NREL
NATIONAL RENEWABLE ENERGY LABORATORY





AAPA
ENVIRONMENT COMMITTEE MEETING

Brett Oakleaf, NREL - Ports/Airports Collaboration Leader

April 10, 2018

Topics

1) Electrification Progression

2) Electrification Needs

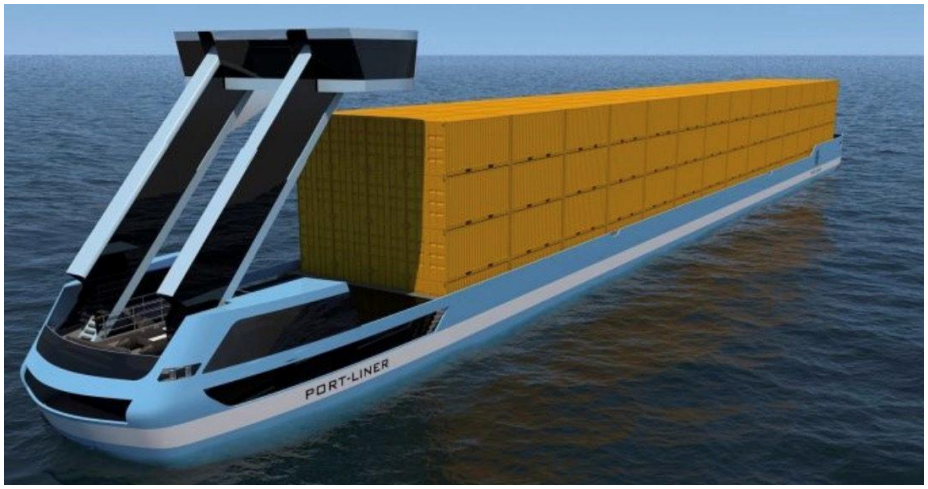
3) Renewable Energy Trends
- Off-Shore Wind
- Solar PV
- Energy Storage

4) Growing areas of interest with Ports
- Visualization/Collaboration with City
- Increasing resiliency
- Growing collaboration with Federal Agencies

Marine Electrification

Hybrid (Diesel/Electric) propulsion

Easy integration
Greater fuel efficiency
Lower emission
Wartsila, Rolls-Royce, Siemens



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)

Marine Electrification

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

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)

Semi (Class 8) Trucks

Electric

Cummins, Thor, Tesla
Lower cost of ownership
No emissions
~300 - 500 mile range

Port Implications

- *Significant charging demands*
- *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*
  - *Coordinating infrastructure needs*
  - *Significant load growth (10MW/Cruise ship)*
- *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*
- *Could this be a negotiation tool for Port to work with Electric Utility to implement?*
  - *Utility perspective (low/declining low growth, new business model)*
  - *Port Perspective (valuable customer with unique energy characteristics)*
  - *Win-win for Port and Utility*

Future Power Supply

Where is this power going to come from?

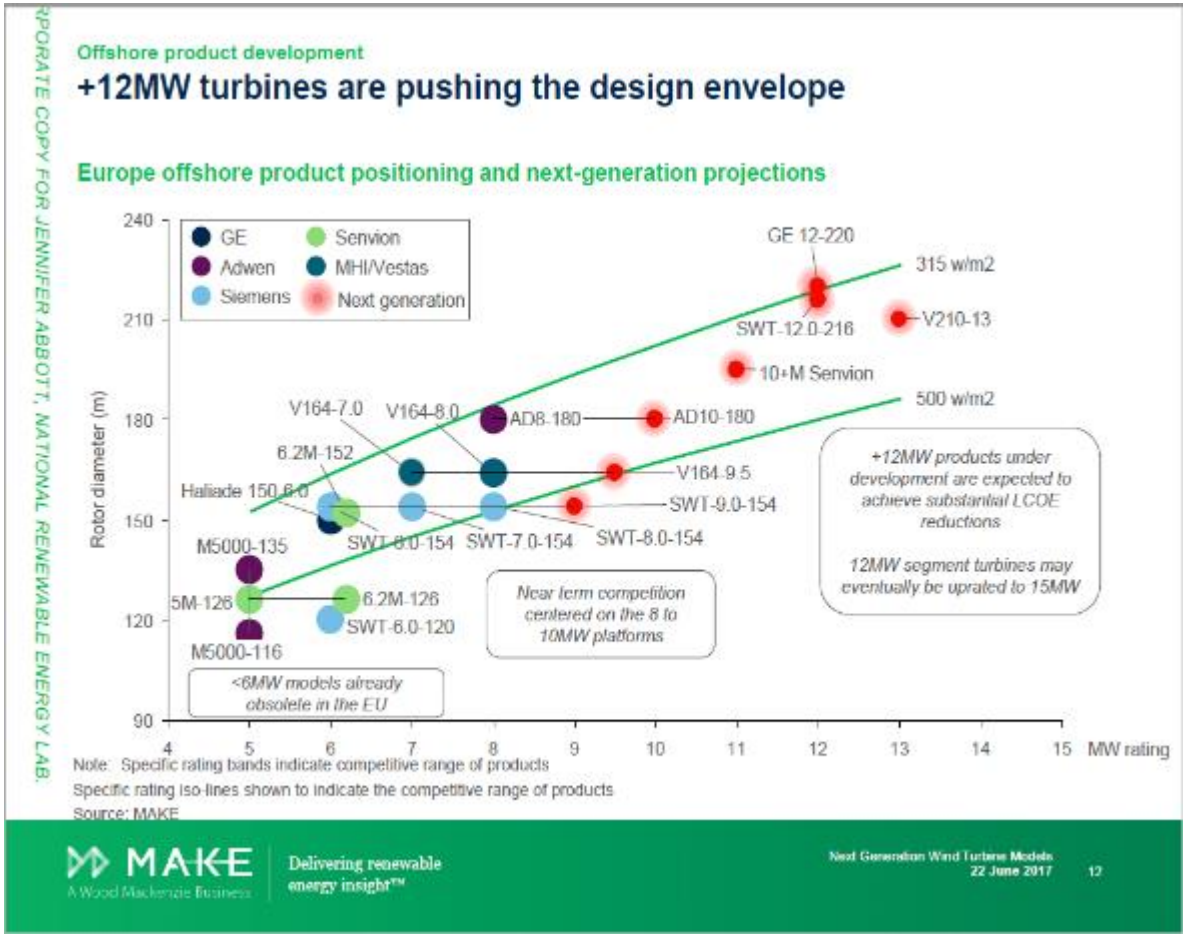
Oil and Gas Experience Helped Accelerate First Generation

- 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

Knowledge Transfer

Scaling Turbines to 15-MW - New Technology Challenges

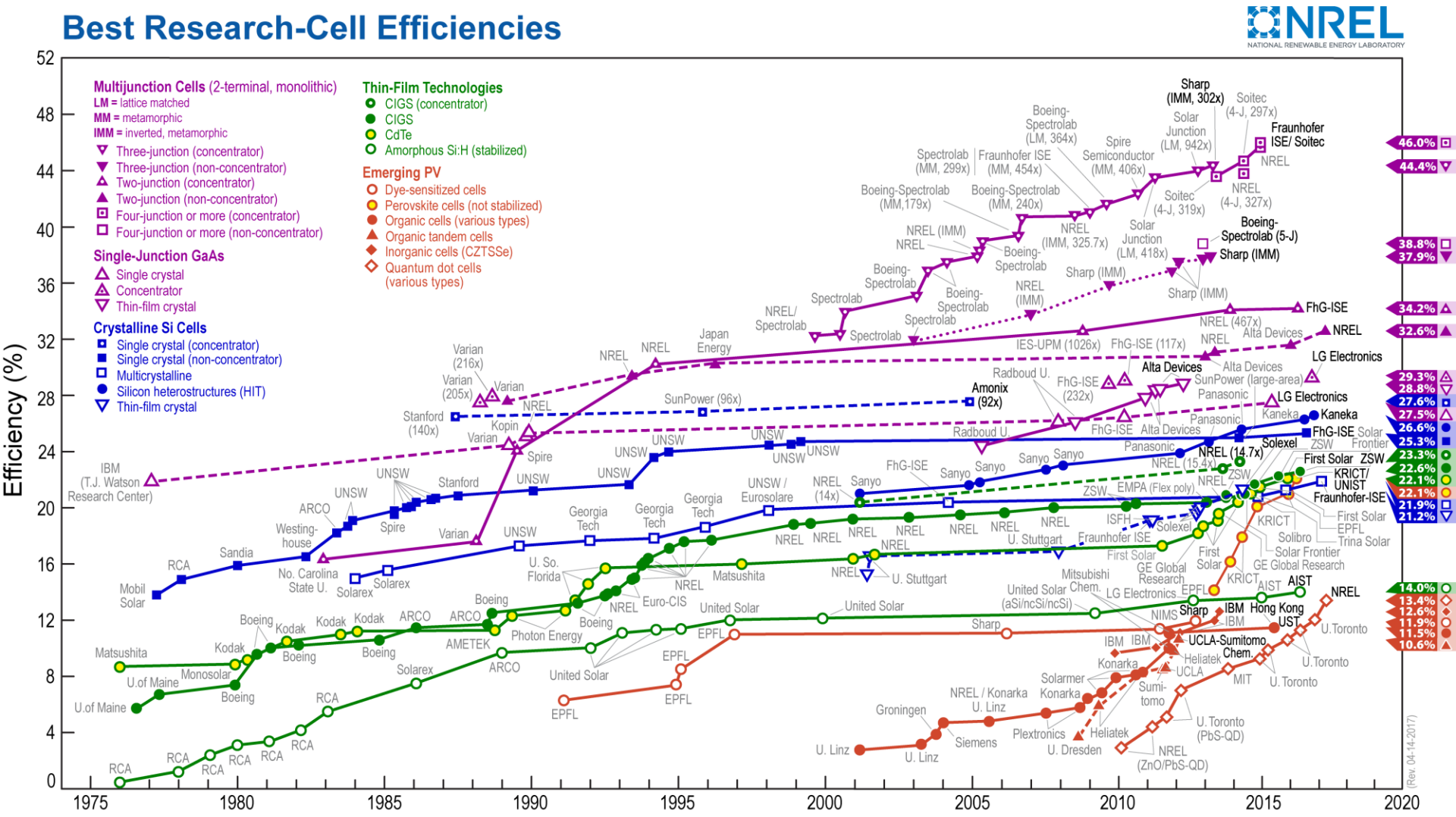
- Key system cost reduction driver is turbine size (5x land-based)
- Component weight minimization a strong imperative; blades, generators, towers, substructures
- 110-m blade lengths: more modular designs, lighter materials, sub-component testing, innovative manufacturing
- Larger test facilities and alternative test methods
- Reduced dependence on vessels



Data Source: MAKE Consulting 2017

Will mature large-scale offshore wind turbines be adapted for future land-based wind plants?

PV Record Cells – Current Status



PV Costs – Falling Rapidly

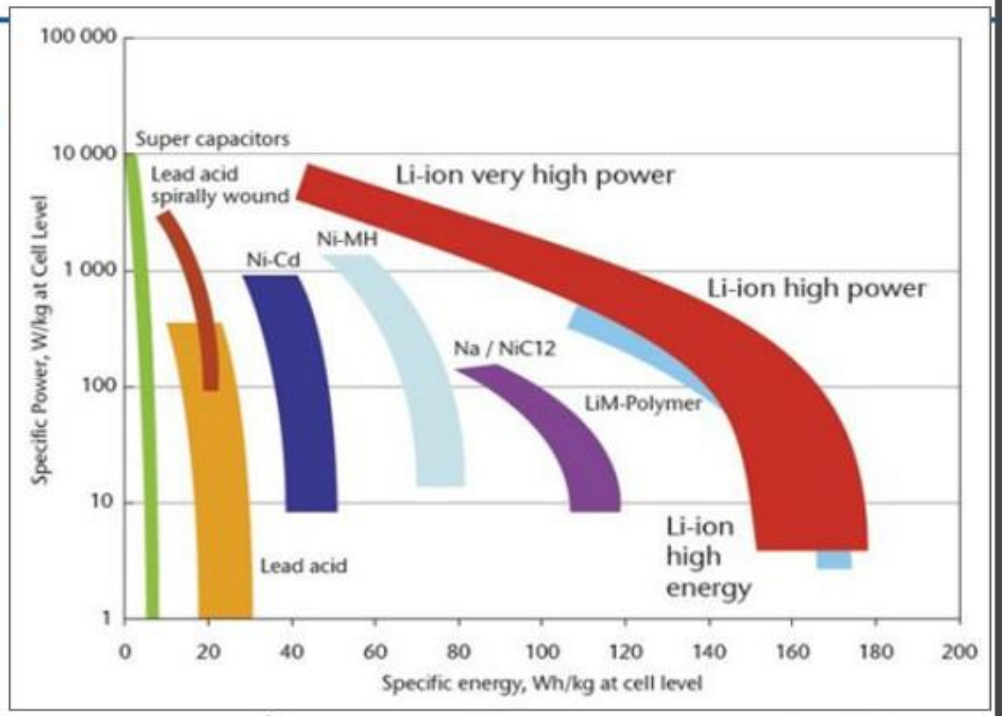
2017 Xcel Energy (Colorado) RFP Bid Responses

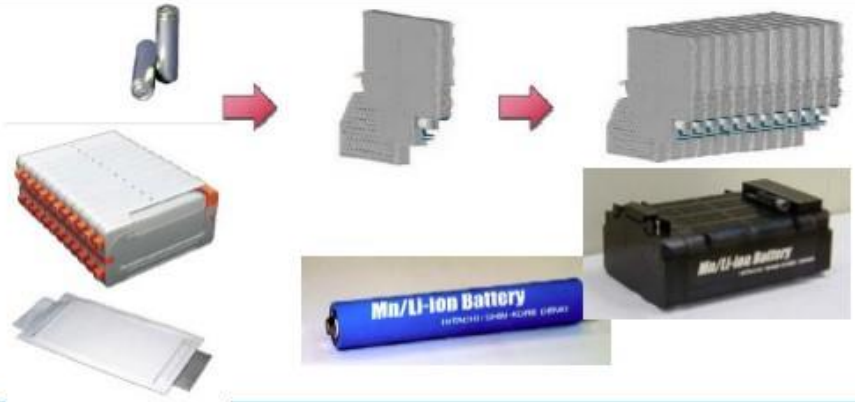
RFP Responses by Technology

Generation Technology	# of Bids	Bid MW	# of Projects	Project MW	Median Bid Price or Equivalent	Pricing Units
Combustion Turbine/IC Engines	30	7,141	13	2,466	$ 4.80	$/kW-mo
Combustion Turbine with Battery Storage	7	804	3	476	6.20	$/kW-mo
Gas-Fired Combined Cycles	2	451	2	451	[redacted]	$/kW-mo
Stand-alone Battery Storage	28	2,143	21	1,614	11.30	$/kW-mo
Compressed Air Energy Storage	1	317	1	317	[redacted]	$/kW-mo
Wind	96	42,278	42	17,380	$ 18.10	$/MWh
Wind and Solar	5	2,612	4	2,162	19.90	$/MWh
Wind with Battery Storage	11	5,700	8	5,097	21.00	$/MWh
Solar (PV)	152	29,710	75	13,435	29.50	$/MWh
Wind and Solar and Battery Storage	7	4,048	7	4,048	30.60	$/MWh
Solar (PV) with Battery Storage	87	16,725	59	10,813	36.00	$/MWh
IC Engine with Solar	1	5	1	5	[redacted]	$/MWh
Waste Heat	2	21	1	11	[redacted]	$/MWh
Biomass	1	9	1	9	[redacted]	$/MWh
Total	430	111,963	238	58,283		

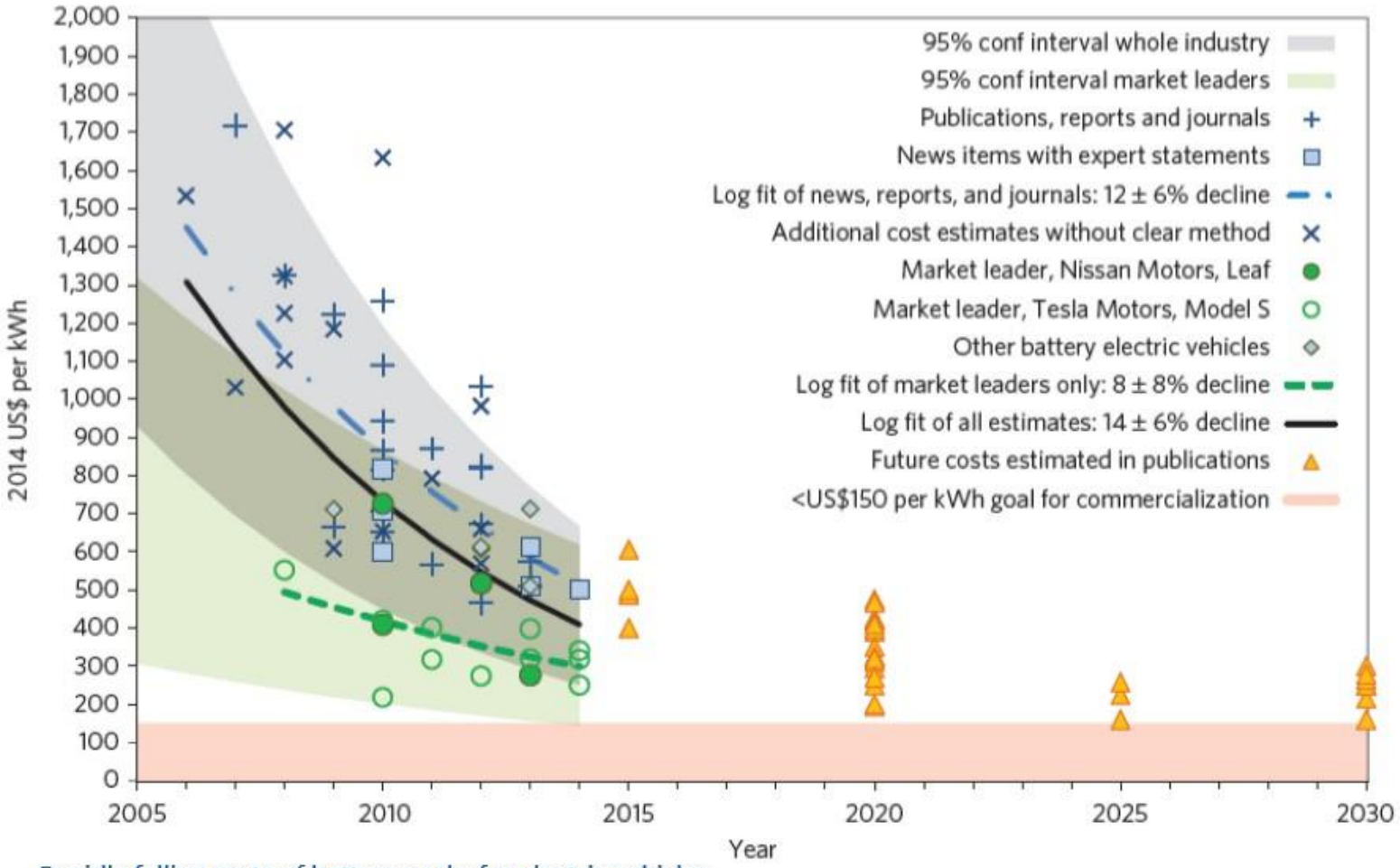
Li-Ion Batteries

- 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)

Ports: Main Economic Engine for City/Region

Metropolitan Mobility Optimization through High Performance Computing

Driving Energy-efficiency and Productivity at the Nexus of Regional Mobility, Major Airports, and Autonomous Vehicles

Three HPC Project Concepts

Regional Mobility:
- Digital Twin
- Cyber Physical Control

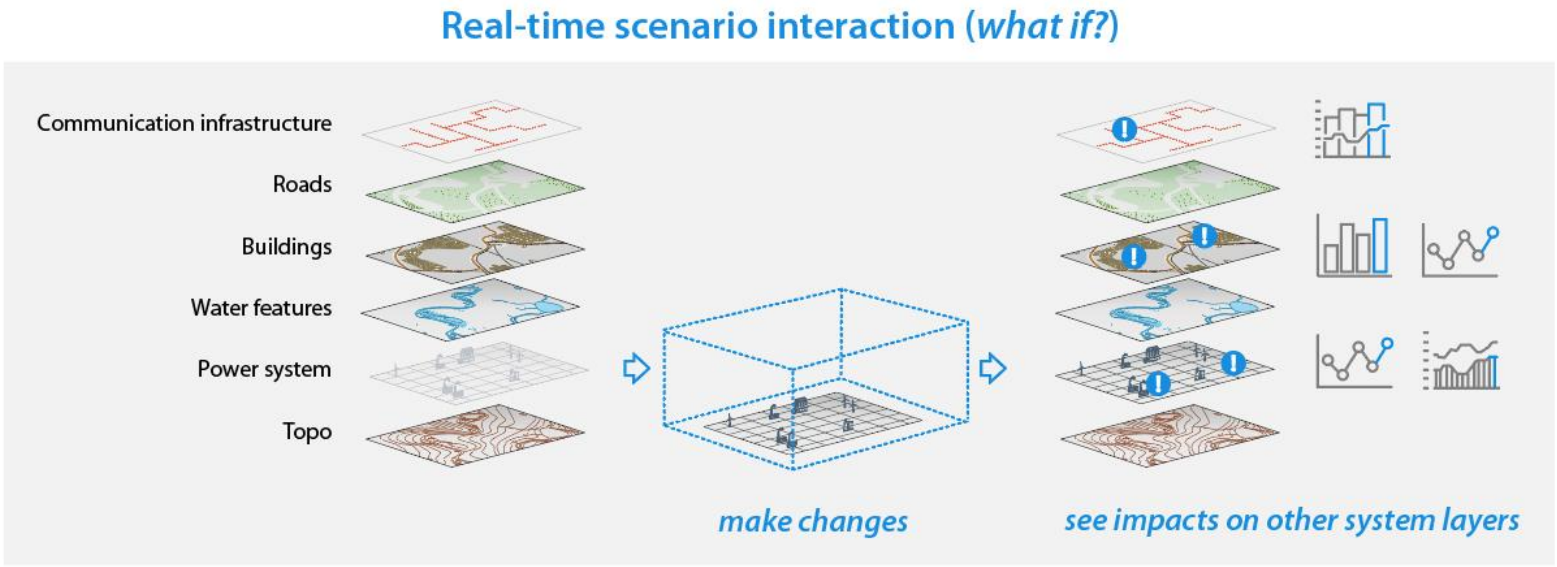
Airport and Freight:
- Energy Productivity
- Disruptive Mobility Technologies

Connected and Autonomous Vehicle:
- Control Algorithms
- Deep Learning
- V2I Communication for Cyber Physical Mobility Control

Metropolitan Mobility Redefined by Confluence of Projects

HPC-Driven Transportation Optimization for:
- Energy Efficiency
- Productivity
- Mobility

Vision: Systems approach to integration with near real time analytics

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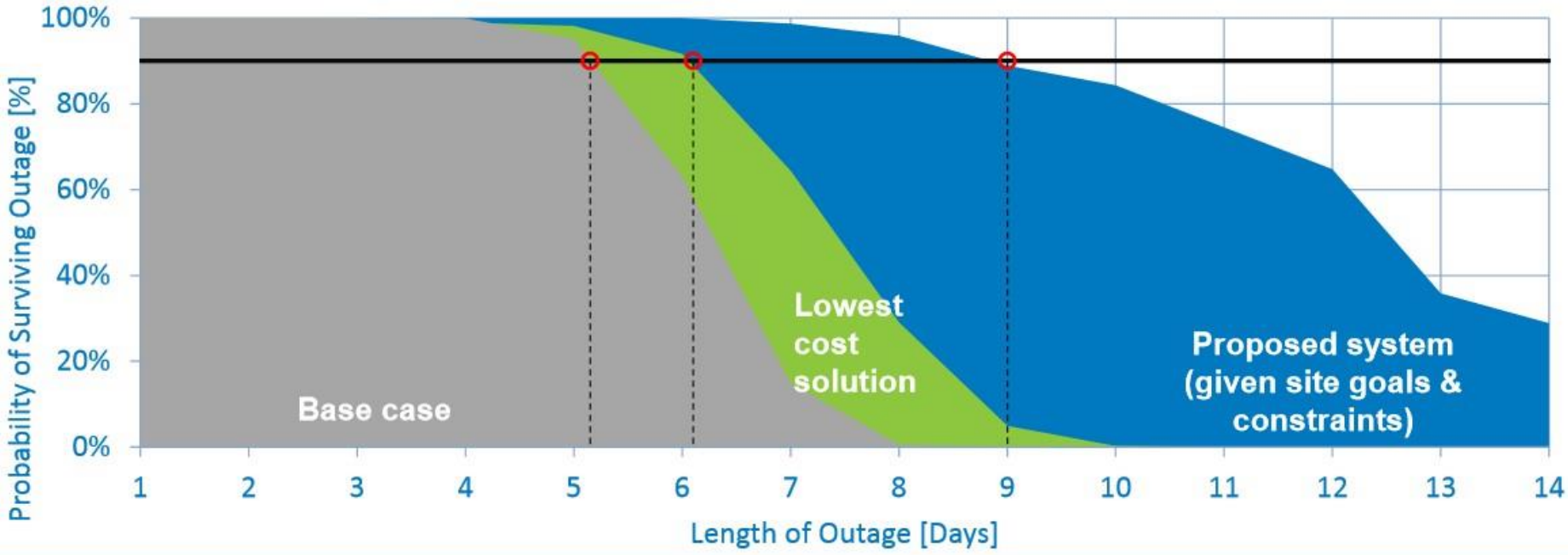
South (10 kW)
Garage (270 kW)
East (1,153 kW)

Using RE to Extend Survivability

REopt Integration and Optimization

NREL evaluated thousands of random grid outages and durations throughout the year and compared number of hours the site could survive with a diesel generator and fixed fuel supply vs. generator augmented with PV and battery

	Generator	Solar PV	Storage	Lifecycle Cost	Outage
1. Base case	2.5 MW	-	-	$20 million	5 days
2. Lowest cost solution	2.5 MW	625 kW	175 kWh	$19.5 million	6 days
3. Proposed system	2.5 MW	2 MW	500 kWh	$20 million	9 days



Growing collaborations with Federal Agencies

- *Department of Transportation*
  - Office of Port Infrastructure Development
- *Department of Energy*
  - Vehicle Technologies Office
- *Department of Homeland Security*
  - FEMA

➢ *Themes*
  - Resiliency
  - Economic growth
  - Innovation

Summary

- *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*
  - *Load control from buildings, reefer racks, cold warehouses*
- *Opportunities for increasing Port wide resiliency*
  - *Flexibility planning*
- *Interest from federal, state, local level in collaborating with Ports*

Glimpse of the Future

- *How will Ports change in the coming decade?*

Thank you

www.nrel.gov

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Time for Boat Tour