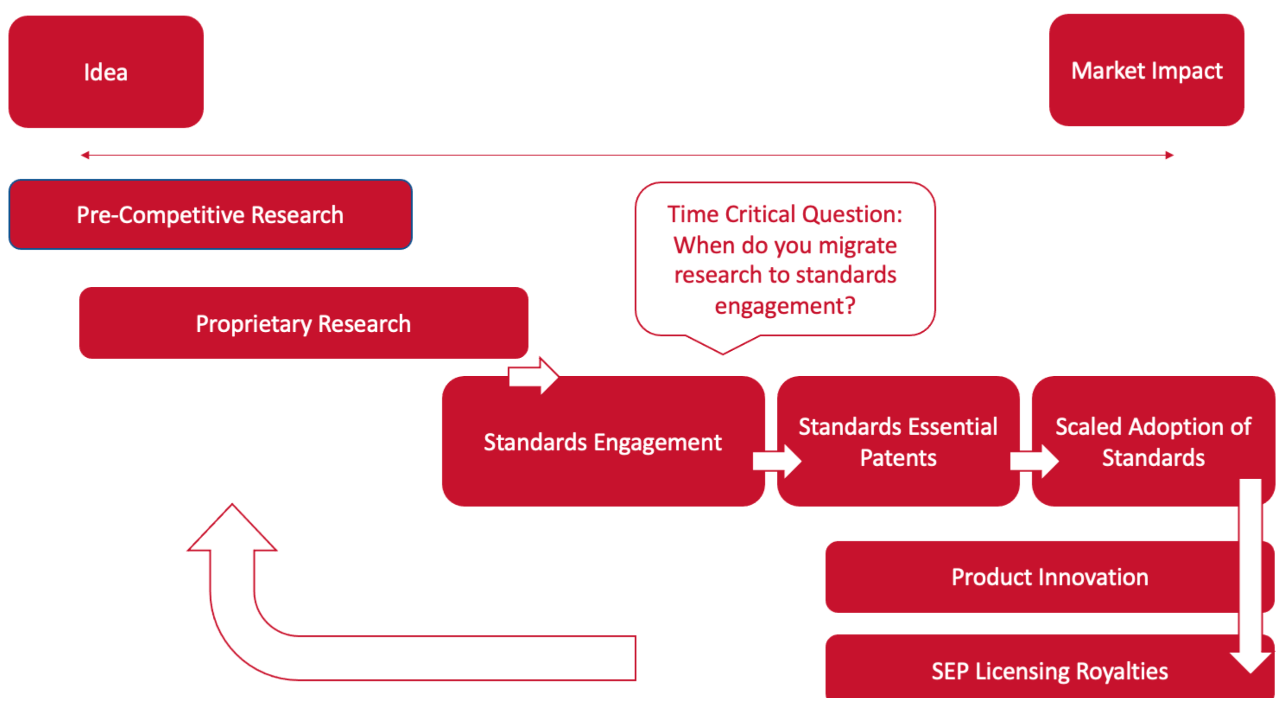
Part 3: The Role of R&D

The Standards Value Chain

Particularly for private stakeholders, setting standards poses a delicate balance between divulging critical intellectual property to competing stakeholders and effectively contributing to open consensus-based processes that are equally important to fundamental technical specifications, product innovation, and process standards that foster overall industry competitiveness. Ultimately, striking this balance amid information asymmetries within industries, can result in non-linearity within the standards-setting process. Whereas SDOs are critical to minimizing this information asymmetry, technical standard specifications can also be set by de facto market dynamics (i.e., first mover's advantage, corporate bargaining power, etc.) and through collaborative R&D.

This section aims to map the fluidity of the standards-setting process between various stakeholders, from idea to market impact. Different elements showcased in this value chain should be understood to be part of a fluid system that is malleable to evolving scientific discovery, behaviors in technology and/or process adoption, and resulting market dynamics.

Figure 3. The Fluidity of the Standards-Setting Process



Pre-Competitive vs. Proprietary Research

The R&D ecosystem for science and technology development is critical to scientific discovery, technological innovation, and market competitiveness for a diverse array of industries. In the context of standards, R&D is a fundamental source of critical reference materials, technical engagement between stakeholders within a technology value chain, and the development of standards-essential patents. In this context, there are two categories of R&D to consider: pre-competitive collaborative R&D as compared to proprietary research within a single company or organization.

Pre-competitive research refers to basic and applied research that facilitates critical information exchange within the scientific and technical community, which supports the consensus building processes that are essential to the finalization of standards and technical specifications. Pre-competitive research ensures that diverse stakeholders within the value chain of a technology have access to fundamental information on which they can develop differentiated products.

Proprietary research is conducted primarily by large corporations given their greater financial resource, infrastructure and expertise which affords them the ability to substantively invest in R&D, with the aim of productization of scientific discoveries and critical technologies. Smaller companies, startups, and research institutions also contribute to the R&D landscape; while they may not have the same level of resources as large corporations, these smaller entities can still develop innovative products and technologies, sometimes with the support of government funding, venture capital, or strategic partnerships.

R&D investment not only fosters competitive advantage in product development, but also allows firms to produce standards-essential patents (SEPs) that in turn, generates licensing revenues from standards adopters. According to many large corporations, these royalties are critical to reinvestments in the R&D process. In other cases, companies are willing to license their SEPs on a royalty-free basis because of associated benefits that they anticipate receiving from the inclusion of their technology in a standard.

What are Standard Essential Patents

Standard Essential Patents (SEPs) are a type of patent that protects core technologies, developed by private companies, universities, and other research organizations that are essential to the implementation of a specific industry standard. These patents typically cover inventions that must be used to comply with a technical standard, meaning that any product or service conforming to that standard cannot avoid infringing upon the SEP (think of things like USB, LTE, Wi-Fi, Video Compression types, etc.). To prevent abuse of market power and promote innovation, patents that help develop a standard are almost always required to license their SEPs to other companies on Fair, Reasonable, and Non-Discriminatory (also known as FRAND) terms unless they disclose their unwillingness to do so prior to the final adoption of the standard. This ensures that competing firms can access the necessary technology to develop products and services that comply with the established standards, while the patent holders are fairly compensated for their innovations at an agreed market rate negotiated between the parties within the constraints of the FRAND commitment.

In the semiconductor industry, SEPs play a significant role in facilitating the development and adoption of new technologies. SEPs protect the underlying innovations that enable these standardized technologies, allowing for the continuous advancement and evolution of semiconductor products. By licensing SEPs on FRAND terms, the semiconductor industry fosters a competitive and collaborative environment that drives innovation, while still protecting the intellectual property rights of inventors. This balance between access to essential technologies and protection of intellectual property is crucial for the growth and competitiveness of the U.S. semiconductor industry, as it enables companies to build upon existing industry and technical knowledge, in addition to pushing the boundaries of technology. [22]

Key Players in Standards-Essential R&D

- **NIST** is the leading national laboratory for critical basic and applied research related to standards, measurement, and testing for interoperability, quality assurance, and security across a wide-ranging number of functionalities (information technology, engineering, materials, communication, etc.). NIST laboratories, research test beds, and user facilities provide critical reference materials to industry. NIST also functions as a convener and coordinator for basic research for a variety of stakeholders in academia and industry.[23]

- **Universities & Research Institutions:** Universities are a critical component of the overall R&D infrastructure in the United States, contributing nearly half of all U.S. basic research and approximately 10-15 percent of U.S. R&D, overall. As of 2017, the National Science Foundation (NSF) reported that academic institutions conducted approximately 48 percent of federally funded basic research, and 18 percent of all applied research in the United States. The federal government is the largest funder of academic R&D, providing funding for more than 53 percent of total R&D capacity in the United States. [24]

- **Private Industry:**[25] Overall, U.S. businesses are the dominant players in R&D, accounting for 75 percent of all U.S. R&D as of 2019. Private industry is also the largest source of funding of R&D ecosystems. This sector is the predominant player in experimental development, conducts more than 50 percent of all applied research, as well as approximately 32 percent of total basic research in the United States.

Role of Small and Medium-sized Enterprises (SMEs) in the Semiconductor Value Chain

This section provides a closer look at one particular stakeholder in the standards ecosystems: small and mid-size enterprises. This analysis is prompted by Sec. 10245 of the CHIPS and Science Act which includes a capacity building pilot program for grants to small businesses to participate in international standards development. [26]

- **SMEs are important in the semiconductor value chain because of their agility[27] and incentive to respond quickly to market demands.** SMEs often have specialized knowledge and experience that can help shape standards to specific markets and segmentations, compared to larger organizations that may have a broader product portfolio.

  SMEs may be more focused on specific niche markets and develop specialized components that conform to industry standards, while large organizations may have broader product portfolios that include many different types of components. For example, SMEs may focus on developing specialized fiber optic components, such as connectors, transceivers, or amplifiers that conform to industry standards established by larger organizations. They can develop a deep understanding of specific niches within the fiber optics market, such as medical or military applications, and can leverage their expertise to design and manufacture components that meet unique market requirements.

- **Resource constraints:** SMEs usually have fewer resources than large organizations, both in terms of funding and personnel. This can limit their ability to participate in standards-setting organizations or invest in R&D. However, SMEs can often leverage their size and flexibility to innovate and bring new products to market more quickly than larger organizations.

- SMEs must have a specific agenda for participation in standards-setting activities due to their resource constraints that can potentially limit their ability to fully engage in the standards development process. SMEs may have to prioritize their participation in standards-setting organizations based on their specific business objectives, which could lead to a lack of representation from certain SMEs or industries.
- SMEs may also face challenges to navigate the complex standards development processes, which can be time-consuming and require significant technical expertise, as well as sophistication, based on long experience, about how the standards game is played. This gap can hinder SMEs' full participation in the standards development process, especially if they lack the resources to dedicate to standards development activities or rely on external consultants or experts.

Questions for Further Research Regarding SMEs

Is there a need to push more SMEs toward standards-setting organizations, particularly in industries where larger firms tend to dominate the standards development process? Or is this current model fit for purpose?

Are there significant differences in the standards-setting practices and priorities of SMEs versus larger organizations, and if so, how can these be effectively addressed in the standards development process?

Part 4: Implementation Considerations

The Politicization of Standards-Setting Processes

Inherently, standards-setting activities take place in an interconnected world where complex dynamics vis-à-vis politics, institutional differences between jurisdictions, and heightened market competition are lived realities. Often, such geostrategic considerations can risk the politicization of standards-setting processes.[28] Whereas critical legal frameworks and institutional mechanisms exist,[29] to ensure the transparency, fairness, and accessibility of standards-setting systems, it is important to consider how external dynamics and other critical priorities may, occasionally, be at odds with the purpose and intentions of the standards ecosystem.

- **Geopolitical Rivalries and Market Competition:** Geopolitical tensions, trade disputes, and general competing interests between state actors and between industry players may foster policies and rhetorical signaling that frame standards-setting processes and the treatment of intellectual property rights as a zero-sum game.[30] In so doing, rival stakeholders may signal to each other and escalate the utilization of the standards system as a vehicle for national strategic advantage, market dominance, and/or global power and influence that conflict with its intended purpose of fostering open access, interoperability, and free trade.[31]
- **Protecting National Security Interests:** Governments have a vested interest and an institutional mandate to protect their national security interests. This objective may take the form of protecting critical infrastructure from malign foreign influence and/or ensuring the security and resilience of global supply chains for national and allied interests. Policies intended for these purposes may at times inadvertently place restrictions or impose ambiguities around free and open engagement between standards stakeholders.[32]

Public Purpose Consideration

What are the harms posed by a politicized standards process?

1. ***Reduced interoperability:*** A politicized standards process can lead to the development of conflicting or incompatible standards, making it difficult for products, services, and systems to work seamlessly across different regions or industries. This creates trade barriers that impede the overall functionality, efficiency, and innovation potential of the global market.

2. ***Stifled innovation:*** When political interests dominate the standards-setting process, it can result in the prioritization of certain technologies or approaches over others, regardless of their technical merits. This may stifle innovation by discouraging the development and adoption of novel or superior solutions.

3. ***Fragmented markets:*** A politicized standards process can contribute to the fragmentation of international markets, as countries or regions adopt divergent standards in an attempt to protect or promote their domestic industries. This can create trade barriers, limit access to new technologies, and hamper the growth of the global economy.

4. ***Undermined trust:*** Trust is a key component of the standards-setting process, as it relies on a transparent, consensus-based approach that considers the perspectives and needs of various stakeholders. The politicization of standards can undermine this trust, making it difficult for parties to collaborate and reach agreements.

5. ***Compromised safety and quality:*** The prioritization of political interests over technical excellence in the standards-setting process can result in the adoption of suboptimal standards, potentially compromising the safety, quality, and reliability of products and services.

6. ***Weakened international cooperation:*** The politicization of standards can exacerbate geopolitical tensions and erode international cooperation in science, technology, and trade. This may hinder the development of global solutions to pressing challenges, such as climate change, public health, and cybersecurity.

Challenges

This section identifies key challenges that should be considered as implementers seek to enact CHIPS provisions related to standards.

- **Picking winners and losers.** As with any government intervention and funding intervention, it is extremely important to focus efforts on correcting market failures and avoid generating unsustainable market distortions. In this case, it is critical to ensure that technical standards are developed in an open and transparent manner, with broad participation from a range of stakeholders, including smaller companies and individuals. This can help to ensure that technical standards are fair and unbiased, and that they promote innovation, competition, and choice in the marketplace.
    - **Influence over standards-setting organizations:** Large organizations or industry consortia may have more influence over standards-setting organizations than smaller companies or individuals. This can give them a greater ability to shape technical standards to favor their own technologies or products, while excluding or disadvantage competing technologies or products.
    - **Limited participation:** Smaller companies or individuals may not have the resources or expertise to participate fully in standards-setting organizations or to influence the development of technical standards. This can result in their technologies or products being excluded from consideration or disadvantaged by technical standards that are biased toward larger organizations or technologies.
    - **Technical barriers to entry:** Technical standards that are biased toward certain technologies or products can create barriers to entry for new companies or technologies. This can limit competition and innovation in the marketplace, and ultimately lead to higher prices and reduced choice for consumers.
- **Interaction with Guardrails.**[33] Export restrictions and other security-minded commercial guardrails on trade and investment related to supply chain and investment security, may pose added risk to companies seeking to engage in international standards. In some cases, it may preclude their participation altogether, which in turn, has adverse implications for their global competitiveness. Companies that are affected by the legislation may be less likely to participate in standards-setting organizations that include Chinese company representatives.
    - **Access to information and expertise:** Standards bodies are critical forums for sharing and building consensus around pre-competitive basic R&D. Companies that are restricted from working with companies or individuals under U.S. export and other trade-related controls may have less access to information and expertise on critical R&D, emerging technologies,

and industry trends.

- **Fragmentation of the Standards Ecosystem:** Export controls and other investment security measures that deter global firms from robust standards engagement could lead to fragmentation in the development of technical standards. With minimal engagement between global firms, different countries or regions may develop siloed standard specifications for critical technologies that then reduce interoperability, increase market barriers, and create inefficient market dynamics for global firms.

Note: *In 2022, an interim final rule revising the Export Administration Regulations, provided explicit guidance on releasing certain technology and software for standards-related activity, including in a forum where listed entities are present. The changes addressed concerns over previous ambiguity in the Bureau of Industry and Security licensing process on engagement of U.S. industries in legitimate standards engagement.*[34]

Red Lines

Here we discuss the "Red Line" principles that should guide the consideration of promoting the standardization ecosystem, emphasizing the key considerations that policymakers and industry stakeholders must keep in mind to promote efficient and effective standardization. These principles focus on maintaining the integrity of the process, promoting international cooperation, encouraging inclusivity and openness, and emphasizing the importance of outcomes rather than specific actions. By following these principles, we can ensure that the standardization process remains effective and beneficial for all stakeholders involved.

1. **Recognize the non-zero-sum nature of standards:** Acknowledge that standards are not a zero-sum game and that those which best address consumer and market needs will ultimately thrive and proliferate. By acknowledging that standards addressing consumer and market needs will ultimately thrive (and these can come from a variety of global sources), policymakers can focus on creating an environment that promotes the adoption of such standards while simultaneously fostering domestic semiconductor production.

2. **Address limitations imposed by U.S. entity list restrictions:** Considering the impact of U.S. entity list restrictions and similar policies on the standardization process will be important to ensure that calculations also consider potential hindrance to the competitiveness of U.S. semiconductor companies.

3. **Maintain parallel yet independent development:** Ensure that standards development occurs in parallel to, but remains independent from, product development in order to preserve the integrity

of both processes. When standardization and product development processes are conducted independently, it allows for unbiased and objective decisions regarding the best technical solutions to be established as industry standards. This ensures that the standardization process focuses on creating guidelines that genuinely benefit the industry and the market, without being unduly influenced by the interests of individual companies or their products.

4. **Provide government support without interference**: Uphold the principle that industry desires the support of government in standardization efforts without direct government involvement in the process. The standardization process is typically driven by industry stakeholders who possess the technical expertise and understanding of market needs. Direct government intervention could disrupt the consensus-driven approach and potentially introduce bureaucratic inefficiencies or biases that might hinder the development of effective and widely accepted standards.

5. **Encourage adoption of international standards:** Promote the use of international standards among other economies and discourage the development of country or region-specific standards that may hinder global compatibility and cooperation. As the semiconductor supply chains still currently span across multiple countries and companies, the adoption of international standards ensures seamless integration of products and processes throughout the global market. This facilitates trade and collaboration between the United States and other countries, enabling the U.S. semiconductor industry to maintain a strong presence in the global landscape. Fostering global compatibility and cooperation through the adoption of international standards also allows the U.S. semiconductor industry to benefit from the critical global exchange of knowledge, technology, and best practices. This type of collaboration leads to more rapid advancements in semiconductor technology and contributes to the overall growth and competitiveness of the U.S. semiconductor sector.

6. **Effective interagency communication and coordination:** Internally, government agencies with competing priorities must expand communication channels to minimize implementation of policies and/or guardrails with counterintuitive outcomes to standards development.

7. **Focus on outcomes rather than specific actions:** Emphasize the consequences of actors not adhering to standards, rather than their specific actions, and trust in the efficacy of institutional safeguards to prevent a race to the bottom.

Recommendations

To enhance the standards-setting process in the U.S. context, we offer a series of recommendations that could be considered in the context of standards and the CHIPS & Science Act. By adopting these recommendations, the standards-setting process can become more effective, efficient, and responsive to the needs of all stakeholders, driving innovation and promoting the growth of industries in the United

States and worldwide.

1. **Incorporate enforceable language for organizations receiving federal funding to include standards development engagement as a priority.** The recently released White House strategy[35] outlines that the NSF will amend proposals of awards and grants that are federally funded. Such prioritization language should be included for other federal agencies that receive funding and should not be limited to R&D but also be applicable in the manufacturing and product development phases, depending on the type of project. This will need to be an active and continuous line of effort to prioritize and build standards development expertise and leadership.

2. When the U.S. government must serve as the representative in the international standards development process, **ensure that technically sound and experienced professionals are engaged.** Government representatives should have industry knowledge and demonstrate strong relationships with private and industry stakeholders in the standards space.

3. **Facilitate international access for standards meetings:** Prioritize visa processing for specialized experts traveling for standards-related events, thereby encouraging global participation in the U.S.-hosted standards-setting forums.

4. **Identify gaps in the standards-setting process:** Conduct a thorough analysis of the current standards-setting process to pinpoint areas of improvement and address any shortcomings.

5. **Improve career opportunities in standardization:** Address the aging standards workforce by promoting standardization as a viable and rewarding career path, and by providing resources for skill development. This can be done by establishing a specific task force that collaborates with technical national labs and encourages partnerships to develop pipelines of trained workforce.

6. **Enhance standards education in engineering programs:** Evaluate the effectiveness of Criterion 5, which mandates that engineering degrees include an explicit design program incorporating standards and propose improvements to better meet industry needs.

7. **Encourage agencies to conduct pre-standardization work:** Empower agencies such as NIST to undertake critical measurement-related research and provide technical support, thus laying the groundwork for robust standardization efforts.

8. **Establish a distinct pipeline for clear and transparent communication between NIST and respective stakeholders**. Create positions within CHIPS Program Office and/or NIST to oversee and liaise progress to related stakeholders. Such liaisons should also identify areas of opportunities for partnerships and or coordination with other federal agencies, maintain knowledge on industry trends and ensure updates relevant to CHIPS legislative initiatives are facilitated to stakeholders outside of government. Dedicated personnel to streamline communication of initiatives will allow NIST to be more efficient as a convener and facilitator.

General Questions for Further Research

- To what extent does open consensus-based standards-setting processes conflict with critical supply chain security?
- What and where are the potential trade-offs between international standards-setting processes and national security objectives, and how can these be effectively balanced?
- To what extent do national security guardrails impact the ability of U.S. companies to engage in international standards-setting processes, particularly in countries or regions with restrictions on technology transfer or trade?
- What are the implications of national security concerns for the global standards-setting ecosystem, particularly in industries that are highly interconnected and rely on international collaboration?
- Should export control regimes incorporate and communicate explicit exceptions for standards engagement between U.S. companies and restricted firms?
- Does non-standardization have a role?

About the Technology and Public Purpose (TAPP) Project

The arc of innovative progress has reached an inflection point. It is our responsibility to ensure it bends toward public good.

Technological change has brought immeasurable benefits to billions through improved health, productivity, and convenience. Yet as recent events have shown, unless we actively manage their risks to society, new technologies may also bring unforeseen destructive consequences.

Making technological change positive for all is the critical challenge of our time. We ourselves - not only the logic of discovery and market forces - must manage it. To create a future where technology serves humanity as a whole and where public purpose drives innovation, we need a new approach.

Found by former U.S. Secretary of Defense Ash Carter, the TAPP Project works to ensure that emerging technologies are developed and managed in ways that serve the overall public good.

TAPP Project Principles:

1. Technology's advance is inevitable, and it often brings with it much progress for some. Yet, progress for all is not guaranteed. We have an obligation to foresee the dilemmas presented by emerging technology and to generate solutions to them.

2. There is no silver bullet; effective solutions to technology-induced public dilemmas require a mix of government regulation and tech-sector self-governance. The right mix can only result from strong and trusted linkages between the tech sector and government.

3. Ensuring a future where public purpose drives innovation requires the next generation of tech leaders to act; we must train and inspire them to implement sustainable solutions and carry the torch.

For more information, visit: www.belfercenter.org/TAPP

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