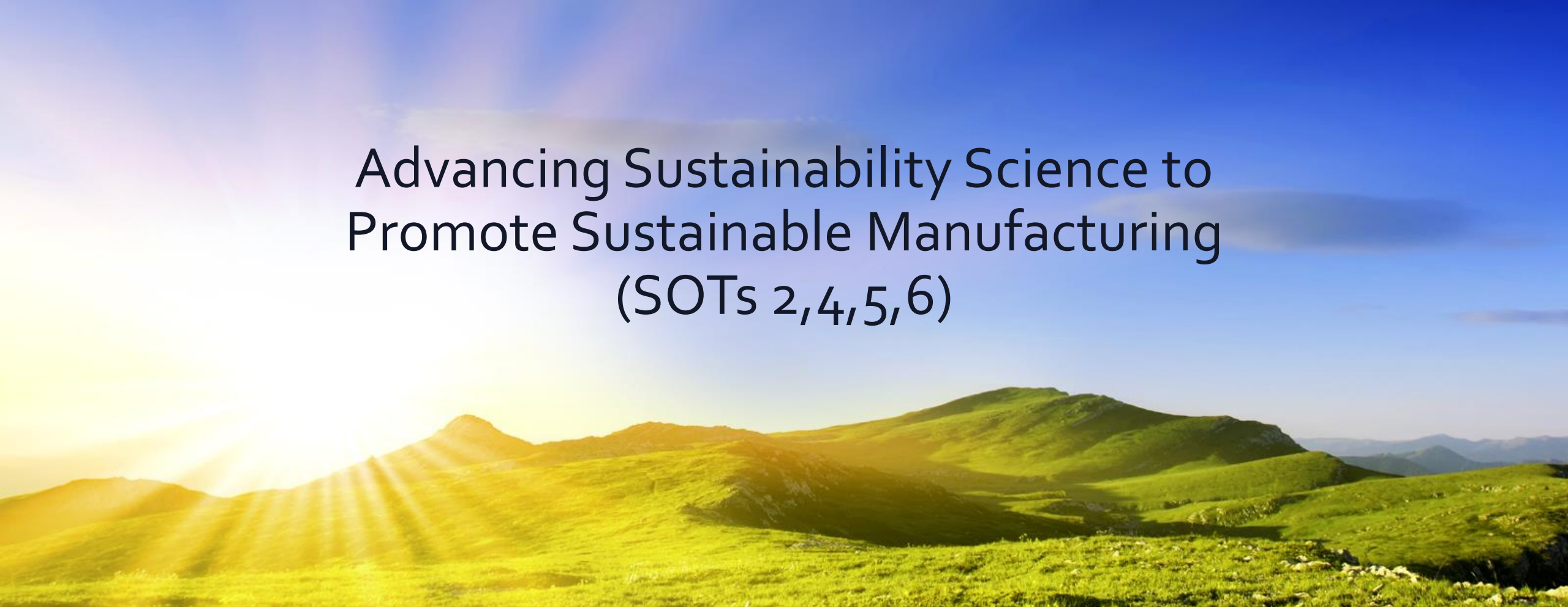


Advancing Sustainability Science to Promote Sustainable Manufacturing (SOTs 2,4,5,6)

NAS/NAE/NAM Workshop on the Transition toward Sustainability after 15 Years
Newport Beach, CA (January 14, 2016)

Steve Skerlos
Aruthur F. Thurnau Professor of Mechanical Engineering, Civil and Environmental Engineering
Co-Director, UM Center for Socially Engaged Design & Director, Sustainability Education Programs
University of Michigan

Is Manufacturing Environmentally/Socially/Economically Important?

According to the Dept. of Commerce (2012):

- $1.65 Trillion value in U.S.
- >300,000 facilities
- 36% of Industrial CO2 Emissions
- 20% of U.S. Energy Consumption
- 6B tonnes of solid waste per year
- Contributor to Criteria Air Pollutants
- Contributor to Water Pollution / Consumption

Sustainable Manufacturing

"…the creation of manufactured products using processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound"

US Department of Commerce

Necessary Conditions:

Sustainable Manufacturing Systems

(Skerlos, 2015)

THE ANSWERS TO ALL THESE QUESTIONS MUST BE **FAVORABLE**

1. does the system make significant progress toward an unmet and important environmental or social challenge?
2. is there potential for the system to lead to undesirable consequences in its lifecycle that overshadow the environmental/social benefits?
3. is the system likely to be adopted and self-sustaining in the market?
4. is the system so likely to succeed economically that planetary or social systems will be worse off?

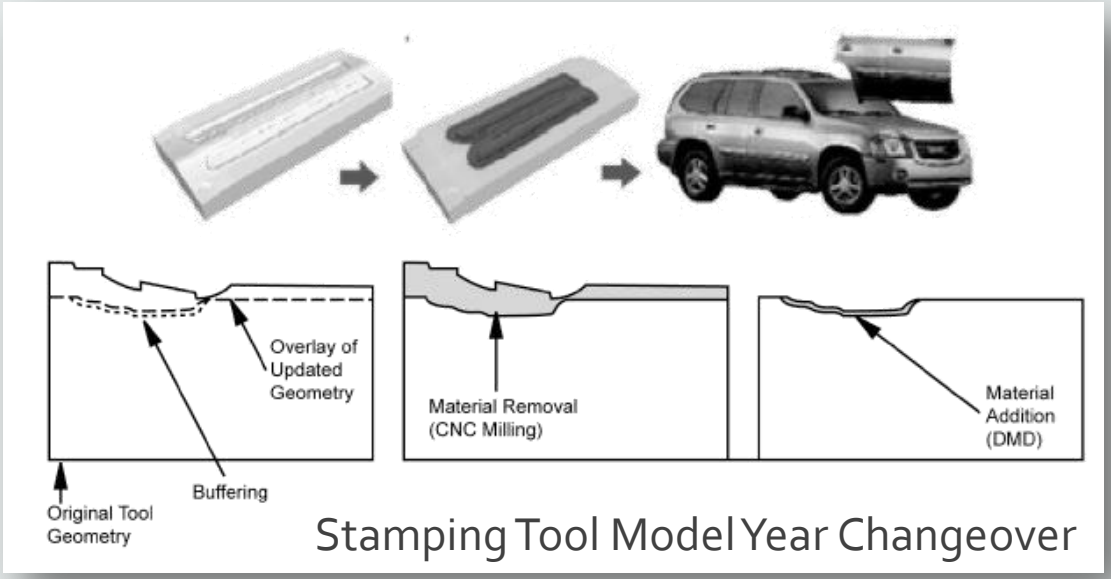
Available online at www.sciencedirect.com
ScienceDirect
Journal of Cleaner Production 15 (2007) 932–943
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Environmental aspects of laser-based and conventional tool and die manufacturing

W.R. Morrow [a], H. Qi [b], I. Kim [b], J. Mazumder [b], S.J. Skerlos [a,*]

[a] Department of Mechanical Engineering, Environmental and Sustainable Technologies (EAST) Laboratory, The University of Michigan at Ann Arbor, 2250 GG Brown Building/2350 Hayward Street, Ann Arbor, MI 48109-2125, USA
[b] Department of Mechanical Engineering, Center for Laser Aided Manufacturing (CLAIM), The University of Michigan at Ann Arbor, 2250 GG Brown Building/2350 Hayward Street, Ann Arbor, MI 48109-2125, USA

Evaluating Direct Metal Deposition with Respect to Necessary Conditions of Sustainable Manufacturing



Stamping Tool Model Year Changeover

- 10 ton tool converted via minimal combined additive/subtractive operations.
- Significant greenhouse gas emissions reductions and avoidance of HAPs
- Not to mention: $250K and 35% lead time reduction.

Available online at www.sciencedirect.com

ScienceDirect

Journal of Cleaner Production 15 (2007) 932–943

Journal of Cleaner Production

www.elsevier.com/locate/jclepro

ELSEVIER

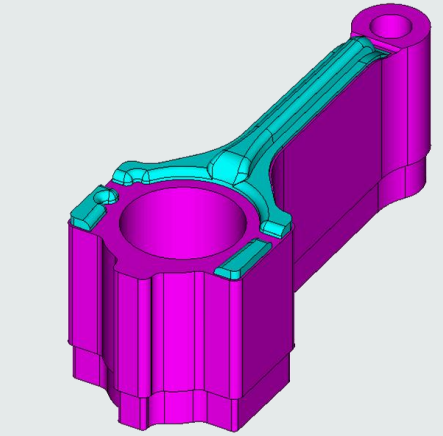
Environmental aspects of laser-based and conventional tool and die manufacturing

W.R. Morrow [a], H. Qi [b], I. Kim [b], J. Mazumder [b], S.J. Skerlos [a,*]

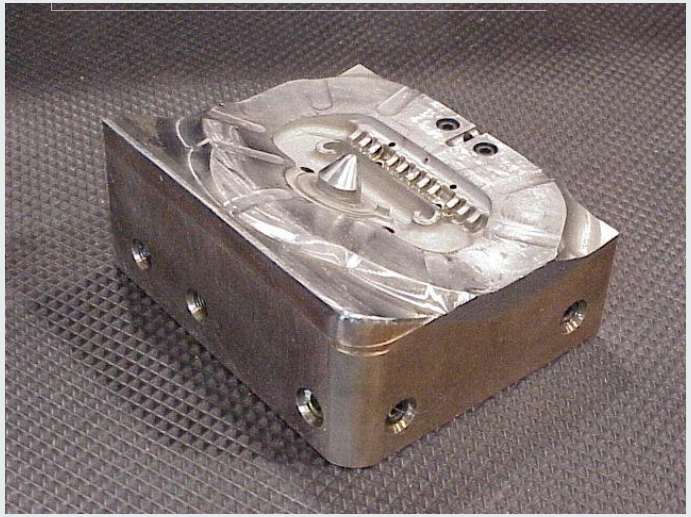
[a] Department of Mechanical Engineering, Environmental and Sustainable Technologies (EAST) Laboratory, The University of Michigan at Ann Arbor, 2250 GG Brown Building/2350 Hayward Street, Ann Arbor, MI 48109-2125, USA

[b] Department of Mechanical Engineering, Center for Laser Aided Manufacturing (CLAIM), The University of Michigan at Ann Arbor, 2250 GG Brown Building/2350 Hayward Street, Ann Arbor, MI 48109-2125, USA

Evaluating Direct Metal Deposition with Respect to Necessary Conditions of Sustainable Manufacturing



- Application of Highly Wear Resistant Alloys
  - Tool life increases by factor of 3.
  - Manufacturing system productivity increases by 5%.
  - Air/water emissions reduced by millions of pounds per year.



- Mixed Material Molds
  - 25% faster production than currently possible.
  - Electricity consumption reduced by 125,000kW*hr
  - CO2 reductions by 20 tons.
  - This process raises major concerns, however, about recycling

SOT 5: How can advances in other frameworks for environmental decision making inform advances in and be integrated with sustainability manufacturing?

The major challenge for sustainable manufacturing is the integration of sustainability context into decision making regarding product, process, and policy

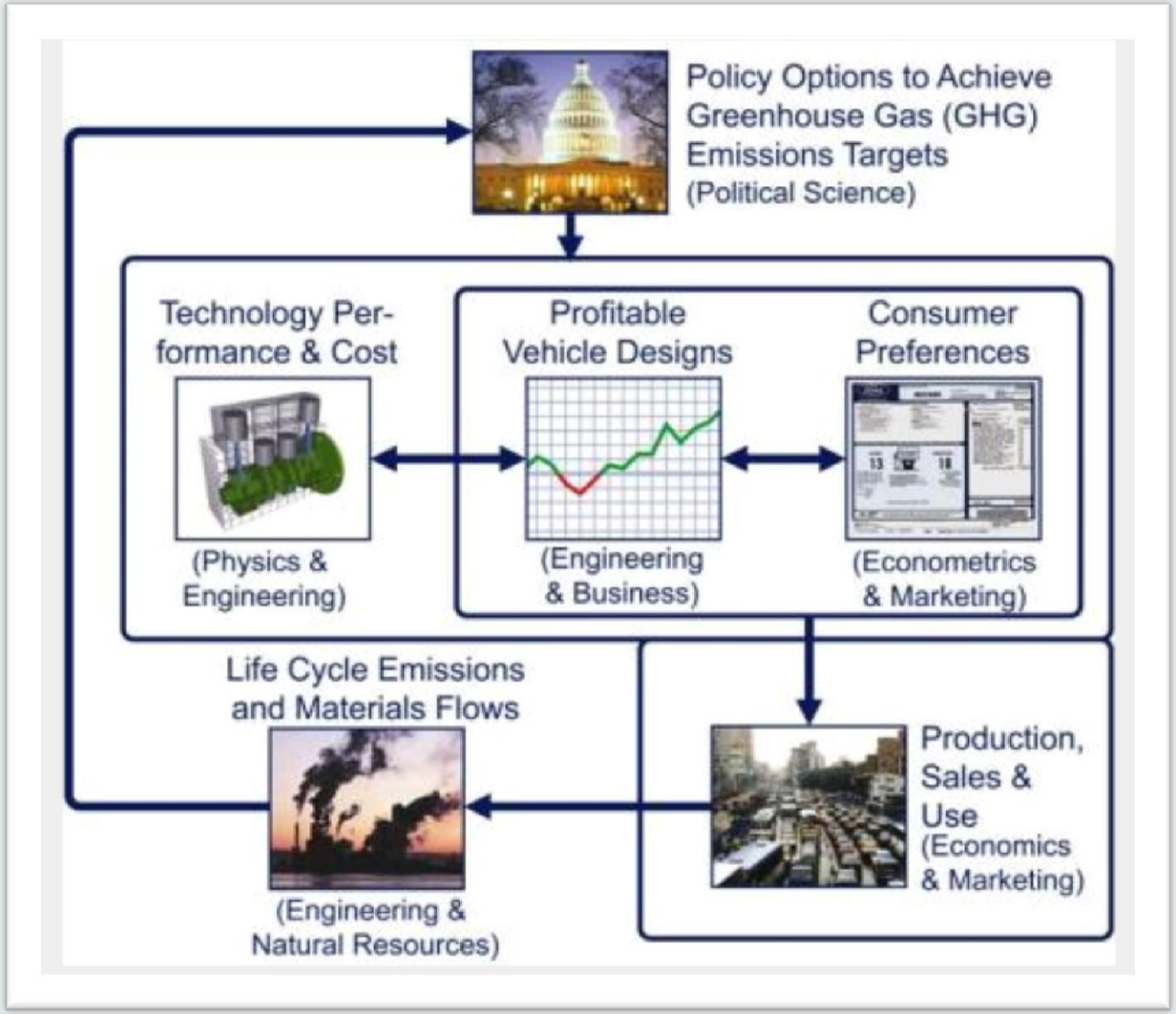
This requires new decision frameworks (SOT 5) that integrate:

- Models of regulated market behavior that are inclusive of consumer behavior
- {Environmental, Social, Cost} Life Cycle Assessment Models
- Local/regional impact models of manufacturing supply chains

SOT 5

Evaluating Necessary Conditions for Sustainable Manufacturing *Systems*

Consequential Life Cycle Assessment with Market Driven Design

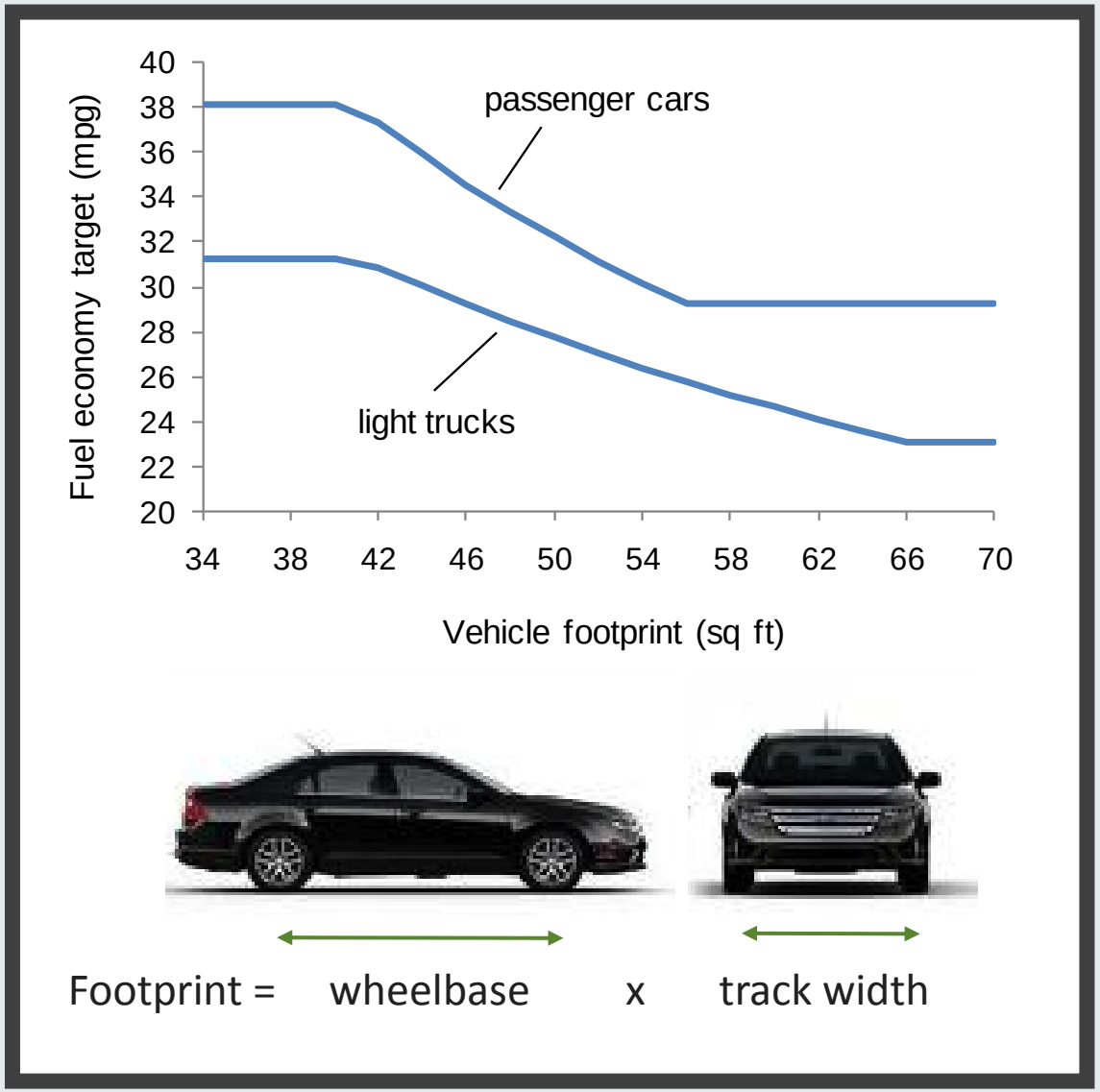


$2M National Science Foundation Grant / CMMI: 0628162

MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

Could higher fuel economy standards (CAFE) increase vehicle size?

- Automakers that sell vehicles with larger footprint are assigned lower fuel economy targets
- Could this create an incentive for firm's to **increase** the size of their vehicles?
- Traditional methods cannot test this hypothesis



Thanks:
Prof. Katie Whitefoot (CMU)

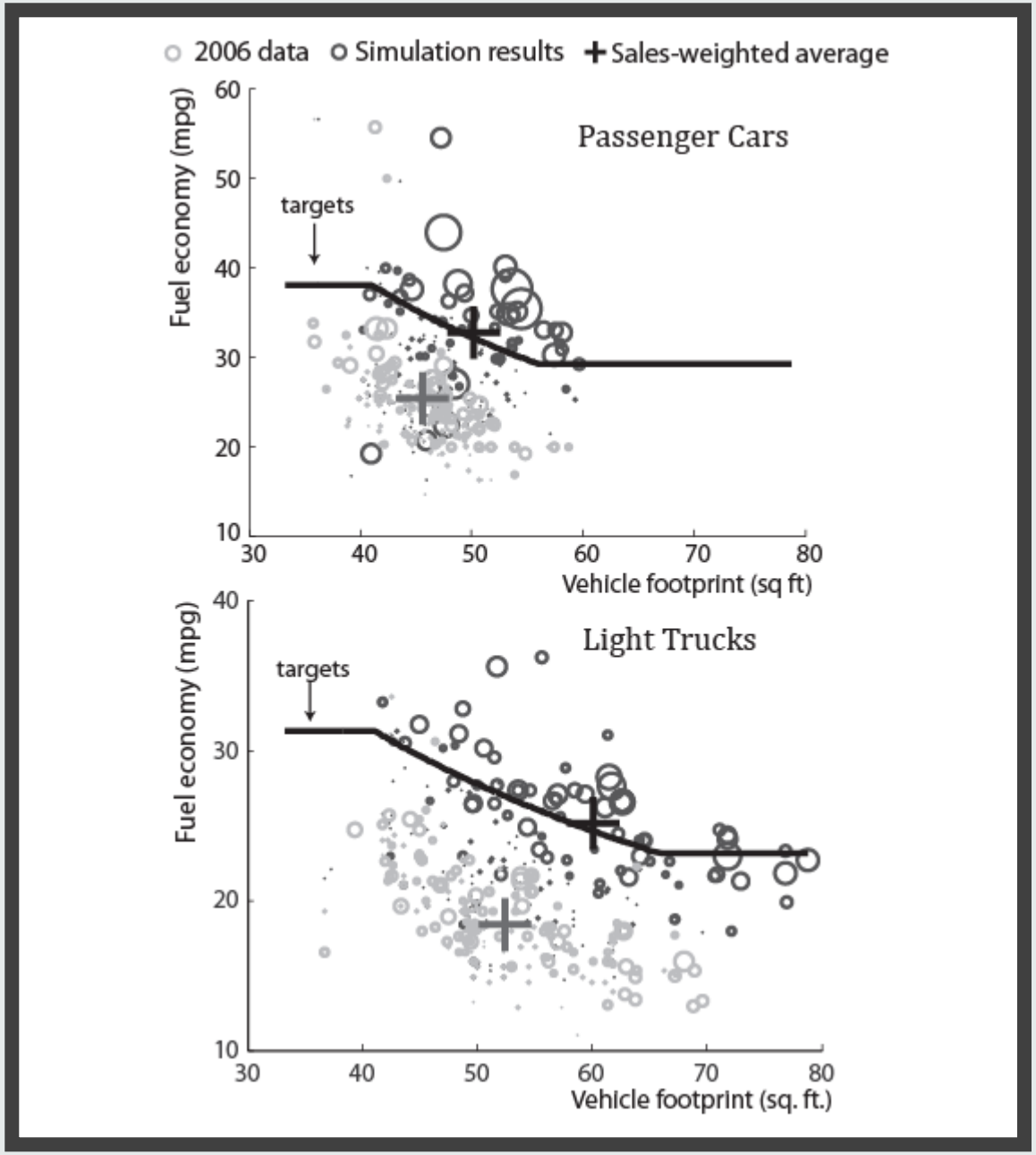
Results suggest divergence of passenger car and light truck size

- Compliance cost to firms from light truck standard is higher than passenger car standard
- Incentive to increase footprint is larger for light trucks
- May cause safety risk because spread of vehicle size is larger (NAS 2002, NHTSA 1997)

Design incentives to increase vehicle size created from the U.S. footprint-based fuel economy standards

Kate S. Whitefoot [a,*], Steven J. Skerlos [a,b]

[a] Design Science, University of Michigan, Ann Arbor, MI, United States
[b] Mechanical Engineering, University of Michigan, Ann Arbor, MI, United States



FUEL ECONOMY:

New standards could spur production of more SUVs -- study

Jason Plautz, E&E reporter

Greenwire: Wednesday, December 21, 2011

The Obama administration's push to boost automotive fuel efficiency might contain a loophole big enough for a fleet of new SUVs, according to a new study by University of Michigan researchers.

The decision to shun a flat nationwide average in favor of a so-called footprint standard will allow larger cars to meet a weaker fuel economy target than smaller cars, the study says.

While new SUVs and trucks would be more fuel-efficient than their predecessors, researchers said, the overall effect would be to drag down the goal of making automakers meet a 54.5 mpg standard by 2025.

Popular Mechanics

http://www.popularmechanics.com/cars/news/fuel-economy/study-cafe-standards-could-mean-bigger-cars-not-smaller-ones

Study: CAFE Standards Could Mean Bigger Cars, Not Smaller Ones

The Obama administration's aggressive new fuel-economy standards—54.5 mpg average across the fleet by 2025—would seem to suggest cars are going to get much smaller, and hybrids more prevalent. But a catch in the rules—along with consumer demand for big cars—means the opposite might become true.

BY ERIK SOFGE

President Barack Obama speaks on fuel efficiency standards for model years 2017-2025 cars and light trucks July 29, 2011 at the Walter E. Washington Convention Center in Washington, DC.

Mandel Ngan/AFP/Getty Images

The automotive industry is bracing for its biggest engineering challenge in decades. The pending changes to federal Corporate Average Fuel Economy (CAFE) regulations call for a stunning 5 percent increase in fuel economy per year, culminating in a fleet average of 54.5 mpg by 2025. Common sense—and a fair amount of industry experts—would indicate that cars are about to get smaller, or at the very least stop getting bigger, and that SUVs will continue their steady decline in popularity.

According to a new paper from the University of Michigan College of Engineering, however, CAFE will likely have the opposite effect: It will lead to an increase in size for most vehicles, and more SUVs and light trucks on the road.

The Washington Post | PostTV | Politics | Opinions | Local | Sports | National | World | Busin

Full Archive

Loophole in new fuel rules could lead to bigger cars

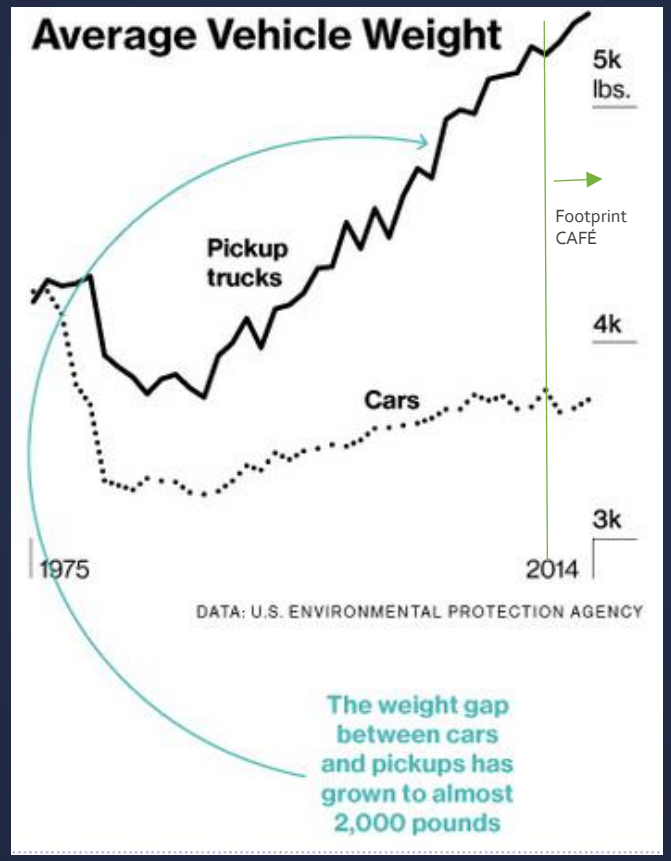
Posted by Brad Plumer at 02:36 PM ET, 12/14/2011

One of the odder side-effects of the old fuel-economy standards for vehicles, first introduced in 1975, is that they ushered in an era of bigger, heavier automobiles in the United States. The Corporate Average Fuel Economy standards had two sets of rules — one for cars and a looser one for light trucks. Automakers quickly realized that they could build more SUVs and light trucks (as well as cars designed to meet light-truck standards, like the Subaru Outback) in order to sidestep the rules. All in all, CAFE standards *did* help constrain gasoline consumption, but as economist Christopher Knittel has found, their effects were blunted by these "bigger car" loopholes.

And so, in the past few years, Congress and the Obama administration have drawn up a new, stricter batch of CAFE standards that are supposed to avoid these pitfalls and boost fuel economy to 54.5 miles per gallon by 2025. To that end, the light-truck loophole was shuttered in 2007. Yet according to a new study from University of Michigan researchers Kate Whitefoot and Steven Skerlos, automakers probably will still have incentive to churn out bigger, hulking cars. And, once again, this loophole could undermine the regulation's effectiveness.

Whitefoot and Skerlos start off by observing that the new fuel-economy standards for 2011 to 2016 are "footprint-based," which means that larger vehicles have lower fuel-economy targets. They then tried to game out how automakers would respond to these rules by running hundreds of different model simulations, looking at various tradeoffs, including the cost of modifying vehicle footprints, the cost of complying with stricter fuel rules, shifts in consumer demand, and so forth. And what the researchers found was that, by and large, it would be more profitable for automakers to keep building larger and larger vehicles.

CAFE standards increased the weight distance between large and small vehicles



http://www.bloomberg.com/news/articles/2015-02-19/bigger-pickups-are-result-of-change-in-fuel-standards

BloombergBusiness | News | Markets | Insights | Video

Watch Out for That Truck!

A change in fuel standards has led to even heavier, more dangerous pickups

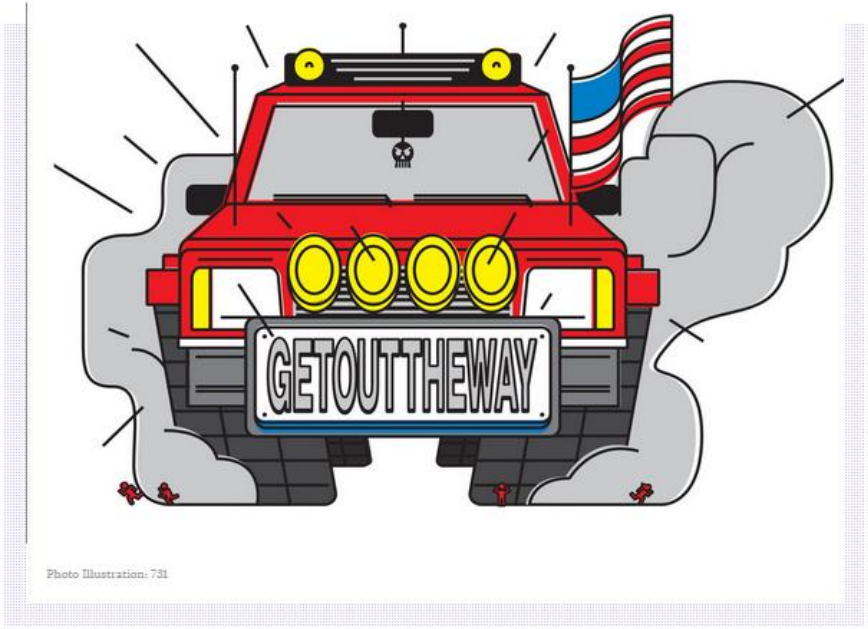


Photo Illustration: 731

Don't Miss Out —

Follow us on:

by
Peter Coy

5:01 PM EST
February 19, 2015

Last July 7 a Nissan Titan pickup truck traveling on a state highway south of Tivoli, Texas, collided head-on with a Honda Civic. All the occupants in both vehicles were wearing seat belts, police said. But the pickup truck, weighing about 5,000 pounds, had physics on its side. The five occupants of the Titan escaped with injuries, but all four occupants of the Civic, which weighs about 2,700 pounds, were killed.

The bottom line: *Fuel-efficiency standards free automakers to sell bigger pickups that are likelier to cause fatalities in car crashes.*

http://www.umtri.umich.edu/what-were-doing/news/fuel-economy-down-last-year

Fuel economy down last year

JANUARY 9, 2016

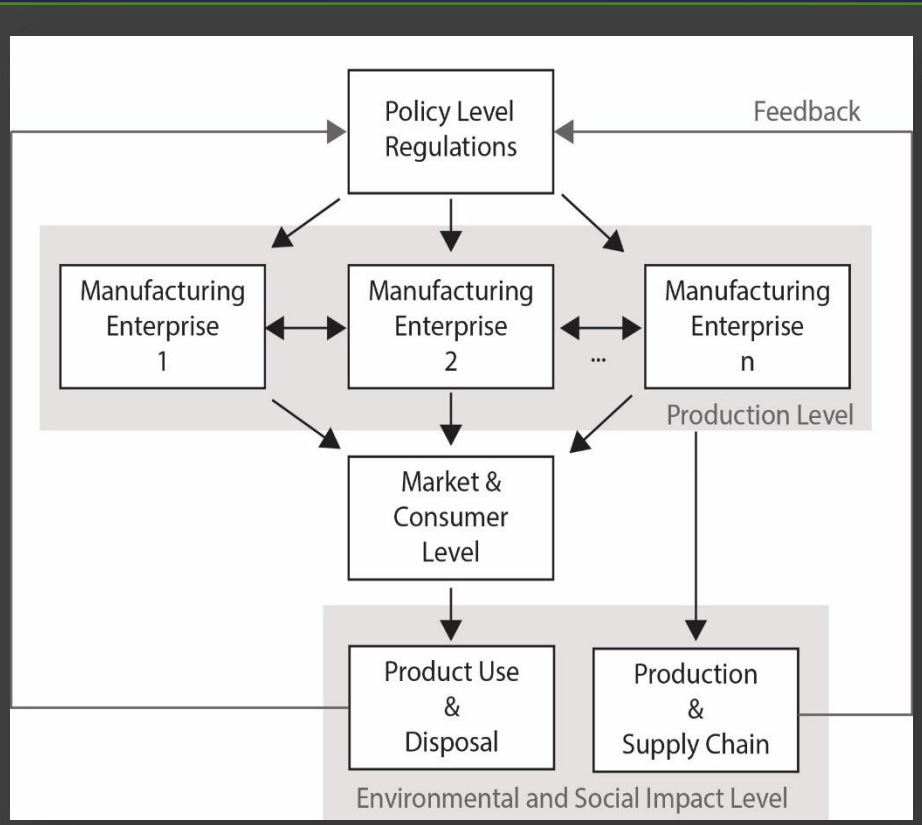
Fuel economy of vehicles sold in calendar year 2015 fell slightly compared to 2014. The average fuel economy (window-sticker value) of new vehicles sold in the U.S. last year dropped to 25.3, down 0.1 from the value for the vehicles sold in 2014. During December, fuel economy was 24.9 mpg—down 0.2 mpg from the revised value for November.

"This decline likely reflects the continuing drop in the price of gasoline in December, and the consequent increased sales of pickup trucks, SUVs and crossovers," said UMTRI's Michael Sivak.

Overall, fuel economy is down 0.9 mpg from the peak reached in August 2014, but still up 4.8 mpg from October 2007—the first full month of monitoring by Sivak and colleague Brandon Schoettle.

Target for combined cars & trucks was 33.8mpg
http://www.epa.gov/otaq/climate/regulations/420f10014.pdf

General Sustainable Manufacturing Decision Framework



Other Applications Beyond Auto Policy

- *Selection of Metalworking fluids for Sustainable Manufacturing*
- *Cost Optimal Technology Deployments to Meet GHG Reductions by 2050*
- *Electrical System Responses to the Clean Power Plan*
- *Cost Optimal Deployment of CCS Technology*
- *End-of-Life Treatment Methods for Unused Pharmaceuticals*
- *Energy Recovery from Wastewater*

SOT 2: What progress has been made in establishing sustainable manufacturing indicators, what are the remaining gaps, and what have been critical barriers to progress?

Indicators are strong on resource (material/energy) consumption

Indicators Needed to Quantify Impact of Manufacturing Facilities :

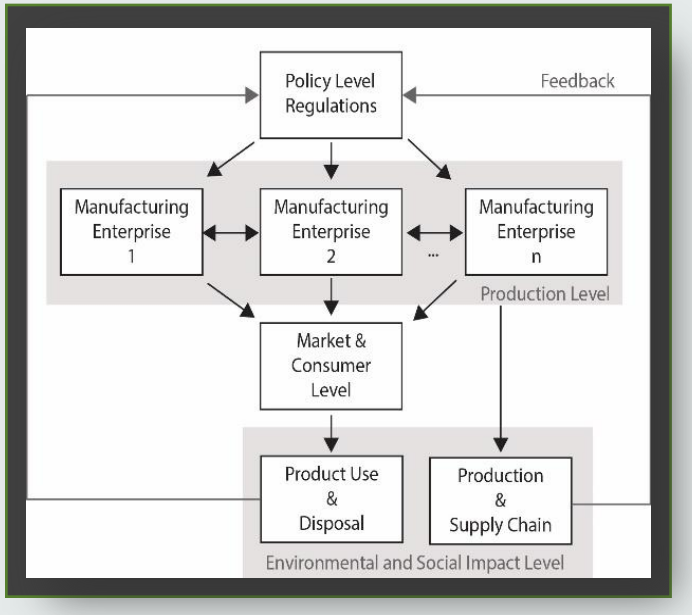
- Local/Factory Human health
- Local/Regional Ecosystems
- On supply chains

While many indicators have been proposed, basic data is lacking even on the simplest ones.

Environmental Impact	- GHG emission (ton CO_2 eq./unit) - Ratio of renewable energy used (%) - Total water consumption (ton/unit)
Energy Consumption	- In-line energy consumption (kWh/unit) - Energy consumption on maintaining facility environment (kWh/unit) - Energy consumption for transportation into/out of the line (kWh/unit)
Cost	- Labor cost ($/unit) - Cost for use of energy ($/unit) - Maintenance cost ($/unit)
Operator Safety	- Exposure to corrosive/toxic chemicals (incidents/person) - Injury rate (injuries/unit) - Near misses (near misses/unit)
Personal Health	- Chemical contamination of working environment (mg/m^3) - Mist/dust level (mg/m3) - Physical load index (dimensionless)
Waste Management	- Mass of disposed consumables (kg/unit) - Consumables reuse ratio (%) - Ratio of recycled chips and scraps (%)

(Haapala et al., 2013)

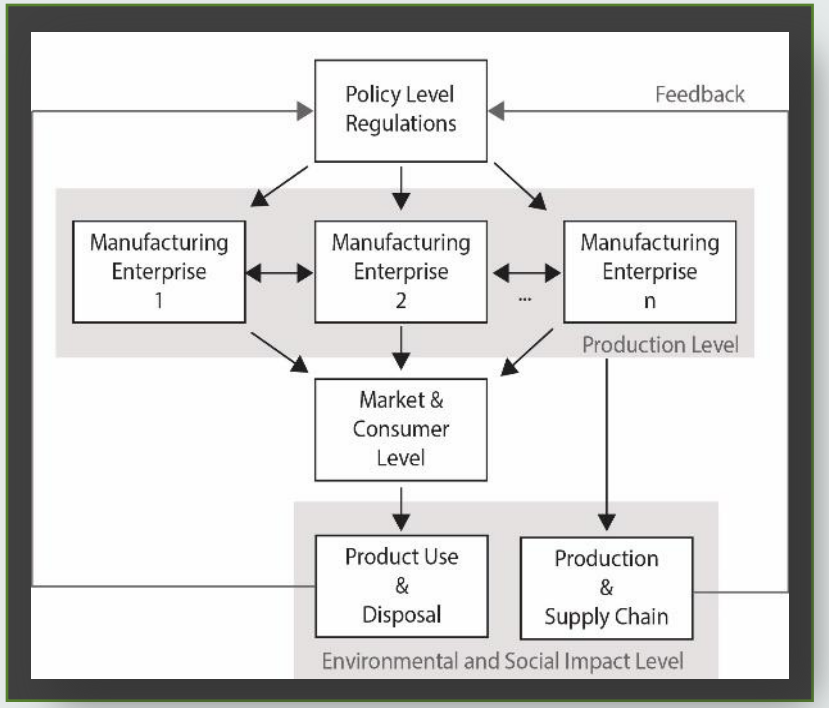
SOT 4. What advances in other areas of science might be usefully applied to advancing sustainable manufacturing?



Model for Integrating Context into Sustainable Manufacturing Decisions

- Understanding diffusion and adoptability of sustainable processes and products
- Understand delocalization effects of globalized manufacturing and consumption
- Understanding of impact of manufacturing chemicals on chronic worker health
- Artificial intelligence based factory resource/emissions management (Bridge, 2014)

SOT 6. What new efforts might be needed to address the range of needs and opportunities related to sustainable manufacturing?



Model for Integrating Context into Sustainable Manufacturing Decisions

- Education effort in socially engaged design for scientists and technologists
- Support for integrative, industry-by-industry models to evaluate useful regulatory strategies, market incentives, and technology pathways for sustainable manufacturing.

Thank you!

Advancing Sustainability Science to Promote Sustainable Manufacturing (SOTs 2,4,5,6)

NAS/NAE/NAM Workshop on the Transition toward Sustainability after 15 Years
Newport Beach, CA (January 14, 2016)

Steve Skerlos
Aruthur F. Thurnau Professor of Mechanical Engineering, Civil and Environmental Engineering
Co-Director, UM Center for Socially Engaged Design & Director, Sustainability Education Programs
University of Michigan