Process Trade-off Analysis for Green Manufacturing

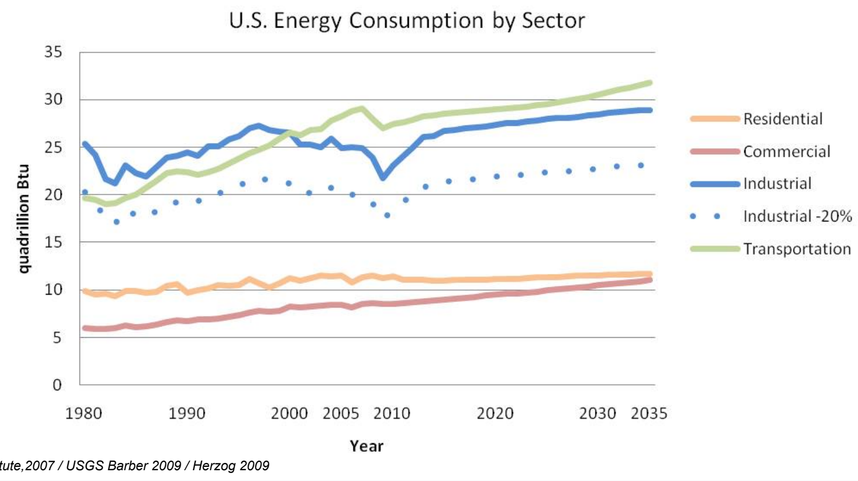
Stefanie Robinson © 2011 LMAS contact email: SLR@me.berkeley.edu

Funding Source: Caterpillar Inc.

Motivation

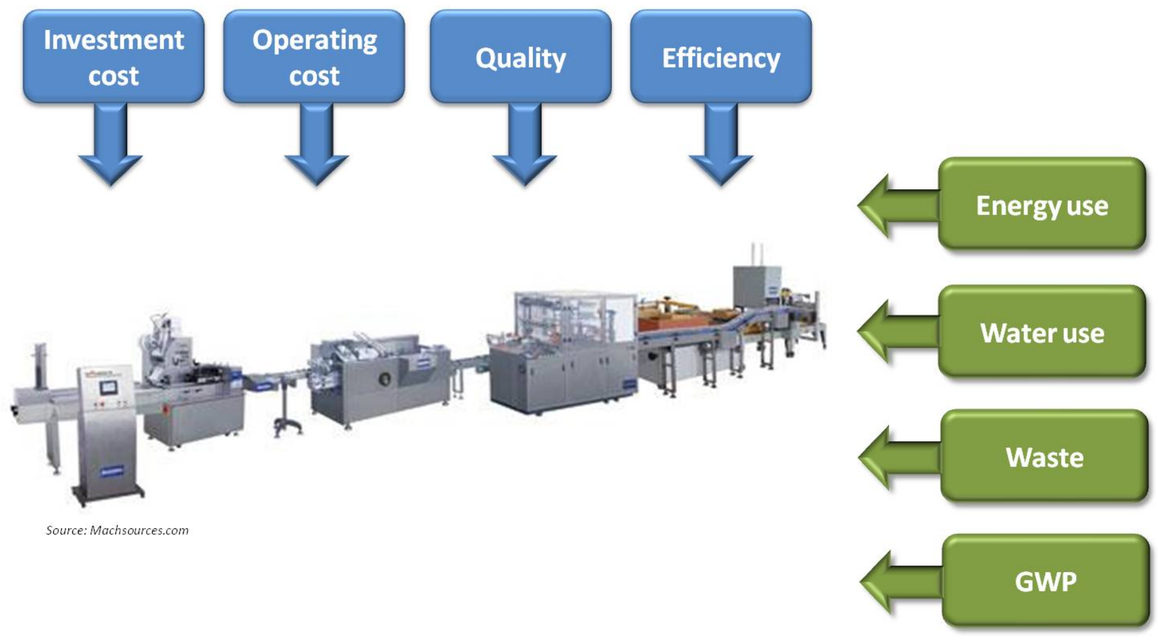
- Manufacturing processes are resource intensive
  - 33% of total U.S. energy consumption occurs in industrial sector
  - 19% of total world global warming potential (GWP) emissions
  - Self-supplied industrial water use is ~4% of total withdrawals

Estimated untapped potential to increase energy efficiency is 16-22% of the global industrial end-use energy demand



Sources: U.S. EIA 2011 / McKinsey Global Institute,2007 / USGS Barber 2009 / Herzog 2009

Production Planning



Source: Machsources.com

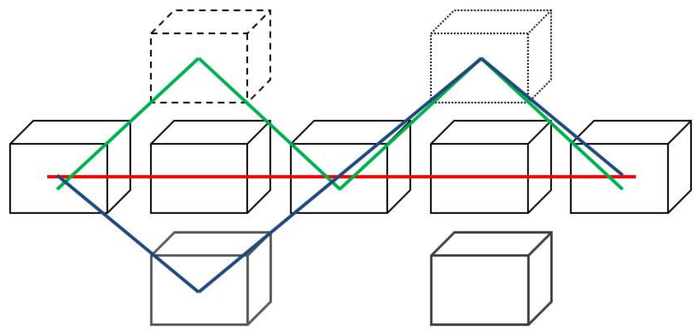
Goals & Approach

- Assess resource consumption for multi-station operations using life cycle assessment methodology

Energy use Water use Waste

- Develop a tool to provide decision support for manufacturing process and process chain selection for multi-station operations
- The tool can be used to better understand resource consumption and environmental and financial impacts of manufacturing process chains used to make a product

Process Chain Variations



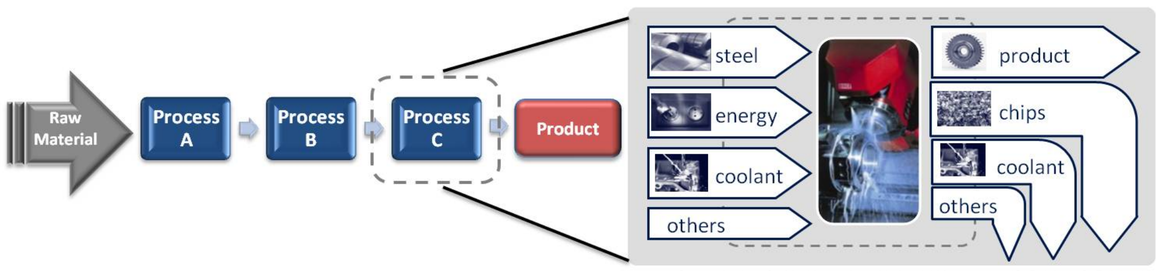
Source: J. Chien, LMAS (2010)

Examples of fabrication processes:

Plate Steel →Laser Cutting & beveling →Plate Bending →Joint Preparation-Cleaning→ Tacking →GMAW welding →Machining

Plate Steel →Plasma Cutting & beveling →Plate Bending →Joint Preparation-Cleaning→ Machining →Tacking →FCAW welding

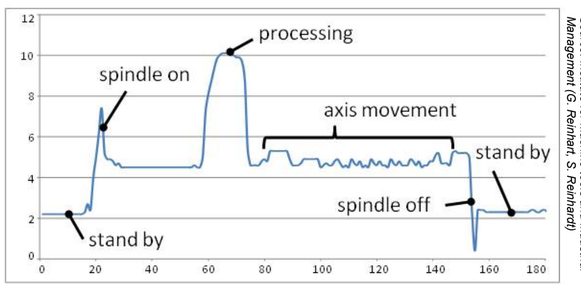
Process Analysis



Source: Institute for Machine tools and Industrial Management (G. Reinhart, S. Reinhardt)

- Each manufacturing process of the process chain has to be analyzed individually
- For each process multiple inputs and outputs will be assessed

Quantifying the energy consumption according to different machine states

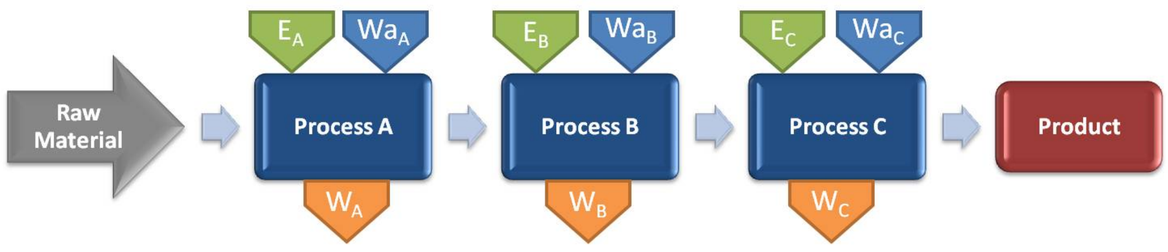


Source: Institute for Machine tools and Industrial Management (G. Reinhart, S. Reinhardt)

Example Machining Process

Process Chain Analysis

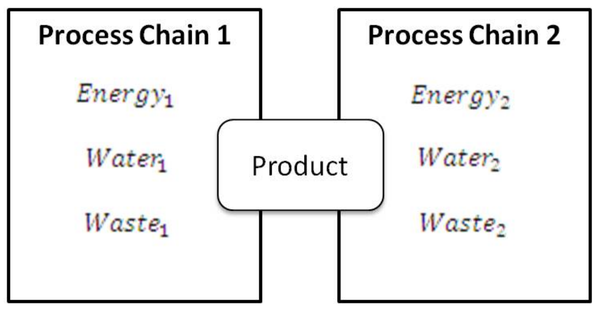
Process Chain 1...2...*n*



$$Energy_1 = \sum E_1 = E_A + E_B + E_C$$

$$Water_1 = \sum Wa_1 = Wa_A + Wa_B + Wa_C$$

$$Waste_1 = \sum W_1 = W_A + W_B + W_C$$

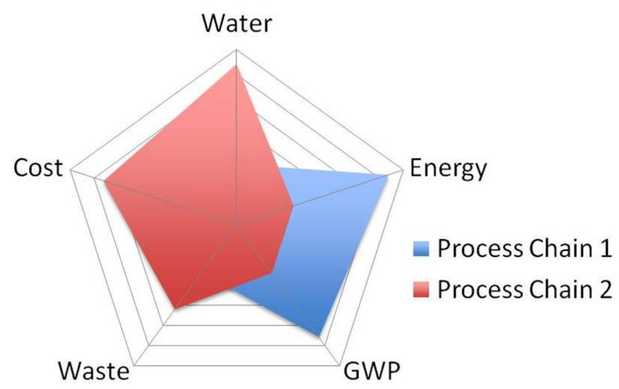


Impact Analysis

Energy use
Water use
Waste

→

Operating cost
GWP



Conclusions & Future Work

- Comparing different manufacturing processes and process chains can be used to inform trade-off decisions that influence operating costs, resource consumption, and impacts on the environment
- These comparisons could also inform production decisions including:
  - Production location
  - Production floor and line layout
  - Future factory planning
- Production location considerations:
  - Local cost of resources *(energy, water, etc.)*
  - Carbon intensity of energy mix at production location

Future Work

- Define and assess manufacturing processes
- Develop a standard assessment approach for each resource group (water, energy, and waste)
- Develop a software tool to include the assessment and evaluation methodology

Berkeley
UNIVERSITY OF CALIFORNIA