Challenges and Opportunities in Decarbonizing Construction and Mining Equipment

NREL Decarbonization Workshop

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Introduction to Komatsu

**About Komatsu**

- **Headquarters**
  Tokyo, Japan

- **Founded**
  May 13, 1921

- **Main businesses**
  Manufacture and sales of construction, mining, utility (compact machines), forestry equipment, and industrial machinery

**Employees**

- Japan: 32%
- Overseas: 68%

**A diverse range of products**

- Construction
- Forestry
- Forklift
- Mining
- Stamping & Cutting

**Global operations**

**Sales by region** (Construction, Mining, Utility equipment)

<table>
<thead>
<tr>
<th>Strategic Markets</th>
<th>Africa</th>
<th>Middle East</th>
<th>Oceania</th>
<th>Asia</th>
<th>China</th>
<th>CIS</th>
<th>Latin America</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2020 Sales</td>
<td>53%</td>
<td>2%</td>
<td>12%</td>
<td>7%</td>
<td>7%</td>
<td>6%</td>
<td>15%</td>
</tr>
</tbody>
</table>

- Traditional Markets
  - Japan: 15%
  - North America: 23%
  - Europe: 9%

Note: $1US ≈ ¥110
Creating a sustainable future together

At Komatsu, we are committed to minimizing environmental impact through our business, focusing on:

- CO2 emissions from product use and production: decrease by 50% by 2030
- Rate of renewable energy use: increase to 50% by 2030
- Challenge target: carbon neutrality by 2050

The UN has created 17 Sustainable Development Goals (SDGs) for global entities. Komatsu focuses on these five:
Construction, mining and utility products

Decarbonization Challenges
- Very large power requirements
- Remoteness of sites
- Limited green energy availability
- 24x7 production
- TCO sensitivity

Construction Equipment
- Moderate power requirements
- Infrastructure variability of sites
- Limited green energy availability
- Wide use profiles
- Very cost sensitive
- Job site changes fairly rapidly

Mining Equipment
- Job site may change daily

Utility Equipment
- Low power requirements
- Space available on vehicle
- Wide use profiles
- Very cost sensitive
- Job site may change daily
Construction, mining and utility products

Decarbonization Approaches
- Battery / Trolley Charge
- Battery / Static Charge
- HFC / Battery
- HICE
- Bio Diesel / SynFuels

Mining Equipment
- Crawler excavators
- Wheel loaders
- Dozers
- Rigid dump trucks

Construction Equipment
- Crawler excavators
- Wheel loaders
- Dozers
- Rigid dump trucks
- Articulated dump trucks
- Wheeled excavators
- Motor graders

Utility Equipment
- Mini excavators
- Mini wheel loaders
- Skid-steer loaders
- Backhoe loaders
- Forklifts

NREL Off-Road Decarbonization and Energy Systems Integration Workshop
## Electric dump truck product line

<table>
<thead>
<tr>
<th></th>
<th>Electric Drive Trucks</th>
<th>Ultra Class Electric Drive Trucks</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>730E-8 728,800 GtW</td>
<td>930E-4/930E-4SE 1,106,670 GtW/1,115,000 GtW</td>
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<tr>
<td></td>
<td>830E-1AC 850,750 GtW</td>
<td>960E-2K 1,270,000 GtW</td>
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<tr>
<td></td>
<td>860E-1K 947,700 GtW</td>
<td>980E-4 1,378,500 GtW</td>
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<tr>
<td>GROSS HP</td>
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<tr>
<td></td>
<td>200 244 280</td>
<td>320 360 400</td>
</tr>
</tbody>
</table>

CAPACITY (sh. tons)
The road to zero emission haulage

Tier 1 MCRS Advantage

Pre-Electrification

Stage I Electrification + Tier 4

Migration of several supporting systems to all electric.

Fuel Consumption (Stage I + Tier 4) 100%

Emissions (Stage I + Tier 4) 1.9

Today

Stage II Electrification + Trolley

Introduction of an innovative future proof platform that supports multiple propulsion systems.

Fuel Consumption (Stage II + Trolley) 48%-68%

Emissions (Stage II + Trolley) .17% .46%

Mid-term

Stage III Electrification + Battery/ Hybrid/ Hydrogen

• Selectable Option Power Systems
• Choose from:
  • Diesel
  • Trolley
  • Electric Hybrid
  • Battery
  • Hydrogen Fuel Cell

Future

DieSEL/Trolley

Fuel Consumption 48%-68%

Emissions .17%

Electric/Hydrogen

Fuel Consumption 0

Emissions 0

Note: Emissions reduction includes; NOx, Hydrocarbons, and Particulate Matter. Emissions reductions are a result of improvements made in Fuel Consumption and Engine Design including the addition of SCRs and DEF.

NREL Off-Road Decarbonization and Energy Systems Integration Workshop
Mining – key issues to consider regarding the energy transformation

- Long life of mining equipment (up to 25 years) – need to enable technology transitions throughout lifecycle
- Significant investments in R&D are required for development of zero emission mining equipment, all ICE equipment will have to be redesigned.
- Development of battery electric and hydrogen fuel cell are competing for the same resources. Government incentives for manufacturers will be necessary to increase pace of equipment development.
- Significant investment is required for supporting technology and systems such as:
  - Green energy (wind, solar, geothermal…) and storage
  - Hydrogen production, distribution, storage and filling
- Uncertainty in market demand, mine operators need to support a specific decarbonization strategy/approach (i.e. BEV, HFC, trolley assist) and make long lead investment decisions (i.e. green energy production & storage, hydrogen production, distribution, and storage…)
- The maturity of key decarbonization technologies are low for mining applications:
  - Battery systems
  - Hydrogen production/distribution/storage
  - Hydrogen fuel cells
- The total cost of ownership (TCO) of zero emission mining equipment will likely start out higher compared to current solutions but will reduce over time and with sufficient scale and technology maturity it may reach a point more competitive than existing models. Expectation is the TCO needs to be competitive with current offerings.
Mining – challenges associated with adoption of green energy

- **Mine Profile**
  - Most mines are very remote and in challenging environments
  - Availability of green energy is variable but generally poor to nonexistent
  - Skilled technician availability can be poor, no current capability around hydrogen
  - Varying profiles due to ore body configuration (i.e. relatively flat, uphill loaded, downhill loaded). Rolling resistance varies considerably to >10% for severe applications
  - 24/365 operation, typically >6000 hours per year

- **Equipment**
  - Ultra class haulage trucks range in size from 205 tons payload / 745k lbs GVW / 2,000 HP (1500kW) to 400 tons payload / 1,384k lbs GVW / 3,500 HP (2,600 kW)
  - Lifetime ranges from 60k (10 years) to greater than 100k hours (15 years)
  - Diesel engines or diesel engine / trolley provide the energy that powers wheel motors
  - Diesel engine life typically varies from 18k to 30k hours (3-5 years) – green technology expectations are similar
  - Number of equipment in service varies by mine, largest operations have greater than 400 trucks, smaller <10, and average about 40
  - Refueling of ICE equipment once every 12 – 24 hours (generally 15-20 minutes per event) - green technology expectations are similar

- **Regulatory**
  - Not well governed for off-road machines (ISO process in infancy)
  - Infrastructure varies greatly across world
Mining – challenges associated with adoption of hydrogen for mining - 2

- **Application**
  - Wide range of environmental conditions ranging from Artic/Northern Latitudes (<-40°C), desert (>50°C), rainforest (>90%RH), to high altitude (>4000m)
  - Most severe – uphill hauls of several kms at **10% grade**
  - Many profiles exist at each operation and vary over time as the mine develops
  - General expectation of mine operators – **zero-emission equipment should have similar performance to current (ICE)**

- **Onboard Systems**
  - **Safety is of prime importance**
  - Space claim of FC and battery
  - Hydrogen tanks physical size and capacity
  - Dust resilience
  - Availability, reliability and maintainability/serviceability

- **Infrastructure**
  - **Safety is of prime importance**
  - Generally, no experience with H2 or cryogenics
  - **Fast fueling is a must**, H2 requirements will be ~1000 kg/day/truck.

- **Commercials**
  - TCO must be competitive!
Summary of key needs

- Hydrogen
  - Infrastructure
    - Safety
    - Low cost H2 production, distribution, liquefaction, storage, and dispensing (<$3/kg all in cost dispensed)
    - Scalable/affordable H2 bulk storage (30-500 tonnes)
    - Fast, reliable, and affordable fueling technology (<10 minutes for 300kg and near zero recovery time)
      › Fix stations
      › Mobile refueling
  - Onboard
    - Safety
    - Air handling/filtration (understanding impact of fine dust particles founding in mining environment on FCs)
    - Thermal management
Thank You

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