Making Supplier Energy Waste Streams Transparent
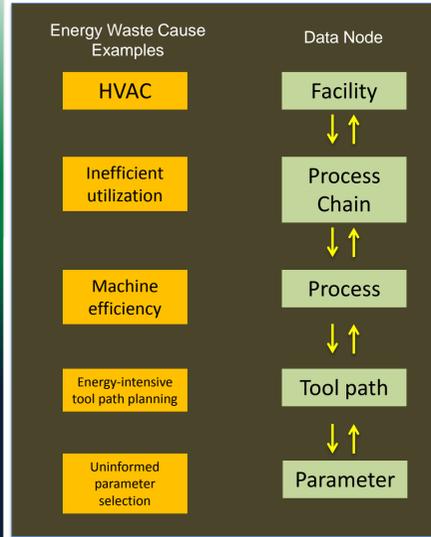
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Motivations and Objectives

- Regulatory agencies and compliance measures have obligated manufacturers to reduce their corporate-wide environmental impact in the recent years, with economic penalties and social stigma otherwise.
- Manufacturers undertake constant, inherent risk of affecting their environmental footprint while they depend on suppliers.
- Frameworks for energy audits are undefined between production enterprises and are dependent on self-reported, unit-inconsistent data by individual suppliers.
- This project aims to develop an energy auditing methodology which enables energy streams to be more transparent for detecting waste points and suggesting improvements.
- This framework may be used in applications such as supplier selection by manufacturers and/or footprint improvements by non-compliant suppliers.

Supplier Google Earth View

Energy Waste Cause Examples	Data Node
HVAC	Facility
Inefficient utilization	Process Chain
Machine efficiency	Process
Energy-intensive tool path planning	Tool path
Uninformed parameter selection	Parameter

- In order to understand and potentially make point-detection of energy wastes, both manufacturers and suppliers can label their energy streams into a energy data hierarchy, analogous to a Google Earth View.
- An energy waste cause can be hypothesized for actual assessment afterward.
- Examples are provided

Parameter Level

Detection

- Sensors
  - Power Meters
  - Watt node
- Functional Unit
  - Volume, V [mm^3]
- Parameters
  - Material Removal Rate, MRR [mm^3/s]
    - Width of cut, w [mm]
    - Depth of cut, d [mm]
    - Feed rate, f [mm/s]

Suggested Improvement

- Model Characterization

$$E = \left(\frac{k}{MRR} + b\right) * V$$

Specific Energy Curve

- Energy Prediction

$$E_x = N * \Delta t \sum_{i=1}^{N}(k + b * MRR_{avg,i})$$

Ref: (Diaz et. al., 2012)

Tool Path Level

Detection

- Sensors
  - Power Meters
  - Yokogawa, 3P3I3W
- Functional Unit
  - Volume, V [mm^3]

Image Credit: keison.co.uk

Suggested Improvement

- Tool path Optimization
  - Traveling Salesman

Ref: (Chen et. al. Presentation, 2013)

Process Level

Detection

- Sensors
  - Watt node / MT Connect

Network

MTConnect® Agent

MTConnect® Client

Device

Image Credit: solution-family.com
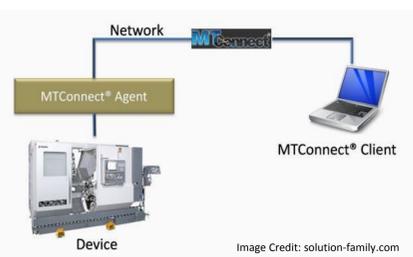
- Functional Unit
  - Machine Energy Consumption, E_m [J]

Suggested Improvement

- Energy Categorization
  - Processing Energy
    - Process Block Examples
      - Milling
      - Drilling
      - Turning
  - Embedded Energy

E_P

Production/operation consumption

E_T

Machine or process "tare" consumption

Embedded

Time

Ref: (Dornfeld, 2010)

Process Chain Level

Example Process Chain

Laser Cutting + GMAW$_{manual}$ + GMAW$_{robotic}$ + Hand Grinding
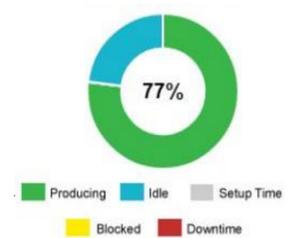
Ref: (Robinson, 2013)

Detection

- Functional Unit
  - Value-added Time per Machine, t_m [sec.]

Suggested Improvement
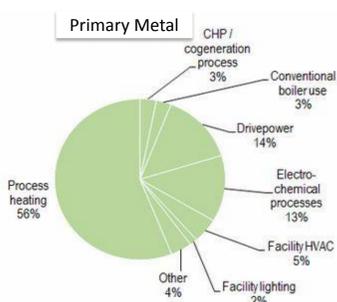
- Process Chain Optimization

Machine Utilization

77%

Producing | Idle | Setup Time
Blocked | Downtime

Ref: (D'Alessio et. al. Presentation, 2014)

Facility Level

Detection

- Functional Unit
  - Factory Energy Demand, E [kJ]

Primary Metal

- CHP / cogeneration process 3%
- Conventional boiler use 3%
- Drivepower 14%
- Electro-chemical processes 13%
- Process heating 56%
- Facility HVAC 5%
- Facility lighting 2%
- Other 4%

Image Credit and Ref.: esource.com

Suggested Improvement

- Improved Factor Design and Utility Planning:
  - Near
    - Equipment Maintenance
      - Ex: Inspect HVAC gasket
  - Long
    - Equipment Upgrade
      - Ex: Waste-heat recovery system

Summary and Future Work

- Manufacturers must understand their suppliers' energy stream through defined data collection standards in order to make accurate assessments.
- This study assumed level-discrete energy waste; hence, neglecting data uncertainty based on accuracy nor precision.
- Users are encouraged to utilize this framework as preliminary point-source detection-to-improvement method.
- Data uncertainties and error propagation will be considered as part of future work.