Prospective Life Cycle and Technology Analysis

Advanced Manufacturing Office Peer Review

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This presentation does not contain any proprietary, confidential, or otherwise restricted information.
• Quantifying, from a life-cycle perspective, the *enabling effects* of advanced manufacturing in achieving AMO’s mission for energy savings across the economy

• Assessing net energy, emissions, and economic effects over different scales of time and space

• Providing robust early information on the drivers and potentials of advanced manufacturing, rooted in deep technical understanding of emerging applications

• Analyzing key emerging technologies and trends: vehicle lightweighting, wide band gap materials, *additive manufacturing*, natural gas to chemicals, and distributed manufacturing
Additive Manufacturing

**Motivation:** Resource efficiency, flexibility, and modular design of additive manufacturing could be transformative, enabling competitiveness and distributed manufacturing.

**R&D challenges**
- Low throughput
- Residual stresses
- Repeatability
- Surface quality
- High cost

**AM industry:** 29% growth in the last three years - predicted to be > 30% CAGR through 2020

**Aircraft industry case study** - key early adopter (12.3% of AM industry)
Additive manufacturing – model framework and methodology

Framework rooted in deep technical understanding of AM process and markets

1. Aircraft component selection
   - Factor: Material use, Geometric volume, Load, Complexity

2. Replaceable mass estimation
   - Major systems: Interior, Engine, Propulsion, Nacelle, Body

3. Cradle to gate life-cycle inventory model
   - Materials Metals: Steel, Al, Ti, Ni alloys
     - Forms: Ingot, Powders
   - Manufacturing CM process: Casting, Machining
     - AM process: SLM, EBM, DMLS
   - Transportation Mode: Road, Air, Ship, Rail

4. Fleet-wide temporal adoption
   - Availability starts at 2019-2034
   - Slow, mid and rapid adoption scenarios

5. Fleet-wide fuel consumption
   - 100kg weight reduction saves 13.4-20.0 TJ of fuel over a 30 year life of an airplane

Rigorous modeling of conventional and emerging metals manufacturing technologies

Technology adoption and stock turnover modeling
Cradle-to-gate life cycle impacts

- Resource production dominates cradle-to-gate energy consumption
- Significant *materials efficiency* gained with AM
- Energy savings potentials vary by component – highlights strategic target markets
Cradle-to-grave life cycle impacts

- Potential metal alloy savings by 2050: 4050 tonnes/year aluminum, 7600 tonnes/year titanium; and 8110 tonnes/year nickel.
- Total primary energy savings potential 70-173 million GJ/year by 2050; cumulative primary energy savings of 1.2-2.8 billion GJ through 2050.
- Most of the energy savings from reduction in use-phase fuel consumption – further lightweighting achievable with improved component design.
- Rapid adoption scenario highlights benefits of aggressive deployment and more immediate progress to overcome engineering limitations (surface roughness, residual stress, etc.).
Additive Manufacturing – Enabling Competitiveness & Distributed Manufacturing

- Consideration of benefits to production economics and competitiveness - shed light on the potential business case for AM investments
- Analysis of projected trends in technology improvement
- Uncertainty and scenario analysis to enable robust AMO assessments
**Publications**

**Published**


**Under final revision**

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