Comments of the Semiconductor Industry Association (SIA) on the Department of Energy "Notice of Request for Information (RFI) on Energy Sector Supply Chain Review"

86 Fed. Reg. 67695 (Nov. 29, 2021) [Docket No. DOE–HQ–2021–0020]

Submitted January 14, 2022

The Semiconductor Industry Association (SIA) is the voice of the semiconductor industry, one of America's top export industries and a key driver of America's economic strength, national security, and global competitiveness. Semiconductors – the tiny chips that enable modern technologies – power products and services that have transformed our lives and our economy. The semiconductor industry directly employs nearly a quarter of a million workers in the United States, and U.S. semiconductor company sales totaled $208 billion in 2020. SIA represents 98% of the U.S. semiconductor industry by revenue and nearly two-thirds of non-U.S. chip firms. Through this coalition, SIA seeks to strengthen leadership of semiconductor manufacturing, design, and research by working with Congress, the Administration, and key industry stakeholders around the world to encourage policies that fuel innovation, business, and international competition. We appreciate the opportunity to provide input on the Department's efforts to formulate solutions to the supply chain challenges that face our energy sector.[1] This submission pertains to Area 9 of the Request for Information, relating to semiconductors.

I. Executive Summary

Innovative uses of semiconductors can make significant contributions toward solutions to global climate change. Economy-wide deployment of information and communications technology (ICT) enabled by semiconductors can achieve dramatic improvements in energy efficiency and the production of clean energy. The unique properties of wide bandgap semiconductors are particularly important for the energy sector, as high-power density, low energy consumption, high temperature resistance, and high luminous efficiency features are critical to achieving energy efficiency and climate objectives. Moreover, as the number of semiconductor chips continues to grow with digitization, semiconductor-enabled technologies present opportunities to drive dramatic reductions in emissions across all sectors of the economy. According to the World Economic Forum, semiconductor-enabled technologies creating solutions in the energy, manufacturing, agricultural, building, and transportation spaces can reduce greenhouse gas emissions by 15 percent - almost one-third of the 50 percent reduction required by 2030.[2]

U.S. companies have for decades led the world in semiconductors, and our country's leadership in this technology has played a vital role in securing America's status as the world's largest economy and producer of the most advanced technologies. This leadership is due to a range of factors, including high levels of investment in research and development (R&D) by both the U.S. government in the early years of the industry, and by large manufacturers in the later years. This has led to significant capital expenditure further sustained by access to global markets and the ability to leverage a complex global supply chain and the best talent in the world.

The U.S. industry, however, faces multiple challenges. Namely, while the U.S. remains the global leader in semiconductor design and R&D, most chip manufacturing now occurs in Asia. This trend is supported by broad incentives and policies by foreign countries. Additionally, supply chain disruptions in the COVID-19 era have created a perfect storm of unprecedented challenges with rippling effects. In 2020, the pandemic throttled supply and created

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[1] For more details on the semiconductor supply chain writ large, see SIA's April 5, 2021 comments to the Department of Commerce's notice (86 Fed. Reg. 14308) in response to Executive Order 14017 ("America's Supply Chains"). (https://www.semiconductors.org/wp-content/uploads/2021/04/4.5.21-SIA-supply-chain-submission.pdf)

[2] https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/

unanticipated swings in demand. Some downstream sectors reduced production and chip purchases while others saw soaring demand for semiconductors to maintain critical functions during lockdowns around the world. The massive dislocations in global logistics and transportation networks coupled with shortages of raw materials, key components, and intermediary products exposed extensive vulnerabilities in highly interdependent and globalized value chains. Among the supply chain disruptions occurring worldwide, the global semiconductor shortage has played a particularly consequential role.

It is essential that industry participants and governments join in efforts to address these vulnerabilities and make the value chain more resilient, while also continuing to facilitate worldwide access to markets, technologies, capital, and talent.

SIA's main points in this submission are the following:

1. Securing the semiconductor supply chain is critical to U.S. energy security and the sustained progress of the green economy;
2. Foreign government investment, pandemic supply chain issues, and natural disasters pose challenges to maintaining U.S. leadership in the semiconductor industry;
3. The federal government must seize the opportunity to strengthen the U.S. semiconductor industry by funding the CHIPS Act, passing an enhanced FABS Act, promoting free trade, and supporting green technologies; and
4. Aligning immigration and STEM education policies with the growing demand for engineering talent is key to continued U.S. leadership in the semiconductor industry.

II. Responses to Specific Questions from the RFI

1. What is the current state of U.S. and global supply chains for both conventional semiconductors used in data and sensor applications related to the energy sector and wide bandgap semiconductors used for controlling power flow in power electronics applications? What are the current and future semiconductor supply chain vulnerabilities as we scale up our efforts to transform the energy sector (energy supply, energy efficiency, demand technologies, grid, fuels, etc.) to support decarbonization? Of these vulnerabilities, which are the most crucial for the U.S. to address and focus on and why?

Role of Conventional and Wide BandGap (WBG) Semiconductors in the Energy Sector

A wide range of semiconductors are used in applications across the U.S. economy, and each chip segment has a unique and complicated supply chain. Digital applications rely heavily on logic and memory semiconductors for 67% to 82% of their chips, while the industrial, power management, automotive, and energy sectors rely on the Discrete, Analog, Other (DAO) category for up to two-thirds of their chips. These are semiconductors that transmit, receive, and transform information dealing with continuous parameters such as temperature and voltage: 1) Discrete products include diodes and transistors that are designed to perform a single electrical function such as the switch and control of electric power. 2) Analog products include power management integrated circuits found in any type of electronic devices and radio frequency (RF) semiconductors that enable smartphones and base stations to receive and process the radio signals coming from cellular networks. 3) Other products include optoelectronics, such as optical sensors to sense light used in cameras, as well as a wide variety of non-optical sensors and actuators that can be found in Internet of Things devices.

Additionally, certain usages of chips in the green economy require higher processing frequencies that lead to the heating up of the device. Such heating degrades the silicon and can shorten the overall lifespan of electronics – resulting in increased waste and a less sustainable lifecycle. Fortunately, innovations in Wide Bandgap (WBG) semiconductors allow devices to function at higher processing frequencies in addition to minimizing energy dissipation into heat. These WBG semiconductors, which can manifest as each of the above three product categories, are widely used in 5G stations, home appliances, electric vehicles and charging stations, smart grids, high-speed trains, and military applications.

To achieve these attributes, WBGs are often built with Silicon Carbide and Gallium Nitride, and these chips are in high demand for the alternative energy and automobile sectors.[3] Without this power optimization, renewable energy would not be transferable onto the grid. Research shows that silicon carbide (SiC), which is key to the breakthrough material technology WBG, not only enables the delivery of solar energy through microgrids, but also enables the handling of bigger loads on the national electricity grid.[4] In the automotive sector, higher voltage power semiconductors (enabled by materials like silicon carbide and WBG) can reduce the amount of electrical power wasted in the car, decrease vehicle fuel consumption and CO2 emissions.[5] Although the infrastructure and supply chains for these new materials are not yet at the maturity of silicon, they will continue to drive energy efficiency until they reach widespread adoption.[6]

Material and Equipment Supply Chains

Across the spectrum of DAO and advanced logic chips to WBGs, firms involved in semiconductor manufacturing rely on complex supply chains for critical material inputs and manufacturing tools. Semiconductors typically require as many as 300 different inputs, including raw wafers, commodity chemicals, specialty chemicals, sputtering targets and bulk gases, and many of them also require advanced technology to produce. Semiconductor-grade polysilicon is provided primarily by just four companies, with a combined global market share above 90%. Ultra-Pure Hydrogen Fluoride (UPHF) is another key material used extensively throughout semiconductor manufacturing, and only one manufacturer of UPHF has a facility in the U.S. Similarly, sputtering targets are provided by 4 primary suppliers constituting 90% of the market, most of which are outside the U.S. Only one manufacturer produces targets for advanced semiconductors in the U.S. Lastly, a large portion of the world's electronic polymers used in photolithography, masking, and spin on dielectric applications in the chip manufacturing process are supplied by companies based outside of the U.S.

Additionally, semiconductor manufacturing for both mainstream and leading-edge chips uses more than 50 different types of sophisticated wafer processing and testing equipment provided by specialist vendors for each step in the fabrication process. Most of this equipment, such as lithography and metrology tools, incorporates hundreds of technology subsystems such as modules, lasers, mechatronics, control chips, and optics. The highly specialized suppliers involved in semiconductor design and fabrication are often based in different countries.

State of Global DAO Manufacturing

The global DAO market for both conventional and WBG technologies is dominated by European, Japanese, and American semiconductor fabless firms and manufacturers. Unlike leading-edge logic chips, which are fabricated on large wafers with scaling transistor size associated with smaller nodes for performance and cost benefits, the DAO group is generally manufactured with mature nodes and specialty process technologies on 6-to-12-inch wafers. These manufacturing techniques are acceptable as DAO semiconductors use circuit types and

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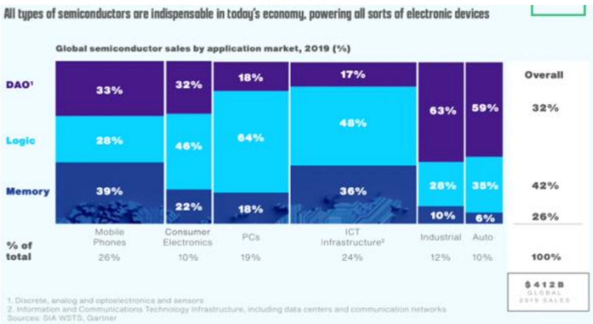
[3] "How is the Energy Efficiency of Chips Evolving?", Semiconductor Review (18 September 2020). https://www.semiconductorreview.com/news/how-is-the-energy-efficiency-of-chips-evolving-nwid-159.html
[4] https://www.energy.gov/eere/solar/silicon-carbide-solar-energy
[5] https://semiengineering.com/using-ics-to-shrink-autos-carbon-footprint/
[6] https://www.energy.gov/eere/articles/infographic-wide-bandgap-semiconductors

architectures that do not need to work at more miniaturized scales. Critically, mature technologies also provide the reliance and stability needed by energy applications.



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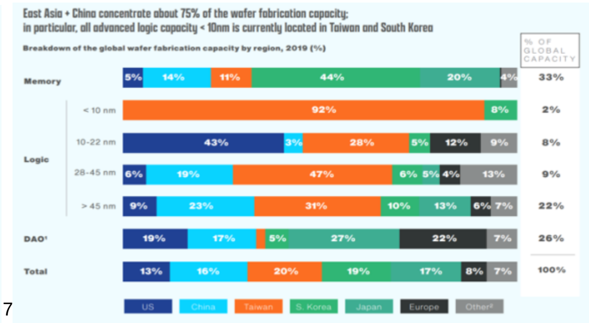

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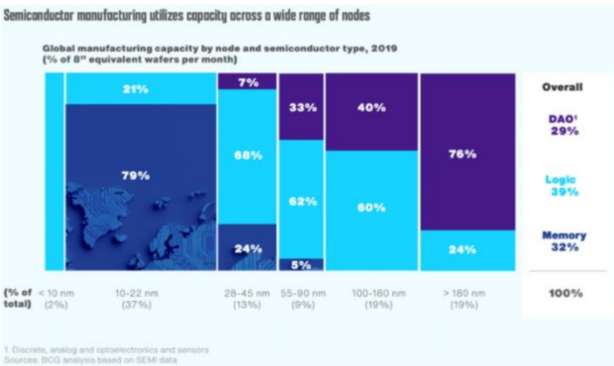
As a result, wafer manufacturing for conventional and wide bandgap semiconductors used in the energy sector takes place across a range of nodes from 28 to above 180 nanometers, accounting for 7% to 76% of the global capacity of each node type.



Geographically, Europe, Japan, and the U.S. combined hold 68% of the global DAO capacities. However, China's role in this sector is rising as it is cheaper and technologically easier to build DAO fabs and develop low-to-median-end DAO technologies than it is to produce advanced logic or memory chips.[9]

2. For both conventional and wide bandgap semiconductors used in the energy sector, where in the supply chain does it make sense for the U.S. to focus and prioritize its efforts both in the short-term and the long-term, and why? Where in the supply chain do you see opportunities for the U.S. to build domestic capabilities for semiconductors manufacturing? What areas of the supply chain should the U.S. not prioritize for attraction or expansion of domestic manufacturing capabilities, and why? For areas in the supply chain where U.S. opportunities to build domestic manufacturing capabilities are limited, which foreign countries or regions should the U.S. government prioritize for engagement to strengthen/build reliable partnerships, and what actions should the government take to help ensure resilience in these areas of the supply chain?

Under the CHIPS for America Act's authorizing legislation in the FY 2021 National Defense Authorization Act, the Department of Commerce can consider whether a proposed grant project manufactures semiconductors necessary to address gaps and vulnerabilities in the domestic supply chain across a diverse range of technology and process nodes ((S. 1260 § 2506(b)(1)(D)). To help inform the Department of Commerce as it prepares implementation

[7] https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf (p. 10)

[8] Ibid at 35.

[9] Ibid at 18.

plans for the CHIPS grants, SIA submitted comments in April 2021 outlining the nature of global semiconductor supply chains, and more details are available in that document.[10]

For reasons outlined in the Commerce supply chain comments, it is not possible for any single country to develop fully self-sufficient semiconductor supply chains. Therefore, when gaps cannot be filled domestically, it is necessary to work multilaterally with U.S. allies. To that end, the White House reaffirmed after the inaugural meeting of the U.S.-E.U. Trade and Technology Council that the two regions would cooperate on rebalancing supply chains, communicating shared vulnerabilities, and strengthening their respective semiconductor ecosystems.[11]

3. What challenges limit the U.S.'s ability to realize opportunities to build domestic semiconductor manufacturing? What conditions are needed to help incentivize companies involved in the semiconductor supply chains to build domestic manufacturing capabilities and scale up manufacturing? How do these challenges and conditions differ between conventional and wide bandgap semiconductors?

The U.S. share of global semiconductor manufacturing has experienced a steady decline from 37% in 1990 to 12% in 2020, despite a 7% annual growth rate in U.S. manufacturing capacity over the last 30 years.[12] Fab economics explain this decline: government incentives and labor costs. The rise in U.S. installed capacity has been outpaced by that of several Asian countries, whose governments have ambitiously invested in domestic manufacturing through favorable grants, tax incentives, and other government incentives. To prevent further reductions in the U.S.'s share of global semiconductor manufacturing, the U.S. government must take immediate action to level the global playing field.

The result of these investments has led to approximately 75% of the world's semiconductor manufacturing capacity being concentrated in East Asia, but there are important distinctions. For example, U.S. allies and partners currently account for the majority of leading-edge logic and memory chip production.[13] However, China has grown significantly as an important producer of DAO semiconductors. The Chinese government continues to prioritize the semiconductor industry as a driver of economic growth and technological leadership and is expected to add about 40% of new global capacity through 2030. Additionally, by 2030 China is forecasted to take 49% of the DAO capacity worldwide.[14] Conversely, current data on planned fab construction indicates that only 6% of new capacity currently in development will be located in the U.S. without incentives such as those in the CHIPS Act and an expanded FABS Act.[15]

Another important factor driving the dynamics is that many of the DAO semiconductors are produced on 200mm and 150mm wafers with older processing techniques. Over the past two decades, to save costs, an increasing number of DAO IDMs have gone to fab-lite, becoming increasingly reliant on outsourced foundry manufacturers. As many semiconductor manufacturers have prioritized investment in advanced nodes (12nm and below) fabs, investment in legacy processes and 200mm wafer facilities have become slow.

Wide BandGap semiconductors face their own set of challenges on their path to increased commercialization. As a relatively new technology, inputs for SiC and GaN-based WBGs are not available in as large volumes as those for conventional semiconductors, resulting in a higher cost to manufacture these chips. New measuring and packaging equipment is also necessary

[10] https://www.semiconductors.org/wp-content/uploads/2021/04/4.5.21-SIA-supply-chain-submission.pdf
[11] https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/29/u-s-eu-trade-and-technology-council-inaugural-joint-statement/
[12] SIAxBCG Report on "Government Incentives and US Competitiveness in Semiconductor Manufacturing" (2020)
[13] Ibid
[14] Ibid
[15] Ibid

as these tools have traditionally been developed to work within the specifications of silicon. Because WBGs function at current levels significantly higher than those of conventional chips, measuring tools must be developed to greater accuracy, and ultra-low inductance packages are needed to prevent destruction from the high voltage spikes caused by rapid switching. Fundamentally, new technology calls for new skills in the workforce to optimize the utility of WBGs and address their challenges.[16]

Supply chain disruption in the COVID-19 era has been an economy-wide phenomenon. With border controls, mobility restrictions, and closures of factories and ports to contain COVID-19, 75% of companies across sectors report facing the effects of lockdowns on facilities and workforce around the world.[17] Factory and port closures have been worsened by unanticipated weather events. Resulting manufacturing shortages in raw materials, intermediate goods, and key components produced rippling downstream effects on numerous end markets. And supply and demand shocks exposed vulnerabilities in global supply chains already strained by geopolitical friction and lean production strategies pre-dating COVID-19. In an economy as interconnected as the United States, disruptions to the global value chain have created a perfect storm, to which the semiconductor supply chain has not been immune.

Global Incentives

Over the past year, governments worldwide have been fast-tracking legislation to provide subsidies and incentives to the semiconductor industry to address the global chip shortage. In 2021 alone, Japan, India, South Korea, and the EU – all major players in the semiconductor industry – have announced billions of dollars in government subsidies for semiconductor manufacturing and R&D within their borders, of which more than $68 billion has been appropriated. Meanwhile, the CHIPS Act continues to face delays in the U.S. Congress.

1. **India:** On Dec 15, 2021, India approved the Production Linked Incentive Scheme of $10 billion over 6 years for semiconductor manufacturing, design, and display ecosystems.[18]

2. **European Union:** On Sept 15, 2021, the EU Commission announced plans to introduce a forthcoming "European Chips Act" to reduce the bloc's dependence on Asia, as a "matter of tech sovereignty." Specifically, the EU Chips Act seeks to create a "state-of-the-art European chip ecosystem, including production" and calls for the establishment of a dedicated European Semiconductor Fund of an undisclosed amount.[19]

3. **Japan:** On Nov 25, 2021, Japan put together a package of $6.7 billion of government support for its semiconductor industry, targeting both semiconductor production and next-generation semiconductor technology R&D.[20]

4. **South Korea:** On May 12, 2021, South Korean President Moon Jae-in unveiled a new national semiconductor industrial policy aimed at securing the country's leading position in chips by 2030. The plan includes tax credits of up to 50% for R&D and 16% for manufacturing, $886 million USD in long-term loans, $1.3 billion in federal R&D investments, eased regulations, and upgraded infrastructure.[21]

Largely as a result of these massive incentives by foreign governments, the difference in total cost of ownership (TCO) of a new fab located in the U.S. is approximately 25-50% higher than

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[16] https://www.power-electronics.org.uk/wp-content/uploads/sites/10/2020/04/2020_03-PEUK-Position-Paper-final.pdf

[17] https://www.accenture.com/us-en/insights/consulting/coronavirus-supply-chain-disruption

[18] https://pib.gov.in/PressReleasePage.aspx?PRID=1781723

[19] https://ec.europa.eu/commission/presscorner/detail/en/speech_21_4701

[20] https://www.asahi.com/ajw/articles/14488773

[21] https://world.kbs.co.kr/service/contents_view.htm?lang=e&menu_cate=business&id=&board_seq=403357

in Asia. To prevent the further reduction of the U.S.'s share of semiconductor manufacturing, the U.S. government must take immediate action to level the global playing field. The next section will speak to the role of the CHIPS for America Act and FABS Act in doing that, as well as to the urgency of prompt funding and passage.

4. How can government help private sector and communities involved in semiconductor manufacturing build domestic manufacturing capabilities and scale up semiconductor manufacturing? What specific government policies or investments will be most important in supporting semiconductor manufacturing and supply chain resilience?

While the industry is working aggressively to meet demand, there is no short-term solution that can immediately ease the current shortages. Overcoming the global chip shortage requires market foresight aimed at building long-term capacity and supply chain resiliency. There are several actions that can boost semiconductor production.

1. Funding the CHIPS for America Act and Enacting a Strengthened FABS Act to Incentivize Expanded Capacity in the U.S.

At the heart of the problem, demand for semiconductors outstrips supply across all sectors of the economy. A solution to the chip shortage requires policy aimed at fundamentally strengthening the entire industry. The most constructive actions that the U.S. government can pursue to bolster domestic production and help level the global playing field are: (i) funding the CHIPS for America Act, which provides incentives for domestic chip production and research investments; and (ii) enacting a strengthened version of the FABS Act, which provides an investment tax credit for both semiconductor manufacturing and design.

A $52 billion federal incentive program under the CHIPS Act will have an enduring impact on the nation's semiconductor industrial infrastructure and broader economy, including an additional $24.6 billion in GDP. Over this six-year build-out period, the cumulative annual impact of such an incentive program on GDP would be $147.7 billion. An investment of this magnitude would enable the construction of 19 new advanced fabs in the U.S. over the next ten years (or many more DAO fabs), doubling the expected number of fabs to be built and increasing capacity located in the U.S. by 57%.[22] Companies intending to construct non-leading edge DAO fabs are equally eligible for the primary CHIPS Act manufacturing grants, but the legislation also sets aside an additional $2 billion specifically for constructing fabs that make mainstream chips for the automotive, energy, industrial, and other critical industries. These benefits would be magnified by the FABS Act, which would create a 25% investment tax credit for investments in semiconductor manufacturing, both for manufacturing equipment and the construction of fabs. An enhanced FABS Act would expand these incentives to design.

2. Trade Policy to Expand Global Markets

There are many other steps government can take beyond manufacturing incentives and investment tax credits to make stronger supply chains. That includes advancing trade policies that expand global markets and open them to be more attractive to our goods. The majority of semiconductor demand is driven by products ultimately purchased by consumers, including laptops and communication devices such as smartphones, and 80 percent of the chip industry's consumers are overseas.[23]

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[22] SIAxOxford Economics Report on "Chipping In: The Positive Impact of the Semiconductor Industry on the American Workforce and How Federal Industry Incentives Will Increase Domestic Jobs" (2021), available at https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINALMay-19-2021_2.pdf.
[23] https://www.semiconductors.org/wp-content/uploads/2021/05/2021-SIA-Factbook-FINAL1.pdf

3. Implement policies to drive adoption of semiconductor-enabled climate solutions

The government should establish comprehensive policies to encourage the adoption of smart technologies as a means of improving efficiency and reducing emissions. Through an appropriate mix of regulations and incentives, government can create an economic incentive for businesses, individuals, and other entities to adopt measures to reduce emissions, increase energy efficiency, and encourage the use of renewable energy. For example, the EPA has a program called the Green Power Partnership to encourage businesses, schools, and local governments to procure green energy, and many SIA member companies are involved in the program to source green energy for their data centers and manufacturing facilities.

4. Fund technology and climate research

Continued innovation will be key to addressing the challenge of climate change. To that end, federal funding for research is needed to address the technical challenges to meeting ambitious climate goals. For example, ever rising energy demand for computing can be offset by new computing paradigms that offer opportunities with dramatically improved energy efficiency. The semiconductor industry has targeted >1,000,000x improvement in computing energy efficiency.[24] Additionally, semiconductor fabrication requires the use of process gases with high global warming potential (GWP), so research is needed on alternatives with lower GWPs.

5. What are opportunities for improving energy efficiency in semiconductors? How can the government help the private sector achieve competitive advantages in domestic manufacturing of more energy efficient semiconductors?

The use of products and systems enabled by semiconductors is increasing rapidly, and continued innovation is necessary to ensure total energy consumption is decoupled from rising ICT demand. The Decadal Plan for Semiconductors[25] offers a roadmap of research to address the key challenges facing the semiconductor industry, and it identifies the need to improve energy efficiency as one of the "seismic shifts" facing the industry.[26]

The semiconductor industry has long benefited from the dramatic increases in computing power and energy efficiency powered by Moore's Law, the observation that the semiconductor industry will double the number of transistors on a piece of silicon every 18-24 months. However, the rate of doubling is slowing due to physical limits. These limits must be surmounted if the increasing demand for computation is to be sustainably met, so the Decadal Plan calls for research into hardware that utilizes bits more efficiently.[27] To date, the industry has made great progress toward this end in data centers, individual devices, and transmission networks:

Data Centers
The number of Internet users has doubled, and internet traffic has grown 12-fold since 2010. These trends will likely continue as online services play a more prominent role in our economy and all facets of our lives. Remarkably, despite this strong growth in usage, overall energy use at data centers has remained flat due to the energy intensity of data centers decreasing 20 percent annually since 2010.[28] This stands in stark contrast to the total energy consumption in the U.S., which has risen from 2,923.9 terawatt hours in 1990 to 4,194.4 terawatt hours in

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[24] Semiconductor Research Corporation and Semiconductor Industry Association, "Interim Report for the Decadal Plan for Semiconductors" available at https://www.semiconductors.org/wp-content/uploads/2020/10/Decadal-Plan_Interim-Report.pdf. (p. 17)
[25] Ibid at 123.
[26] Ibid at 4.
[27] Ibid at 17. *See *"bit utilization efficiency"*
[28] IEA, "Data Centres and Data Transmission Networks" available at https://www.iea.org/reports/data-centres-and-data-transmission-networks

2019.[29] Not only have these commercial data centers become more efficient themselves, but consumers have generally moved much of their data from personal devices to the cloud. As a result, data has migrated relatively low efficiency servers (personal devices) to centralized facilities of much greater and rapidly improving efficiency.

Individual Devices
The past decade has seen remarkable advances in the efficiency of individual devices. A study on consumer electronics found that the U.S.'s over 3.4 billion consumer electronics consumed 143 terawatt hours of electricity in 2017, representing about 10% of residential electricity consumption and 4 percent of total U.S. electricity consumption. Critically, this 2017 consumption statistic showed a 14% decline from individual devices' total energy consumption in 2013, due to consumer adoption of new generations of products.[30]

However, individual devices have not increased energy efficiency entirely on their own. The shrinking energy consumption of these products also derives from the fact that they often send data straight to "cloud" data centers. Because these facilities are large and centralized, they allow consumers to store information on platforms that are efficient due to economies of scale.[31]

Transmission
A recent study of studies shows that from 2000 to 2015 the electricity intensity of transmission networks has declined by a factor of about 170.[32] In a world where data is increasingly mobile, reductions in the energy intensity of transmission are significant. As consumers send more and more of their data out from their devises and into the cloud, efficiency improvements will ensure that electricity use is minimized at the start, finish, and along the way of every computation.

Future Opportunities – Internet of Things

Semiconductors can support decarbonization by transforming countless existing industries. By deploying smart heating, smart transport, smart manufacturing, smart agriculture, etcetera, the deployment of 5G is projected to help reduce greenhouse gas emissions by 350 million metric tons by 2025, an impact comparable to removing 81 million vehicles from U.S. roads in any given year. Water optimization is another key area, where technologies such as smart sensoring made possible by 5G's low latency and high reliability, can reduce water usage by 450 billion gallons by 2025, an amount greater than the annual water usage of 4 million U.S. households.[33]

Such innovation is achievable because the semiconductor industry annually invests nearly one-fifth of its revenue in research and development, but the rate of federal investment in chip research has held flat as a share of GDP.[34] To attain a range of innovation goals across chips segments, the Decadal Plan recommends $3.4 billion in annual investment in semiconductor research priorities, and $750 million of this should be allocated to improving the compute trajectories for memory and storage chips.[35] The Department of Energy plays a key role in this research framework through the national labs.

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[29] IEA Data and Statistics, "Explore energy data by category, indicator, country or region" available at https://www.iea.org/data-and-statistics/?country=USA&fuel=Energy%20consumption&indicator=TotElecCons
[30] https://cdn.cta.tech/cta/media/media/advocacy/pdfs/energy-consumption-of-consumer-electronics-in-u-s-homes-in-2017-(fraunhofer-usa,-commissioned-by-cta,-december-2017).pdf?_ga=2.247598151.1769537939.1617080309-889824261.1617080309
[31] Jonathan Koomey et. al., "Smart Everything: Will Intelligent Systems Reduce Resource Use?", Annual Review of Environment and Resources (2013).
[32] Joshua Aslan & Kieren Mayers, "Electricity Intensity of Internet Data Transmission: Untangling the Estimates," Journal of Industrial Ecology (7 November 2017).
[33] https://www.qualcomm.com/media/documents/files/5g-and-sustainability-report.pdf
[34] https://www.semiconductors.org/wp-content/uploads/2021/09/2021-SIA-State-of-the-Industry-Report.pdf
[35] Semiconductor Research Corporation and Semiconductor Industry Association, "Interim Report for the Decadal Plan for Semiconductors" available at https://www.semiconductors.org/wp-content/uploads/2020/10/Decadal-Plan_Interim-Report.pdf. (p. 19)

6. What specific skills are needed for the workforce to support semiconductor manufacturing? Of those skills, which ones are lacking in current education/training programs? What resources (including time) and structures would be needed to train the semiconductor technology workforce? What worker groups, secondary education facilities, and other stakeholders could be valuable partners in these training activities? What new education programs should be included (developed?) to prepare the workforce?

Attracting and retaining U.S. semiconductor talent

There is bipartisan support for reforming current green card policies for highly skilled immigrants, and strong government leadership is needed to make progress on this issue. The government should act swiftly to end per-country green card caps and exempt advanced STEM degree graduates of U.S. universities from existing green card caps.[36]

Drastically increasing the pipeline of diverse and underrepresented minorities in U.S. STEM students interested in semiconductor fields

STEM education programs should be rigorously evaluated, and funding should be allocated to scale up successful models for broader implementation. Several government funded programs, and industry funded programs, are available that seek to strengthen the pipeline of U.S. STEM talent, and these are ripe for larger investments to expand their impact. For example, the Department of Defense's Scalable Asymmetric Lifecycle Engagement (SCALE) program is a public-private-academic partnership that supports university engineering departments and matches participating students with private sector employers. While the program first received seed funding from DOD's Trusted & Assured Microelectronics in FY 2019, the 2021 report by the National Security Commission on Artificial Intelligence (NSCAI) recommended fully funding the production phase of SCALE at $24.7 million per each of its five technical verticals over five years.

Leveraging federally funded R&D to develop the domestic semiconductor workforce

Increased federal investment in semiconductor research is critical in addressing the future workforce in the industry. Government investment in semiconductor research provides the "pipeline" of highly educated talent that can drive innovation in the semiconductor industry for decades to come. Federally funded projects provide learning opportunities and experience that firms cannot provide or fund on their own (e.g., Exascale, Quantum Computing, or Electronics Resurgence Initiative programs). Unfortunately, federal investment in research relevant to the semiconductor industry has been flat or declining in recent years. This decline in federal research investment is particularly harmful given that our global competitors are increasing their commitment to funding research, placing U.S. leadership in the semiconductor industry at risk.

7. What other input should the federal government be aware of to support a resilient supply chain of this technology?

Semiconductors have driven transformative advances in nearly every modern technology, from computers to the Internet itself, and they play a critical role in innovations in energy. The U.S. industry has long supported this innovation through massive capital and research investments, but the federal government has a critical role in incentivizing manufacturing and investing in research. We appreciate the Department of Energy's attention to the role of semiconductors in energy supply chains, and we hope to continue supporting your efforts.

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[36] For more details, see: https://www.semiconductors.org/wp-content/uploads/2021/04/4.5.21-SIA-supply-chain-submission.pdf