



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Basic Research Needs for Transformative Manufacturing

Basic Energy Sciences Advisory Committee
July 12, 2019

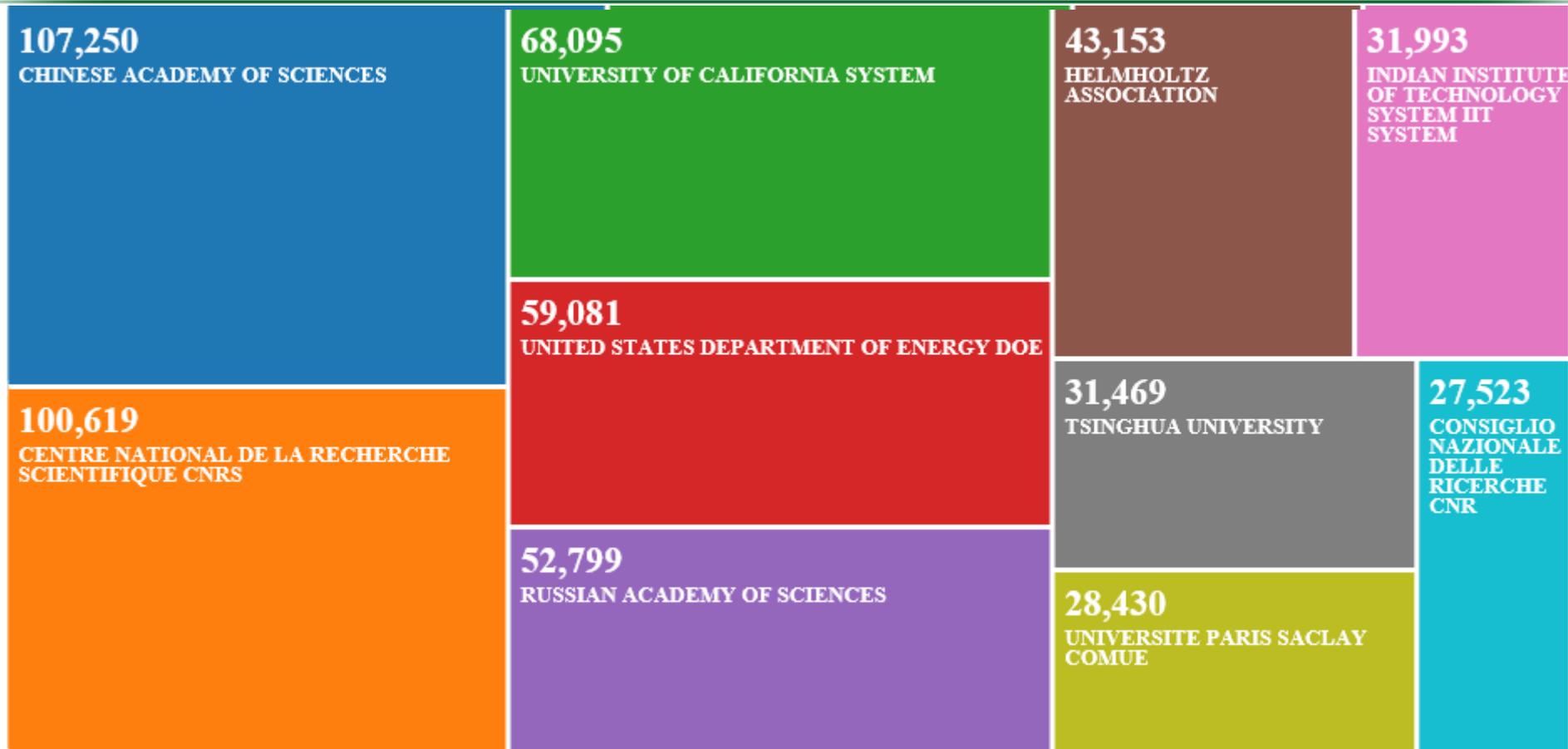
Linda Horton
MSE Division Director
Basic Energy Sciences, Office of Science

Manufacturing Facts and Stats

- Manufacturing is a broad and complex field, including traditional and advanced materials fabrication, chemical industries, component assembly, etc.
- The U.S. manufacturing sector uses approximately 25% of the nation's energy, thus energy is a significant cost in manufacturing.
- Manufacturing represents nearly 12% of the GDP of the United States (<https://tradingeconomics.com/united-states/gdp-from-manufacturing>)
- Internationally, the United States ranks second to China in manufacturing. China became the leading country in 2010. (<https://fas.org/sgp/crs/misc/R42135.pdf>)
- The United States has 12.75 million manufacturing jobs, ~ 8.5 percent of the workforce. (<https://www.thebalance.com/u-s-manufacturing-what-it-is-statistics-and-outlook-3305575>)
Manufacturing employment fell by 25% from 1990 to 2016. (<https://fas.org/sgp/crs/misc/R42135.pdf>)
- For applied research and technology, there are several national initiatives and programs – including Manufacturing, USA (<https://www.manufacturingusa.com/>), a public-private network of 14 manufacturing institutes
 - 4 managed by DOE-EERE Advanced Manufacturing Office
 - Research and development collaborations to solve technology challenges and train people on advanced manufacturing skills



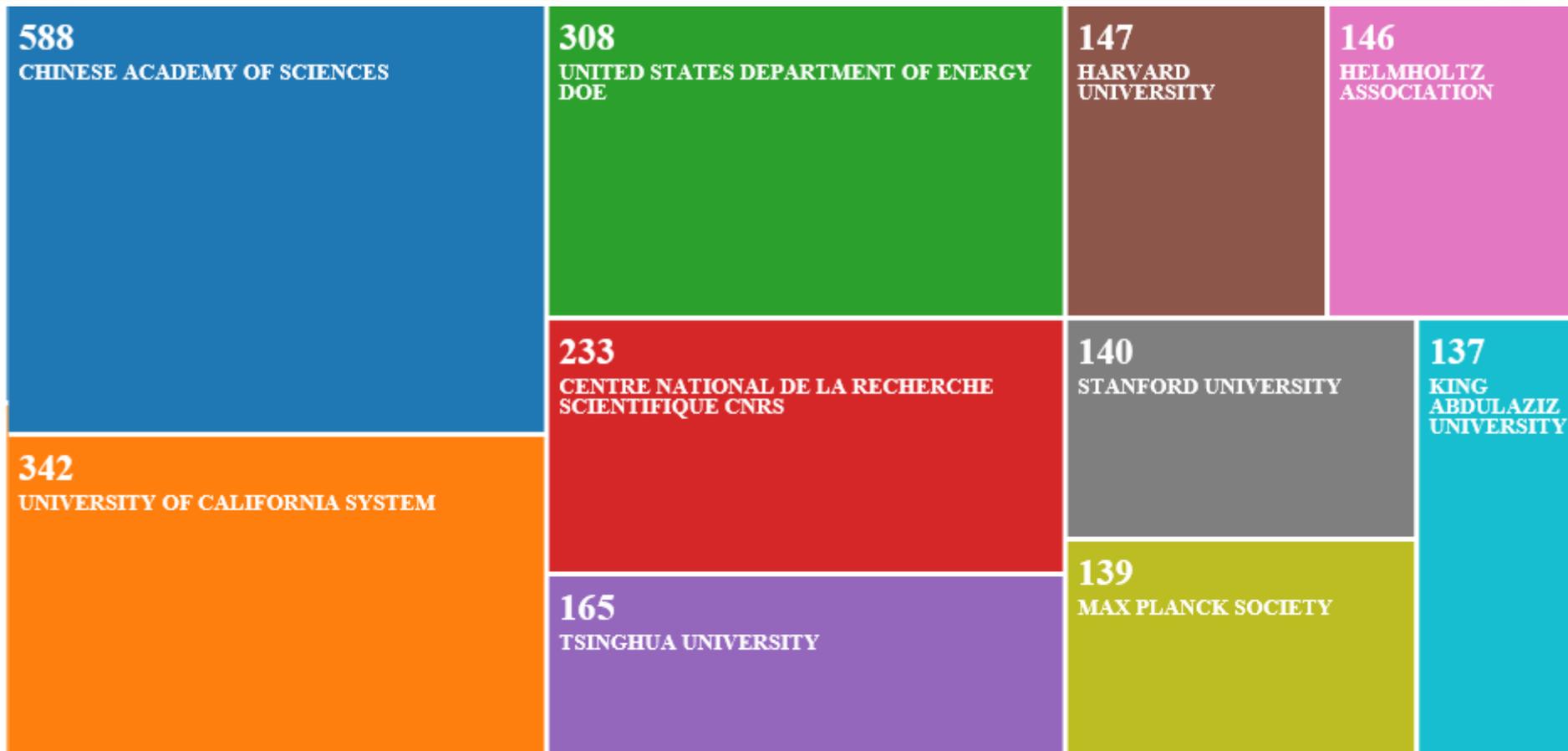
Manufacturing, Processing, Fabrication – Web of Science Analysis



- 3.9 M publications for key words “manufacturing OR processing OR fabrication”; “health” related topics removed; images limited to the largest categories – there are many more!
- ~22% US, >22% Europe, 20% China
- 1.5% DOE – the opportunity



Web of Science Analysis: Highly Cited for FY 2016, 2017, 2018



Web of Science citation analysis requires less than 10,000 records – this analysis shown above is for the high cited papers for 2016-18 -- ~6,600 publications

Organization analysis shows DOE for 308 of these papers, nearly 5%

BRN Workshop on Transformative Manufacturing



Workshop Chair: Cynthia Jenks (ANL)

Co-chairs: Jennifer Lewis (Harvard)
Ho Nyung Lee (ORNL)

Workshop Date: December 10-12, 2019

Location: Rockville Hilton

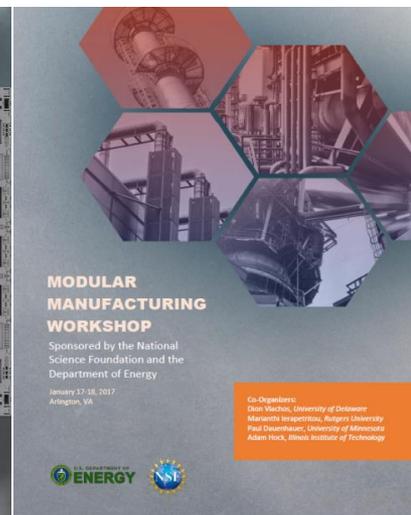
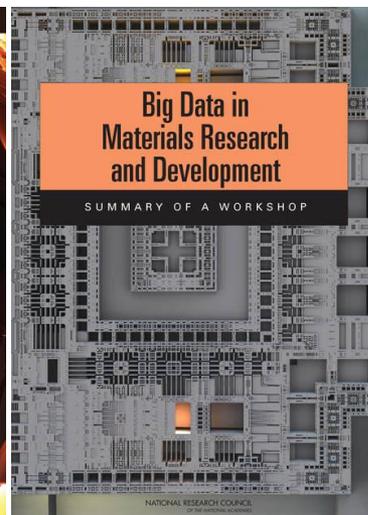
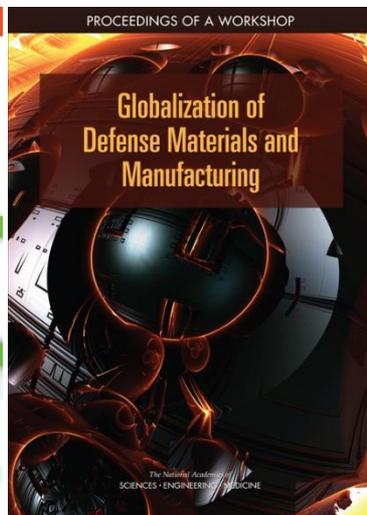
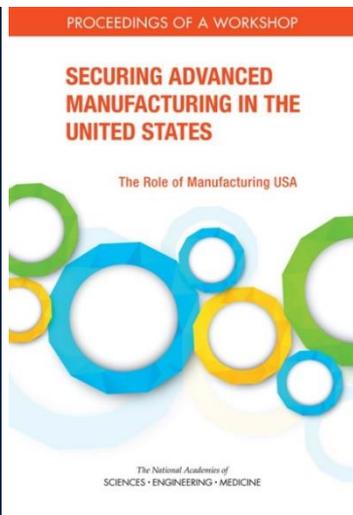
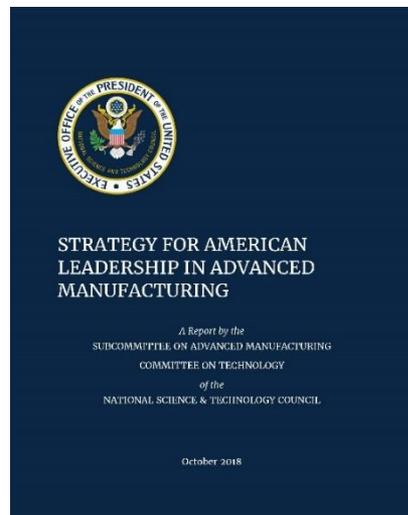
Background and Charge:

- Manufacturing is an emphasis area for DOE: Energy use in primary industries and national priorities related to other sectors
- To date, BES Basic Research Needs workshops have not directly assessed barriers and opportunities related to future manufacturing
 - Microelectronics BRN included one dimension, with a follow-on round table on lithography in planning stages
 - Foundational discussion in other BES reports including the Synthesis Science BRN, Extreme Environments BRN, Catalysis BRN, Polymer Upcycling roundtable
- Identify fundamental research to overcome scientific and technical barriers for innovations that would transform manufacturing in the future
 - Working with the DOE EERE Advanced Manufacturing Office to establish a status document for the participants



National Academy, OSTP and DOE Reports Highlight Aspects of Manufacturing

- Many assessments and reports are available – largely technology focused
- Relevant discussions and recommendations:
 - Develop and transition new manufacturing technologies
 - Allow for flexibility in operation, improve energy efficiency
 - Data issues in manufacturing
 - Develop physics-based models across scales
 - International awareness
 - Workforce issues



Science Could Provide Solutions to Manufacturing Roadblocks

Examples

MANUFACTURING ROADBLOCKS

- Poor device performance
- Material defects introduced upon scaling
- Non-linear scaling relationships
- Unexpected effects during processing
- Poor quality products

SCIENCE SOLUTIONS

- Control atomic-level interactions and reactivity
- Develop precision material synthesis and crystal growth methods
- Understand fluid dynamics and non-equilibrium chemistry
- Develop synthesis simulation methods across scales
- Design catalysts that are robust to commodity chemical impurities

Example: Overcoming Scaling Nonlinearity

Batch reaction scaling

- Scaling up of reactions discovered in the laboratory is, for the most part, an art
- Basic research needed to improve our understanding of non-equilibrium chemical synthesis



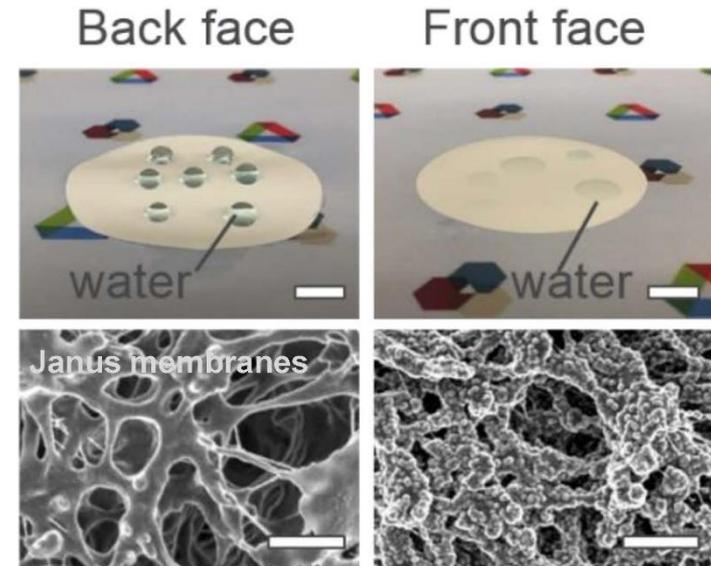
Understanding non-equilibrium processes that become important when scaling up would decrease time to market



Example: Improving Manufacturing Quality

Membranes and sorbents with engineered interfaces

- Precise control of interfacial properties in porous substrates can enable efficient filtration and sorption
- Scaling-up requires basic understanding of substrate-precursor interactions



Basic understanding of precursor interactions with porous substrates would inform efforts to scale these technologies

EERE Advanced Manufacturing Office View – Manufacturing Technical Areas



BRN workshop will consider enabling science that could support many of EERE AMO's focus areas

Preliminary Panel Topics for the Workshop

- Precision Synthesis Science
 - Chemistry, materials, biomimetic; Composites, heterogeneous building blocks
- Processing and Scale-Up Science
 - From lab-scale towards larger quantities and complexity
 - Beyond synthesis to include secondary treatments
- System Integration Science
 - Hybrid or integrated manufacturing processes; Components, modular assemblies
 - Decentralized chemical processes
- Sustainable Manufacturing
 - Full life cycle manufacturing; Substitutes
 - Energy efficient processes; Alternatives to traditional heating
- Digital Manufacturing
 - Rapid in situ characterization / closed feedback control; Qualification (codes)
 - Multiscale computational algorithms & predictive design tools
- Crosscutting topics
 - Defects, interfaces, heterogeneity
 - Theory, modeling, AI, data, machine learning, etc.

Questions

