REPORT TO THE PRESIDENT ON CAPTURING DOMESTIC COMPETITIVE ADVANTAGE IN ADVANCED MANUFACTURING

Executive Office of the President

President's Council of Advisors on Science and Technology

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The President's Council of Advisors on Science and Technology

Capturing Domestic Competitive Advantage in Advanced Manufacturing

AMP Steering Committee Report

EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

President Barack Obama
The White House
Washington, DC 20502

Dear Mr. President,

We are pleased to present you with the report entitled, *Capturing Domestic Competitive Advantage in Advanced Manufacturing*, prepared by the Advanced Manufacturing Partnership (AMP) Steering Committee. The President's Council of Advisors on Science and Technology (PCAST) hereby adopts this report, which builds on our report to you last year on *Ensuring American Leadership in Advanced Manufacturing*.

The AMP Steering Committee, chaired by Susan Hockfield and Andrew Liveris, and whose membership you announced when releasing PCAST's 2011 report, sought wide-ranging input in order to identify opportunities for investments in advanced manufacturing that have the potential to transform U.S. industry. More than 1200 stakeholders representing industry, academia, and government at all levels participated in four regional meetings around the country. A diverse set of experts in advanced manufacturing technology, education, and policy issues were also consulted to build upon the ideas presented by the stakeholders.

The Nation's historic leadership in advanced manufacturing is at risk. The threat to our advanced manufacturing sector places our economy as a whole at risk, jeopardizes our international trade, and, above all, undermines the innovation that our Nation needs to thrive in the future. However, with a sustained focus, alignment of interests, and coordinated action by industry, academia, and government, the Nation can retain its leading position in advanced manufacturing.

PCAST has considered and adopts the recommendations of the AMP Steering Committee. These recommendations fall in three key areas: (1) enabling innovation, (2) securing the talent pipeline, and (3) improving the business climate. They include a call to establish a national network of manufacturing innovation institutes (in line with what you announced on March 9th); an emphasis on investment in community college training of the advanced manufacturing workforce; an approach to evaluate platform manufacturing technologies for collaborative investment; a plan to reinvigorate the image of manufacturing in America; and proposals for trade, tax, regulatory, and energy policies that would level the global playing field for domestic manufacturers.

Moving forward vigorously with your Advanced Manufacturing Partnership will help to create the "economy built to last" that you articulated so eloquently in your State of the Union Address earlier this year. Thank you for the opportunity to provide our input on an issue of such critical importance to the Nation's future.

Sincerely,

John P. Holdren
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Eric Lander
Co-Chair

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Capturing Domestic Competitive Advantage in Advanced Manufacturing

Executive Report of the AMP Steering Committee

Advanced manufacturing is not limited to emerging technologies; rather, it is composed of efficient, productive, highly integrated, tightly controlled processes across a spectrum of globally competitive U.S. manufacturers and suppliers. For advanced manufacturing to accelerate and thrive in the United States, it will require the active participation of communities, educators, workers, and businesses, as well as Federal, State, and local governments.

The Advanced Manufacturing Partnership (AMP) Steering Committee proposes that the Nation establish a national advanced manufacturing strategy. This strategy will serve as a national framework that, when implemented by states and local communities, will bring about a sustainable resurgence in advanced manufacturing in the United States.

The AMP Steering Committee developed a set of 16 recommendations around three pillars:

- Enabling innovation
- Securing the talent pipeline
- Improving the business climate

These recommendations are aimed at reinventing manufacturing in a way that ensures U.S. competitiveness, feeds into the Nation's innovation economy, and invigorates the domestic manufacturing base. The objective is to position the Nation to lead the world in new disruptive advanced manufacturing technologies that are changing the face of manufacturing.

The AMP Steering Committee believes that a number of important steps taken now will be critical to strengthen the Nation's innovation system for advanced manufacturing. While some of the largest U.S. firms have the depth and resources to be ready for this challenge, a significant number of small and medium-sized U.S. firms operate largely outside the present innovation system. The United States will only lead in advanced manufacturing if all companies are able to participate in the transformations made possible through innovations in manufacturing.

The AMP Steering Committee proposes 16 recommendations that will set the stage for advanced manufacturing to thrive in the United States:

Enabling Innovation

1. **Establish a National Advanced Manufacturing Strategy:** The AMP Steering Committee proposes establishing and maintaining a national advanced manufacturing strategy by putting in place a systematic process to identify and prioritize critical cross-cutting technologies.

2. **Increase R&D Funding in Top Cross-Cutting Technologies:** In addition to identifying a "starter list" of cross-cutting technologies that are vital to advanced manufacturing, the AMP Steering Committee proposes a process for evaluating technologies for research and development (R&D) funding.
3. **Establish a National Network of Manufacturing Innovation Institutes (MIIs):** The AMP Steering Committee proposes the formation of MIIs as public-private partnerships to foster regional ecosystems in advanced manufacturing technologies. MIIs are one vehicle to integrate many of the Committee's recommendations.
4. **Empower Enhanced Industry/University Collaboration in Advanced Manufacturing Research:** The AMP Steering Committee recommends a change in the treatment of tax-free bond-funded facilities at universities that will enable greater and stronger interactions between universities and industry.
5. **Foster a More Robust Environment for Commercialization of Advanced Manufacturing Technologies:** The AMP Steering Committee recommends that action is taken to connect manufacturers to university innovation ecosystems and create a continuum of capital access from start up to scale up.
6. **Establish a National Advanced Manufacturing Portal:** The AMP Steering Committee recommends that a searchable database of manufacturing resources is created as a key mechanism to support access by small and medium-sized enterprises to enabling infrastructure.

Securing the Talent Pipeline

7. **Correct Public Misconceptions About Manufacturing:** Building excitement and interest in careers in manufacturing is a critical national need, and an advertising campaign is recommended by the AMP Steering Committee as one important step in this direction.
8. **Tap the Talent Pool of Returning Veterans:** Returning veterans possess many of the key skills needed to fill the skills gap in the manufacturing talent pipeline. The AMP Steering Committee makes specific recommendations on how to connect these veterans with manufacturing employment opportunities.
9. **Invest in Community College Level Education:** The community college level of education is the "sweet spot" for reducing the skills gap in manufacturing. Increased investment in this sector is recommended, following the best practices of leading innovators.
10. **Develop Partnerships to Provide Skills Certifications and Accreditation:** Portability and modularity of the credentialing process in advanced manufacturing is critical to allow coordinated action of organizations that feed the talent pipeline. The AMP Steering Committee supports the establishment of stackable credentials.
11. **Enhance Advanced Manufacturing University Programs:** The AMP Steering Committee recommends that universities bring new focus to advanced manufacturing through the development of educational modules and courses.

12. **Launch National Manufacturing Fellowships & Internships:** The AMP Steering Committee supports the creation of national fellowships and internships in advanced manufacturing in order to bring needed resources but more importantly national recognition to manufacturing career opportunities.

Improving the Business Climate

13. **Enact Tax Reform:** The AMP Steering Committee recommends a set of specific tax reforms that can "level the playing field" for domestic manufacturers.
14. **Streamline Regulatory Policy:** The AMP Steering Committee recommends a framework for smarter regulations relating to advanced manufacturing.
15. **Improve Trade Policy:** Trade policies can have an adverse impact on advanced manufacturing firms in the United States. The AMP Steering Committee recommends specific actions that can be taken to improve trade policy.
16. **Update Energy Policy:** The manufacturing sector is a large consumer of energy, and consequently, domestic energy policies can have a profound impact on global competitiveness. The AMP Steering Committee makes specific policy recommendations regarding energy issues of importance in manufacturing.

With sustained focus, alignment of interests, and coordinated action to implement the above recommendations, the United States can and will lead the world in advanced manufacturing. Already today, there are examples of new manufacturing technologies emerging from research laboratories that will have a transformative effect on the way manufacturing is done in America. Together, government, industry, and academia must commit to re-invent the national manufacturing base to ensure our Nation's future.

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I. Advanced Manufacturing Partnership

"Advanced manufacturing is a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies."

—President's Council of Advisors on Science and Technology Report to the President on Ensuring American Leadership in Advanced Manufacturing, p. ii

Genesis

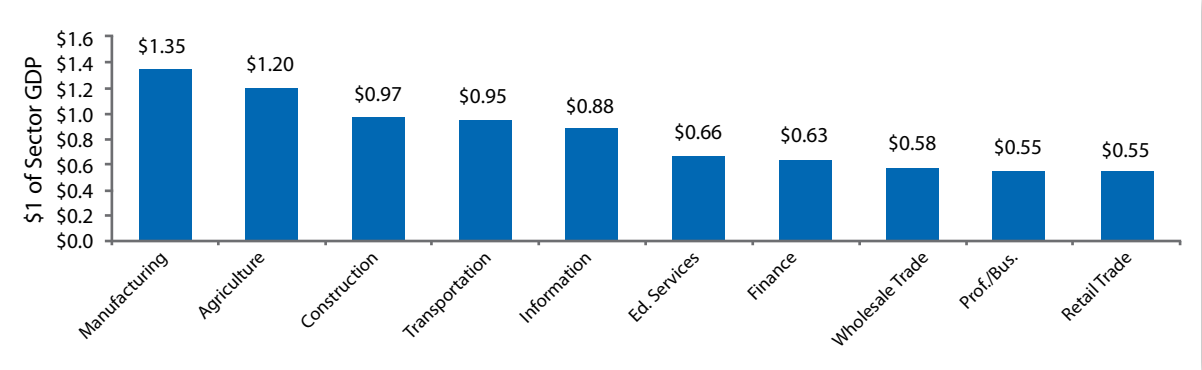
The United States has long thrived as a result of its ability to manufacture goods and sell them to global markets. Manufacturing has supported our economic growth, contributing to the Nation's exports, and employing millions of Americans. Manufacturing has driven knowledge production and innovation in the United States by supporting two-thirds of private sector research and development (R&D) and by employing scientists, engineers, and technicians to invent and produce new products.[1]

Advanced manufacturing encompasses all aspects of manufacturing, including the ability to quickly respond to customer needs through innovations in production processes and innovations in the supply chain. As manufacturing advances, it is increasingly becoming knowledge-intensive, relying on information technologies, modeling, and simulation. Manufacturers are also increasingly focusing on environmentally-sustainable practices that lead to improved performance and reduced waste.

The benefits to focusing on advanced manufacturing are many. As Figure 1 shows, manufacturing creates more value across the economy per dollar spent than any other sector. Manufacturing produces new goods that fundamentally change or create new services and sectors.

1. President's Council of Advisors on Science and Technology, "Report to the President on Ensuring America's Leadership in Advanced Manufacturing," June 2011, www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

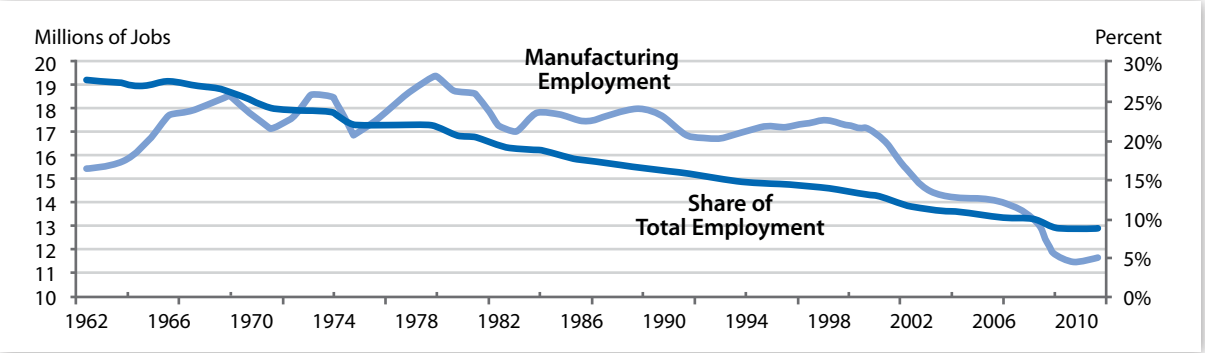
Figure 1. Economic Activity Generated by $1 of Sector Output, 2010



Source: AMP Steering Committee based on data from Bureau of Economic Analysis, Input-Output Tables available at www.bea.gov/iTable/index_industry.cfm.

However, the nation's historic leadership in manufacturing is at an inflection point. Although the United States has been the leading producer of manufactured goods for more than 100 years, manufacturing has been declining as a share of U.S. gross domestic product (GDP) and employment (Figure 2).

Figure 2. Employment Trends, 1962–2010



Source: AMP Steering Committee based on data from Bureau of Labor Statistics, Current Employment Statistics, 1962–2010 provided in Table B-1 at www.bls.gov/ces/tables.htm#ee.

The loss of U.S. leadership in manufacturing is not limited to low-wage jobs in low-tech industries, nor is it limited to our status relative to low-wage nations. The hard truth is that the United States is lagging behind in innovation in the manufacturing sector relative to high-wage nations such as Germany and Japan, and the United States has relinquished leadership in some medium- and high-tech industries that employ a large proportion of highly-skilled workers. In addition, the United States has been losing significant elements of the research and development (R&D) activity linked to manufacturing to other nations, as well as its ability to compete in the manufacturing of many products that were invented and

innovated here—from laptop computers to flat panel displays to lithium ion batteries. Recognizing this, in June 2011, the President's Council of Advisors on Science and Technology (PCAST) and the President's Innovation and Technology Advisory Committee (PITAC) issued a report to the President on *Ensuring American Leadership in Advanced Manufacturing*.[2] The report provided a strategy and specific recommendations for revitalizing the Nation's leadership in advanced manufacturing.

To ensure that the United States attracts manufacturing activity and remains a leader in knowledge production, the report recommended the following two strategies:

1. "Create a fertile environment for innovation so that the United States provides the overall best environment for business, through tax and business policy, robust support for basic research, and training and education of a high-skilled workforce; and
2. Invest to overcome market failures, to ensure that new technologies and design methodologies are developed here, and that technology-based enterprises have the infrastructure to flourish here."[3]

Based on the PCAST report, on June 24, 2011, President Obama launched the Advanced Manufacturing Partnership (AMP), a national effort bringing together industry, universities, the Federal Government, and other stakeholders to identify emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance U.S. global competitiveness.

Operating within the framework of PCAST, the AMP Steering Committee had three targeted outcomes, which fit intimately together and will have an additive effect when implemented:

1. Develop a permanent model for evaluating, prioritizing, and recommending Federal investments in advanced manufacturing technologies,
2. Recommend a set of partnership projects, focused on advancing high-impact technologies and creating models for collaboration that encompass technology development, innovation infrastructure, and workforce development,
3. Provide recommendations to the Administration on the actions required to support investment in advancing manufacturing in the United States.

Process

After its launch, the AMP Steering Committee initiated five workstreams with the objectives listed in Table 1.

2. *Ibid.*
3. *Ibid.*

Table 1. Workstream Objectives

Workstream	Objectives
Technology Development	• Determine a permanent mechanism to be used for identifying and developing key manufacturing technologies • Determine a set of top technology areas that would ensure U.S. manufacturing competitiveness
Shared Infrastructure & Facilities	• Assess opportunities to de-risk, scale-up, and lower the cost of accelerating technology from research to production through unique capabilities and facilities that serve all U.S. based manufacturers, in particular, small and medium-sized enterprises
Education & Workforce Development	• Identify tangible actions to support a robust supply of talented individuals to provide human capital to companies interested in investing in advanced manufacturing activities in the United States
Policy	• Make recommendations to the Administration on economic and innovation policies that can directly impact the overall climate and the ability to improve research collaboration and the pathway to commercialization in support of U.S.-based manufacturing and jobs
Outreach	• Conduct stakeholder outreach and reviews • Conduct and consolidate findings of regional meetings

Source: AMP Steering Committee

The AMP Steering Committee engaged in extensive consultations with stakeholders across the country to identify opportunities for investments in advanced manufacturing that have the potential to transform U.S. industry. Most notably, four regional meetings were conducted—in Atlanta, Georgia; Cambridge, Massachusetts; Berkeley, California; and Ann Arbor, Michigan—providing a forum for 1,200 attendees, representing industry, academia, and government, to openly share their observations, views, and recommendations. (See Annex 6 [which is available online] for summaries of these meetings.) In addition, extensive surveys were conducted through various manufacturing and academic trade and professional associations.

These consultations contributed significantly to the recommendations of the AMP Steering Committee to PCAST. The Steering Committee firmly believes that these recommendations will provide the foundation for future breakthroughs by building a national roadmap for advanced manufacturing technologies, speeding ideas from the drawing board to the manufacturing floor, scaling-up first-of-a-kind technologies, training our future workforce, and developing the infrastructure and shared facilities to allow small, mid-sized, and large manufacturers to innovate and compete.

Each workstream prepared a report, providing the basis for this AMP Steering Committee report and its recommendations. These reports can be found in the following annexes, which are available on-line:

- Annex 1: Technology Development Workstream
- Annex 2: Shared Facilities and Infrastructure Workstream
- Annex 3: Education and Workforce Workstream
- Annex 4: Policy Workstream
- Annex 5: Outreach Workstream

II. Advanced Manufacturing Matters

Role of Advanced Manufacturing in the Global Economy

During the 20th century, U.S. manufacturing increased production at a relatively steady rate. Overall investment in capacity steadily expanded. Manufacturing employment held at roughly 17 to 18 million from the late 1960s through the late 1990s. Over the last decade, however, this equation changed. Production has been nearly flat for over a decade. The United States lost one-third of its manufacturing workforce, and investment in new production capacity stalled.[4] Productivity gains alone cannot be blamed for the loss in manufacturing employment over this period; it is rather the overall loss in the competitiveness of the sector. There are many contributing factors. These losses have led to large trade deficits in manufactured goods, including in advanced technology products, and a loss in global share of manufacturing production. There are growing concerns that the loss in capacity over the last decade has also impacted our domestic innovation and manufacturing capabilities, impeding new investment in domestic manufacturing.

Advanced manufacturing serves a critical role in today's economy. Manufacturing contributes disproportionately to U.S. innovation. Proximity to the manufacturing process creates innovation spillovers across firms and industries, leading to the ideas and capabilities that support the next generation of products and processes. In this way, a vibrant manufacturing sector is inextricably linked to our capacity as a nation to innovate.

Despite recent declines in manufacturing employment, manufacturing industries still employ nearly 12 million workers. These industries are responsible for a significant portion of domestic R&D investment—a key driver of innovation. Small and medium-sized enterprises in the manufacturing sector are a critical component of the U.S. economy, representing 84 percent of manufacturing establishments in 2009[5] and employing 51 percent of the U.S. manufacturing workforce in 2010.[6]

The impact of a healthy manufacturing sector has a ripple effect on the economy. On average, each manufacturing job supports 2.5 jobs in other sectors, and, at the upper end, each high-tech manufacturing job supports sixteen others.[7] Each dollar in final sales of manufactured goods supports $1.35 in output from other sectors of the economy.[8] Compared to all other sectors, manufacturing has the largest multiplier.[9] Manufacturing not only spurs tremendous economic activity, it encourages innovation and research wherever it occurs. In 2009, manufacturing domestic business R&D spending in the

4. Stephen J. Ezell and Robert D. Atkinson, *The Case for a National Manufacturing Strategy,* Information Technology and Innovation Foundation, 2011, www2.itif.org/2011-national-manufacturing-strategy.pdf.

5. Census Bureau, Statistics of U.S. Businesses, 2009, www.census.gov/econ/susb/.

6. Bureau of Labor Statistics, Current Employment Statistics, 2010, bls.gov/ces/cessizeclass.htm#TB_inline?height=200&width=325&inlineId=ces_program_links.

7. Ross DeVol et al., "Manufacturing 2.0: A More Prosperous California," Milken Institute, June 2009, www.milkeninstitute.org/pdf/CAManufacturing_ES.pdf.

8. Bureau of Economic Analysis, Industry-by-Industry Total Requirements after Redefinitions (Producer Price Indexes), 2010, www.bea.gov/iTable/index_industry.cfm.

9. The Manufacturing Institute, *The Facts about Modern Manufacturing*, 8th Edition, 2009, www.nist.gov/mep/upload/FINAL_NAM_REPORT_PAGES.pdf. Data are presented in Figure 1.

United States reached $195 billion, accounting for 70 percent of all domestic business R&D performed in the United States.[10]

The importance of manufacturing to employment is not measured by simply counting the numbers of production workers. The production stage affects employment throughout long product value chains, from the innovation and input stages for product design and production including resources, components, suppliers, to the output stages including distribution, sales and the maintenance and repair life cycle service for the product. Total employment for manufacturing, and therefore its economic impact, is much bigger than simply those engaged at the production moment itself.

Manufacturing also has a significant effect on the global trade balance. Over the prior decade, manufactured goods represented 65 percent of U.S. trade.[11] A decline in the U.S. manufacturing base over the last two decades has led, in part, to chronic trade deficits. The United States has, in fact, run a trade deficit in advanced technology products every year since 2002.[12] There is simply no way to reduce these chronic trade deficits without a vibrant manufacturing sector; it is not possible for this deficit to be balanced through the service sector alone.

To reinvigorate the U.S. economy and pursue long-term economic prosperity, America must reject the notion that the Nation should let go of its manufacturing sector in favor of services. No other sector creates more high paying jobs that sustain a vast swath of American households. Instead, the United States needs to recognize that manufacturing and services are interdependent and the success of one sector affects the other. Those in the industry know it is not effective to separate the manufacturing and service sectors; manufacturing and innovation go hand-in-hand. Economic growth will not be sustainable if the two are decoupled. If the Nation attempts to rely on innovation alone, innovation—and the value it creates—will follow manufacturing overseas.

Importance of Manufacturing to National Security

Maintaining technological superiority in advanced manufacturing is a national security issue and is critically important for sustaining U.S. global competitiveness. A strong manufacturing sector not only ensures a ready supply of defense and commercial goods and services, but also ensures the integrity of these goods, especially electronics and other mission critical items. However, U.S. national security is not limited to the products and technologies that are required for national defense; it also entails the products and technologies required for our nation's energy security, food security, heath security, cybersecurity and economic security.

Moving forward, the United States must maintain access to low-cost, secure sources of energy. The Nation has already made great strides in photovoltaics, advanced energy storage devices, and alternate feedstocks, but it needs to accelerate the development of advanced manufacturing technologies to deliver cost competitive economics. The United States, and the world, is witnessing the global impor-

10. National Science Foundation, National Center for Science and Engineering Statistics (NSF/NCSES). InfoBrief NSF 12-309, March 2012, www.nsf.gov/statistics/infbrief/nsf12309/nsf12309.pdf.

11. National Science and Technology Council. *A National Strategic Plan for Advanced Manufacturing,* 2012. www.whitehouse.gov/sites/default/files/microsites/ostp/iam_advancedmanufacturing_strategicplan_2012.pdf.

12. U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Products, 2011, www.census.gov/foreign-trade/balance/c0007.html.

tance of food security; advanced manufacturing will enable the world to feed its growing population in a sustainable, efficient manner through high-tech seeds and plant genomics. An aging global population is increasingly relying on cutting edge pharmaceuticals and medical technology, a sector in which advanced manufacturing plays a pivotal role. Finally, every sector of the economy is increasingly dependent on information technology systems; hence, not only is information technology vitally important to national security, but to leadership in the global economy. Breakthrough information technologies require advances in manufacturing to deliver the next generation of systems and tools, and advanced manufacturing is depending on these future systems for next generation processes.[13]

Interplay Between Innovation and Advanced Manufacturing

Other countries have witnessed the unparalleled economic prosperity created by a manufacturing economy, and appreciate the inherent value of manufacturing. They are actively competing for manufacturing technologies and manufacturing production. The major economic competitors of the United States recognize the benefits from a vibrant manufacturing sector, and they have developed approaches for attracting manufacturing investment. In doing so, other countries are capturing the R&D that follows the manufacturing. As economist Gregory Tassey of the National Institute of Standards and Technology writes: "The issue of co-location of R&D and manufacturing is especially important because it means the value-added from both R&D and manufacturing will accrue to the innovating economy, at least when the technology is in its formative stages."[14] Many argue that R&D and manufacturing can be separated with the United States focusing on R&D and design. However, studies have shown that offshoring of manufacturing leads to later loss of R&D competencies. "Losing this [manufacturing] exposure makes it harder to come up with innovative ideas."[15] Related to this argument, building manufacturing plants in the United States has additional benefits of providing quicker access to supplies of intermediate goods and services; access to a larger pool of workers; proximity to consumers; and increased flow of knowledge spillovers across firms through the supply chain and worker mobility.[16]

The problems the world faces are complex. They cannot be solved by services alone. They require the innovation, creativity, and ingenuity of manufacturing companies, together with that of academia and national research laboratories. As the world's population rises and new economies emerge, society requires novel solutions to meet its pressing needs for energy, water, food, health, security, and public infrastructure. Solutions to these challenges are complex and require novel approaches. No longer can the problems be solved by singular disciplines. They require interdisciplinary approaches and collaboration between the private and public sectors. They require partnering among the world's best universities, entrepreneurs, national labs, and small, medium, and large enterprises to address the world's most pressing challenges, uncover scientific fundamentals, discover new molecules and materials, and scale new processes and operations.

13. Department of Commerce, "The Competitiveness and Innovative Capacity of the United States," January 2012, www.commerce.gov/sites/default/files/documents/2012/january/competes_010511_0.pdf.

14. Gregory Tassey, *The Technology Imperative* (Northampton, MA: Edward Elgar, 2007).

15. Erica R. H. Fuchs, "The Impact of Manufacturing Offshore on Technology Development Paths in the Automotive and Optoelectronics Industries," Massachusetts Institute of Technology, June 2006, esd.mit.edu/people/dissertations/fuchs.pdf.

16. Michael Greenstone, Richard Hornbeck, and Enrico Moretti, "Identifying Agglomeration Spillovers: Evidence from Winners and Losers of Large Plant Openings," April 2010, emlab.berkeley.edu/~moretti/mdp2.pdf.

U.S. Global Competitiveness

By failing to update and realign its policies, the United States is slowly ceding its position as the long-standing leader in advanced manufacturing. Nations around the world are offering a more positive climate for new industrial plants and to encourage business investment locally. Public policies should encourage investment. World-class educational systems and workforce training practices serve as magnets for manufacturers. In recent years, the R&D system support by the U.S. Government has had very limited focus on technology advances needed for advanced manufacturing. This benign neglect has taken its toll and is in sharp contrast to Germany, Korea, Japan, and China.

Hence, the AMP Steering Committee asserts that the United States must establish a national economic framework that sets a strategy and takes supporting action to restore America's economic health and long-term strength in advanced manufacturing.

To achieve this goal, the Steering Committee recommends that the United States pursue an advanced manufacturing agenda to improve global competitiveness in the next five years. Ensuring long-term, sustainable growth requires the United States to prepare the workforce, to attract and retain skilled workers from outside its borders, and to provide incentives that encourage long-term business investments in key global growth areas.

The Steering Committee recommends the establishment of a national strategy and common agenda for advanced manufacturing to thrive in America.

III. Recommendations

The Advanced Manufacturing Partnership Steering Committee has developed a set of recommendations built around three pillars: enabling innovation, securing the talent pipeline, and improving the business climate. The Committee's recommendations aim to re-invent manufacturing in a way that ensures U.S. competitiveness, feeds into the innovation economy, and grows a robust domestic manufacturing base. We focus on positioning the Nation to lead the world in new disruptive advanced technologies that are changing the face of manufacturing. We believe that several key steps should be taken, but among the most critical is to strengthen our innovation system for advanced manufacturing. While some of the Nation's largest firms have the depth to be ready for the manufacturing challenges of the future, there are over 300,000 small and mid-sized firms that are largely outside the U.S. innovation system.[17] The United States will only lead in advanced manufacturing if it harnesses the strength of its innovation system through the manufacturing sector to create technological advantage.

The United States can and will lead the world in advanced manufacturing. Already today, we see examples of new manufacturing technologies emerging from research laboratories that will have a disruptive effect on the way things are made. Examples include novel nano-manufacturing technologies that reduce the cost of capital dramatically, bio-manufacturing and separation methods that lower the energy consumption of conventional processes, innovative additive processes and materials that reduce waste, and intelligent manufacturing tools and methods that reduce hazards, optimize supply chains, and maximize yields. Each of these innovation examples directly affects factors such as the cost of capital, quality of materials, and availability of energy.

Critical to the deployment of new advanced manufacturing technologies will be a skilled workforce trained and ready to lead this revolution in manufacturing. Exciting examples of novel partnerships between industry, educational institutions, and the public sector have come to the attention of the Steering Committee that address skills gaps in manufacturing. These partnerships are at the regional level and engage community colleges. A focus on these best practices and participation of all players (government, industry, and academia) will lead to further innovations in education and new excitement for the careers that will be created by a vibrant advanced manufacturing sector in the United States.

We see significant opportunities to exercise policy "levers" that improve the business climate for domestic manufacturing. In addition to important tax and trade policies that level the playing field, we see opportunities to engage regulatory agencies early in the development of manufacturing processes to develop a more streamlined regulatory framework and to update energy policy as well.

Finally, the Steering Committee's recommendations include concepts that can accommodate both the regional and the national aspects of any manufacturing strategy. We envision a set of regional Manufacturing Innovation Institutes (MIIs) that bridge the gap between research and commercial application of advanced manufacturing technologies. These public-private partnerships will form a national infrastructure network that eases access to new technologies while also supporting educational efforts in these new technologies. Unlocking advanced manufacturing innovation at a regional level is critical to transforming U.S. global competitiveness in manufacturing by enabling unique partnerships

17. BLS, Current Employment Statistics, *op. cit*.

that leverage regional competencies. This regional focus also strengthens the collective "industrial commons" of the nation.[18]

Table 2. Summary of Recommendations	
Pillar I: Enabling Innovation	
1	*Establish a National Advanced Manufacturing Strategy* Through a systematic process to identify and prioritize cross-cutting technologies, a national advanced manufacturing strategy should be developed and maintained.
2	*Increase R&D Funding in Top Cross-Cutting Technologies* In addition to identifying a "starter list" of cross-cutting technologies that is vital to advanced manufacturing, the AMP Steering Committee has laid out a process for evaluating technologies for R&D funding.
3	*Establish a National Network of Manufacturing Innovation Institutes* Manufacturing Innovation Institutes (MIIs) should be formed as public-private partnerships to foster regional ecosystems in advanced manufacturing technologies. These MIIs are one vehicle to integrate many recommendations.
4	*Empower Enhanced Industry/University Collaboration in Advanced Manufacturing Research* The treatment of tax-free bond-funded facilities at universities should be changed in order to enable greater and stronger interactions between universities and industry.
5	*Foster a More Robust Environment for Commercialization of Advanced Manufacturing Technologies* The AMP Steering Committee recommends actions to connect manufacturers to university innovation ecosystems and create a continuum of capital access from start up to scale up.
6	*Establish a National Advanced Manufacturing Portal* A searchable database of manufacturing resources should be created to serve as a key mechanism to support access by small and medium-sized enterprises to enabling infrastructure.

18. Gary P. Pisano and Willy C. Shih, "Restoring American Competitiveness," *Harvard Business Review* 87 (July–August 2009), hbr.org/hbr-main/resources/pdfs/comm/fmglobal/restoring-american-competitiveness.pdf.

Pillar II: Securing Talent Pipeline	
7	*Correct Public Misconceptions About Manufacturing* Building excitement and interest in careers in manufacturing is a critical national need, and an advertising campaign should be undertaken as one important step in this direction.
8	*Tap the Talent Pool of Returning Veterans* Returning veterans possess many of the key skills needed to fill the skills gap in the manufacturing talent pipeline. The AMP Steering Committee makes specific recommendations on how to connect these veterans with manufacturing employment opportunities.
9	*Invest in Community College Level Education* The community college level of education is the "sweet spot" for impact on the skills gap in manufacturing. Investment in this sector should be increased, following the best practices of some of the leading innovators in this space.
10	*Develop Partnerships to Provide Skills Certifications and Accreditation* Portability and modularity of the credentialing process in advanced manufacturing would allow coordinated action of organizations that feed the talent pipeline.
11	*Enhance Advanced Manufacturing University Programs* Universities should bring new focus to advanced manufacturing through the development of educational modules and courses.
12	*Launch National Manufacturing Fellowships & Internships* The creation of national fellowships and internships in advanced manufacturing is recommended to bring needed resources but more importantly national recognition to manufacturing career opportunities.
Pillar III: Improving the Business Climate	
13	*Enact Tax Reform* A set of specific tax reforms should be enacted that "level the playing field" for domestic manufacturers.
14	*Streamline Regulatory Policy* A framework for smarter regulations should be created for advanced manufacturing.
15	*Improve Trade Policy* Specific trade policy proposals are advanced to improve the business climate.
16	*Update Energy Policy* Energy issues of importance in manufacturing must be addressed.

Source: AMP Steering Committee

These three pillars are closely interrelated. No one set of recommendations stands on its own. Real progress will require coordinated action with respect to all three pillars. In the following sections, the AMP Steering Committee discusses each of the three pillars and the recommendations that comprise each pillar.

Pillar I: Enabling Innovation[19]

Recommendation #1: Establish a National Advanced Manufacturing Strategy

The research and innovation ecosystem of the Nation is highly dependent on the presence of a manufacturing base that provides constant feedback in terms of problems and challenges to be solved.

Product innovation is most effective and efficient when coupled with intimate knowledge and control over the manufacturing process. Hence, the design of the product inherently involves the design of the manufacturing process by which the product will be made. The two are inseparable; severing them, as is being done increasingly often, has a very adverse effect on each because they are so interdependent.

Technology is always advancing. What was only recently on the cutting edge can quickly become a commodity. Thus, a major goal of the Advanced Manufacturing Partnership should be to develop and establish a permanent mechanism to identify the next generation of advanced manufacturing technologies that will have the greatest impact on the growth and competitiveness of the United States.

Historically, the United States has had a vibrant manufacturing base and active programs in both basic and applied research. The distinguishing feature of U.S. research activity has been the sheer scale, breadth, and vitality of U.S. investments.

Unlike the United States, other leading industrialized countries are using a more systematic planning process that is explicitly aligned to their national interests and strategies. There are benefits to implementing key elements of a structured planning process. We recognize, however, that U.S. strengths lie in flexibility and ingenuity, along with assets such as research universities and private and national labs. In cases where the risk to develop a novel, breakthrough technology is too great to be borne by one entity alone, public-private partnerships can accelerate the transformation of ideas to marketable goods while de-risking the investment during development. By leveraging underlying strengths that enable U.S. manufacturing enterprises to be responsive to changes in the global market, and combining them with an appropriate amount of structure, innovation in key, cross-cutting manufacturing technologies will be accelerated.

The Federal Government, industry, and academia must collaborate on the creation of a sustainable process that fosters the efficient identification and commercialization of technologies that will fuel the future success of manufacturing in the United States.

To do so, we recommend that a technology lifecycle process be followed. The mechanism should have four distinct phases:

19. Further details related to the recommendations within this Pillar can be found in Annexes 1, 2, and 4.

- **Phase I: Create a National Advanced Manufacturing Strategic Plan & Objectives:**
  - The AMP Steering Committee acknowledges and supports the recommendations recently published in the National Science and Technology Council's report "A National Strategic Plan for Advanced Manufacturing."[20]
  - Moving forward, we recommend that the Advanced Manufacturing National Program Office,[21] coordinate the creation of a national advanced manufacturing strategy in close collaboration with industry and academia. During this phase, future scenarios and forecasts would be created based on the analysis of strategic national (defense, energy, health, security, economic) and global (market) needs, as well as forecasted macroeconomic trends. This analysis should be conducted every five years and include industrial, academic, and government leaders and should be an inclusive process inviting opinions, using collective intelligence and building up consensus among participants. Criteria for prioritizing goals should be aligned against U.S. national security needs (defense, energy, food, health, and economic), global market demand, U.S. readiness for commercial competitiveness, and global technology readiness.
  - Table 3 lays out a framework and a directional view of the nature of the analysis required. The relative importance (high to low) and readiness assessment (high to low) will define resulting implications and define the type of technology required to drive U.S. competitiveness. It will also guide what role the U.S. Government, industry and universities should play to advance the technology.

Phase I Output→Prioritized list of strategic needs and required technologies

- **Phase II: Create Technology Roadmaps:**

With the national priorities in hand, working teams of industrial, academic, and agency experts should be commissioned to develop roadmaps to enable strategic planning for developing new technologies and transferring them into existing supply chains. The roadmaps should include guidance on key value and performance metrics. For mature industries this exercise should be driven by consortia composed of industrial, government, and academic leaders. For nascent technologies, the Federal government should establish working teams composed of key subject matter experts.

Phase II Output→Technology roadmaps for each of the prioritized technologies

20. National Science and Technology Council, "A National Strategic Plan for Advanced Manufacturing," www.whitehouse.gov/sites/default/files/microsites/ostp/iam_advancedmanufacturing_strategicplan_2012.pdf.

21. National Institute of Standards and Technology (NIST), "National Program Office for the Advanced Manufacturing Partnership Established at NIST," Press Release, December 19, 2011, www.nist.gov/public_affairs/releases/npo-121911.cfm.

- **Phase III: Create and Manage Programs:**
  - Based on the technology roadmaps created in Phase II, the AMP Steering Committee recommends that multi-year programs with stable funding be established to develop research capacities and create an institutional hub for coordinating technology transfer to existing firms and the re-training of incumbent workers. Wherever possible, it is critical that a co-funded model be used wherein both industry and government contribute. For mature industries, consortia should create and manage the programs. For nascent industries and technologies where the government plays a larger role in driving research and infrastructure, and is therefore the primary stakeholder, programs should be managed by dedicated program managers from Federal agencies. Wherever possible, established programs should use the proposed Manufacturing Innovation Institutes to conduct research, and develop and maintain the talent pipeline for industry. It is critical that the more than 300,000 small and medium-sized enterprises and members of the extended value chain are also involved and gain the required access to research infrastructure. Due to programs being funded by a variety of stakeholders, policies must clearly define intellectual property access rights for industry participants.
  - We recommend a competitive selection process be used for disbursing project funding based on clearly established metrics for proposal evaluation and awards. Specifically, the NIST gate-oriented approach is recommended and should include such key metrics as novelty of approach, impact on tradability/differentiation, business case, and return on investment from commercialization of the technology.

Phase III Output→Technology programs established and executed

- **Phase IV: Review Progress and Correct Course:**
  - Key stakeholders, agency representatives, and experts from academia and industry should conduct periodic reviews of programs to identify key successes and course correction needs. Standing program review teams should provide real-time technical assistance and ongoing and iterative advice as the program ramps up. While program funding must be stable, we recommend that allocations within the portfolio be subjected to review and adjustment based on rigorous, metric-based analysis—such as measure of commercialization rates, number of small and medium-sized enterprises (SMEs) served, reductions in the amount and types of energy used, or education and retraining successes. The implications of changing macroeconomic conditions should also be considered.

Phase IV Output→Periodic review of program portfolio by key stakeholders

Table 3 provides a framework for setting priorities for advanced manufacturing investments.

Table 3. Framework for Priorities for Federal Investments in Advanced Manufacturing Technologies

US National Needs	Global Market Demand	US Manufacturing Competitiveness	Global Technology Readiness	Implication	Technology Required to Drive US Manufacturing Competitiveness	Role of US Government	Role of Industry	Role of University
High	High	High	High	Mature field. US strong global exporter.	Applied research & development to maintain leadership.	Strategic demand requires capability.	Leads research & production investment.	Conduct applied research.
High	High	High	Low	US positioned for strong global leadership. Technology not available.	Basic to applied research.	Strategic demand requires capability.	Defines road maps, develops technologies and establishes manufacturing capabilities & facilities.	Conduct basic research.
High	High	Low	High	US lags. Net importer.	Big investment required to dose gap.	Strategic demand drives establishing US manufacturing base.	Establish globally competitive manufacturing capabilities & facilities.	Breakthrough technology.
High	High	Low	Low	New field. High export potential. No global leader. New technology & infrastructure required.	Basic research.	Strategic demand drives research & infrastructure build.	Partner with universities & national labs to conduct basic & applied R&D & establish required infrastructure.	Conduct basic research.
High	Low	High	High	US specific need. Technology mature. Government road map drives infrastructure investment.	Infrastructure investment.	Strategic demand requires capability & drives future infrastructure investment.	Establish infrastructure to meet national demand.	Breakthrough technology.
High	Low	High	Low	US specific demand. Government road map drives research and infrastructure investment.	Basic to applied research.	Strategic demand sets requirements.	Establish infrastructure to meet national demand.	Conduct basic research.
High	Low	Low	High	US needs; others produce. Low global demand. US vulnerable.	Big investment required to close gap.	Strategic demand drives infrastructure build & incentives.	Only establish capability if government funds.	Breakthrough technology.
High	Low	Low	Low	US needs; no one produces; invention required.	Basic research.	Strategic demand drives research.	Establish infrastructure to demonstrate technology & meet national demand.	Breakthrough technology.
Low	High	High	High	US leads; strong exporter. Industry drives research based on global demand.	Applied research.	Incentivize exports.	Industry leads research & invests in production.	Breakthrough technology.
Low	High	High	Low	US leads; strong exporter. Industry consortium leads future road mapping.	Basic to applied research.	Incentivize exports.	Industry defines road maps, develops technologies and establishes infrastructure.	Conduct industry funded basic & applied research.
Low	High	Low	High	US not global leader. Commoditized market.	Big investment required to close gap.	Unless US vulnerable, no action required.	Only invest if breakthrough enables global competitiveness.	Breakthrough technology.
Low	High	Low	Low	New field. High export potential. No global leader. New technology & infrastructure required.	Basic research.	Incentivize exporters.	Drives research & infrastructure investment. Partners with universities to conduct basic research.	Conduct industry funded basic research.
Low	Low	XXX	XXX	No demand. Don't do it.				

Source: AMP Steering Committee

Recommendation #2: Increase R&D Funding in Top Cross-Cutting Technologies

Eleven cross-cutting technology areas were selected as the initial list on which the Advanced Manufacturing National Program Office should focus its attention. While time did not permit the development of detailed technology roadmaps for each of these technologies, they consistently emerged as the top candidates for further consideration through consultations with key stakeholder groups, including the AMP Steering Committee itself, AMP Steering Committee Regional Meeting participants, and members of MAPI, the National Center for Manufacturing Sciences (NCMS) and the Association of Public and Land-grant Universities (APLU). (See Annex 1.)

These technologies address key national needs such as defense, energy independence and efficiency, food security, homeland security, and health care. They are pivotal in enabling U.S. manufacturing competitiveness, both in terms of differentiation and tradability of goods. Universities, national labs, intermediate technology institutes, independent research institutions, and community colleges will need to work together with industry to support research, development, and deployment of these manufacturing technologies, and to develop the talent pipeline for industry.

- Advancing Sensing, Measurement, and Process Control
- Advanced Materials Design, Synthesis, and Processing
- Visualization, Informatics, and Digital Manufacturing Technologies
- Sustainable Manufacturing
- Nanomanufacturing
- Flexible Electronics Manufacturing
- Biomanufacturing and Bioinformatics
- Additive Manufacturing
- Advanced Manufacturing and Testing Equipment
- Industrial Robotics
- Advanced Forming and Joining Technologies

Specific interests are as follows:

- **Advanced Sensing, Measurement, and Process Control (including Cyber-Physical Systems):** This set of technologies has applicability across almost all industry domains. These technologies are critical for enhancing tradability by way of end-to-end supply chain efficiency (e.g., low cost and pervasive sensors in plants and logistics systems, automatic control and coordination of systems-of-systems). In addition, megatrends of energy and resource efficiency, better safety, and higher quality also depend highly on advances in sensing and automatic process control. Finally, emerging technologies such as nanomanufacturing and biomanufacturing need specialized sensors and control models.
- **Advanced Materials Design, Synthesis, and Processing:** These technologies include the design and synthesis of small molecules, nanomaterials, formulated solutions, coatings, com-

posites, and integrated components (e.g., photovoltaic devices). They entail integration of computational modeling, state-of-the-art synthesis tools (e.g., high throughput), and advanced research analytics (e.g., materials genome). Almost all the megatrends for the future—energy efficiency or alternate energy devices, new materials to counter resource shortages, next-generation consumer devices, and new paradigms in chemical safety and security—depend heavily on advanced materials. Advanced materials will fuel emerging multi-billion dollar industries.

- **Visualization, Informatics, and Digital Manufacturing Technologies:** This area entails research focused on embedded sensing, measurement and control systems for highly corrosive, high temperature processes impacting everything from chemical synthesis to lightweight materials to aircraft engines. It also includes control systems enabling manufacturing of high performance, highly-controlled structures and devices. Finally, it entails modeling, simulation and visualization technologies that can optimize a product and its manufacturing in virtual space before actual physical production is started (therefore bypassing time-consuming and expensive physical testing and experimentation). The data generated can also potentially support conclusions regarding product warranties and product reliability.

  Examples of these technologies include integrated enterprise level smart manufacturing methodologies, e.g., moving directly from computational /digital design to chemical and materials planning, purchasing, and delivery to manufacturing of customized products and components. One aspect deals largely with manufacturing competitiveness through end-to-end supply chain efficiency—reduced manufacturing cycle time, lower worker injury and illness rates, higher process yields, higher energy efficiency, etc.—brought about by more networked information, and the control and management of information across various entities in the value chain spanning multiple enterprises. The other aspect deals with the speed with which products are designed, manufactured, and brought to market, which will be a key differentiator.

- **Sustainable Manufacturing:** This approach aims to maximize every atom of matter and joule of energy. As a key national need, sustainable manufacturing involves technologies and systems that enable optimal raw material, energy, and resource utilization, including areas as diverse as high performance catalysis, novel separations, and new reactor and waste management systems. A major area of focus will be energy efficient manufacturing— where high energy-consuming manufacturing processes need to be substituted by lower energy-consuming alternatives. Areas such as re-manufacturing (i.e., using recycled components) also need to be researched. In addition to savings in energy consumption and higher profitability, many accompanying benefits can aid the competitiveness of industry.

- **Nanomanufacturing:** Nanomaterials are forecasted to play a game-changing role in applications ranging from high-efficiency solar cells and batteries, environmental control through nanotech-based filters, and nano-biosystem-based medical applications to next-generation electronics and computing devices. Similarly, microstructures on devices will play a key role in delivering new features or enhancing current functionality. The possibilities are limitless, but processes and quality control systems must be developed to reach the full potential of nanomanufacturing. The challenge will be to scale up and reduce costs.

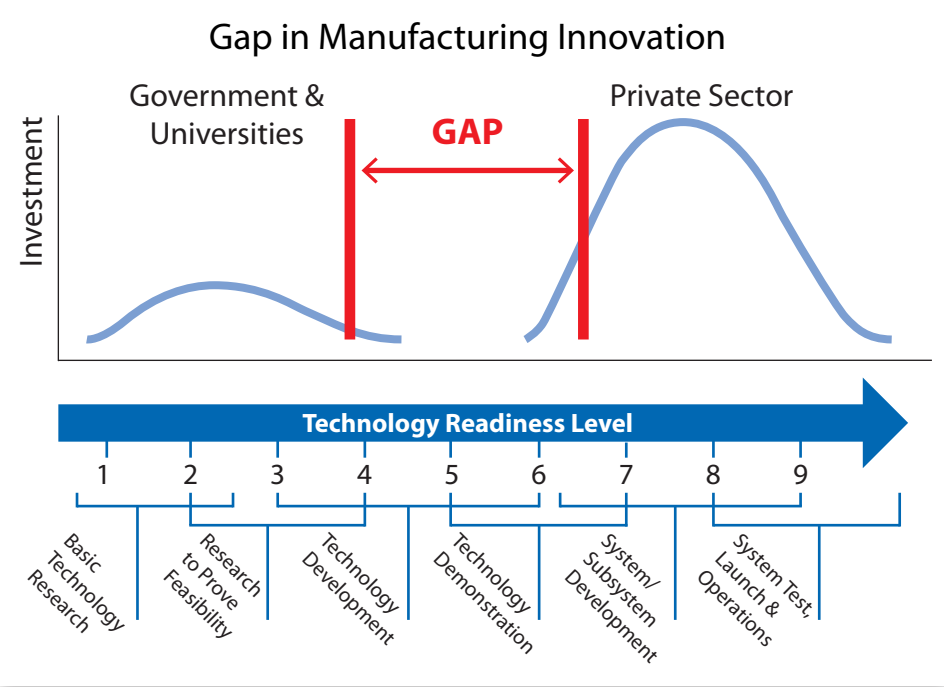
- **Flexible Electronics Manufacturing:** Technologies for flexible electronics manufacturing will be major differentiators in the next generation of consumer and computing devices. Some of these devices are expected to be among the fastest growing product categories over the next decade.
- **Biomanufacturing and Bioinformatics:** Technologies to improve healthcare will require newer, more effective, and cheaper molecules. Food security is a key concern of the future, where biomanufacturing, proteomics, and genomics will play a critical role. In addition, this technology has the inherent potential to enable energy efficiency in manufacturing. For instance, it offers room-temperature synthesis routes that can possibly replace current high-temperature processes. Innovations in the bio–nano interface such as bio-inspired manufacturing using self-assembly have the potential to simplify and scale up many complex and expensive nanomanufacturing technologies and make them economically viable.
- **Additive Manufacturing:** A growing application of manufacturing is the production of highly customized and personalized products. Additive manufacturing (e.g., three-dimensional printing) is a key technology that holds this promise. In addition, the technology has several characteristics that enable unique capabilities and features. For example, multiple materials can be processed, enabling smart components to be fabricated with embedded sensors and circuitry. Internal features can be produced that significantly enhance performance and therefore differentiate products (e.g., internal cooling channels that are optimized for thermal performance that are not possible with current manufacturing techniques). Also, materials can be processed efficiently with little waste, enhancing the sustainability of organizations that adopt additive manufacturing technologies.
- **Advanced Manufacturing and Testing Equipment:** Advanced manufacturing takes place worldwide. In those cases where it occurs outside of the United States, it is still possible for U.S. firms to maintain a significant advantage through the production and supply of high-value manufacturing equipment, such as bioreactors, CNC machine tools, or other high-technology production tools. Being the supplier of choice of advanced capital equipment will continue to yield advantages in terms of innovation and advanced engineering, as well as economic benefits.
- **Industrial Robotics:** Automation and use of industrial robots in labor-intensive manufacturing operations, such as assembly, product inspection, and testing can enable high endurance, speed, and precision. Equally important is their use in processing high temperature, corrosive and toxic substances, and materials. This technology has great potential to enhance safety and productivity of the U.S. workforce and enable the United States to compete with low-cost economies, both for domestic and export markets. Future needs in this area are being driven by the intersection of bio-nanotechnologies and their associated manufacturing needs.
- **Advanced Forming and Joining Technologies:** Most current mechanical manufacturing processes continue to depend largely on traditional technologies, mainly for metals, such as casting, forging, machining, and welding. These technologies will continue to be mainstays of future production processes. However, there are new and expanding needs for joining a wider variety of materials with greater energy and resource efficiency. In addition, improved performance requires continued innovation and the search for transformative technologies that will help maintain U.S. competitiveness in industries ranging from transportation to infrastructure.

Recommendation #3: Establish a National Network of Manufacturing Innovation Institutes

The United States has a long history and solid reputation for being a global leader in research and discovery. This achievement has been enabled by our preeminent research universities and national laboratories. Many of our research discoveries, however, have not been quickly translated into U.S.-manufactured products. Many technologies fail to move to commercialization because the private sector, particularly SMEs, often does not have adequate technical resources and is not able to make sufficient investments in early technologies. In fact, the stage between research and production is a perilous period in business development and is often called "the valley of death."

In part, the valley of death is attributable to the significant differences in the way activities in research and in manufacturing are conducted. Basic research and new discoveries tend to be curiosity driven, with the end goal often being validation of an idea. Conversely, manufacturing activities are competitive, focused, and systematic, driving system engineering to design, develop, and scale replicable high yield, high quality, low cost products and processes. Figure 3 depicts the gap in investment between technology readiness level (TRL) 4, the technology development phase, and TRL 6, the technology demonstration phase.

Figure 3. Manufacturing Innovation: Investment Gap



Source: AMP Steering Committee

Extensive benchmarking (see Annex 2) identified several desirable attributes of a shared national infrastructure for supporting the translational activities for bridging fundamental research to manufacturing:

- Long-term partnership between industry and universities, enabled by Federal, State, and local governments;
- Sustained focus on technology innovation with a strong brand identity and reputation;

- Ability to identify critical emerging technologies with transformational impact and capacity in translating these technologies into products and businesses for the market;
- Ability to form effective teams of industrial and academic experts from multiple disciplines to solve difficult problems from pre-competitive research to proprietary technology or product development;
- Dual appointments of faculty and students in both research universities and application-oriented institutions to develop leaders familiar with research applications, new technologies, and production systems;
- Ability to engage and assist SMEs that need new technologies by providing highly trained personnel to work in multiple regional innovation centers; and
- Ability to assist community colleges to develop and offer courses in various manufacturing technologies.

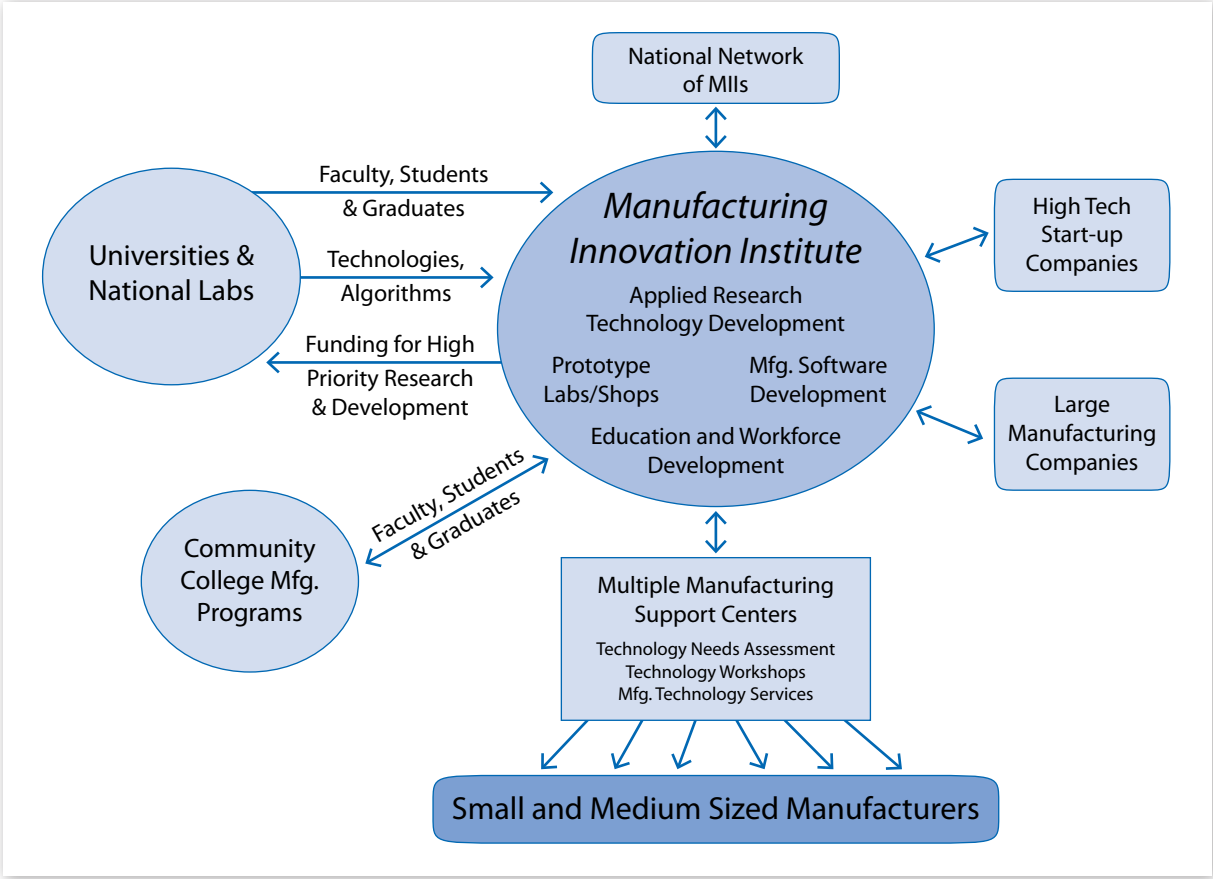
To enable the United States to successfully translate discoveries into products or applications in manufacturing, we recommend the establishment of a national network of Manufacturing Innovation Institutes (MIIs) to bridge the gap between basic research performed in universities and national laboratories, and our production enterprises, particularly SMEs. These Institutes would serve as anchors for technology development, education, and workforce training as illustrated in Figure 4. In effect, the MIIs would function as embedded nodes within a distributed network of research institutes concurrently anchoring both a national and a regional innovation system.

MIIs should support priority areas in cross-cutting manufacturing technology, focusing initially on those recommended above, and subsequently on priority new technologies as they arise. Future areas of support would be expanded to include areas of emerging technologies that have the greatest potential for commercialization into new products, and adoption to create faster, cleaner, and better production processes. These areas are to be identified using the proposed model and roadmap process for prioritizing investment in advanced manufacturing technology. An open, competitive process with peer review should be used to establish the MIIs.

Each Manufacturing Innovation Institute should:

- Focus on an area of U.S. national economic strength or a promising emerging technology.
- Be hosted by an industry consortium (two or more members) and a university or national lab. New or existing partnerships can apply for government matching funds to create an MII with the membership of two or more large companies, the participation of related SMEs, and at least one major research university, with active participation by other regional universities and community colleges.

Figure 4. Manufacturing Innovation Institute Model



Source: AMP Steering Committee

- Be governed by a Board of Directors composed of representatives from business, academic, and government organizations supporting the MII.
- Operate independently with contractual flexibility, with the provision that all MIIs will be members of the national network and will follow a similar governance model defined by a national governing board.
- Be staffed with full-time applied researchers, engineers, and innovation enablers who support the process of technology commercialization, industrial scientists and engineers in residence, part time faculty, post-doctoral researchers, and student interns.
- Serve as hands-on "training centers" for university and community college manufacturing programs.

- Conduct projects that include pre-competitive research and proprietary technology and product research, with a strong intellectual property (IP) protocol that favors manufacturers.
- Receive support via a mixed funding model from industry, academia, and government, with government (State or Federal) funding guaranteed for a minimum of 5 years with the potential of renewal for a total of 10 years.
- Receive an industrial 1:1 match to government funding for each MII.
- Establish distributed manufacturing support centers throughout the region to assist SMEs that want to adopt new technologies.
- Provide assistance to community colleges wishing to develop and strengthen advanced manufacturing programs.
- Provide grants to other universities and businesses that are developing complementary and enabling technologies.
- Provide a shared infrastructure for technology development and serve as a "collaboratory" for research universities and businesses by providing existing and startup businesses with greater access to research, students, internships, workforce development, technology transfer, and commercialization.
- Provide a variety of business services such as design, digital manufacturing, prototype and test services, and staff training.

Recommendation #4: Empower Enhanced Industry/University Collaboration in Advanced Manufacturing Research

Achieving the full potential for the development of Manufacturing Innovation Institutes also requires a U.S. commitment to reinvigorate the environment for industry and university research collaboration. Robust research partnerships between industries and universities are a historical strength of the United States. The imperatives created by increased global competition in emerging technologies, the demands for new models of interdisciplinary research, and the shorter time horizons between fundamental discovery and applied research necessitate an examination of opportunities to enhance the climate for robust industry/university collaboration in research and commercialization.

The Advanced Manufacturing Partnership Steering Committee has identified a critical need to deepen industry and university collaboration and invest more resources at the nation's leading universities. The evolving nature of global competition creates imperatives for more rapid project and agreement development, and at times, greater focus on exclusive rights and licensing arrangements.

To remove policy barriers to more robust partnership development, we recommend the United States take action to end the restrictive tax policies that impede the speedy development of industry/university research collaborations and partnerships. Specifically, we recommend establishing a waiver mechanism or exception to Revenue Procedure 2007-47 to remove the cap on private-use activities in buildings constructed with tax-exempt bonds.

Recommendation #5: Foster a More Robust Environment for Commercialization of Advanced Manufacturing Technologies

There is a critical need to more fully integrate manufacturers into the robust innovation ecosystems that have evolved in universities over the last several decades. These ecosystems commonly feature seed funds, mentoring, incubation, and entrepreneurship training programs. While we recommend fostering stronger integration between manufacturers and university innovation ecosystems, we also realize that fundamental barriers impede SMEs from engaging with university research and that access to capital for new technologies is limited. A starting point to address this challenge is to create stronger synergy and a true continuum between programs to aid start-ups and those that are capable of supporting the scale-up of emerging manufacturing technologies through innovative, targeted procurement initiatives.

> *"Since January 2006, less than 10% of all U.S. venture capital dollars went to seed funds investing in financing rounds in the $1–4 million dollar range, and 69% of those dollars went to three states."*
>
> *—Small Business Administration, Early Stage Innovation Small Business Investment Company (SBIC) Initiative, March 2012*

Next steps could include:

- Building a manufacturing component into university innovation ecosystems
  - Incorporate manufacturing impact measures into the annual performance reports issued by the Association of University Technology Managers that reflect domestic production and employment captured from both start-ups and licensing activity. Including these measures would place manufacturing front and center in university technology transfer strategy development and stimulate a vibrant exchange on best practices. The annual measures would encourage a greater focus on manufacturing in regional economic development partnerships and among universities and manufacturers in the development of sponsored research partnerships.
  - Build stronger linkages between manufacturing support resources and university efforts to support start-ups by expanding the work of the nation's Manufacturing Extension Partnership (MEP) centers to create direct supply chain development, prototyping, and early stage engineering services for advanced manufacturing spin outs. This action will place the MEP's and manufacturing considerations at the heart of university spin out support activities.
- Foster a continuum of enhanced capital access from start up to scale up
  - Create a special "Phase 0" section of the Small Business Administration's Small Business Innovation Research (SBIR) program. This program would provide support for the critical pre-early stage funding activities associated with testing the commercial potential of new technologies—including early prototype development and market development.

> *"The Small Business Investment Company invested $2.5 billion in FY2011 in high growth small businesses. According to the program statistics, about one in five dollars between 2007 and 2010 directly supported manufacturers."*
>
> *—Small Business Administration, Agency Financial Report, FY2011 and Program Statistics*

- Expand the resources available for early stage growth and accelerate startup interaction with major manufacturers. Mechanisms such as the NSF-created 501(c)3 Innovation Accelerator should be expanded nationwide to support startups emerging from Federal advanced manufacturing research programs.
- Clear the pathway from startup to pilot scale production by generating greater interagency coordination of procurement programs such as Defense Production Act Title III funding. The Title III program is intended to provide the Department of Defense with "a powerful tool to ensure the timely creation and availability of domestic production capabilities for technologies that have the potential for wide-ranging impact on the operational capabilities and technological superiority of U.S. defense systems." We recommend the creation of a formal collaboration between the Advanced Manufacturing National Program Office and Department of Defense Title III program, as well as other relevant Federal procurement programs, to establish a focused effort that can help complete a continuum of capital support from pre-company formation through to early phase pilot and scale up production.

Recommendation #6: Establish a National Advanced Manufacturing Portal

SMEs in the manufacturing sector are a critical component of the U.S. economy, representing 84 percent of manufacturing establishments in 2009[22] and employing 51 percent of the U.S. manufacturing workforce in 2010.[23] Their growth is inextricably linked to our continued prosperity, and they are an important source of innovation. A key driver of that growth is information—specifically, technical assistance and resources. Our work revealed that SMEs are hampered by the lack of access to this technical assistance and information. It is scattered across numerous databases and individual websites, requiring time-consuming research to access.

Firms as well as experts reported that conventional web searches for such information did not produce useful results. This problem is in part due to the vast variation and complexity of the research and innovation conducted in cooperative research centers. Simply put, finding practical answers to basic questions common to advanced manufacturing is onerous for small firms with limited time and R&D staff.

To address this issue, we propose the creation and launch of a National Advanced Manufacturing Portal: a single online destination where companies, organizations and individuals can search for federally funded cooperative research centers that best meet their needs. With this harmonized central repository of information from various sources, firms can develop short and long-term R&D plans. A National Advanced Manufacturing Portal would advance the goal of pushing innovation down the supply-chain by providing businesses with the ability to plan their process innovations as well as the design and development of new products. It would connect SMEs to the existing network of publicly-funded R&D resources that are intended—by legislative intent and design—as access points for them to gain technical assistance and information about advanced manufacturing processes.

A National Advanced Manufacturing Portal would provide an updated, harmonized catalog of information about the portfolios of the cooperative research centers and the most frequent kinds of technical assistance and resources requested by SMEs. It would also allow state and local science and technology

22. Census Bureau, Statistics of U.S. Businesses, 2009, www.census.gov/econ/susb/.
23. Bureau of Labor Statistics, Current Employment Statistics, 2010, bls.gov/ces/cessizeclass.htm#TB_inline?height=200&width=325&inlineId=ces_program_links. (*STPI Calculations)*

policymakers to ascertain existing federally funded resources so they could be leveraged. In addition, it would allow researchers to determine the relative coverage of science and technology resources in a given area or targeted technology. This knowledge could lead to more efficient science and technology policy investment and coordination.

The up-front resource requirements to launch a National Advanced Manufacturing Portal are relatively small, since cooperative research centers could provide and update the information on their own facilities through a web reporting interface using a standard format. This reporting would produce the content portion of the portal. The online information clearinghouse itself would need to be hosted and maintained long-term by the appropriate Federal agency.

We propose that the initial implementation of the portal should be limited to peer-reviewed facilities such as grant recipients of public funding to ensure the quality of facilities listed.

The portal would also provide answers to frequent questions such as the availability of training, fees for access, presence of scale-up facilities on site, and whether production runs could be conducted. It would include a search by keyword feature.

The portal would be launched using the mailing lists of existing programs. For example, the NIST Manufacturing Extension Partnerships have more than 7,000 client firms.[24] We recommend that NIST serve as the administrative host agency to coordinate with portal initiatives in the Department of Energy, Department of Defense, and Federal Government agencies focused on aspects of the pre-production process. The database would be linked to websites such as Manufacturing.gov and non-profit and public web portal networking initiatives such as Autoharvest.com.

Pillar II: Securing the Talent Pipeline[25]

To renew and revitalize its manufacturing prowess and competitive edge, the United States must continue to generate a steady stream of skilled manufacturing professionals. However, in recent years, persistent public misperceptions about the manufacturing sector have taken hold, tarnishing its image as a desirable long-term career focus. The false conventional wisdom about the manufacturing sector is that the work is based on repetition of tasks and evocative of the past. The main misperceptions about employment in manufacturing can be summarized by the three "D's" that characterize the work as dull, dirty, and dangerous. In addition, with the loss and export of millions of manufacturing jobs over the past few decades, a career in manufacturing is seen as offering little, if any, job security, and no long-term career development path.

The reality is that manufacturing can be exciting, engaging, essential and environmentally sustainable, offering a pathway to upward mobility and the realization of the "American Dream."

A recent report from Booz & Company noted that a "contributing factor to this employee scarcity is traditional manufacturing's lack of appeal to students." The company surveyed more than 200 undergraduate students in engineering, science, and mathematics, and found that only 50 percent of the engineering students and 20 percent of the math and science students regarded manufacturing as an attractive

24. NIST, "Re-examining the Manufacturing Extension Partnership Business Model," October 2010: 7, www.nist.gov/mep/upload/MEP_Bus_Model_Full_Report_October2010_a.pdf.

25. Further details related to the recommendations within this Pillar can be found in Annex 3.

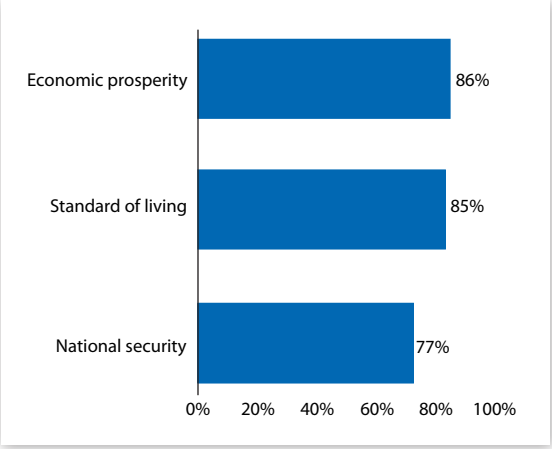
career. The report also observed that "[a]round the same time, Siemens reported having nearly 3,500 open manufacturing positions" in the United States requiring STEM skills, but "with low expectations of filling many of them."[26]

As fewer students select careers in manufacturing, the demand for manufacturing-related programs across all sectors of the educational system is sharply reduced. These institutions, K-12 through universities, respond by de-emphasizing manufacturing-related curricula and courses in classical engineering and engineering technology programs such as two and four year mechanical and manufacturing engineering programs.

Perhaps the worst misperception of all among young people is that "America is not committed to remaining a manufacturing powerhouse in the world and that all manufacturing will eventually be done outside our borders."[27] This perception must be reversed. For the United States to remain competitive, talented employees with a high level of technical skill are needed to revitalize, sustain, and improve U.S. manufacturing.

Employment opportunities for skilled operators and technicians are increasing at a rate exceeding the availability of qualified candidates, impeding industrial growth. These innovative professionals are essential to a corporation's long-term competitiveness. In a recent survey conducted by the Manufacturing Institute and Deloitte, manufacturing was nationally viewed as core to our economic prosperity and preferred as an industry for creating local employment (Figure 5). Respondents ranked new manufacturing facilities first when asked what type of new industry facility they would support to create 1000 new jobs (Table 4).[28]

Figure 5. Percentage of respondents who believe the manufacturing industry is very important to U.S. economic prosperity, standard of living, or national security



Source: Deloitte and the Manufacturing Institute, "Unwavering Commitment: The Public's View of the Manufacturing Industry Today," 2011 Annual Index, themanufacturinginstitute.org/~/media/2AB778520C734D888156A90B667C1E70.ashx.

26. Arvind Kaushal, Thomas Mayor, and Patricia Riedl, "Manufacturing's Wake-Up Call," *Strategy & Business* 64, Booz & Company and Tauber Institute for Global Operations, University of Michigan (August 3, 2011): 38, www.tauber.umich.edu/docs/Manuf-WakeUp_w_Cover.pdf.

27. Joe Anderson, Council Chairman, and Mike Laszkiewicz, Workforce Development Subcommittee Chair to Department of Commerce Secretary Gary Locke, "The Manufacturing Council," July 2011, www.trade.gov/manufacturingcouncil/documents/MC_Workforce_08222011.pdf.

28. Deloitte and the Manufacturing Institute, "Unwavering Commitment: The Public's View of the Manufacturing Industry Today," 2011 Annual Index, www.themanufacturinginstitute.org/~/media/2AB778520C734D888156A90B667C1E70.ashx.

Table 4. Ranking by respondents of the type of new industry facility they would support to create 1,000 new jobs in their communities

Facility	Rank
Manufacturing facility	1
Energy production facility	2
Healthcare facility	3
Technology development center	4
Communications hub	5
Retail center	6
Financial institution	7

Source: Deloitte and the Manufacturing Institute, "Unwavering Commitment: The Public's View of the Manufacturing Industry Today," 2011 Annual Index, themanufacturinginstitute.org/~/media/2AB778520C734D888156A90B667C1E70.ashx.

Another survey of manufacturers by the Manufacturing Institute and Deloitte on available skills to support manufacturing growth revealed that 82 percent of manufacturers reported moderate-to-serious gaps in the availability of skilled manufacturing candidates.[29] Fifty six percent anticipated the shortage to grow worse in the next three to five years.[30] Additionally, 74 percent of manufacturers reported that this skills gap has negatively impacted their company's ability to expand operations. This skills gap has resulted in five percent of all manufacturing jobs going unfilled, even in the face of our current unemployment levels.[31] To close this gap, the focus needs to be on securing and developing a strong pipeline of prepared manufacturing candidates as a key enabler to advancing manufacturing in the United States.

The Nation needs to rely upon successful public-private partnerships if it is to effect lasting improvements in its approach to education and talent development. The AMP Steering Committee looks both to the Nation's classrooms and its veterans to find the game-changing concepts that will secure the manufacturing talent pipeline going forward.

Challenges facing the manufacturing industry cannot be successfully addressed by individual companies, academia, or Federal agencies alone. Instead, the opportunities must be examined through partnerships to identify and use the best solutions. Partnerships are a strong platform from which to address the quickly changing needs of manufacturers in the United States. Identifying and responding to technological innovation can be expensive and time-consuming, but these hurdles are best overcome through partnerships of similarly motivated groups. Developing a highly skilled professional manufacturing workforce is as critically important to the 21st Century manufacturing sector as any other single element. We studied examples of successful partnerships to identify and review best practices and

29. Deloitte and the Manufacturing Institute, "Boiling Point? The Skills Gap in U.S. Manufacturing," 6, www.themanufacturinginstitute.org/~/media/A07730B2A798437D98501E798C2E13AA.ashx.

30. Deloitte and the Manufacturing Institute, "Unwavering Commitment: The Public's View of the Manufacturing Industry Today," 2011 Annual Index, www.themanufacturinginstitute.org/~/media/2AB778520C734D888156A90B667C1E70.ashx.

31. Ibid.

attributes. While no two partnerships are alike, even in the same region with similar partners, successful workforce partnerships of academia, industry, and government share the following six characteristics. See Annex 3 for a full list of the resources and exemplary partnerships that formed the foundation for identification of these characteristics.

- **Have a Passion for Learning and a Vision for the Future:** Successful manufacturing partnerships have at their roots a shared passion for life-long learning. They have a vision of success and commitment to being globally competitive. Benchmarking, research, and exploring are essential ingredients of the most advanced partnerships. There is a balance between incumbent worker training and new worker training for young people coming into the workforce from the K-12 and community and technical school systems.
- **Embrace Change:** The future of manufacturing will be radically different from its past. The status quo curricula, teaching methods, and silos must be replaced with a collaborative, innovative, life-long learning culture. A nation rich with human capital simply cannot tolerate the loss of its competitive edge and international standing in the science, technology, engineering, and mathematics (STEM) disciplines.
- **Convene Organizations to Share Their Expertise:** In order to facilitate and drive change, each region or community will need a respected organization capable of convening the necessary parties. The most effective convening organizations are neutral non-profits, knowledgeable about, but not responsive to, political or other influences. Professional organizations and academic institutions are well positioned to act as convening organizations. The Manufacturing Innovation Institutes could serve this critical

Project SHINE (Shaping High-quality Integrated Nebraska Education)

Created in 2009, Project SHINE's goal is to increase student interest and participation in high demand technical careers. Project SHINE integrates Nebraska's manufacturing, energy, biofuels and food processing businesses with secondary and college STEM educators and their students.

Project SHINE's approach to engaging education and business professionals in teaching and learning is by exposing educators and students to "real-world" business environments, and build partnerships between education and business. Each group benefits through opportunities to participate:

- Educators participate in externships with business partners through curriculum development workshops that focus on problem-based learning.
- Students explore careers through the Nebraska Career Connections and summer camp activities that focus on how math and science are used for business applications.
- Industry partners benefit through the growth of potential pipeline of local skilled technicians for their business.

Since 2009, 72 STEM educators and almost 5,000 Nebraska middle and high school students have participated in the National Science Foundation-funded Project SHINE. An additional 200 students participated in the SHINE STEM summer camps. Project SHINE's impact will reach even further as nearly 200 Project Based Learning (PBL) resources developed through the project are disseminated through an online e-library.

Source: Project SHINE Webpage, mechatronics-mec.org.

convening function and link education and training efforts to firm networks already engaged in the R&D services provided by these institutes. By using the MIIs as convening spaces for both technology development and workforce development programming, there is an institutional recognition of the synergy between building a regional labor market and sustaining innovation capacity.

- **Collaborate with a Common Purpose:** To be effective, manufacturing partnerships must be based on mutual respect and a spirit of cooperation, a candid recognition of strengths and weaknesses, and shared goals reached in the spirit of collaboration and consensus. The academic community offers the expertise to teach students, but learning must be developed and applied by collaborating with industry, which in turn, needs a steady stream of STEM talent, and must become vastly more engaged in K-20 education and community activities. Community colleges should deliver the curricula associated with the technical training of both new and incumbent workers. The implementation would involve industry and technology experts recommending industry-specific skills in order for these curricula to stay current.
- **Have Clear, Specific Roles:** In order to align partners towards a common goal, the partners should negotiate and agree first upon the goal, then upon the resources and roles that each of the stakeholders will bring to the partnership.
- **Maintain Flexibility:** Manufacturing technology is developing as rapidly as information technology. To adapt to this increasing pace of change, all parties must be ready and willing to adapt and act quickly. This adaptation will require flexibility and collaboration among all parties, and the coordinated use of existing training and educational facilities to prevent wasted time and redundancy.

Effective manufacturing partnerships build a sustainable culture of dynamic change so that acceleration in manufacturing technology is injected back into education and training. Change introduced through partnerships is most effective when it meets the fundamental needs of people and society and is presented consistently and clearly. Project-based learning provided in partnership with manufacturing ensures that the subject matter is relevant and applicable to developments outside the classroom. The U.S. Government's role is most effective when it funds impactful academic programs; defunds ineffective programs; sets the boundaries to ensure fair opportunity to all; and fills the gaps that industry and academia are unable to fill.

As education provides a foundation for the future, there is a need to modify traditional teaching methods used to train the manufacturing workforce at all levels. Success in advanced manufacturing and entrepreneurship will require fundamental STEM skills as well as broad problem-solving skills, decision-making skills, and people skills that do not emerge from a conventional K-20 education. It is necessary to pursue initiatives that can expand the manufacturing workforce in the near-term, such as support for veterans programs and community colleges, which can expand the future pipeline.

The benefits of manufacturers participating in academia at all levels are many for the students who choose careers in manufacturing. Effective manufacturing partners engage K-12, community colleges, undergraduate and graduate students and professors through internships, apprenticeships, projects,

research, co-ops, endowments, scholarships, and hiring. These offer opportunities for academics and students alike to stay current in the field of manufacturing and contribute to research and discovery.

Academia should bring manufacturing directly into the classroom, providing real world projects and research opportunities that engage students and inherently provide professional development to teachers. Teachers across our K-20 system must be encouraged to embrace project-based learning of all varieties, take advantage of summer internships, and engage with manufacturing experts. In turn, industry simply must be an active, responsive partner in the classroom.

The AMP Steering Committee encourages the adoption of project-based learning of all kinds, and to varying extent based on the local needs, across the K-20 spectrum; a number of these projects should be selected for their relevance to manufacturing-relevant skills, such as supply-chain management, design for manufacturability, estimation of tolerances and requirements, economics, and team management. To stimulate these new initiatives, educational partnerships between industry, academia, and local and regional government must be established.

Recommendation #7: Correct Public Misconceptions About Manufacturing

In order to lay the foundation for a secure, sustainable manufacturing talent pipeline, the AMP Steering Committee recommends the creation of an aggressive, integrated "Image of Manufacturing" public service announcement campaign that would raise awareness and correct misperceptions about manufacturing in the United States.

Recommendation #8: Tap the Talent Pool of Returning Veterans

Veterans have many of the work-life and job skills that are in high demand and that are often missing in the general workforce. These include maturity, discipline, and the ability to work effectively in groups and leadership. In addition, many veterans have undertaken extensive technical training, resulting in skills that could be easily transferred to manufacturing positions, and have become technicians, operators of complex equipment, and craftsmen. Despite their skills, the veteran population that served in the military in the period since September 2001 (called Gulf War-era II veterans) is experiencing a higher rate of unemployment than its civilian counterpart. The Bureau of Labor Statistics found the unemployment rate for this cohort of veterans was 12.1 percent in 2011.[32] Similarly, with the withdrawal of troops from Iraq and Afghanistan and potential cuts to Defense Department funding, the number of veterans seeking employment is certain to rise in the coming years. There are two obstacles to overcome in bringing veterans to manufacturing careers: low awareness of the opportunities in the sector and difficulty equating military skills with private sector job qualifications. We recommend providing a training module on the career opportunities in advanced manufacturing to the Department of Defense's Transition Assistance Program, which provides support and information to transitioning veterans about career options post-service. In addition, the Departments of Defense and Labor should accelerate their efforts to categorize military occupational codes and translate them to civilian skills, as well as providing the opportunity for active duty servicepersons to earn professional accreditations.

32. Bureau of Labor Statistics, BLS Economic News Release: Employment Situation of Veteranc-2011, March 20, 2012, www.bls.gov/news.release/vet.nr0.htm.

Recommendation #9: Invest in Community College Level Education

Manufacturing jobs have changed, requiring highly skilled workers. The largest gap between manufacturing employers' needs and new employee skills exists in the occupations of technician and equipment operator. This gap has left many workers unqualified for available positions. Community colleges currently provide training for the missing skills, but a significant gap remains.

Community colleges already enroll many of the people who should train for advanced manufacturing careers, and these institutions have partnerships, infrastructure, and teaching methods that are focused on regional needs. They grew after World War II to train returning GIs to join the workforce. This founding principle can help train and retrain today's workforce to meet the needs of local manufacturers. Investing in community colleges and promoting engagement between community colleges and industry, universities, national labs, and K-12 programs are important steps. Modest changes to government-funded grant opportunities to encourage partnering with community colleges could create stronger regional partnerships with industry, universities and national laboratories.

To advance these programs, the AMP Steering Committee recommends:

- Modification of the Department of Education's Graduate Assistance in Areas of National Need (GAANN) program to have a focused solicitation on manufacturing fellowships/scholarships at the university and community college level. This opportunity could be structured to encourage collaboration between industry, community colleges, and universities or have separate scholarship programs aimed at the different educational levels.
- Creation of a national network of manufacturing educators by integrating educational programs among the National Science Foundation, the Department of Education, and the Department of Labor in order to share best practices, curricula, and resources. This national network could build on the institutional infrastructure provided by the national network of Manufacturing Innovation Institutes. Industry and national manufacturing associations and societies should be included in the network.
- Proposal and implementation of changes to align ongoing solicitations for federally funded research programs to encourage partnerships with community colleges. The MIIs should serve as a resource for trained personnel who can assist community colleges in developing appropriate courses as well as providing hands-on projects and coordination of internships with regional manufacturing companies.

Recommendation #10: Develop Partnerships to Provide Skills Certifications and Accreditation

The AMP Steering Committee recommends a national focus on education and training that can produce workers capable of operating and troubleshooting modern factory equipment. The approximately 1,500 community colleges located across the United States provide an opportunity to develop location-specific curricula to meet the needs of local manufacturers. We encourage the accreditation of programs, the development and standardization of community college curricula where appropriate, and the use of stackable professional credentials to meet the needs of manufacturing.

In order to support the development of a robust and high-skilled pipeline of manufacturing talent, national standards, credentials, and certifications are critical to provide manufacturing the consistent baseline ability to qualify candidates as to their educational, behavioral and leadership knowledge, manufacturing experience, and individual competencies. An efficient market for employees with necessary knowledge and skills depends on reliable and appropriate credentials and certifications. To succeed, any new credentials and certifications require a critical mass of national recognition, and acceptance and adoption by industry, education, and government. Such credentials and certifications work when they:

- Involve quality assessments, accurately gauging worker skills;
- Include an accreditation regimen that ensures the quality of the program and alignment with the changing needs of industry;
- Evolve and continuously update to accommodate the changing needs of workers and the manufacturing sector; and
- Result in nationally portable, industry-recognized credentials that support preferential consideration and job search mobility.

This recommendation can be implemented by leveraging existing efforts. In 2009, the Manufacturing Institute partnered with ACT, Manufacturing Skills Standards Council, National Institute for Metalworking Skills, American Welding Society, and Society of Manufacturing Engineers to build a comprehensive model for certifications, which can provide the core framework and partnerships. This partnership is called the Manufacturing Skills Certification System (MSCS), and it is in the process of adding more industry-recognized credentials at this time.

Aligned with this partnership, we recommend support for a coalition of industry associations, professional societies, and educational organizations to establish a national framework of standards, accreditations, and certifications at each level of the advanced manufacturing competency model. (See Figure 6.)

We further recommend that an accreditation-like review system be set up regionally for community college manufacturing programs, and that the requirements for professional credentials be used as a foundation for curricular development in high schools, community colleges, and universities.

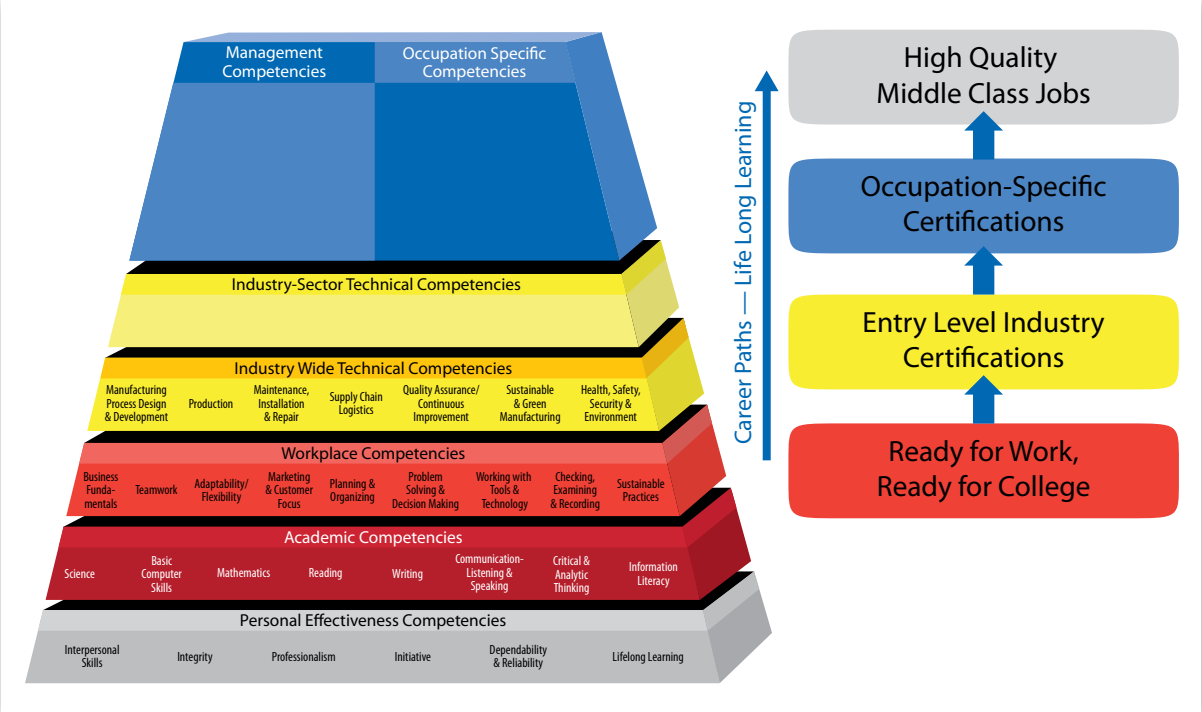
Right Skills Now is a partnership between government and industry that is building a fast-track, 16-week training program that supports the workforce needs of manufacturers of all sizes.

-Manufacturing Institute, Right Skills Now

Any path forward must incorporate two key functions—accreditation and certification—and result in two key outcomes—common education and training standards—to satisfy current and emerging competencies, and yield portable certifications for individuals.

National associations involved in manufacturing should initiate and coordinate a register of certifications that are available in all regions and can be "stacked" one after another to assemble complete programs of training in advanced manufacturing.

Figure 6. Department of Labor Advanced Manufacturing Competency Model



Source: Advanced Manufacturing Competency Model, Adapted from Department of Labor's Employment and Training Administration www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y.

Recommendations #11 and #12: Enhance Advanced Manufacturing University Programs, and Launch Manufacturing Fellowships and Internships

Major research universities in the U.S. have a key role in defining the fundamental elements of advanced manufacturing and developing the next generation of educators and industrial leaders. They can qualitatively advance the manufacturing profession and retool its image as a challenging and rewarding career.

Universities, however, are uncertain about where the discipline of manufacturing best fits in academia. It does not fit well into normal boundaries of degree programs, departments or even schools, and as a result often finds itself marginalized.

The AMP Steering Committee therefore recommends augmenting existing engineering curricula with manufacturing coursework, and creating new graduate-level programs that provide students with a comprehensive overview of manufacturing as well as technological and operational perspectives in a professional engineering context.

Public-private partnerships are critical to ensuring U.S. manufacturing excellence to implement this recommendation. As with community college programs, it is expected that the Manufacturing Innovation Institutes will play a significant role in providing course development and hands-on training, as well as assisting with internships in local manufacturing establishments. This recommendation requires implementation at multiple levels:

- **University level:** Establish new masters-level professional degrees in manufacturing leadership at research universities. These degree programs should be comprehensive in their integration of technologies, such as robotics and advanced automation, with methods, such as supply chain management and human systems integration.
- **Government level:** Fund National Manufacturing Fellowships and Veterans Leadership in Manufacturing Fellowships, traineeships, and curriculum development. These initiatives could help to correct the misperceptions of manufacturing held by the future workforce.
- **Industry level:** Encourage industry participation by providing a professional career path for graduates of advanced manufacturing programs. By teaming with universities on both curricular and career development, industry can help to solidify the profession of manufacturing and make it a highly attractive field for study and practice. Internship programs can expose students to careers in manufacturing leadership. During the educational process, industry representatives should serve as mentors and role models to students entering and emerging from these new programs and provide relevant, hands-on manufacturing experiences for graduate students.

While it is impossible to separate the educational system into discrete pieces, we believe the most impactful recommendations are at the high school and community college levels, followed by undergraduate education. Industry has identified deficiencies in both content mastery and soft skills. These skills could be taught through the use of project-based learning, which has proven its unique capacity to prepare young people for a 21st century workplace. The deficiencies in content mastery and soft skills can be remedied through this approach when coupled with a marked improvement in teaching skills.

Pillar III: Improving the Business Climate[33]

The United States is at risk of losing leadership in manufacturing, most importantly its ability to manufacture the high-technology products that are invented and innovated in this country. To attract investment and production, the United States must promote a competitive business environment, which includes a robust talent pipeline, 21st century infrastructure, and strong investment in R&D. While these are important to the overall health of the U.S. economy, they are particularly important for the advanced manufacturing sector, which faces intense global competition. Major economic competitors are making it increasingly attractive for companies to invest in locations outside the United States.

The AMP Steering Committee does not believe that it is the role of government to formulate a national industrial policy of direct investment in or subsidies to specific firms. However, we recommend that the United States create a national framework to create a favorable business climate for manufacturing that spurs investments and fosters partnerships across government, academia and industry.

For the United States to continue to be an attractive location for businesses, we recommend building a policy framework that spurs investments and fosters partnerships between government, academia, and industry. The foundation of that framework should be constructed through targeted policies in four areas:

33. Further details related to the recommendations within this Pillar can be found in Annex 4.

- Tax Policy
- Regulatory Policy
- Trade Policy
- Energy Policy

Recommendation #13: Enact Tax Reform

A key focus of the Advanced Manufacturing Partnership is on the linkage between U.S.-based innovation, R&D, and manufacturing. To encourage investment in the United States, we recommend that the corporate tax system create a more attractive environment for businesses to compete globally. The United States has the highest statutory corporate tax rate, including Federal and State taxes, among the 34 members of the Organization for Economic Co-operation and Development. This system is an impediment to U.S.-headquartered businesses and businesses interested in investing in the United States.

Comprehensive U.S. tax reform is particularly important for the advanced manufacturing sector. Manufacturing is a source of direct and indirect high-paying jobs. Our current tax system discourages domestic capital investment in manufacturing, thereby undercutting the stability of the innovation and jobs engine that has produced unparalleled economic prosperity in the last century. The tax system distorts investment by industry, with manufacturing, construction and other high-wage and asset intensive industries paying a globally non-competitive statutory tax rate. The result is a decrease in aggregate investment in manufacturing.

For these reasons, there is a need to reform the tax system to address the existing distortions and disincentives for manufacturing in the United States. A more favorable tax climate would serve a two-fold benefit: provide incentives for U.S.-based businesses to increase investment and encourage more foreign direct investment in the United States, leading to an increase in investment, innovation, and jobs. Tax reform should also yield a tax system that is internationally competitive with others around the world in attracting and retaining advanced manufacturing and its associated innovation engine.

While there is a need for broad tax reform to make all U.S. companies more internationally competitive, our recommendations are targeted to the promotion of advanced manufacturing in the United States. They add up to an integrated package of proposals that address the mobile nature of capital and intellectual property, and enhance the incentive for retaining and reinvigorating the historical strength of closely connected U.S. R&D and production capabilities. We recommend that additional tax incentives should flow to those entities that engage in all three critical advanced manufacturing roles: U.S.-based innovation, R&D, and manufacturing.

We propose lowering the corporate tax rate to bring it more in line with other advanced economies. A rate reduction, combined with a broadening of the tax base, would encourage additional investment in manufacturing by U.S. corporations, and would position the United States as a more attractive region for direct investment by foreign corporations.

We recommend the following actions:

- *Recognize the importance of manufacturing through the tax code.* Given global competition and the ripple effect of manufacturing to the economy, any tax reform should encourage investment in manufacturing. This can be done through a reduction of the tax rate for domestic manufacturing activity.
- *Strengthen R&D tax credits.* Increase the R&D alternative simplified credit to 20% and make it permanent.
- *Create an internationally competitive corporate tax system.* The U.S. tax system must be redesigned in a way that encourages companies to invest in the United States by addressing the current law on foreign earnings of U.S.-based companies. In addition to lowering the overall corporate rate, reform must consider the tax treatment of overseas earnings of U.S. based corporations, including the consideration of a competitive partial exemption system similar to the type adopted recently by the U.K. or a minimum tax regime like Japan. Ultimately, comprehensive tax reform must ensure that U.S. companies are competitive when operating abroad and in the United States.

We recognize that efforts to address long term U.S. fiscal issues may well bring about significant proposals that include a mix of rate reductions. We urge that this debate be particularly mindful of the imperative to recognize how such actions may impact the climate for advanced manufacturing. We also caution against any new measures that could impede an improved climate for U.S.-based production or discourage investment in the United States.

Recommendation #14: Streamline Regulatory Policy

Regulation is an oft criticized, but vital function carried out by government. Well-conceived, science-based, and effectively implemented regulations are important tools for protecting consumers, workers, and the environment. When done right, regulation provides important benefits for society and can encourage greater competence and confidence in industry. Done excessively or inappropriately, or without adequate attention to its consequences, regulation can hamper innovation and international competitiveness. We recommend the following:

- **Early Engagement:** Collaboration between regulators and the regulated community can drive significant improvements in the quality of final rules. Robust dialogue between agencies and businesses ideally should occur well before the comment period. Improved use of the Advanced Notice Rulemaking Process[34] would allow manufacturers to contribute to cost-benefit analyses in a meaningful way that could make compliance more cost-effective.
- **Objective Cost Benefit Analyses:** We recommend that cost benefit analyses and risk assessments rely on the best available science.

34. Advanced rulemaking is intended to solicit comments and information from all segments of the public interested in a particular issue prior to an agency determining whether a rule (regulation) will be proposed.

Recommendation #15: Improve Trade Policy

A fair and open international trading system provides the greatest opportunities for U.S.-based innovative manufacturing and, ultimately, for sustaining current and creating new jobs. We recommend that the U.S. Government take the lead on a progressive trade policy, building on recent successes such as passing the U.S.-Colombia, U.S.-Korea and U.S.-Panama Free Trade Agreements (FTAs). FTAs level the playing field for U.S. exporters, eliminating tariff barriers to market access, reducing non-tariff barriers, and allowing access to dispute settlement systems.

Trade policy is an important consideration for manufacturers choosing to site new facilities, and the United States must not let its competitors outpace it in the race to negotiate further agreements. The Nation must prioritize policies that help ensure access to foreign markets and promote global competitiveness; these policies must include a focus on non-tariff barriers and export control policies. The TransPacific Partnership (TPP) is an example of a high-standard, ground-breaking negotiation that will cover new emerging barriers for cutting-edge technologies, promote regulatory coherence, address competition with state-owned enterprises, and provide a template for economic integration across the Asia-Pacific region.

In balance with trade liberalization, the U.S. Government should ensure a strong focus on enforcing trade rights, particularly addressing market-distorting subsidies, unfair trade practices, and intellectual property violations to level the playing field for U.S.-based manufacturing.

As near-term goals, the United States should:

- **Pursue increased market access:** The future key barriers are not tariffs; they are non-tariff barriers—regulatory and standards impediments that represent *de facto* market barriers. Examples of non-tariff barrier areas are innovation principles, regulatory reform and customs facilitation, forced technology transfer and weak intellectual property enforcement. We recommend that the U.S. Government strengthen the interagency process to create a consistent agenda on regulatory issues and to strengthen cooperative, capacity-building initiatives with other key trading partners.
- **Launch new negotiations:** The U.S. Government has actively solicited input from industry on core economic trading partners for new negotiations. A number of regions, such as the Middle East and North Africa, can benefit from near-term capacity-building efforts that could lead eventually to full trade liberalization efforts. In the interim, we recommend that the U.S. Government prioritize a TransAtlantic Partnership (TAP) negotiation that would leverage the advanced economies of the United States and the European Union and allow both partners to address trade barriers as a model for future multilateral trade liberalization.
- **Reform export controls:** We recommend that the U.S. Government accelerate the reform of outdated export control regimes. This process could start with rebuilding the U.S. Munitions List by harmonizing export control licensing and administrative procedures across all involved agencies and transitioning them to a single information technology platform.

Recommendation #16: Update Energy Policy

Energy is a basic building block for today's advanced manufacturing applications. Advanced manufacturing uses innovative technologies to add value to inputs in order to produce modern materials and solutions, including electronic materials, pharmaceutical breakthroughs, and clean energy alternatives. However, energy policy in the United States must fully account for the impacts of energy costs to manufacturers and the potential to drive investment into new markets and applications as the United States seeks to transition to a sustainable energy future. Therefore, any effort to reinvigorate advanced manufacturing in the United States would not be complete without an examination of energy policy that seeks ample supplies to catalyze economic growth and prosperity. We recommend the following steps:

- **Focus on energy efficiency and conservation:** Energy efficiency is the most affordable and most available way to lower energy costs and reduce carbon emissions and is particularly important to the manufacturing sector. Every dollar saved through energy efficiency efforts can be redeployed to expand business and preserve manufacturing jobs. For example, according to the Brookings Institute, if all eligible buildings in the United States were retrofitted over the next decade, it would create roughly 215,000 direct jobs, 127,000 of which are in manufacturing.[35] We recommend policies that provide incentives for power generators and distributors to undertake cost-effective and innovative energy efficiency measures and the promotion of tools and incentives to assist manufacturers of all sizes in implementing energy efficiency measures.
- **Increase and diversify domestic supplies:** Economic growth will continue to rely on hydrocarbon energy, whether from oil, naphtha, natural gas, ethane, or coal, and will require additional domestic supplies to improve energy security and reduce price volatility. These inputs are critical for the manufacturing process as both fuel and feedstock, serving as the basic building blocks of materials used in 96 percent of all manufactured goods, including products enabling the further development of renewable sources of energy such as solar panels and wind turbine blades. Onshore, increased supply from unconventional sources, such as natural gas, oil and natural gas liquids from shale will be important resources for the United States over the next several decades. The availability of these resources for value-added products must be a policy imperative to ensure economic growth and job creation. Producers and regulators need to work together to ensure that potential reserves can be brought to market in an environmentally acceptable manner at an affordable cost. Natural gas at stable, competitive prices will continue to incentivize U.S. manufacturers to invest and create jobs in the United States. Today, industrial uses of natural gas as a feedstock are driving multi-billion dollar investments. In turn, multiplier effects from these investments will be felt across the economy, including by other U.S. manufacturers that are less dependent on hydrocarbon feedstocks.
- **Speed development of renewable sources of energy:** There is a role for government, industry, and academia to work together to accelerate the development of effective and more sustainable alternative energy sources, including renewable sources. As global demand for clean sources

35. Susan Helper, Timothy Krueger, and Howard Wial, "Why Does Manufacturing Matter? Which Manufacturing Matters? A Policy Framework," Brookings Institute, February 2012. www.brookings.edu/~/media/research/files/papers/2012/2/22%20manufacturing%20helper%20krueger%20wial/0222_manufacturing_helper_krueger_wial.pdf.

of energy grows, the United States has the opportunity to play a key role in the manufacturing of advanced technologies such as energy storage equipment, photovoltaics, and wind power technologies. Since 2008, the United States has nearly doubled renewable energy generation. In 2011, U.S. solar installations grew 109 percent with the overall solar market surpassing $8.4 billion.[36] However, renewables remain a small fraction of U.S. energy use. Policies are needed that primarily focus on driving down costs, which will help drive increased demand. We recommend the continued extension of financial incentives for public/private research into promising technologies and storage devices. Further, any incentives that spur the early adoption of innovative technologies such as low and no-carbon sources originating from coal, solar, natural gas, wind, tidal, and geothermal energy must be targeted at technologies that demonstrate a path towards economically viability.

- **Transition to a low carbon economy:** We believe that to create a sustainable energy future over the long term the United States needs to shift to a low carbon economy. The right mix of fundamental research, innovation, and aggressive implementation is needed to achieve both this transition and continued economic growth. The development and implementation of a broad portfolio of technologies is essential for this transition. The United States has the technical capacity to accelerate development of sustainable energy options, but large-scale commercialization of new capital-intensive manufacturing solutions will require increased public-private partnership. We recommend a targeted approach to promote aggressive basic R&D with accelerated demonstration and deployment of clean energy and next generation energy efficient technologies. Government policy can help most in specific situations, such as when the costs and market development risks of critical technologies exceed the commercial capabilities of individual companies, where the regulatory or liability risks are beyond the capacity of the private sector, and when investment timelines exceed the private sector's capabilities.

36. Solar Energy Industries Association, *U.S. Solar Market Insight 2011*, March 14, 2012. www.greentechmedia.com/research/ussmi/.

IV. Conclusion

The Advanced Manufacturing Partnership Steering Committee offers a comprehensive set of recommendations built around three critical pillars:

- Enabling innovation
- Securing the talent pipeline
- Improving the business climate

These recommendations are aimed at reinventing manufacturing in a way that ensures U.S. competitiveness, feeds into the Nation's innovation economy, and invigorates the domestic manufacturing base. Rather than debate whether the manufacturing jobs lost in past decades can return, we should instead focus on leading the world in the new technologies that are changing the face of manufacturing. We stress the vital importance of strengthening the U.S. innovation system for advanced manufacturing.

With sustained focus, alignment of interests, and coordinated action to implement the recommendations outlined in this report, the United States can and will lead the world in advanced manufacturing. Already, we see examples of new manufacturing technologies emerging from research laboratories that will have a transformative effect on the way America makes things.

Industry, academia, and government, nationally and locally, must act now to ignite the ingenuity to make it in America.

Together the Nation must commit to re-invent the manufacturing base to ensure its future.

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Appendix B: Experts Consulted

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