THE IMPACT OF ENERGY AND DIGITAL TRANSFORMATION ON RAIL

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Energy and digital transformation will force and enable a new rail business model.
Energy Market Transformation
We’ve hit the tipping point for a structural change to energy costs

3 Cents/kWh Electricity Generation: New Solar & Wind Projects

**United States:** 100 MW solar array to be built by 2019 by Tucson Electric Power and NextEra Energy Resources in AZ

**China:** Pledged to invest $367B in renewable power generation by 2020. In one year, China installed the equivalent of all solar development in Germany

**Morocco:** 850 MW capacity over five windfarms to be built by consortium, incl. GE and Siemens, operational late 2017

Source: Oliver Wyman analysis.
The world is shifting away from fossil fuel power generation – even the oil majors can see it happening.

Oil Majors: Projected Energy Supply Outlook and Renewable Scenarios

Percent share of global market

Source: BP Energy Outlook, IEA Medium Term Renewable Energy Market Report, The Outlook for Energy: A View to 2040 (Exxon) and Shell energy scenarios to 2050

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Coal production and demand are declining in the US...

Source: Association of American Railroad (2017) and BP Statistical Review of World Energy (June 2017)
...And globally as well

Change in Global Coal Plant Pipeline, January 2016 to January 2017

kMW impacted

<table>
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<th></th>
<th>Announced</th>
<th>Pre-permit</th>
<th>Permitted</th>
<th>Started (past 12 mo.)</th>
<th>In Construction</th>
<th>Completed (past 12 mo.)</th>
<th>Retired (past 12 mo.)</th>
<th>Operating</th>
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<td>Jan-2017 kMW</td>
<td>247</td>
<td>225</td>
<td>100</td>
<td>65</td>
<td>-19%</td>
<td>-29%</td>
<td>-26%</td>
<td>3%</td>
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</tbody>
</table>

Source: Platts WEPP database (December 2016)

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Energy changes are being driven by multiple technology trends:

- Improving technology to produce renewables
- Improvements in battery storage
- Increasing Distributed Energy Resources (DERs)
- Growing reliance on Artificial Intelligence
- Development of distributed ledgers
- “Internet of Things,” e.g., smart grids, smart homes
In energy, technology trends are underpinning the acceleration of change...and so are the profits

Cumulative Installed Capacity (GW) of Wind Projects: Successive revisions of IEA WEO projections


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The same megatrends are driving disruption in both energy and transport

<table>
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<tr>
<th>Demographic asymmetries</th>
<th>Economic globalization</th>
<th>Resources constraints</th>
<th>Innovation acceleration</th>
<th>New governance models</th>
<th>Evolving consumption</th>
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<td>Selective deindustrialization</td>
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<td>Digital &amp; data</td>
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<td>Smart devices &amp; infrastructure</td>
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<td>Rise of Asian &amp; African middle class</td>
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<td>Ecosystem at risk</td>
<td>Life sciences booming</td>
<td>Low/cost premium polarization</td>
<td></td>
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<tr>
<td>Aging societies</td>
<td>Usage economy</td>
<td>Climate change</td>
<td>Industry 4.0</td>
<td></td>
<td>Anxiety</td>
</tr>
<tr>
<td>Gender gap decrease</td>
<td>Rise of digital disruptors</td>
<td>War for talent</td>
<td></td>
<td></td>
<td>Homing</td>
</tr>
</tbody>
</table>

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Digital Transformation of Rail Technologies
Propulsion innovation will occur first in road technologies
Where does North American rail fit in to the world?
The US has 36,000 locomotives, of which only 12 percent are the latest tech generation...

North American locomotive/multiple-unit fleet: 39,011 units
Tiers III & IV: 4,339 units

Source: Railinc, The North American Locomotive Review 2017; Trains, Locomotive Annual, various years; and Oliver Wyman analysis
Photo source: Andrew Jennings
…But the world has seven times the number of locomotives/EMUs as does the US…

Worldwide locomotive/multiple-unit fleet: 216,939 units

North America 18%

Source: Australasian Railway Association; Trainline 2: Statistical Report, 2014; International Union of Railways, Railway Statistics, various years; Saudi Railways website; TransNet website; and Oliver Wyman analysis
Photo source: David Lehlbach
© Oliver Wyman
…And the commercial heavy truck fleet is 675x larger than the US rail fleet

Innovations for rail – such as modern energy storage – will increasingly come from outside rail and outside the US

Worldwide heavy freight truck fleet: 24,000,000 units

Locomotive and multiple-unit fleets
- World 0.89%
- North America 0.16%
By 2030, rail vehicles will account for less than one percent of the autonomous tech market, versus 78 percent for digital tools.

Autonomous Technologies: Global Market 2030 Forecast

$ billions

- $740
- $370
- $1,170
- $1,150

Total = $3,430B

- Tighter integration of MRO & Aftermarket services, Assets & Onboard systems
- Training & Data management services
- Cybersecurity & City services
- Services, systems & data

Operations & services (78%)

Vehicles (22%)
Energy innovations will again transform the rail model by powering new technology adoption.

**Energy Efficiency**  
% of primary energy converted to usable power

- Steam: 18%
- Diesel: 30%
- Lithium battery: 86%

**Mechanical Employees per Billion RTMs**  
1955 and 2016

- 1955 Steam: 438
- 2016 Diesel: 18
- 2025 Battery: ?

Source: Battery University, US Bureau of Labor Statistics, US Surface Transportation Board, Oliver Wyman analysis

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Rail overseas is already using advanced energy technologies

**Alstom Citadis Ecopack**
- On-board energy storage integrated w/ tramway
- Catenary-free, recharges in 20 seconds at station stops
- More than 18 million kilometers of daily operation

**Bombardier PRIMOVE battery**
- On-board energy storage via rechargeable lithium battery, catenary-free
- Partial recharge at intermediate stations in 45 seconds; full recharge at end stops in 10 minutes

**Metrolinx Hydrail project**
- Issued RFP for concept design of a hydrogen fuel cell bi-level EMU
- Plan is to study the feasibility of hydrogen fuel cells as an alternative to catenary for commuter rail in Toronto area

Source: Alstom, Bombardier, Metrolinx, Oliver Wyman analysis. Photos, l-r: Kevin B., Luoxingyang000, Secondarywaltz, all under CC BY-SA licenses via Wikimedia Commons. © Oliver Wyman
Is this the predecessor of a future local locomotive?

Local service was where diesel won the first battles with steam...expect a repeat process

- The local operations opportunity in NA rail is large and ripe for leapfrogging in technology
- In North America, there were ~12,000 four-axle locomotives in 2016
- The estimated average age of these units is 33 years

In the future, your local switch engine may be fixed at the local truck repair shop

Source: NS, CSX, Trains Magazine, Railinc, Oliver Wyman analysis
Photo source: Bob Litts, Frontier Rail,
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In the past, rail innovation was not patient and rarely elegant...but it was leading edge

Locotrol 1980 – 40 tons

Locotrol 2017 – 15 lbs.

Rail must partner in rapidly and broadly testing technologies from new areas

Photo source: left, D. Phillips, right: Rod Case
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Rail Growth Through Digital Acceleration
Rail’s conundrum

- Bigger trains: $41 per 1,000 RTM
- Smaller shipments: $200 per 1,000 RTM

Source: Bureau of Transportation statistics. Photo source: left, Andrew Jennings; right, Getty Images

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Worse…rail is increasingly disconnected from the economy’s base growth and most interesting areas of growth

Key Rail Commodity Volumes vs. GDP

- Grain
- Coal
- Intermodal

Source: Oliver Wyman analysis

Compound Growth Rate of US Retail E-commerce
Adjusted for GDP growth

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Intermodal scenarios for the end game with AV trucks…still large but under considerable price pressure

Rail Intermodal Length of Haul Share

- 500 Miles (Current POI)
- Most likely POI: 1,200 miles Share loss: 33%
- Better for rail POI: 800 miles Share loss: 18%
- Better for truck POI: 1,500 miles Share loss: 37%

Source: Freight Analysis Framework, v4; Intermodal Association of North America, Intermodal Market Trends and Statistics; Surface Transportation Board, Public Waybill Sample; Oliver Wyman analysis
Carload offers leverage for new growth in rail

<table>
<thead>
<tr>
<th>Single Network Capacity</th>
<th>Segment Train Capacity</th>
<th>Supply Chain @ SKU Level</th>
</tr>
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<tbody>
<tr>
<td>• General purpose trains</td>
<td>• Train capacity is segmented in blocks</td>
<td>• Differentiate between pipeline needs versus on-time delivery needs</td>
</tr>
<tr>
<td>• Stable daily operations</td>
<td>• Commodity and service differentiation is designed in blocks</td>
<td>• Get inside the boxcar or container and manage SKUs</td>
</tr>
<tr>
<td>• Repetition drives out dwell and wasteful activities</td>
<td>• Block management complexity is driven at the terminal and local level</td>
<td>• Leverage the costs of inventory and reduced safety stocks to increase total revenue linked to rail move</td>
</tr>
<tr>
<td>• “Muscle memory” in local and terminal operations drives natural service consistency</td>
<td>• Provides multiple service offers while not losing network efficiencies</td>
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We’ve been here before... in 1966

A US example of a small market premium rail product and pricing

- New York Central – Operation Sunset in 1966
- LCL/LTL offer with premium delivery
- Retail service offer with significantly higher average per RTM pricing
- Network interconnections used to provide sub-trainload service lanes
- Merchandise trains and terminals used to maintain train economics
- Very labor intensive

Class I RTMs are three times larger today compared to 1966

Photo source: Wikimedia Commons
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The premium product was broad and leveraged merchandise

Operation Sunset: 1966 Westbound

- 41 cities
- 44 trains
- 97 train-to-train connections
In 1966, this niche premium service was as fast as today… but it was supported in the merchandise network

New York City to Chicago schedule comparisons

<table>
<thead>
<tr>
<th>Service</th>
<th>Hours</th>
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<tbody>
<tr>
<td>LS-1 (1966)</td>
<td>28 hours, 10 minutes</td>
</tr>
<tr>
<td>Lake Shore Limited (2017)</td>
<td>19 hours, 5 minutes</td>
</tr>
<tr>
<td>Intermodal train (2017)</td>
<td>27 to 30 hours</td>
</tr>
</tbody>
</table>

Source: Amtrak, On-Time Performance; Amtrak, Passenger Timetable; CSX, Intermodal Schedules; New York Central, Hudson Division Employee Timetable 19, April 24, 1966; Norfolk Southern, Intermodal Schedules; Oliver Wyman analysis
We are here again...in the merchandise network

Using the power of rail network economics and supply chain orientation is proven to accelerate traffic growth

**Operational Excellence**

- More trains on the same network
- Tighter connections
- Complexities well managed; more levers available

**Service and Network Design**

- Rapid product deployment
- Fewer assets, lower inventory
- Rail-based supply chain gains

**Market Innovations**

**PROFITABLE GROWTH OUTPACING GDP**

Change in Revenue Ton-Miles 2015 versus 2006

- US Rail -2%
- CN Merchandise 22%
- US Trucking 18%
It’s a different world of costs now, as labor-intensive work is increasingly automated

Warehouse Automation

Switching Automation

Photo sources: left: National Museum of American History; top right: Getty Images; bottom right: Andrew Jennings
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The whole supply chain is being automated

- **Autonomous production**
  - Autonomous robots in factories
  - -25% Supply chain costs

- **Autonomous delivery**
  - Drone delivery to customer door
  - AV moving terminal containers

- **Autonomous transportation**
  - Warehouse storage management
  - rolls-Royce

- **KUKA**
  - Robots moving merchandise
  - +30% Time-to-market

- **IROBOTIC**
  - Autonomous facility surveillance
  - +50% Customer choice
Rail is at the tipping point – retrench or innovate

The Challenge
• Rail’s competitive advantages: network location and aggregation model
• Rail must maintain superior margins to reinvest in the network
• Energy transformation
  – Declining rail volumes of coal
  – Electricity getting cheaper
  – Renewable production moving into profit zones and localizing
• Technology innovations are targeted at road competitors and are global in scale

The Opportunity
• Rail is vertically integrated and thus can better control its destiny
• Market offers and complex production have been proven to be growth engines
• Technology has eliminated or reduced many non-value added rail costs
• Technology is at a tipping point that could transform the rail model – as it has done before

Rail’s great periods of innovation came during crises. Let’s not wait this time!
Others most certainly are not waiting...

Proposed Amazon Drone EMUs

Source: Imaginactive, used with permission (http://imaginactive.org)