

**Advanced Manufacturing and Sustainable Innovation:
The Third Wave of Industrial and Urban Economic Growth
for Minas Gerais**

A Report to the Federation of Industries of Minas Gerais (FIEMG)

by Global Urban Development (GUD)

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Executive Summary

Minas Gerais has succeeded in its first century-long wave of economic growth through industrialization and urbanization, made great strides over the past decade in the second wave of economic growth through rising incomes and growing consumer demand, and is now poised for a third wave of globally competitive prosperity and productivity driven by Sustainable Innovation. Minas Gerais already has developed several new Sustainable Innovation Pipelines, from biomedical to information technology. The next great surge for the Third Wave, the newest and most dynamic and productive Sustainable Innovation Pipeline for Minas Gerais, will be in Advanced Manufacturing. Brazil can compete directly with Advanced Manufacturing public policies and private companies throughout the world; and Minas Gerais can become one of Brazil's national leaders in this rapidly growing industrial technology field.

GUD recommends that FIEMG collaborate with CETEC and SENAI, focusing on the CETEC and its surrounding area, including Carlos Prates Airport, as a key anchor for a statewide **Advanced Manufacturing Sustainable Innovation Strategy**, to be implemented through the six key initiatives:

- 1) Advanced Manufacturing Sustainable Innovation Center*
- 2) Advanced Manufacturing Business Accelerator*
- 3) Advanced Manufacturing Technology Industrial Park*
- 4) Advanced Manufacturing Business Advisory Services*
- 5) Advanced Manufacturing Skills Training*
- 6) Advanced Manufacturing Sustainable Innovation Zone*

In the following pages, GUD provides a detailed explanation of the possibilities and opportunities of an **Advanced Manufacturing Sustainable Innovation Strategy**; an overview of the strategic implementation framework for each of the six key initiatives; and numerous international best practices and other major examples. In addition, GUD briefly highlights two other potential initiatives to be considered in the near future: **Global Branding**, and **Gifts of Nature**.

Introduction

In June 2011, members of FIEMG's Youth Council, representing FIEMG President Olavo Machado Junior, asked Global Urban Development (GUD) to provide strategic advice for the "Innovation-Led Economic Transformation of Minas Gerais" over the next several decades. GUD agreed to assist, and in collaboration with FIEMG's Euvaldo Lodi Institute (IEL), began work on the Youth Council initiative in March 2012. Over the next half year, GUD's team carefully reviewed dozens of documents and reports from FIEMG, ACMinas, and other business organizations, from the State Government and other public agencies, from consultants, academics, international entities, and civic groups. In addition, over a five-week period of various GUD experts visiting Minas Gerais and in the months that followed, we have met with and interviewed more than 100 key leaders and stakeholders from throughout Minas Gerais, including many people in Belo Horizonte.

By engaging in these numerous interviews, the GUD team learned many important lessons with respect to the vital industrial leadership role of FIEMG, and we learned a great deal of information about a wide range of recent economic development initiatives, including the efforts to strengthen industry clusters, building a new Industrial Airport and Technological Industrial Park at the Tancredo Neves International Airport in Confins, investing in major metropolitan and statewide transportation investments, promoting the 2014 World Cup and international tourism, and much more. In addition, we analyzed the 20th century evolution of

economic development of Minas Gerais, through detailed historical studies such as *Tropical Capitalism: The Industrialization of Belo Horizonte, Brazil*.

This report was written by Dr. Marc Weiss, GUD Chairman and CEO; Nancy Sedmak-Weiss, GUD Secretary-Treasurer and Chief Legal Officer; and Ian Bromley, GUD Senior Fellow. Members of the GUD team doing research and participating in interviews and site visits included Paul Krutko, GUD Senior Fellow; James Nixon, GUD President; Emilia Queiroga, GUD Senior Fellow; Ernani Machado, GUD Director of Technology Research; Dr. Elaine Yamashita Rodriguez, GUD Senior Fellow; Ellya Jeffries, GUD Fellow; Alexandre Michalick, GUD Fellow; Celeste Farias, GUD Fellow; and Brittany Jenkins, GUD Fellow.

We want to thank FIEMG President Olavo Machado Jr.; IEL Director Mauricio Tiburcio; FIEMG Youth Council President Daniel Junqueira (and the entire Youth Council leadership); Fabio Veras, Deputy Secretary of Economic Development for the State of Minas Gerais; and Mauro Borges Lemos, President of the Brazilian Agency for Industrial Development (ABDI).

Adair Marques, IEL Executive Adviser, organized all of the meetings, accompanied us, introduced us, and translated for us. He has become our special colleague and collaborator, and we are very grateful for his wise advice, gracious assistance, and warm and caring friendship.

The First Wave: Industrialization and Urbanization

Through this intensive research process we have learned a great deal about the strong business-government collaboration that generated substantial economic growth through industrialization and urbanization, which we call the First Wave, dating back to the planning and building of Belo Horizonte as a new state capital beginning in the 1890s, but especially since the 1940s and 50s, when Juscelino Kubitschek served first as Mayor of Belo Horizonte, then as Governor of Minas Gerais, and finally as President of Brazil. This First Wave was driven by many key strategic public and private investments and actions, including:

- Creating a major energy company, CEMIG, to generate and distribute high volume, low-cost, hydropower-based electricity.
- Establishing the Development Bank of Minas Gerais (BDMG), to provide capital for attracting and expanding manufacturing industries.
- Designing a statewide economic development system, including INDI and Fundacao Joao Pinheiro, to promote domestic and international private investment in growing Minas companies.
- Building a transportation infrastructure of major roads and highways for cars and trucks, and a freight rail system for transporting iron ore and other minerals, which in addition to promoting exports to the rest of Brazil and around the world, also helped foster and support a local iron and steel industry.

- Developing Belo Horizonte as a modern city and metropolitan region, both for manufacturing and for business services, including the pioneering Cidade Industrial, which gave birth to a major industrial center spreading west from the city to Betim and Contagem.
- Creating an advanced higher education system, with leading engineering and industrial development experts graduating from many key institutions, including the School of Mines at the Federal University of Ouro Preto (UFOP) and the Faculty of Economic Science at the Federal University of Minas Gerais (UFMG).
- Attracting a major Fiat assembly plant and creating a substantial local supply chain of auto parts manufacturers. Building on this strong foundation, expansion of the motor vehicles industry in Minas Gerais continues today, including the recent recruitment of Mercedes-Benz to Juiz de Fora.
- Attracting several major multinational steel producers, enabling Minas Gerais to move up the value chain by using iron ore to expand metal-based industries, instead of exporting all of the raw iron.
- Expanding agriculture and mining productivity and technology with the help of advanced research through Minas Gerais universities, EPAMIG, CETEC, and other institutions.
- Growing businesses, jobs, and incomes in cement, chemicals, food and beverage processing, clothing and textiles, leather goods and footwear, wood and metal furniture, electrical and mechanical equipment, and other manufactured products.

- Improving skills training and workforce development to help support industry expansion through SENAI, SESI, and related educational organizations.

The Second Wave: Rising Incomes and Growing Consumer Demand

Strategic investments made during the First Wave eventually bore fruit, such that by the 1990s, once Brazil's national currency and debt problems finally stabilized, Minas Gerais was poised for a major growth spurt. This brought on the Second Wave of the past decade, when Brazil has experienced major employment and income growth. An export-led boom of iron ore, soya, coffee, and other commodities has increased overall incomes, plus various federal government initiatives have helped to substantially raise the standard of living for lower income families. Such dramatic change has resulted in rising consumer spending for a growing range of products, including locally produced goods and services, further contributing to business and employment expansion. Real average income in the Belo Horizonte metropolitan region rose by 46 percent from 2006 through 2010. As a symbol of this Second Wave boost in disposable income and consumer demand, Belo Horizonte recently opened Boulevard Shopping, a thriving multi-level retail mall located near a regenerating moderate-income neighborhood.

The Third Wave: Advanced Manufacturing and Sustainable Innovation

Having successfully navigated the First and Second Waves of industrial and urban economic growth, Minas Gerais is now rapidly moving forward down the path of the Third Wave of enhanced prosperity in the 21st century, driven by Sustainable Innovation. Sustainable Innovation is the key to promoting advanced technologies, labor and energy productivity, and global competitiveness to expand businesses, increase jobs, raise incomes, strengthen families, and improve communities. Sustainable Innovation will enable Minas Gerais to “move up the value chain” by producing and selling higher value-added goods and services that will generate greater additional revenues, incomes, and profits. GUD uses the term “Sustainable” to reflect both of its meanings: 1) creating a self-sustaining, momentum-building dynamic of positive, continuous, long-term, and broad-based economic growth and prosperity; and 2) generating prosperity and quality of life by conserving and reusing resources much more efficiently and in far greater harmony and balance with ecosystem cycles and the natural environment.

Minas Gerais already has developed and is currently implementing a Sustainable Innovation economic growth strategy, which is thoroughly summarized in the 58-page publication, *Innovate in Minas*, published in 2010 by the Secretary of State for Science, Technology, and Higher Education, and the Secretary of State for Economic Development. The Innovation Institute, one of many new start-up companies spawned by UFMG researchers, produced this excellent and comprehensive report as

a consultant to the State Government. *Innovate in Minas* provides detailed information about what GUD calls the “Fundamental Assets” – in particular the many institutions and initiatives that are the engines of Sustainable Innovation for Minas Gerais, including 11 federal universities, two state universities, nine technological institutes, 11 advanced technology industrial parks, 25 business incubators, 47 technological vocational centers, applied research and R&D funding from FAPEMIG and other agencies, financial support from BDMG as well as from the Federal Government through FINEP and BNDES, and early-stage venture financing from local firms such as FIR Capital and Inseed Investments. All of these diverse activities come with a great deal of private sector participation and resources provided through an extensive system of collaborative partnerships.

The main purpose of all these activities is to create a comprehensive Sustainable Innovation Pipeline that moves continuously through all of the stages of innovation: basic and applied research, research and development (R&D) and prototyping, patenting and technology transfer, commercialization of new products and production processes, formation of new business startups, dynamic transformation of existing companies, business and employment expansion and income growth.

Sustainable Innovation Pipelines are most effective when they function as ongoing and long-term non-linear circular feedback loops, with innovative ideas and information flowing back-and-forth continuously between industrial and commercial producers and academic, business, and government researchers. Also, while it is important for Sustainable Innovation to help create and grow new businesses, it is

even more vital for Sustainable Innovation to modernize and strengthen existing companies, especially small and medium-sized enterprises (SMEs). For Sustainable Innovation Pipelines to succeed, they require substantial public and private resources for advanced research, for business financing, for key infrastructure investments to facilitate market access, for quality education and workforce training, for supportive regulatory and tax policies, and for many other vital needs.

Fortunately, Minas Gerais already is developing several Sustainable Innovation Pipelines. One of the most dynamic is the pipeline that starts with faculty, staff, and student research at UFMG, which is one of the top graduate research universities in Brazil and Latin America. The two principal streams of the UFMG pipeline are in the biomedical and software fields, or biotechnology and information technology (IT). This Sustainable Innovation Pipeline includes UFMG's Office of Innovation and Technology Transfer, the Inova business incubator (on-campus), the Biominas Habitat and FUMSOFT business incubators (off-campus), and the recently launched business accelerator, the Belo Horizonte Technology Park (BH.Tec), at the edge of UFMG's campus.

UFMG's Sustainable Innovation Pipeline already has helped generate many new companies, such as Labtest, a rapidly growing firm in the biomedical diagnostic testing field with research activities newly located at BH.Tec, and much larger production facilities in Vespasiano near the airport. Another successful spinoff from UFMG is Akwan, an innovative software business in Belo Horizonte. Google acquired

Akwon in 2005 and converted it to Google's Brazilian Research and Development center and Latin American New Business Development headquarters.

Near Google is "San Pedro Valley" with more than 50 new technology companies such as Samba Tech, developer of the largest online video platform in Latin America. Belo Horizonte's Sao Pedro district is becoming a magnet for young IT entrepreneurs like Samba Tech's founder and CEO, Gustavo Caetano, who is President of the Brazilian Association of Startups.

In addition to the UFMG pipeline, there are other Sustainable Innovation Pipelines centered around major universities and nearby technology parks throughout Minas Gerais, including Vicososa, Lavras, Uberlandia, Juiz de Fora, Ouro Preto, and Itajuba. This pipeline also includes the Inatel and Prointec business incubators in Santa Rita do Sapucaí, focusing on electronics, telecommunications, information technology, and related fields. It also includes many additional institutions, such as the internationally recognized business school, Fundacao Dom Cabral (FDC) in Nova Lima, the Ferrous-Inhotim Environmental Research and Education Center in Brumadinho, Fiat's Giovanni Agnelli Development Center in Betim, Embraer's new Center for Aerospace Technology (CCTA) in Lagoa Santa, Fiocruz in Belo Horizonte, the planned Technology City (CITAT) in Araxa, the proposed Medical City project in Santa Luzia, and JMM Tech's Minas Gerais State Government-funded project in Aracuaí designing and assembling innovative new sustainable technologies to improve agricultural productivity in the Jequitinhonha Valley, among others.

Advanced Manufacturing: The Next Sustainable Innovation Pipeline for Minas Gerais

Given the large number of Mineiro manufacturers and related businesses in the manufacturing supply chain, especially in metal-mechanical-electrical-electronic machines and equipment industries, the next major Sustainable Innovation Pipeline for Minas Gerais should be in the leading-edge technology fields of Advanced Manufacturing. FIEMG is particularly well suited to provide excellent leadership for Advanced Manufacturing, given its extensive engineering and industrial expertise, and its substantial membership of manufacturing and related businesses. Advanced Manufacturing in Minas Gerais will become one of the main engines of Sustainable Innovation, both in terms of new high-value technologies that create successful start-up companies, and more importantly, by dynamically improving the innovation capacity, productivity, global competitiveness, and sustainability of thousands of existing firms. A focus on Advanced Manufacturing will be a vital investment in growing businesses, jobs, and incomes for Minas Gerais, and it will enable the state's economy, especially its industrial base, to become much stronger and more competitive over the long term.

According to the US President's Council of Advisors on Science and Technology and the Executive Office of the President, "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.... 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.... 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.”

Advanced manufacturing is now the “next big thing” in high technology, a major focus of national Sustainable Innovation policy initiatives in many countries throughout the world. In Germany, advanced manufacturing is part of the applied industrial R&D agenda of the numerous Fraunhofer Institutes that are financially supported by private industry and by the Federal and State Governments. Other national models of

this type of engineering and science advanced technology applied industrial research and business development include Denmark's GTS Advanced Technology Group, Japan's National Institute of Advanced Industrial Science and Technology (AIST), France's Carnot Institutes, South Korea's Electronics and Communications Research Institute (ETRI), Finland's VTT Technical Research Centre, Sweden's Governmental Agency for Innovation Systems (VINNOVA), China's Torch High Technology Industry Development Center, and The Netherlands Organization for Applied Scientific Research (TNO).

In the UK, the national government's Technology Strategy Board is promoting and investing in a High Value Manufacturing Catapult, which "provides an integrated capability and embraces all forms of manufacture using metals and composites, in addition to process manufacturing technologies and bio-processing. It draws on excellent university research to accelerate the commercialization of new and emerging manufacturing technologies."

Through the UK's High Value Manufacturing Catapult, which was launched in October 2011, "seven partners are working together to form the new Catapult centre, bringing together their expertise in different and complementary areas of high value manufacturing." The UK Government is investing 200 million GBP in the seven partners, including the Advanced Manufacturing Research Centre with Boeing at the University of Sheffield, focusing on high performance machining, automated assembly, advanced composites and automated processes, structural integrity testing,

and virtual reality modeling of processes and systems; the Nuclear Advanced Manufacturing Research Centre at the Universities of Sheffield and Manchester, focusing on fabrication of nuclear energy components; the Manufacturing Technology Centre in Coventry, focusing on net shape manufacture, intelligent automation, advanced tooling and fixturing, advanced joining techniques, system modeling and operational efficiency, and electronics assembly; the Advanced Forming Research Centre at the University of Strathclyde in Glasgow, focusing on billet forging, sheet forming, and precision forging; the National Composites Center at the University of Bristol, focusing on design and manufacture of composites; the Centre for Process Innovation in Wilton and Sedgefield, focusing on chemical processing, biotechnology, and printable electronics; and the Warwick Manufacturing Group at the University of Warwick in Coventry, focusing on lightweight product system optimization, energy storage and management, and digital verification and validation.

The Advanced Manufacturing processes that are part of the Catapult are used in a variety of industries including aerospace, automotive, energy, biotechnology, and electronics. The UK Government forecasts that their strategic investment will leverage an additional 2 billion GBP in Advanced Manufacturing R&D over the next decade, and the creation of 3,000 new engineering research positions at the seven centers. In the years ahead, the Catapult also will be conducting R&D on high-performance batteries for electric vehicles, off-shore wind turbines, a new generation of nuclear power plants, and a new generation of fuel-efficient passenger airplanes.

Perhaps the most ambitious current effort is in the US, where President Obama's Administration has engaged in an extensive two-year process led by the White House Office of Manufacturing Policy, co-chaired by the Director of the National Economic Council and the Secretary of Commerce, by the White House Office of Science and Technology Policy and the President's Council of Advisors on Science and Technology/President's Innovation and Technology Advisory Committee, and especially by the newly established Advanced Manufacturing Partnership, co-chaired by the President of MIT and the Chairman and CEO of Dow Chemical, with many distinguished corporate CEOs and university presidents serving on the Steering Committee. In addition, many scientists, engineers, professors, industrial researchers, and manufacturing entrepreneurs and suppliers from large, medium-sized, and small businesses are participating in this important and innovative advanced technology initiative. It also involves the Advanced Manufacturing National Program Office at the National Institute of Standards and Technology (NIST) and related programs at the Department of Energy, Department of Defense, National Aeronautics and Space Administration (NASA), Small Business Administration, National Science Foundation, and several other federal agencies, including the Economic Development Administration's Jobs and Innovation Accelerator Challenge. According to Dr. Phillip Singerman, NIST's Associate Director for Innovation and Industry Services, NIST's Advanced Manufacturing National Program Office "was established to coordinate federal agency efforts to accelerate the pace of innovation, promote technology transfer, and more rapidly integrate technology breakthroughs into the commercial market."

During the past year there have been two major reports emerging from this public-private partnership policy process: *Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing* (July 2012), and *A National Strategic Plan for Advanced Manufacturing* (February 2012). These reports emphasize the vital economic role of manufacturing in promoting innovation, productivity, and competitiveness, due to the major contribution of manufacturing firms to industrial and commercial R&D (70 percent of all private sector research and development spending comes from manufacturers), and especially because of the very high multiplier impacts of manufacturing in generating much larger increases in overall employment and output throughout the national economy, including suppliers, services, and sales. The reports highlight “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, and suppliers, to the output stages including distribution, sales, and the maintenance and repair life cycle for the product. Total employment for manufacturing, and therefore its economic impact, is much bigger than simply those engaged at the production moment itself.”

Further, the reports argue that in order to obtain the highest possible economic benefits from Sustainable Innovation, it is necessary to locate manufacturing research and development (R&D) activities in close proximity to factories and industrial

production facilities, in order to maximize the direct interaction and two-way flow of information and ideas that will generate new innovations both in production processes and in new technology-based products: “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.” As NIST Senior Economist Gregory Tassej argues in *The Technology Imperative: The Future of R&D Policy*, “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.”

The Advanced Manufacturing Partnership (AMP) in the US engaged with many key groups, including the Council on Competitiveness, Information Technology and Innovation Foundation, National Association of Manufacturers, and International Economic Development Council, to name just a few. More importantly, the AMP conducted extensive outreach, both through a major national survey of experts, and through highly participatory regional expert meetings, to identify the most technologically significant and economically robust fields of advanced manufacturing to promote and support with greater public and private financial resources. In particular, three major national organizations encouraged their members to provide answers to the survey questions: the Manufacturers Alliance for Productivity and

Innovation, representing large private manufacturers; the National Center for Manufacturing Sciences representing small and medium-sized manufacturing enterprises; and the Association of Public and Land-Grant Universities, representing professors and academic researchers. The results of the surveys, interviews, and regional meetings was clear agreement about the 11 most promising and important areas of Advanced Manufacturing to be emphasized, and some of these that are most relevant to the current capabilities of Minas Gerais should be the starting point for FIEMG's Advanced Manufacturing initiatives. What follows is a very long and detailed quote from the July 2012 report:

“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, composites, 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: Nanomanufacturing 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 health care 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 nano-manufacturing technologies and make them economically viable.”

“Additive Manufacturing (including 3-D Printing): 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...local firms can maintain significant global competitive 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 for 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 workforce...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 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 conservation and resource efficiency. In addition, improved performance requires continued innovation and the search for transformative technologies that will help maintain competitiveness in industries ranging from transportation to infrastructure.”

CETEC-SENAI-FIEMG Advanced Manufacturing Sustainable Innovation Strategy

FIEMG, in collaboration with CETEC (Technological Center of Minas Gerais), SENAI (National Industrial Training Service), and CNI (National Confederation of Industry), should provide leadership for an ***Advanced Manufacturing Sustainable Innovation Strategy*** for Minas, based at the CETEC site in Belo Horizonte. This new initiative will be designed to safely and effectively guide applied research past the so-called “valley of death” to successful technology commercialization and large-scale manufacturing. The gap from ideas to action and from research to production is the main challenge faced by many researchers and entrepreneurs, especially for smaller businesses that often do not have sufficient technical and financial resources to move new innovations and technologies all the way through the pipeline to successful large-

scale and long-term growth. CETEC-SENAI-FIEMG will enable all current and future manufacturers, both large and small, to benefit from the research, learning, testing, commercialization, and scaling-up processes that will help create and develop new Sustainable Innovation technologies both for new startups and for existing businesses.

The ***Advanced Manufacturing Sustainable Innovation Strategy*** includes six key initiatives:

- 1) Advanced Manufacturing Sustainable Innovation Center***
- 2) Advanced Manufacturing Business Accelerator***
- 3) Advanced Manufacturing Technology Industrial Park***
- 4) Advanced Manufacturing Business Advisory Services***
- 5) Advanced Manufacturing Skills Training***
- 6) Advanced Manufacturing Sustainable Innovation Zone***

The State Government of Minas Gerais, as well as the Brazil's Federal Government, can work closely together with CETEC, SENAI, and FIEMG to make the ***Advanced Manufacturing Sustainable Innovation Strategy*** a major success, by providing direct funding and in-kind resources, as well as various tax and regulatory incentives and targeted procurement, to enable new technologies and stronger businesses to grow and thrive from this new Sustainable Innovation Pipeline.

Advanced Manufacturing Sustainable Innovation Center

Similar to the seven centers in the UK's High Value Manufacturing Catapult, or the 15 proposed US national network of Manufacturing Innovation Institutes, the purpose of the CETEC-SENAI-FIEMG initiative will be to create a dynamic Sustainable Innovation Pipeline for Advanced Manufacturing. This means that in addition to SENAI's major infusion of budget resources currently planned for CETEC to host new Technology and Innovation Institutes, including the new BIOERG Institute for energy efficiency, renewable energy, sustainable buildings, and electric mobility, and the SENAI Institute of Innovation and Surface Engineering in partnership with Germany's Fraunhofer Institute, CETEC should establish an ***Advanced Manufacturing Sustainable Innovation Center***. This Center will conduct and promote applied research and technology development, software development, and prototype development and testing of machines and equipment and of new production processes and products. Facilities at the ***Advanced Manufacturing Sustainable Innovation Center*** will include laboratories, industrial workshop areas, and other newly built or renovated research and testing facilities.

According to the International Economic Development Council's recent report, *Jobs in the Making: Economic Development Strategies to Grow Manufacturing*, "In today's complex innovation world, it is often critical to create research organizations that are specifically designed to facilitate cooperative innovation. Advanced manufacturing parks have emerged as one of the leading models for driving cooperative research

and development. Drawing on the knowledge and resources of firms that share interest in specific lines of research and usually engaging the expertise of public research institutions (e.g., universities), advanced manufacturing parks address a variety of the coordination and funding issues that stand in the way of effective collaborative research and development.”

Activities of the *Advanced Manufacturing Sustainable Innovation Center* can include:

- Manufacturing engineers, operations managers, and scientists will collaborate to undertake applied primary and secondary research projects designed to develop and disseminate new production processes in high value-added manufacturing.
- Manufacturing engineers and operations managers will receive higher and continuing education and training in new approaches to computer-aided design, logistics management, manufacturing processes and global best practices in Advanced Manufacturing.
- Engineers and production workers will get training and hands-on experience with the latest equipment and machinery used in Advanced Manufacturing globally.

- Companies will experiment with new techniques and technologies prior to introducing them into their production processes, and work with engineers and scientists to maximize their effectiveness.
- Companies will work with scientists and engineers to develop and test new product prototypes, and new materials and techniques for upgrading existing products.
- Suppliers of Advanced Manufacturing equipment and machinery will demonstrate their latest product offerings to potential buyers.

The ***Advanced Manufacturing Sustainable Innovation Center*** will involve CETEC's current research staff, and it may also be necessary to recruit additional full-time and part-time researchers from universities and industry. Also, it will include affiliated researchers and experts on many aspects of Advanced Manufacturing from other public and private institutions, such as engineers, scientists, professors, business executives, university student researchers, consultants, and advisers. Much of the R&D will be open to all businesses, especially to smaller companies that can benefit the most from the shared resources, facilities, and ideas. This information will be widely shared with entrepreneurs in Minas Gerais through the ***Advanced Manufacturing Business Advisory Services***.

Some of the R&D conducted through the ***Advanced Manufacturing Sustainable Innovation Center*** will be contract research, proprietary and confidential for individual companies. In addition to applied research and development on Sustainable Innovation in Advanced Manufacturing, there will be a very active focus on technology transfer and commercialization. Some of this work can directly support the growth of innovative startups and new firms participating in the ***Advanced Manufacturing Business Accelerator***.

This new CETEC-SENAI-FIEMG ***Advanced Manufacturing Sustainable Innovation Center*** can engage in public-private partnerships with UFMG, the Pontifical Catholic University of Minas Gerais (PUC-MG), and other universities, with major companies such as Embraer, Fiat, Vale, and CEMIG, and with the newly adjacent FAPEMIG headquarters offices, to help coordinate major funding by FAPEMIG for applied research on Advanced Manufacturing. Similar cooperation with EPAMIG to encourage research on Advanced Manufacturing opportunities and applications related to agricultural production in Minas Gerais should be pursued. Statistical analysts at the nearby SERPRO offices might also be able to provide some research support with respect to the Federal Government's data sources.

As an example of this type of approach, President Obama announced in August the creation of the National Additive Manufacturing Innovation Institute (NAMII) in Youngstown, Ohio. NAMII was the winner of a national competition to create a "pilot institute" demonstrating what will eventually become a national network of 15

Manufacturing Innovation Institutes that will be organized and operated as partnerships between industry, government, academia, and others, partly supported by one billion dollars in competitive grant funds from the US Government.

The US Government committed \$45 million for NAMII from the Departments of Defense, Energy, Commerce, NASA, and the National Science Foundation, and this commitment was matched by an additional \$40 million from a consortium of 40 companies, including Boeing, General Dynamics, GE, Honeywell, IBM, Johnson Controls, Lockheed Martin, Northrop Grumman, and Westinghouse, plus several innovative small companies such as M-7 Technologies, Applied Systems and Technology Transfer (AST2), and ExOne. NAMII will be managed by the National Center for Defense Manufacturing and Machining, and the NCDMM will relocate some of its staff from its headquarters in Latrobe, Pennsylvania to the new NAMII facilities in Youngstown.

The NAMII consortium involves nine major research universities located in the “Tech Belt” of northeastern Ohio and western Pennsylvania: Carnegie Mellon University, Case Western Reserve University, Kent State University, Lehigh University, Penn State University, Robert Morris University, University of Akron, University of Pittsburgh, and Youngstown State University. In addition, the NAMII consortium includes five community colleges and 11 non-profit technology research, engineering profession, and economic development organizations, including the Youngstown Business Incubator, where the NAMII facilities will be located. The Youngstown Business

Incubator was renovated with a \$450,000 grant from the US Department of Housing and Urban Development, with new advanced manufacturing machines and equipment, a software center, and research laboratories for an initial staff of up to 20 people.

According to the White House, “The NAMII will provide the innovation infrastructure needed to support new additive manufacturing technology and products in order to become a global center of excellence for additive manufacturing. The pilot institute will bridge the gap between basic research and product development for additive manufacturing, provide shared assets to help companies, particularly small manufacturers, access cutting-edge capabilities and equipment, and create an environment to educate and train workers in advanced additive manufacturing skills.”

“Additive manufacturing, often referred to as 3D printing, is a new way of making products and components from a digital model, and will have implications in a wide range of industries including defense, aerospace, automotive, and metals manufacturing. Like an office printer that puts 2D digital files on a piece of paper, a 3D printer creates components by depositing thin layers of material one after another using a digital blueprint until the exact component required has been created. The Department of Defense envisions customizing parts on site for operational systems that would otherwise be expensive to make or ship. The Department of Energy

anticipates that additive processes would be able to save more than 50 percent of energy use compared to today's "subtractive" manufacturing processes."

The US Secretary of Commerce, who participated in the announcement in Youngstown, explained that "Additive manufacturing allows companies to manufacture a component with intricate shapes and tight tolerances by using a single source material and build the component up layer by layer. If more traditional manufacturing techniques were used, the same component would require methods commonly used in subtractive manufacturing. That is, essentially carving parts out of the material and often having to manufacture smaller pieces separately and then assemble them into a larger component. Additive manufacturing processes are becoming increasingly important for defense, aerospace, and biomedical applications. The technology has the potential to eliminate tooling costs, reduce material waste, and create complex components. Companies can therefore substantially reduce production costs and become more competitive in the global market."

Another excellent model for the CETEC-SENAI-FIEMG ***Advanced Manufacturing Sustainable Innovation Center*** is the Advanced Manufacturing Research Centre at the University of Sheffield, described below. Germany's Fraunhofer Institute also is a good example of industry-oriented applied research on Sustainable Innovation. Recently Fraunhofer has started creating centers in several other countries, including a total of six in the US, such as the Fraunhofer Center for Molecular Biology at the University of Delaware's Technology Park., which, according to Fraunhofer-

Gesellschaft's 2011 *Annual Report*, "was the best performing Fraunhofer center in the USA" with annual revenues of more than \$20 million. "The successful track record of the Fraunhofer Center for Molecular Biology in recent years prompted the US State of Delaware to renew its financing commitment to the center for a further six years. The center's ties to the University of Delaware have been formalized since 2011, enabling joint appointments of staff and the utilization of the university's comprehensive resources." Last year Fraunhofer opened its first center in Latin America, the Fraunhofer Center for Systems Biotechnology in Santiago de Chile, and next year, in partnership with SENAI-MG, Fraunhofer will help open the SENAI Institute of Innovation and Surface Engineering at CETEC.

Advanced Manufacturing Business Accelerator

In order to maximize business, employment, and income growth, an ***Advanced Manufacturing Business Accelerator*** should be built and established at the CETEC site. Its purpose will be to enable new start-up and early stage Advanced Manufacturing-related companies to obtain access to low-cost shared facilities such as reception area, office space, laboratories, workshops, meeting and conference rooms, computer and security services. This will enable new companies with innovative technologies and viable business strategies to benefit not only from the shared facilities, but from the intellectual and technical resources, and from synergy of frequently interacting with relevant experts and entrepreneurs, to obtain venture capital and early stage financing, and to gain access to potential markets from other

businesses and government agencies participating in the ***Advanced Manufacturing Sustainable Innovation Strategy***. For Advanced Manufacturing business opportunities that are directly related to medical equipment and health care devices, the ***Advanced Manufacturing Sustainable Innovation Center*** and the ***Advanced Manufacturing Business Accelerator*** can collaborate and coordinate its activities with the nearby Biominas Habitat business incubator.

The ***Advanced Manufacturing Business Accelerator*** can provide the companies it houses and the entrepreneurs it works with a variety of important services, including advanced technology science and engineering advice and feedback, strategic business market research and advice, professional and technical assistance, legal and financial services, and many other vital needs. These services can include courses and training programs for the business owners, access to mentors, help in developing business plans, access to specialized professional services such as intellectual property lawyers, and access to angel and venture capital investors. While regular access and use of the facilities primarily will be for the firms renting and occupying its space, some of the services can be provided to other early stage entrepreneurs and companies in Minas Gerais who are not physically located at the ***Advanced Manufacturing Business Accelerator***.

The ***Advanced Manufacturing Business Accelerator*** can help accomplish two important objectives:

- Develop entirely new Advanced Manufacturing companies to supply key products that fill gaps in supply chains, possibly with equity investments from the customers themselves.
- Incubate and accelerate the growth of new businesses spun off from existing large industries where those companies have a new product or technology they would like to develop separately from their core operations.

As the companies in the ***Advanced Manufacturing Business Accelerator*** “graduate” and seek more land and building space to begin engaging in larger scale production of components, equipment, machines, and other aspects of the Advanced Manufacturing value chain, some of these companies will be able to locate their factories, workshops, labs, and offices in the ***Advanced Manufacturing Technology Industrial Park***.

An excellent example of a dynamic and thriving business accelerator is the MaRS (Medical and Related Sciences) Discovery District in Toronto, Canada. MaRS began when a key historic property at the corner of College Street and University Avenue in downtown Toronto was to be sold off by its owner, the University Health Network (hospital). The site was both historic and strategically located. It was the traditional research wing of the Toronto General Hospital – a place where medical breakthroughs such as insulin, the artificial kidney, and the pacemaker, were developed. It was also located at the epicenter of six teaching hospitals and the

University of Toronto – which together undertake over a billion dollars of medical research each year.

John Evans, a corporate chairman and President Emeritus of the University of Toronto, convinced a number of private individuals to each contribute one million dollars to seed a not-for-profit, charitable organization to secure the building site and develop a concept and business plan for a major urban innovation center. With this private sector leadership in place, the provincial and federal governments contributed over \$100 million to buy the property and redevelop it.

MaRS opened in September 2005 with 750,000 square feet of space – labs, office space, and meeting rooms. The initial plan was to co-locate technology-related startups and early-stage businesses along with the support services (legal, financial, consulting) that those companies needed. The center was soon filled with tenants paying on average \$45 per square foot – the highest rents in Toronto – and planning began for Phase Two, which in late 2013 will provide an additional 1.5 million square feet of space.

MaRS provides education, information, advice, and access to early stage capital both directly and through service providers and partners. It provides broad education on starting a business through its Entrepreneurship 101 classes. Promising startups or just people with good ideas can apply to become MaRS clients (whether or not they are located in the MaRS center). Becoming a client provides access to a MaRS adviser

as well as market research materials and professional and technical assistance provided pro bono by companies such as Forrester, comScore, MedTrack, and Gartner.

Today, MaRS Discovery District has an annual operating budget of approximately \$40 million, of which about \$5 million is provided by government grants. The vast majority of the budget is derived from rent, fees for events and education programs, corporate sponsorship, and client fees. Even if the government grants were to end, MaRS is now a financially sustainable charitable institution that will carry on with its mission to support the creation and growth of technology businesses in Toronto and Ontario.

Another good example is SPARK in Ann Arbor, Michigan, which operates three regional business incubators together with a range of advanced innovation-oriented business acceleration services. These include a “Boot Camp” for entrepreneurial training, and access to business financing. According to Paul Krutko, SPARK President and CEO, International Economic Development Council Chair, and GUD Senior Fellow, “The Ann Arbor region is ripe with examples of companies that are innovating in the manufacturing space, and using that success to create jobs. Hyundai, and the recent expansion of its facility in Superior Township, is a great example of how manufacturing research and economic development go hand in hand.”

Advanced Manufacturing Technology Industrial Park

Ever since the Stanford Industrial Park near Stanford University in Palo Alto, California played such a major role in the growth of Silicon Valley during the 1960s and 70s, and Route 128 near Boston, Massachusetts, and Research Triangle Park near Raleigh-Durham-Chapel Hill, North Carolina, and similar places served as successful economic development catalysts during that same time period, high-technology industrial parks have become a major focus of efforts by governments, businesses, and universities to promote commercial innovation and manufacturing competitiveness. Sir Peter Hall, a GUD Vice Chair, and Manuel Castells, described and analyzed this global process nearly two decades ago in their insightful book, *Technopoles of the World: The Making of 21st Century Industrial Complexes*.

CETEC-SENAI-FIEMG should develop an ***Advanced Manufacturing Technology Industrial Park*** to effectively create a robust and dynamic Advanced Manufacturing Industry Network in Minas Gerais. The main purpose will be to accelerate the growth of a regional cluster of interrelated growing production companies building and marketing technologically innovative Advanced Manufacturing products, including for international exports. This will provide the opportunity to involve many local firms in the supply chain of equipment and components that can accelerate overall industrial growth in Minas Gerais. By concentrating multiple manufacturers and suppliers near cutting-edge research and R&D activities, the economic benefits of synergy and agglomeration, of specialization and diversity, and of experimentation

and interaction will multiply exponentially for the Belo Horizonte Metropolitan Region and throughout the state in terms of business, employment, and income growth.

The first stage of this process will be to develop a portion of the current CETEC site for a relatively modest-sized ***Advanced Manufacturing Technology Industrial Park***, both for graduates of the ***Advanced Manufacturing Business Accelerator*** to locate their industrial production operations as they begin scaling up the Advanced Manufacturing of new commercial products, and to attract Advanced Manufacturing companies from elsewhere in the state, nation, and world. As the demand for space quickly outgrows the available land at the CETEC site, FIEMG should work with CNI, SENAI, and CETEC to build a newer and much larger ***Advanced Manufacturing Technology Industrial Park*** at the nearby Carlos Prates Airport in Belo Horizonte, to be managed by CETEC-SENAI-FIEMG as part of their overall ***Advanced Manufacturing Sustainable Innovation Strategy***.

Brazil's Federal Government should be strongly encouraged to permanently close Carlos Prates as an airfield and transfer all of its scheduled flights and training activities to other Minas Gerais regional airports. Then this major piece of land, one of the best sites currently available in Belo Horizonte that is well located in relation to CETEC, PUC-MG, and UFMG, can become a world-class production center and an international magnet for Advanced Manufacturers.

The close interrelationship between the ***Advanced Manufacturing Sustainable Innovation Center*** and the ***Advanced Manufacturing Technology Industrial Park*** is similar to the relationship between the University of Sheffield's Advanced Manufacturing Research Centre (AMRC) and the nearby Advanced Manufacturing Park (AMP) in Sheffield. Ian Bromley, GUD Senior Fellow and former International Economic Development Council Chair, served as CEO of the Sheffield City Development Company and Creative Sheffield from 2006-2009. He is quite familiar with Sheffield's AMRC and AMP.

The new Commonwealth Center for Advanced Manufacturing (CCAM) in Petersburg, Virginia, is following the Sheffield model. CCAM is a partnership between the Rolls-Royce Corporation, the Virginia Polytechnic Institute and State University (Virginia Tech), and the University of Virginia, conducting R&D and testing on advanced surface engineering for the aerospace, energy, semiconductor, chemical, and shipbuilding industries. A key feature of CCAM will be the construction of a test factory floor within the center. This will allow testing of more advanced and efficient production techniques, reducing testing costs, and enabling practical, hands-on training to take place separately from the actual factory production facilities.

Case Study: University of Sheffield Advanced Manufacturing Research Centre with Boeing and Advanced Manufacturing Park

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) with Boeing is an internationally recognized center for advanced machining and materials research for aerospace and other high-value manufacturing industries.

AMRC is becoming an innovative model for Advanced Manufacturing research centers worldwide. In 2011, AMRC with Boeing, and the University of Sheffield's Nuclear AMRC, became partners in the High Value Manufacturing Catapult, with funding from the UK Government's Technology Strategy Board intended to create a new national network of advanced technological innovation.

AMRC identifies, researches, and resolves advanced manufacturing problems on behalf of its industrial business members. Over 65 companies have joined as members, from global aerospace corporations to local small- and medium-sized enterprises. More than 200 researchers work with individual companies on specific projects, and collaborate on generic projects for the benefit of all members. The industrial members select AMRC's R&D projects. This ensures that work is focused on high-priority industrial and commercial requirements.

AMRC has four areas of core research:

Machining Research – The AMRC Process Technology Group (PTG) develops innovative techniques and optimized processes for the machining of high-performance materials. Within that scope, PTG focuses on process monitoring, machinability of materials, machining dynamics, process automation, process modeling, chip machining fundamentals, non-conventional machining, and integrated manufacturing.

Advanced Manufacturing Assembly – The AMRC Integrated Manufacturing Group (IMG) specializes in solving problems in low-volume, high-value assembly and difficult-to-handle components. IMG focuses on measurement-assisted assembly, to develop new ways of automatically assembling complex systems for aerospace and other low-volume manufacturing industries. The Group brings together core expertise in robotics, metrology, and design of automation systems.

Composite Materials – AMRC's Composite Centre is a state-of-the-art facility for advanced composite manufacturing research and development, extending AMRC's traditional expertise in metals production into the new generation of carbon fiber composite materials increasingly used in aerospace, marine, automotive, and other industries. With the new composite materials, the Composite Centre focuses on automated production, machining, and advanced curing technologies.

Structural Testing – The Advanced Structural Testing Centre (ASTC) is AMRC's testing and certification center. Product certification is critical to entering the supply chain with new methodologies and manufacturing materials in safety-critical components.

Research projects fall into three categories:

Generic research is conducted on behalf of AMRC's industrial members, with results distributed to every company.

Specific research is conducted for individual members. The members invest directly in the research and have exclusive access to any resulting intellectual property.

Innovation research is conducted on behalf of the entire industrial membership, with results presented to all members. These projects are usually funded by the Engineering and Physical Sciences Research Council (EPSRC), the main UK government agency for funding research and training in engineering and the physical sciences, by the European Commission's Framework Program, or through other external grants, and these projects sometimes include collaborating with other research centers and corporations.

In addition to its European partnerships, AMRC is part of the Boeing Corporation's GlobalNet group of industry-oriented research centers, and the Rolls-Royce

Corporation's AxRC, an international network of Advanced Manufacturing research centers.

The AMRC also provides technical, analytic, and management services to support the activities of its core research groups. Research support teams include microscopy, metrology, quality control, and virtual reality.

Background History

Sheffield's Advanced Manufacturing Park (AMP) is located in the South Yorkshire region that once was a major area for steel manufacturing. With the decline of steel production during the 1980s, Sheffield and South Yorkshire went into a decade-long slump as steel factories and coalmines in adjacent communities were closed. As a result of its economic challenges, South Yorkshire became a European Union "Objective One" region, becoming eligible for one billion GBP in EU funding to enable the region to regenerate its economy. One of the projects local governments invested in was a joint venture of UK Coal (which owned much of the contaminated former coal mines across the UK) and Yorkshire Forward, the Regional Development Agency, to develop the 100-acre Advanced Manufacturing Park near Sheffield.

The AMRC was established in 2001 as a partnership between the University of Sheffield and Boeing, with additional funding from Yorkshire Forward and the European Regional Development Fund. The total initial public-private investment

was 15 million GBP. The University of Sheffield has a strong focus on metallurgy and engineering research, and a tradition of working closely with local industry to develop new manufacturing technologies and processes. University executives and professors collaborated with Boeing to develop a concept for the Advanced Manufacturing Research Centre designed to partner with businesses in finding new solutions for addressing the ultra-high tolerance precision required in advanced technology aerospace manufacturing.

In 2004, AMRC moved into a custom-designed facility as the anchor tenant for the Advanced Manufacturing Park. AMRC grew rapidly and, after securing additional funding, in 2008 officially opened the 4,500 square-meter AMRC Rolls-Royce Factory of the Future. In 2012, AMRC's Composite Centre moved to an expanded 1,800 square-meter facility in the Factory of the Future. The Rolls-Royce Factory of the Future is built according to highly sustainable Building Research Establishment Environmental Assessment Method (BREEAM) standards. The building is designed to make maximum use of natural lighting, heating, and ventilation, and features significant renewable energy capabilities including ground source heat pumps and wind turbines.

The original 2004 AMRC building currently features the Advanced Structural Testing Centre, and will soon undergo a major upgrade and expansion to create a new Design Prototyping and Testing Centre.

Governance

AMRC is a membership-based organization with two tiers of membership:

Tier 1 membership costs 200,000 GBP per year. Tier 1 members get an individual vote on the board of members that makes key decisions about research priorities.

Tier 1 members participate in and obtain the results of all generic projects (distinct from separately funded proprietary research projects). Tier 1 members also have the opportunity to recommend specific projects that are presented to the board of Tier 1 members for ranking and approval as funds become available. There are currently 20 Tier 1 members including Boeing, Rolls-Royce, BAE Systems, Alcoa, and Nikon.

Tier 2 membership costs 30,000 GBP per year. Tier 2 members participate in and obtain the results of all generic research projects, and have privileged access to AMRC's resources and capabilities. Tier 2 partners collectively get one vote on the board of members. There are currently 47 Tier 2 members, including ABB, Volvo Aero, Mitsubishi Electric, and Aero Engine Controls (a joint venture between Rolls-Royce and Goodrich).

Other AMRC and AMP Facilities

The AMRC now forms the core of the University of Sheffield AMRC group, together with the Nuclear AMRC, which is applying the same collaborative industrial member

R&D model to modernizing and improving the nuclear energy Advanced Manufacturing supply chain.

The University of Sheffield is building on the success of its AMRC with Boeing by developing a larger group of industry-focused manufacturing R&D centers and supporting facilities. The University of Sheffield AMRC includes:

Nuclear AMRC

Established in 2009 in collaboration with the University of Manchester, the Nuclear AMRC is applying the University of Sheffield's AMRC model of collaborative research to the nuclear energy Advanced Manufacturing supply chain. The Nuclear AMRC combines university innovation and industry expertise to help UK manufacturers compete globally to manufacture new state-of-the-art nuclear power plants, as well as other innovative energy technologies

The Nuclear AMRC has over 35 member companies, including reactor providers Areva and Westinghouse and leading suppliers such as Rolls-Royce and Sheffield Forgemasters. It is based at a new R&D facility in Sheffield's Advanced Manufacturing Park, with an additional laboratory at the University of Manchester's Dalton Nuclear Institute.

Namtec

Established in 2002, the National Metals Technology Centre (Namtec) provides training and engineering advice to the UK metals manufacturing supply chain.

Namtec joined AMRC in 2012 to help promote Advanced Manufacturing innovation and improve competitiveness for the UK metals industry.

Knowledge Transfer Centre (KTC)

Opened in May 2012, the AMRC Knowledge Transfer Centre (KTC) provides dedicated conference, meeting, and training space to help engage businesses involved in the Advanced Manufacturing supply chain. The building is based around a large training workshop where visitors can experience new Advanced Manufacturing, machining, and assembly techniques developed at AMRC. The KTC also offers highly flexible meeting and teaching rooms, equipped with the latest presentation and networking technology, and its facilities can host large conferences of up to 300 participants.

AMRC Training Centre

Opening in late 2013, the AMRC Training Centre will focus on high-level apprentice training in Advanced Manufacturing, including mechanical engineering, electrical and electronic engineering, fabrication and welding, engineering maintenance, and engineering technical support, for industries such as aerospace, automotive, and

energy. It will train up to 250 apprentices per year from member companies and other local businesses, in cooperative part-time programs. The AMRC Training Centre will be housed in a new 5,000 square-meter building at the Advanced Manufacturing Park.

Industrial Doctorate Centre

The Industrial Doctorate Centre (IDC) in Machining Science offers graduate students the opportunity to learn about cutting-edge Advanced Manufacturing engineering. The IDC is operated jointly by AMRC together with the University of Sheffield's Faculty of Engineering. It provides a four-year Engineering Doctorate program that includes applied R&D addressing real-world Advanced Manufacturing business challenges.

Advanced Manufacturing Business Advisory Services

For the ***Advanced Manufacturing Sustainable Innovation Strategy*** to succeed, it will be important to actively involve the thousands of manufacturers and their supply chain in Minas Gerais, by providing entrepreneurial training, strategic advice, and technical assistance to small and medium-sized engineering and industrial companies. This can be accomplished through the ***Advanced Manufacturing Business Advisory Services***.

The ***Advanced Manufacturing Business Advisory Services*** will offer courses, seminars, and training programs for businesses at CETEC, at the nearby SENAI facility in the Horto area of Belo Horizonte, and at many other FIEMG and SENAI locations in Minas Gerais. In addition, the ***Advanced Manufacturing Business Advisory Services*** will manage an extension service whereby mentors, consultants, and technical specialists will visit a company's production facilities and provide on-site strategic advice about how to reduce expenses by eliminating and recycling waste, enhancing speed and timeliness, expanding markets, and increasing sales revenues and profit margins through specific improvements in innovation, productivity, resource efficiency, and sustainability. Through the ***Advanced Manufacturing Business Advisory Services***, many enterprises will be able to modernize their facilities, machines and equipment, and operations and processes by learning how to utilize new Advanced Manufacturing tools and techniques. This will help open up new markets for innovative firms in the ***Advanced Manufacturing Business Accelerator*** and the ***Advanced Manufacturing Technology Industrial Park***, generating a virtuous cycle of widespread innovation, productivity, and growth among a wide range of industries in Minas Gerais.

One very useful and highly relevant model is the Manufacturing Extension Partnership program, operated by NIST and the US Department of Commerce, and involving state and local governments, private companies, universities and community colleges, and other key institutions. According to Dr. Phillip Singerman, NIST's Associate Director for Innovation and Industry Services, "The MEP is a

longstanding public/private partnership whose work leads manufacturers to new sales, new product development and market expansion, that in turn leads directly to the retention and creation of manufacturing jobs in the United States.” There are MEP Centers in all 50 states and in Puerto Rico. The MEP page on NIST’s website lists all of the centers and describes their effective work with many SMEs to generate efficiency and sustainability savings, innovative productivity improvements, and sales and income growth. Each of the MEP Centers provides case study examples of successful collaboration with manufacturers to improve their “bottom line.”

One such example is from the Delaware Manufacturing Extension Partnership (DEMEEP). DEMEEP worked closely with Eastern Industrial Services Inc. (EISI) and PTM Manufacturing, whose customers include DuPont, AstraZeneca, Verizon, Christiana Health Care System, and the University of Delaware. EISI and PTM obtained support from the Delaware Economic Development Office to increase resource efficiency, productivity, and competitiveness. They received substantial training and advice from DEMEEP on “lean manufacturing” to reduce seven waste streams: over-production, waiting time, transportation, processing, inventory, motion, and scrap. DEMEEP provided advice on how to streamline the production process, including compiling “meticulous value stream maps on such key processes as estimating and bidding jobs....In the new, more efficient system at the facility, EISI and PTM have formulated a unique process that helps identify and assign estimates in a way that balances resources and workloads.” The net result of DEMEEP’s advisory services is that EISI and PTM created 15 new jobs, cut estimating and bidding time by

20 percent, and significantly reduced environmental waste by recycling scrap materials.

Another good model for *Advanced Manufacturing Business Advisory Services* is True Market Solutions (TMS), a California-based company enabling small and medium-sized businesses in several US states to improve their profitability by increasing their resource efficiency and environmental sustainability. TMS was founded in 2010 by GUD Board member Elliot Hoffman, drawing from extensive business experience generating substantial cost savings, enhanced product quality, and greater market appeal through the sustainability of his successful San Francisco company, Just Desserts, as well as from similar experiences by Stoneyfield Farm, Ben & Jerry's, Seventh Generation, and other pioneering sustainability-oriented US firms. As these companies became more sustainable, they also grew larger and more profitable; in other words, they "got richer by becoming greener."

True Market Solutions coaches groups of businesses through Sustainability Circles, with each business working for six months to create a Sustainability Action Plan, and then implementing their plan with advice from TMS experts. Companies participating in Sustainability Circles save an average of more than \$200,000 annually, starting with the first year of implementing their action plans, through basic and inexpensive process and product improvements that help manage, conserve, recycle, and reuse natural resources, supplies, equipment, machines, and people much more efficiently.

Participating firms also gain new business opportunities, supplier relationships, and collaborative ventures with other companies in their Sustainability Circles.

Other models for the ***Advanced Manufacturing Business Advisory Services*** include the Benjamin Franklin Technology Partners of Pennsylvania and the Maryland Technology Development Corporation, which also help early stage technology companies obtain financing and connect them with business incubators and accelerators. In addition, The Natural Step in Sweden, and Enclude, affiliated with Triodos Bank in The Netherlands and Shorebank International in the US and UK, are among the organizations doing excellent work advising, training, and assisting SMEs in many countries, including Brazil, with sustainable, innovative, productive, and inclusive business management and financing solutions.

Advanced Manufacturing Skills Training

In the same way that the ***Advanced Manufacturing Business Advisory Services*** will offer education and training for manufacturers and suppliers, the ***Advanced Manufacturing Skills Training*** will provide vitally needed education and training for skilled jobs in the Advanced Manufacturing field. SENAI and FIEMG already have considerable expertise and a long track record of good experience providing basic and advanced skills training to workers for a wide variety of industrial occupations, and they should take the lead in operating the ***Advanced Manufacturing Skills Training***.

In addition to using the SENAI training center near CETEC as a venue for courses and training programs, the other SENAI facilities in Belo Horizonte and around the state also can be effectively utilized for this purpose. Some of the training can take place at the CETEC site, in collaboration with the ***Advanced Manufacturing Sustainable Innovation Center, Advanced Manufacturing Business Accelerator, Advanced Manufacturing Technology Industrial Park***, and the ***Advanced Manufacturing Business Advisory Services***. Employers will be able to interact with instructors to help design the best possible education and training programs, and the graduates of these courses and programs can then become a high-quality skilled pool of well-trained workers who can be hired to work for Advanced Manufacturing companies in Minas Gerais throughout the entire value chain. Essentially, the ***Advanced Manufacturing Sustainable Innovation Strategy*** will be strengthening and increasing the statewide skilled labor supply in what will become rapidly growing sectors of the Sustainable Innovation economy in Minas Gerais.

The new campus of the State University of Minas Gerais (UEMG) under construction in walking distance from CETEC presents an excellent opportunity to directly involve UEMG in ***Advanced Manufacturing Skills Training***. CETEC-SENAI-FIEMG can work with UEMG to develop certificate and degree programs in various aspects of Advanced Manufacturing.

UEMG can learn from other similar efforts elsewhere, such as the Green Manufacturing Specialist Certificate program offered by Purdue University's Manufacturing Extension Partnership Center and Technical Assistance Program in Indiana, working together with the Society of Manufacturing Engineers, offering workshops on Energy Management, Material Use and Solid Waste Management, Water Supply and Waste Management, Air Emissions and Climate Impact, Managing Chemical Use and Hazardous Waste, and Environmental Business Management. This program provides its courses through community colleges, professional associations, labor unions, utility companies, and economic development organizations.

Another interesting model is the 79/Seventy Manufacturing Certification Program operated by the Career and Technology Education Centers (C-TEC) in Ohio. This trade-specific training program is offered at the Central Ohio Aerospace and Technology Center, with Boeing, Goodrich, and other major local manufacturers participating in the 79/Seventy Advanced Materials Corridor initiative. These manufacturers help identify and provide the training materials, and ensure that the graduates of the certification program are directly connected with employment opportunities. For example, Goodrich's quality control manager teaches a course on his area of expertise. Manufacturers who teach in this program also bring the students to their factories.

Graduates of Ohio's 79/Seventy Manufacturing Certification Program also are eligible for the National Career Readiness Certificate recently developed by the National

Association of Manufacturers, The Manufacturing Institute, and ACT (American College Testing). This newly designed Manufacturing Skills Certification System, also involving the Manufacturing Skills Standards Council, National Institute for Metalworking Skills, American Welding Society, and Society of Manufacturing Engineers, can serve as an instructive model for the work of the ***Advanced Manufacturing Skills Training***. This follows one of the key recommendations of the Advanced Manufacturing reports for the US President. One of the six key strategies for “Securing the Talent Pipeline” is to “Develop Partnerships to Provide Skills Certification and Accreditation.”

The ***Advanced Manufacturing Skills Training*** also can work with the E.E. Professor Fontes Technical High School near the CETEC site to offer certificate programs in Advanced Manufacturing. Currently 1,200 students at this industrial education center are being trained in mechanics, electronics, computers, and related fields. The school may be able to draw some lessons from Chicago’s Austin Polytechnical Academy (APA), founded in 2007 by the Chicago Manufacturing Renaissance Council to provide state-of-the-art curriculum and instruction focusing on scientific, technological, engineering, mathematical, and mechanical skills needed in modern manufacturing. The APA works closely with the 60 industrial partners on its Manufacturing Advisory Committee, and the Center for Labor and Community Research, to offer practical hands-on manufacturing experiences such as partnering with a local brewery to produce a soda from inception to final product. APA has established a Manufacturing and Technology Center to teach students how to operate

manual and digital milling machines, and 73 students already have completed certification programs offered by the National Institute for Metalworking Skills in metal forming and in machine maintenance, service, and repair. This entry-level credential certifies that these students have the basic skills in operations, machining, inspection, and safety necessary for full-time employment in manufacturing industries.

Advanced Manufacturing Sustainable Innovation Zone

One of the special opportunities of the **Advanced Manufacturing Sustainable Innovation Strategy** is to create CETEC and the immediate surrounding area as a very special place, a worldwide destination. To become such an international magnet, being as innovative and sustainable as possible must become a vital part of the vision and the reality. Innovation and sustainability will run through the research, development, and production, the teaching and training, the entrepreneurship and the hard work, and they also can be a very attractive aspect of the look, feel, and daily life and activities in an ***Advanced Manufacturing Sustainable Innovation Zone***.

CETEC's location in the Horto neighborhood of Belo Horizonte is a major physical, economic, and cultural asset, which is why the new FAPEMIG headquarters and the new UEMG campus will become immediate neighbors of CETEC. The area is attractive and interesting, served by two major Metro train stations, Jose Candido da Silveira, and Santa Ines. Last year the Secretary of State for Science, Technology, and

Higher Education officially declared this area as a “City of Science and Knowledge,” recognizing and celebrating the reinvestment by SENAI and FIEMG in CETEC, the new UEMG campus, the new FAPEMIG headquarters, and all of the other institutions: Biominas Habitat, EPAMIG, SERPRO, SENAI, Instituto Agronomico, Natural History Museum, UFMG Botanical Gardens, Plug Minas, and E.E. Professor Fontes. Secretary Narcio Rodrigues recruited professional architect, former Curitiba Mayor and Parana Governor, and GUD Vice Chair Jaime Lerner to advise on urban design to improve the area’s quality of life and vibrancy. This approach to sustainable urban design and mixed-use development can include promoting walkability and public transit, attracting stores and services, and building community and commercial amenities.

GUD recommends that CETEC-SENAI-FIEMG organize a local green transportation system, the Sustainable Shuttle Service, that will involve solar-powered multiple-passenger low-speed electric vehicles running in three continuous loops: 1) the first route would run frequently back-and-forth between CETEC and the Jose Candido da Silveira Metro Station; 2) the second route would run continuously between SENAI and the Santa Ines Metro Station; 3) the third route would circle around the City of Knowledge stopping at all of the major institutions and activity centers. In addition, we suggest that CETEC become the host venue for an original large metal sculpture honoring the spirit of Sustainable Innovation, specially designed by the well-known Mineira artist, Virginia Ferreira.

In the spirit of the recent Sustainable BH Seal certificate awards program by the Mayor of Belo Horizonte for green buildings, especially for buildings substantially reducing energy and water consumption, including FIEMG's new headquarters, and the city's recent hosting of the World Congress of ICLEI-Local Governments for Sustainability, the "City of Science and Knowledge" around the CETEC-SENAI-FIEMG site can become a major international destination showcasing state-of-the-art features of Sustainable Innovation in developing and managing urban communities. Such activities involve renewable energy production, energy and water conservation and efficiency, reducing waste streams, materials recycling and reuse, and many other creative solutions, such as solar and green rooftops, solar canopies in parking lots, wind power, and solar LED lighting.

The ***Advanced Manufacturing Sustainable Innovation Zone*** in Belo Horizonte can join together with other well-known global urban Sustainable Innovation best practices, including Vauban in Freiburg, Germany; Songdo in South Korea; Hammarby Sjostad in Stockholm, Sweden; Masdar City in Abu Dhabi, UAE; Totnes in the UK, birthplace of the international Transition Towns movement; and the EcoDistricts of Portland, Oregon in the US, among many others. EcoDistricts are rapidly spreading in the US, Canada, Australia, Europe, and elsewhere. They can provide important lessons for Minas Gerais.

The ***Advanced Manufacturing Sustainable Innovation Zone*** can be a magnet for economic and community development, job creation, business and income growth,

and a higher quality of life for the neighborhood and its workers, residents, and visitors. It could be a major tourist attraction for Belo Horizonte and Minas Gerais. And finally, it can become a replicable model for the rest of Minas Gerais, including development in the North Vector and in the West, South, and East Vectors of the Belo Horizonte Metropolitan Region.

Future Initiatives: Global Branding and Gifts of Nature

Two future initiatives for FIEMG to consider are **Global Branding** and **Gifts of Nature**. **Global Branding** is needed to create and market a new international image for Belo Horizonte and Minas Gerais as a world center for Sustainable Innovation, with the Advanced Manufacturing activities in and around CETEC being one of the centerpieces of these public relations efforts. Other actions can include international marketing of:

- Minas cheese, including pao de queijo,
- Minas coffee,
- Minas cachaca,
- Minas fashion and design,
- Mineiro culture, including a potential Estrada Real Bicycle Race as a new February event in the annual worldwide professional competition circuit that culminates with the Tour de France.

The other potential initiative – **Gifts of Nature** – involves promoting Sustainable Innovation by identifying higher value-added and advanced technology uses of traditional resources. New uses for minerals include innovative technologies like lithium-ion batteries, and titanium for medical prostheses and orthopedic implants. New innovative uses for trees and plants include developing insulin and other medicinal substances and pharmaceuticals.

Conclusion

This report has outlined for FIEMG a comprehensive **Advanced Manufacturing Sustainable Innovation Strategy** in partnership with CETEC and SENAI. GUD believes that this will be one of the most effective economic development leadership activities for FIEMG, and that it can enable Minas Gerais to take major steps forward on the path of “Innovation-Led Economic Transformation.”