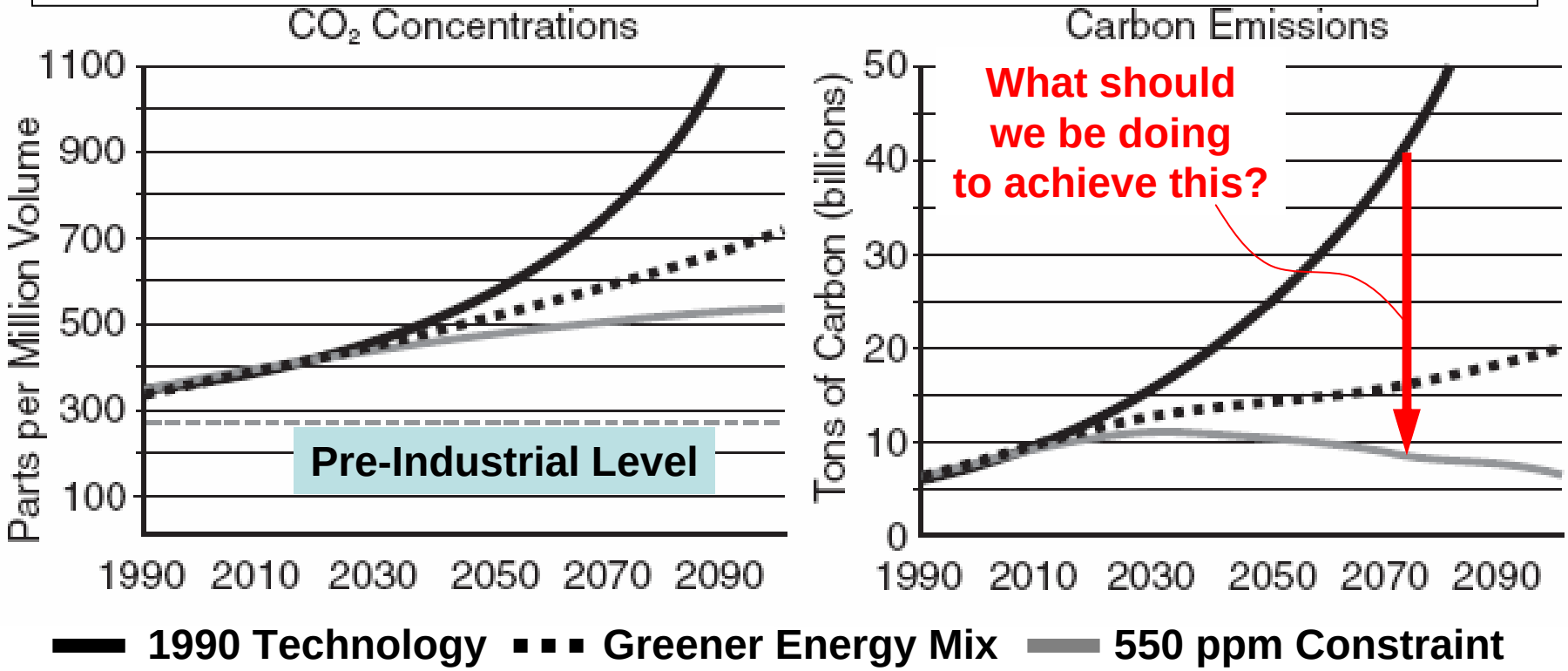
Sustainability: Challenges for the Manufacturing Enterprise

John W. Sutherland, Ph.D.
Professor and Head,
Div. of Environmental and Ecological Engineering,
Purdue University

Sustainability Challenge

- **Many believe we need an order of magnitude improvement in efficiencies (waste reduction and energy/resource consumption)**

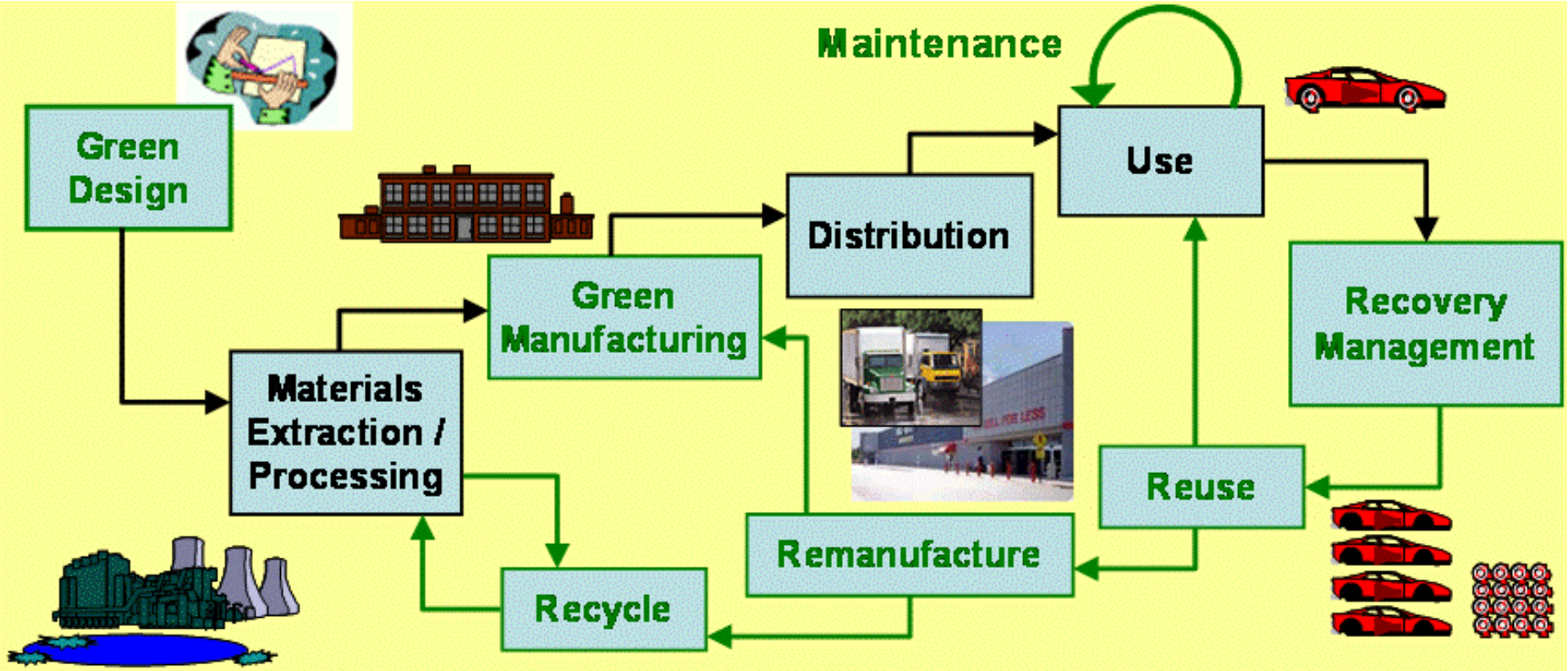


- **What actions are needed from the manufacturing enterprise?**

Responding to the Challenge

- System-level Issues
  - Closing material loops
  - Supply chain
- Product Design
  - Value across the life cycle
  - Embodied energy and energy
  - New product paradigms (IPS)
- Manufacturing Processes
  - Characterize operation emissions – support LCA
  - Greener processes
  - Air quality investigations
  - Remanufacturing / Recycling

System-level: Closing Material Loops



New technologies to help close material/value loops

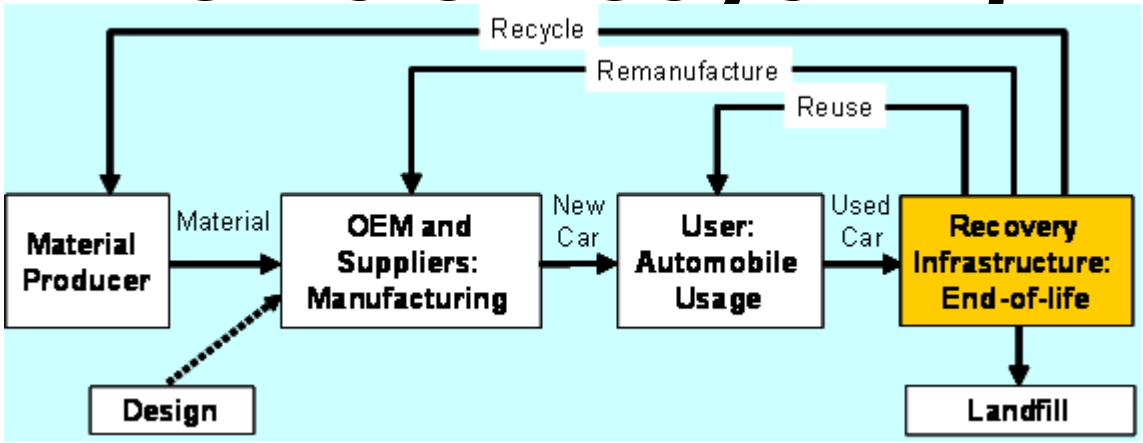
New business models that support this approach

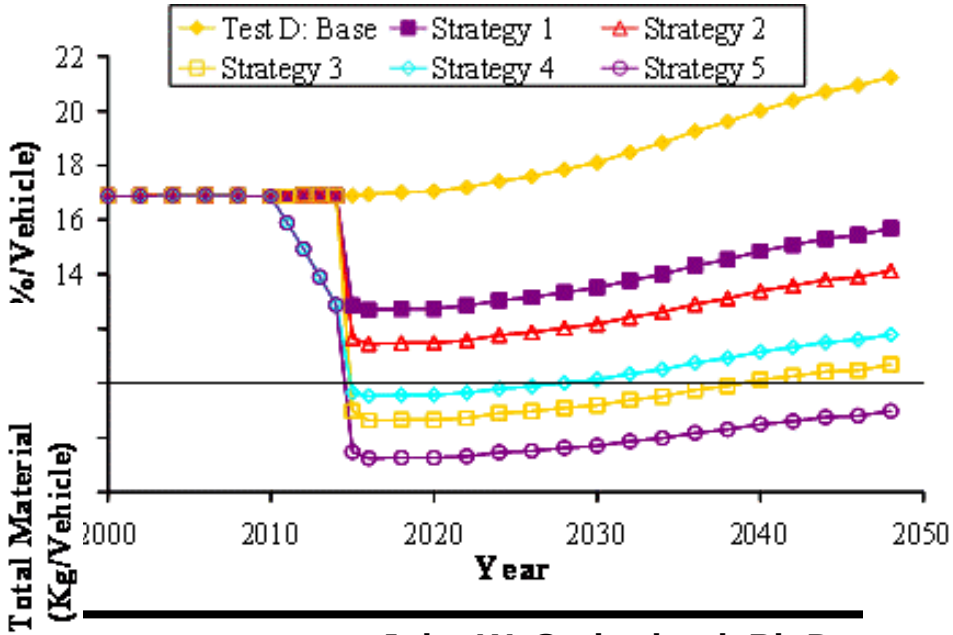
PURDUE UNIVERSITY

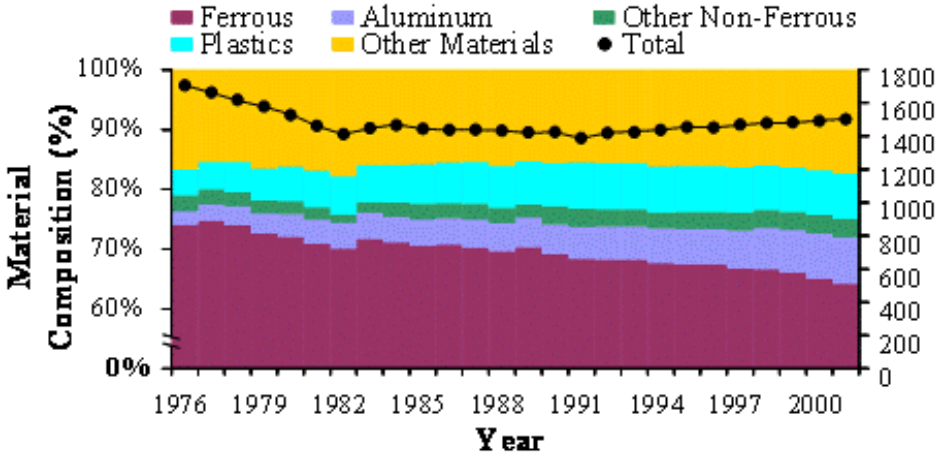
John W. Sutherland, Ph.D.
Division of Environmental & Ecological Engineering

System-level: Vehicle Recycling

- Currently successful?
- More AIVs & CIVs in the future?
- What actions are required to ensure economic & environmental sustainability??







John W. Sutherland, Ph.D.

ision of Environmental & Ecological Engineering

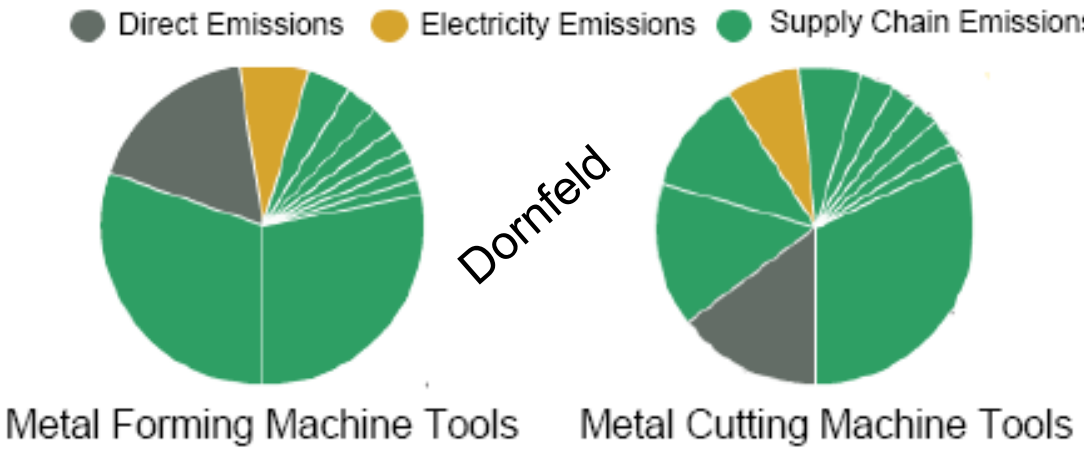
System-level: Supply Chain

- **Growing importance of sustainability may impact:**
  - **Selection of suppliers**
  - **Siting, size, and distribution of facilities**
  - **For example, high energy costs → distributed manufacturing**

Need to determine impact of component by summing impacts across supply chain.

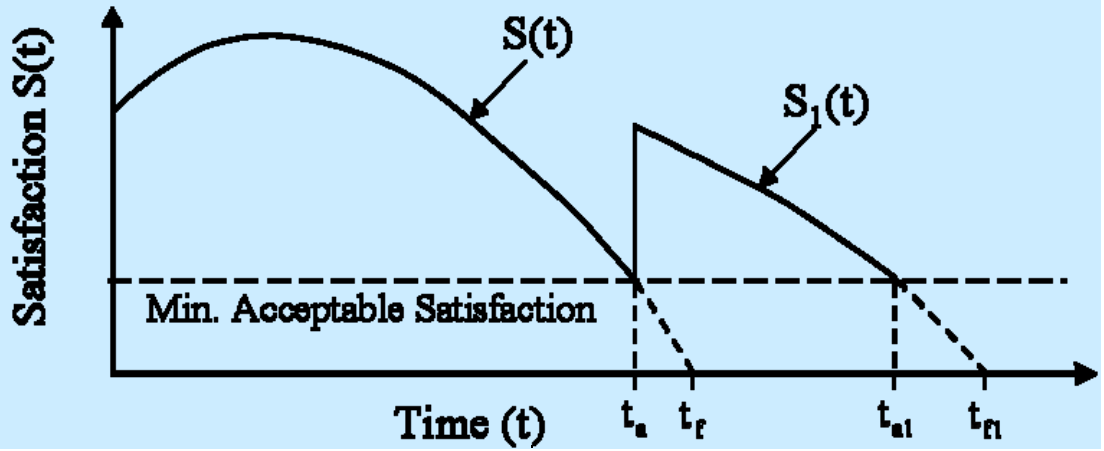
Also investigating <u>Societal Sustainability</u>

Supply Chain Viewpoint (Climate Earth Inc., 2009)



Product Design

- **Understand Value Across Life Cycle**
  - **Need to better understand product value across multiple use cycles**
  - **Role of stakeholder perception on value**



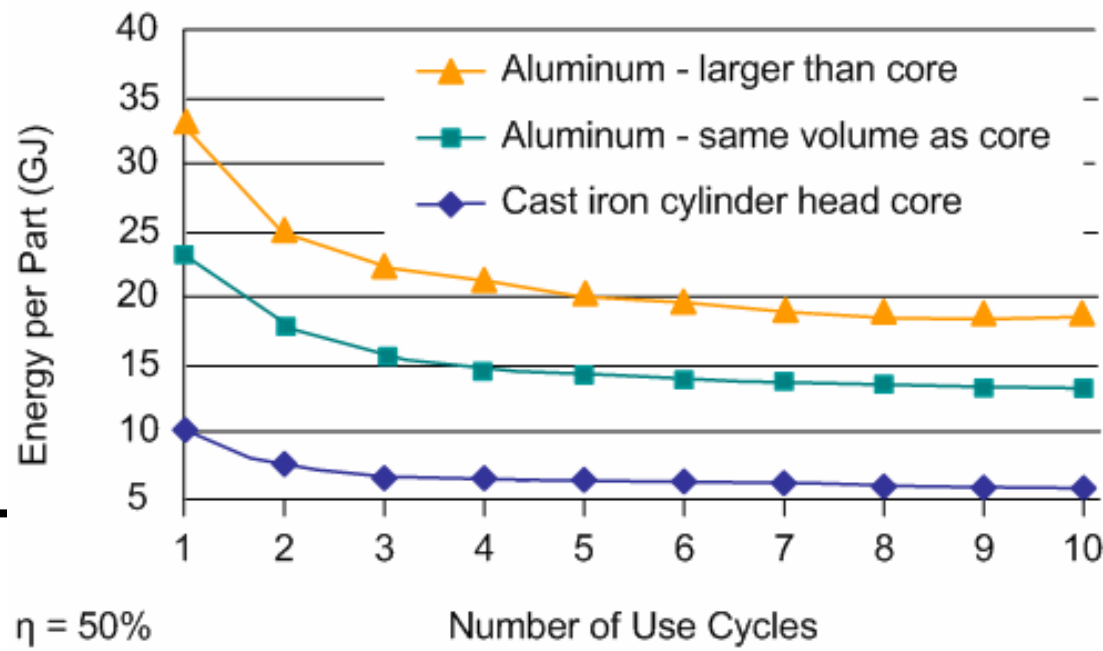
John W. Sutherland, Ph.D.
Division of Environmental & Ecological Engineering

Design/Materials – Embodied Energy

Material	Extraction/ Refining (MJ/kg)	Casting/ Manf. (MJ/kg)	Reman (MJ/kg)
Aluminum	240	16	0.32 – 4.0
Cast Iron	22	28	0.56 – 7.0
Steel	24	17	0.34 – 4.3

Greater use of Alum. in a car, for example, will require more energy-intensive processing of virgin material

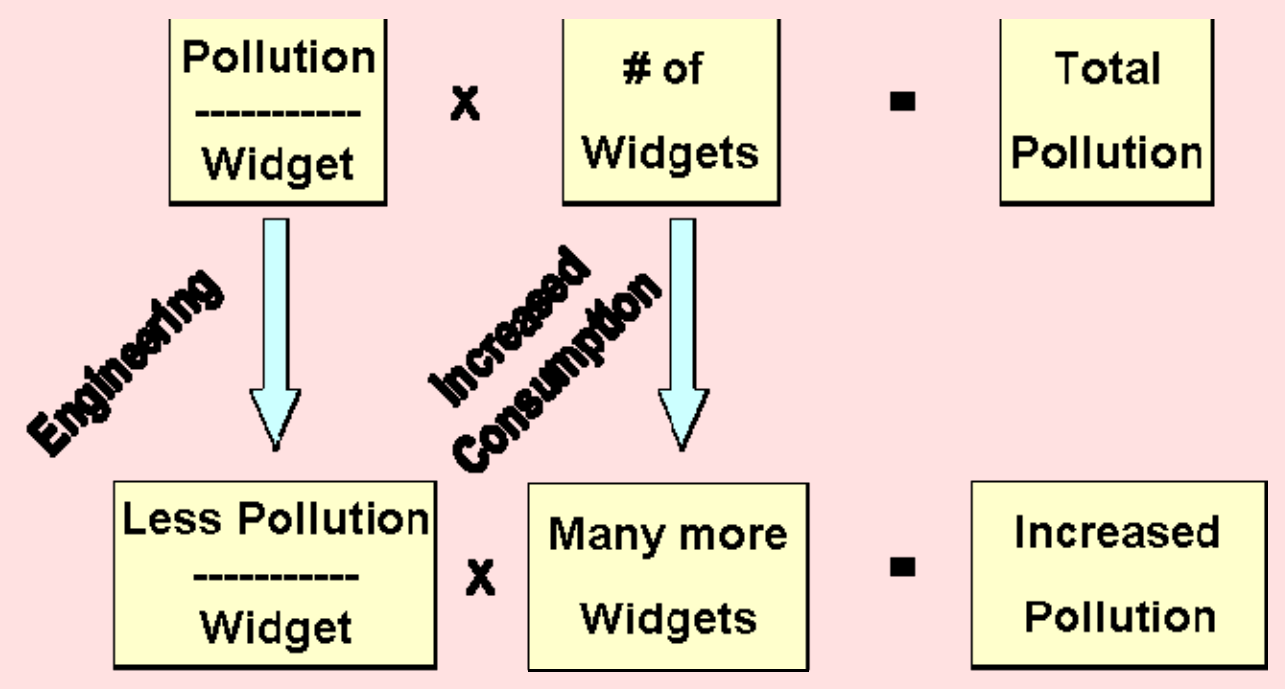
LCA is needed to weigh energy benefits of lower vehicle weight against increased manufacturing energy



PURDUE UNIVERSITY

Integrated Products & Services

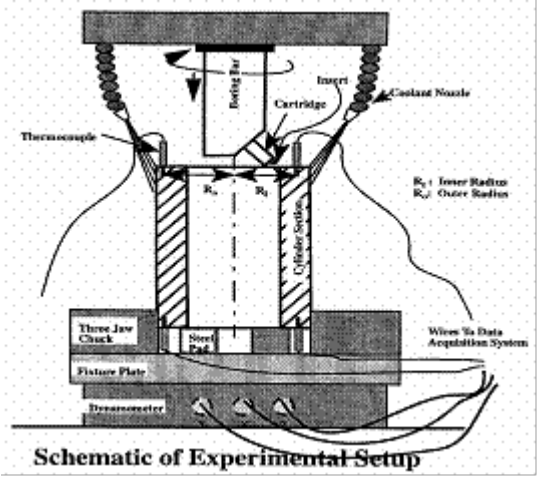
- Classic approach: redesign components to use less material
- Evolving approach: service oriented approach – increase the service content of product-service systems
- In general, need to explore creative ways to:
  - Meet customer needs (services?)
  - Shape customer "wants"



Process Characterization

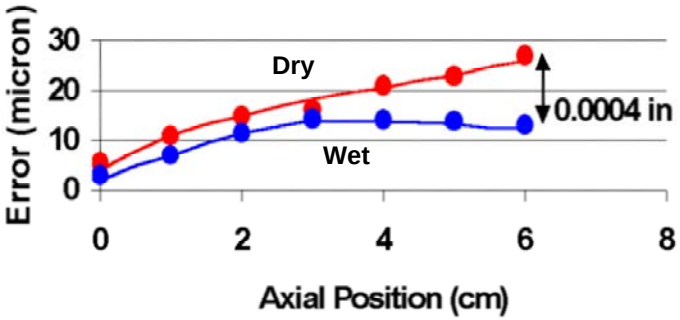
- **Role of Cutting Fluids in Machining**
  - **Experimental component**
    - **Hundreds of tests performed**
    - **Processes (Cylinder Boring, Milling, Drilling, Tapping)**
  - **Analytical component**
    - **Models for heat transfer, lubrication, and thermal distortion for the processes**
    - **Predict effect of fluids on performance**

Develop data to support dry machining applications



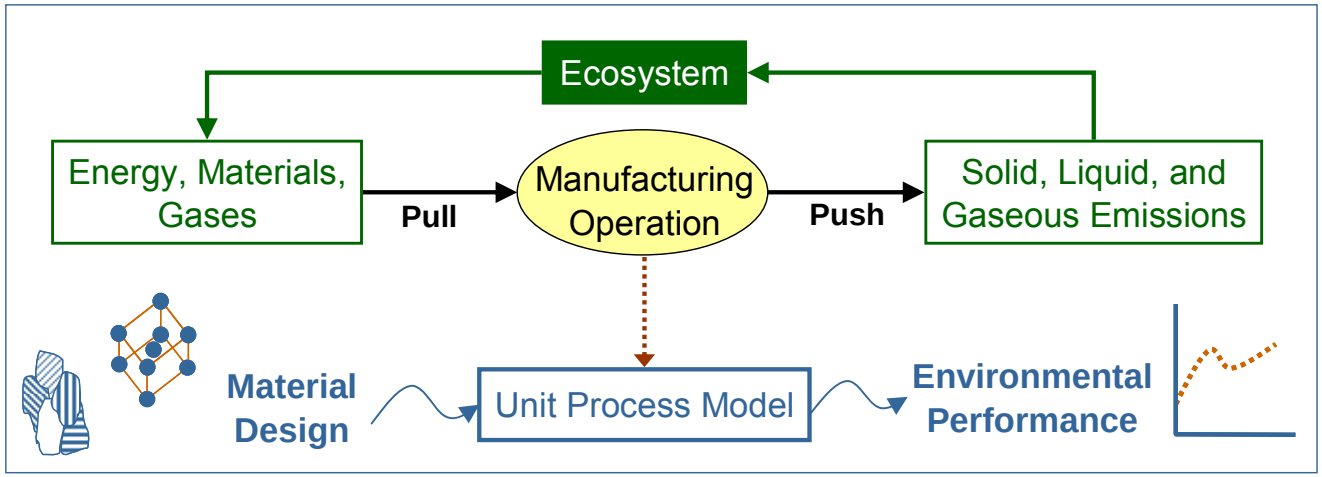
Schematic of Experimental Setup

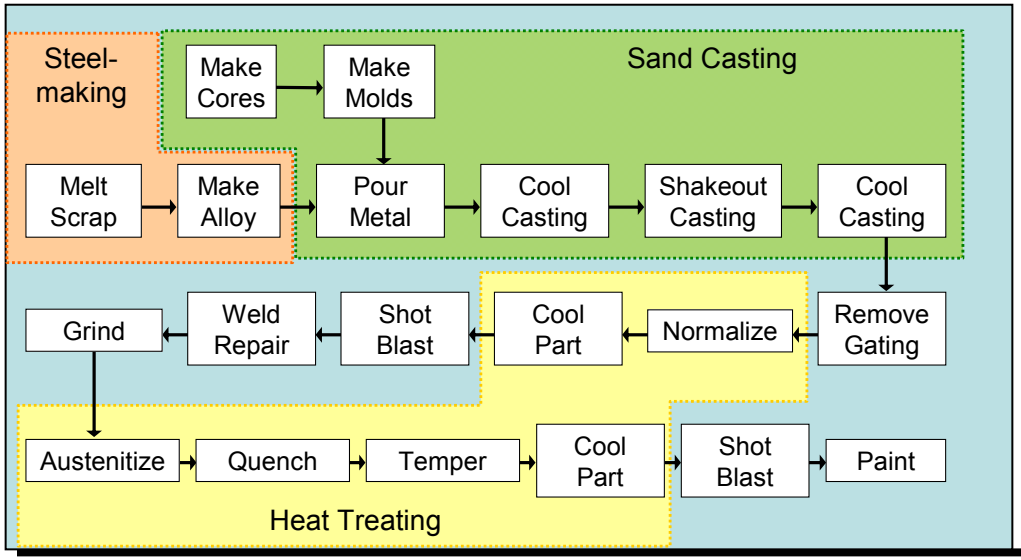
Feed (mm/rev)	Spindle Speed (rpm)	Fluid	Heat Source Strength (W)	% of Heat Entering Work	Conv. Coef. (W/m^2K)
0.100	1000	off	858	77%	6
0.254	1000	off	896	47%	6
0.100	2000	off	1597	43%	6
0.254	2000	off	1496	27%	6
0.100	1000	on	858	77%	2014
0.254	1000	on	896	47%	1561
0.100	2000	on	1597	43%	1496
0.254	2000	on	1496	27%	1575



Process Characterization

How do alloy type and processing conditions affect environmental impact?





Processes considered:

- **Steelmaking**
- **Casting**
- **Heat Treat**

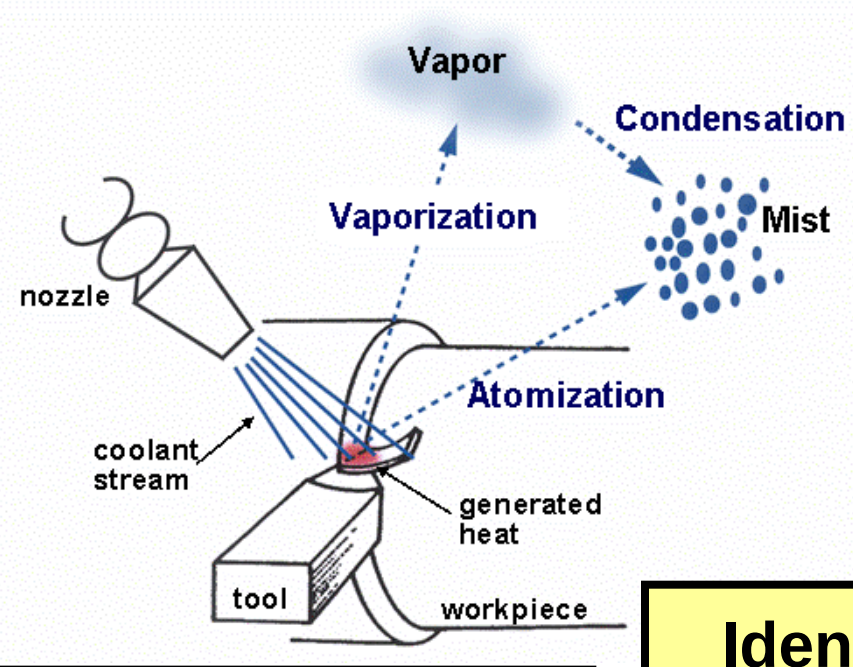
Greener processing and friendlier alloys

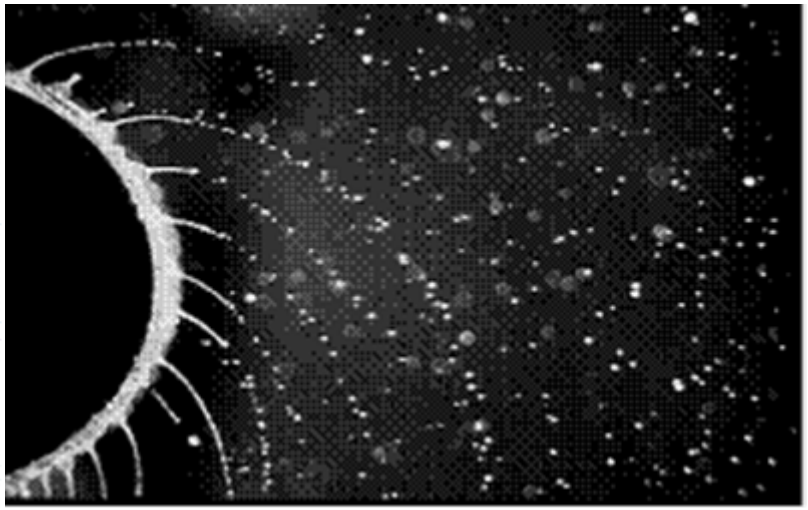
PURDUE UNIVERSITY

John W. Sutherland, Ph.D.

Division of Environmental & Ecological Engineering

Air Quality Issues in Manufacturing





Cutting Fluid Mist – A Potential Worker Inhalation Health Hazard

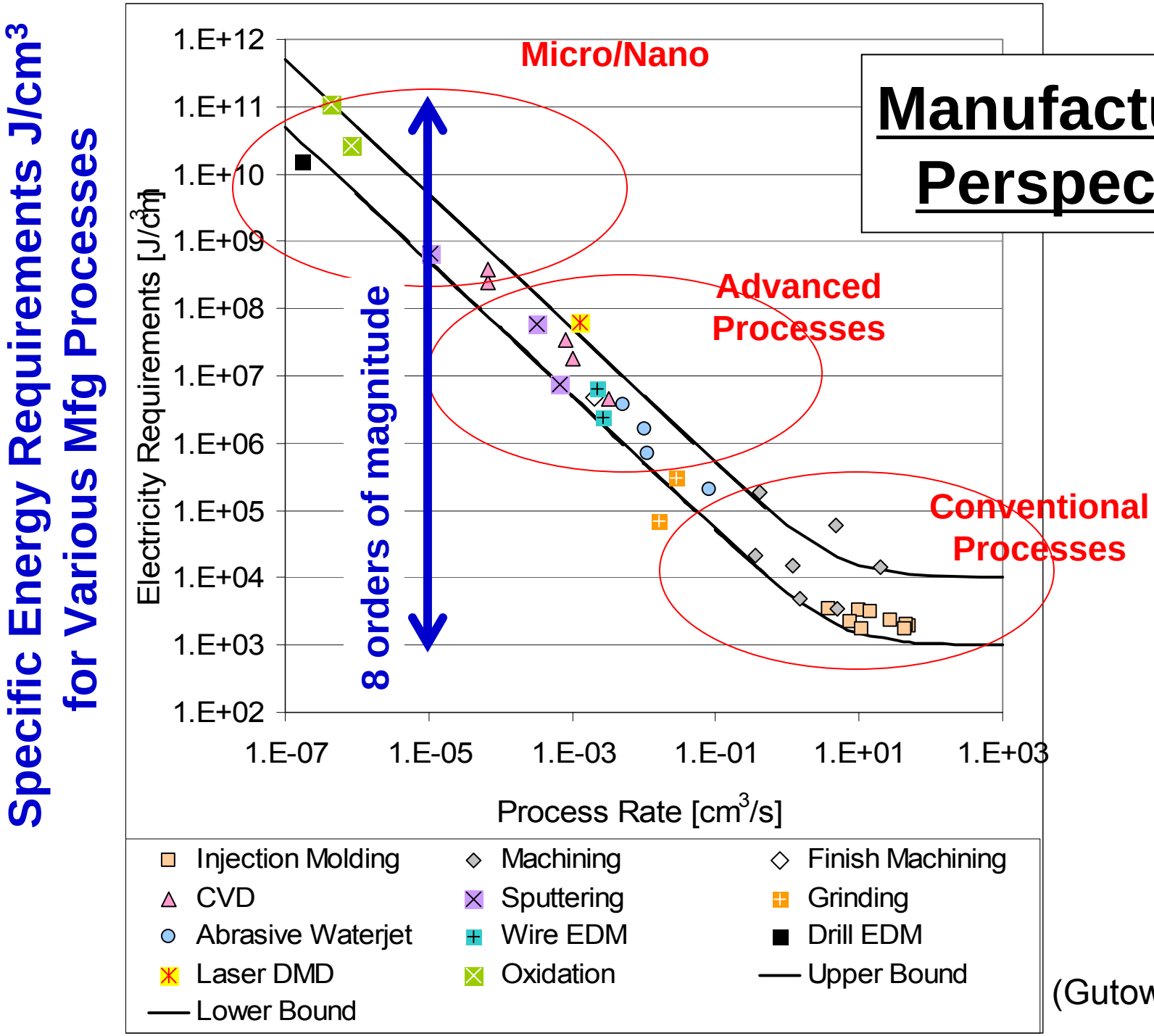
Identify Conditions & Pursue Technologies that Reduce Mist Levels

Air Quality also investigated for: Casting, Welding, etc.

PURDUE UNIVERSITY

John W. Sutherland, Ph.D.
Division of Environmental & Ecological Engineering

Manufacturing Perspective



(Gutowski, 2006)

Remanufacturing Processes

- **Characterize behavior of recycling & remanufacturing processes**

Manufacturing and Remanufacturing Energy (MJ)			
Component	**Material**	**Manufacture**	**Reman**
Engine block	Cast iron	9970	600
Cylinder head	Cast iron	4445	1110
Crankshaft	Steel	2800	110
6 Connecting rods	Steel	330	10
6 Pistons	Steel	555	20
Total energy required (MJ)		**18100**	**1850**
Avoided energy with reman (MJ)			**16250**

John W. Sutherland, Ph.D.
Division of Environmental & Ecological Engineering

Thank You!

John W. Sutherland, Ph.D.
Division of Environmental & Ecological Engineering