Smart Ports
Technology Advancements in Intermodal Transportation

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Topics

1) Electrification Progression
   • Marine
   • Locomotive
   • Semi (Class 8) Trucks

2) Electrification Needs

3) Renewable Energy Trends
   • Off-Shore Wind
   • Solar PV
   • Energy Storage

4) NREL’s capabilities
   • Transportation Group
   • Visualization
   • Cyber Security
Hybrid (Diesel/Electric) propulsion

*Easy integration*
*Greater fuel efficiency*
*Lower emission*

*Wartsila, Rolls-Royce, Siemens*

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All Electric propulsion

*Dutch company: Port-Liner*
*Carrying capacity: 280 containers*
*ISD: Fall 2018*
*Routes: Between ports in Europe*
Marine Electrification

All Electric propulsion

Hauling up to 2,000 tons of coal
2.4 MWh Battery/Super-Capacitors
~ 24 Tesla Model 100D car batteries
~ 50 Mile range
Maiden voyage – November 2017

All Electric propulsion

Sweden company: HH Ferries
~ 800 ft long/~ 8,500 tons
Projected: 7.4M people/1.9M cars
Routes: ~2.5 miles (Sweden – Denmark)
Partner with GE to transform the marine ecosystem

**CLEANER FUELS**
Environmental regulations are catalysts for a move to cleaner fuels and more energy efficient technologies.

**ELECTRIFICATION**
Using electrification to enhance reliability and energy efficiency, ensuring fleet readiness and operational flexibility.

**DIGITALIZATION**
Activating intelligent asset strategies to deliver more automated or autonomous vessels.
Autonomous/Electric

Norwegian: Yara Birkeland
Carrying capacity: 100 – 150 containers
Cost: $25M (3x conventional), but offset by 90% annual operating cost savings
~ 37 Mile range
Maiden voyage – 2018
Transition to full autonomous by 2020

Bottom line:
=> Competitive Advantage to Ports that have these capabilities
Locomotive Electrification

Hybrid Diesel/Electric propulsion
Companies: GE, Toshiba
Limited applications
Yard Shunting, European Passenger

All Electric propulsion
Dutch National Railway
100% Wind powered
Projected: 600K passengers and 5,500 train trips per day
**Locomotive Electrification**

**Electric**

*India Railway*

**Goal:** 100% Electrification

~ 11,000 kM network

**RE Goal:** 175 GW of Solar PV by 2022

(1/2 of installed capacity)

**Autonomous**

*Australia*

*Rio Tinto*

100 kM route

*Port of Houston – Investigating Autonomous Freight Shuttle System*

(5 miles – intraport)
Semi (Class 8) Trucks

Natural Gas (LNG/CNG)
*Freightliner, Mack*
*Lower cost fuel*
*Lower emissions*
*~500 mile range*

Hydrogen Fuel Cell
*Toyota, Nikola*
*Toyota ~ 200 miles*
*Nikola ~ 1200 miles (2020)*
Super Truck II
Government-Industry Collaboration

SuperTruck II aims to improve freight efficiency by more than 100% and demonstrate 55% engine brake thermal efficiency.

5 Industry Teams Led By:

Volvo
Cummins / Peterbilt
Navistar
Daimler Trucks
PACCAR
Electric
Cummins, Thor, Tesla
Lower cost of ownership
No emissions
~300 - 500 mile range

Port Implications
• Ports implementing Emission reduction plans
• Need for regional, nation-wide fast charging network
Growing Inventory of Port Electric Vehicles

**EV Yard Tractors**

**EV Drayage**

**Electric Catenary**

**Automated Guided Vehicles...**

**Challenges / Opportunities**

**Charging Infrastructure**
**Charging Protocols**
**Charge Management**
**Battery Secondary Use**
**Grid Services**
**Extreme Fast Charging...**
Electrification Needs

- **Need for Shore Power**
  - Not only container, but cruise ships too
  - Coordinating infrastructure needs

- **Load control/growth**
  - Don’t want simultaneous charging (new higher peak demand)
  - 5x – 8x load growth

- **Opportunities**
  - Ship 2 Grid (S2G)
  - Opportunities for real time pricing – low cost energy capture
  - Reefer units – load control
Future Power Supply

Where is this power going to come from?
Oil and Gas Experience Helped Accelerate First Generation

- Floating wind is based on oil & gas technology and reliability criteria that have resulted in successful but expensive designs
- Unit October 2017 there were only 6 utility-scale floating wind systems
- First multi-turbine project: October 2017 in Scotland – 30-MW Statoil
- System engineering approach is needed to lower cost
Key system cost reduction driver is turbine size (5x land-based)

Component weight minimization a strong imperative; blades, generators, towers, substructures

110-m blade lengths: more modular designs, lighter materials, sub-component testing, innovative manufacturing

Larger test facilities and alternative test methods

Reduced dependence on vessels

Will mature large-scale offshore wind turbines be adapted for future land-based wind plants?
PV Record Cells – Current Status

Best Research-Cell Efficiencies

Multijunction Cells (2-terminal, monolithic)
- LM = lattice matched
- MM = metamorphic
- IMM = inverted, metamorphic
- Three-junction (concentrator)
- Three-junction (non-concentrator)
- Two-junction (concentrator)
- Two-junction (non-concentrator)
- Four-junction or more (concentrator)
- Four-junction or more (non-concentrator)

Single-Junction GaAs
- Single crystal
- Concentrator
- Thin-film crystal

Crystalline Si Cells
- Single crystal (concentrator)
- Single crystal (non-concentrator)
- Multicrystalline
- Silicon heterostructures (HIT)
- Thin-film crystal

Thin-Film Technologies
- CIGS (concentrator)
- CIGS
- CdTe
- Amorphous Si:H (stabilized)

Emerging PV
- Dye-sensitized cells
- Perovskite cells (not stabilized)
- Organic cells (various types)
- Organic tandem cells
- Inorganic cells (CZTS/Se)
- Quantum dot cells (various types)
There has been a strong, steady downward PPA price trend since 2006, with an average levelized price signed in 2016 of ~$35/MWh.

The median unsubsidized LCOE of utility-scale PV projects built in 2016 was below the DOE 2020 SunShot target of 6 cents/kWh.

Li-Ion Batteries

- Lithium-ion battery technology is expected to be the energy storage choice for (xEVs and grid storage) in the coming years
- Better (energy & power) performance than other existing technologies
- Trends toward large format cells
  - Higher volume &weight efficiencies and packaging
  - Lower # of connections and components
  - Lower system cost
Li-ion Battery Cost is Falling

Rapidly falling costs of battery packs for electric vehicles
Björn Nykvist and Måns Nilsson (Nature Climate Change, March 2015)
Bringing analytic resources to the table for novel research outcomes
Vision: a systems approach to integration with near real time analytics

Real-time scenario interaction (what if?)

- Communication infrastructure
- Roads
- Buildings
- Water features
- Power system
- Topo

make changes

see impacts on other system layers
Vision: a systems approach to integration with near real time analytics
**Unique Value Proposition of NREL’s Cyber Security team**

- **Deep expertise** in:
  - Power systems Supervisory Control and Data Acquisition (SCADA)
  - Cybersecurity
  - Networking
  - Distributed energy resources (DERs).

- **Advanced research capabilities** at the Energy Systems Integration Facility’s (ESIF’s) Systems Performance Laboratory, including:
  - Complete test bed with modular power systems, communications, and cybersecurity capabilities
  - Vendor and technology agnostic perspective
  - Ability to pen test at interface, component, or systems level.

- **Flexibility** to expand to water, oil and gas, and thermal systems testing for cybersecurity and resilience.
Summary

• Growing reliance/need for coordination between IT & energy systems
  • Energy systems & infrastructure often overlooked
  • Vulnerabilities growing (IoT), metering, controls, etc

• Growing vehicle electrification & autonomy
  • Growing collaboration/interdependency between Port, City, and regional freight movement

• Could Port become virtual power plant?
  • Solar PV (Perovskites)
  • Large amount of energy storage
NREL Transportation and Vehicle RD&D Activities

Advanced Combustion / Fuels
- Advanced Petroleum and Biofuels
- Combustion / Emissions Measurement
- Vehicle and Engine Testing

Advanced Power Electronics and Electric Motors
- Thermal Management
- Advanced Heat Transfer
- Thermal Stress and Reliability

Advanced Energy Storage
- Thermal Characterization / Management
- Life/Abuse Testing and Modeling
- Computer Aided Engineering
- Electrode Material Development

Hydrogen and Fuel Cells
- Fuel Cell Electric Vehicles
- Fuel Cell Buses
- Fueling Infrastructure
- Hydrogen Systems and Components
- Safety, Codes and Standards

Mobility Systems
- Connected and Autonomous Vehicles
- Vehicle Systems Modeling
- Technology Adoption
- Cost of Ownership Modeling
- SMART Cities Columbus

Commercial Vehicle Technologies
- Technology Field Testing & Analysis
- Big Data Collection, Storage & Analysis
- Vehicle Systems Modeling
- Super Truck and 21st Century Truck
- Vehicle Thermal Management

Infrastructure and Impacts Analysis
- Vehicle-to-Grid Integration
- Integration with Renewables
- Charging Equipment & Controls
- Fueling Stations & Equipment

Vehicle Deployment / Clean Cities
- Guidance & Information for Fleet Decision Makers and Policy Makers
- Technical Assistance
- Online Data, Tools, Analysis

Regulatory Support
- EPAct Compliance
- Data & Policy Analysis
- Technical Integration
- Fleet Assistance
Thank you

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