



# Grid-Scale Energy Storage Technology Opportunities



Boeing Research & Technology / Boeing Energy

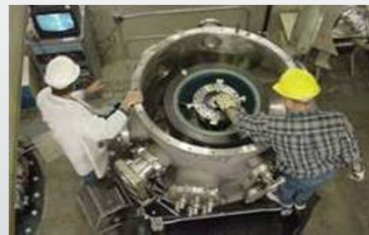
*Mark Henley*  
*The Boeing Company*



# Introducing *Boeing Energy*

## Bringing Boeing engineering & experience ...

- Energy experience in microgrids for space station, solar power for satellites, fuel cells ...
- Cyber-secure, mil-spec, remote/distributed network operations & operations-center expertise
- Decades of system-of-systems integration experience solving large & complex challenges
- Strong commercial, military, and industrial relationships
  - Over 22,000 suppliers & partners globally, with customers in over 90 countries
  - More than 159,000 Boeing employees in 49 states and 70 countries
- Revenue of \$68.3 billion (2009) – resourced like few others to take on very large challenges
- Research, design, & technology-development centers & partnerships around the world



## To solve the toughest energy challenges

- **Clean, abundant, reliable, and secure** energy generation & access
- **Situational awareness** to improve efficiency & reliability
- **Modeling & simulation** to minimize system demands & costs
- **Cyber-security** to protect energy grids
- **Command & control** over distributed infrastructure to respond to failures & attacks
- Partnering with government and other leading energy organizations
- Open-architecture future-proof infrastructure (as grids shift to *ad hoc* distributed generation & EVs)

# Leading via Environmental Commitments

- **Relentlessly Reducing Environmental Footprint**

- Reduced energy consumption by 32% on over 85M square-feet of company facilities (since 2002, revenue-growth adjusted)
- Targeting 25% cuts in greenhouse gas emissions intensity and hazardous waste and 25% further increases in energy efficiency and recycling rates by 2012, even as business grows
- Certified all major manufacturing sites to ISO 14001



- **Pioneering Environmentally Progressive Technology**

- Each new commercial airplane generation will be at least 15% more fuel- and CO<sub>2</sub>-efficient
- Developing air traffic management solutions with substantial near-term environmental improvements
- Advancing renewable energy sources such as sustainable biofuels, fuel cells, and solar cells



- **Strengthening the Industry's Environmental Focus**

- Leading and aligning the aerospace industry on environmental-improvement





# Value of Energy Storage

## Boeing Simulation of NYC Grid Operations

- Boeing originally developed supervisory control and data acquisition (SCADA) for Consolidated Edison of New York over 25 years ago
- Boeing's Service-Oriented Architecture is the solution to interoperability and cyber security in Con Edison's current DOE Smart Grid Demonstration
- Simulations of the NYC Grid have illustrated the great value of energy storage



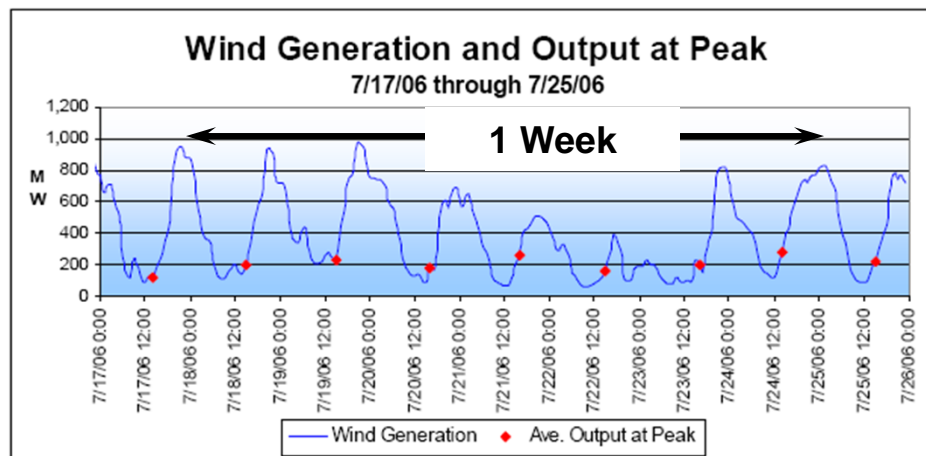
# Renewable Energy Storage Needs

## Example: Wind Generation in California



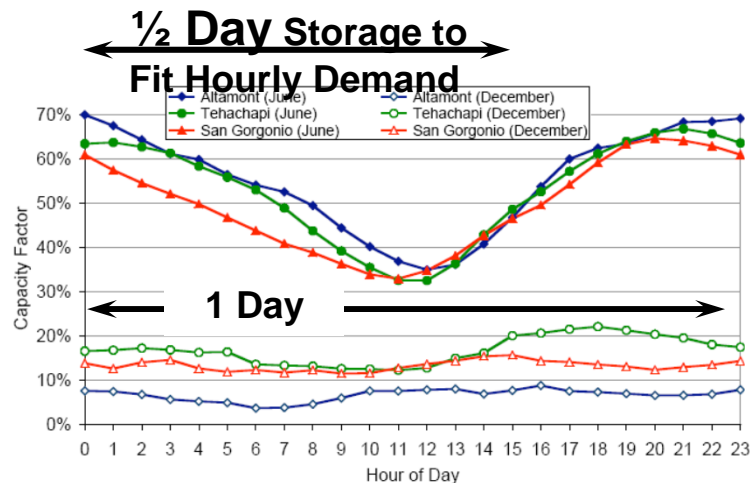
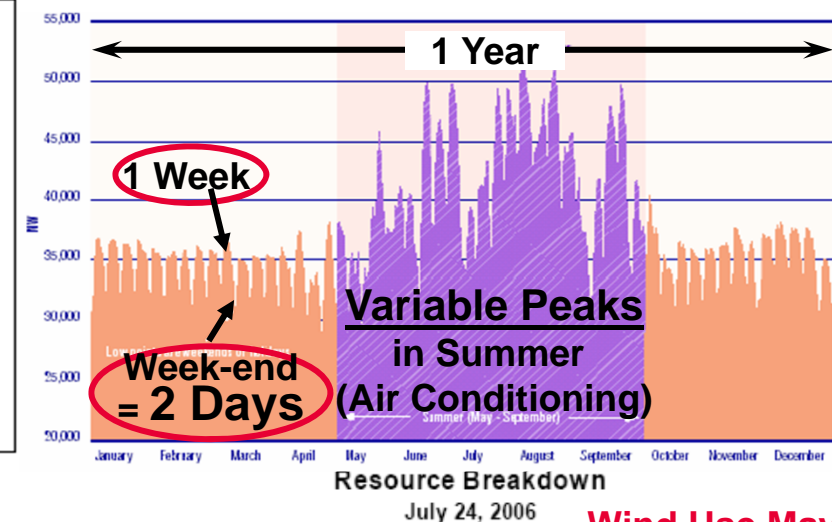
### Wind Power Supply

- Maximum on Summer Nights



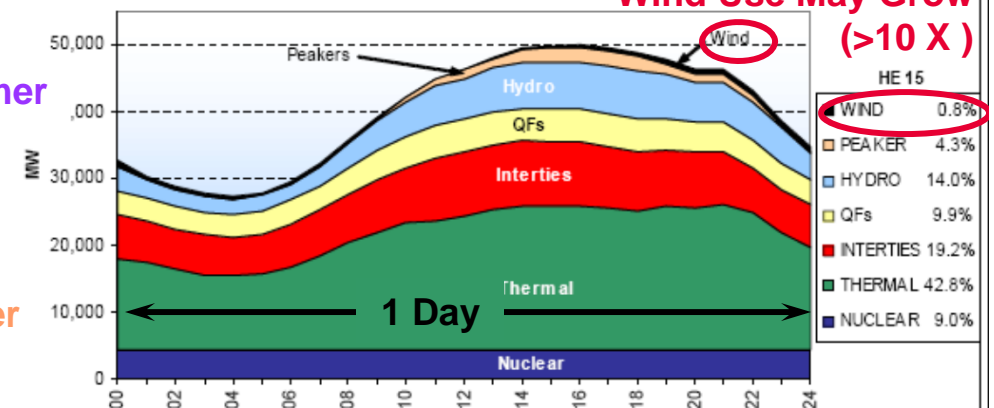
### Grid Peak Power Demand

- Maximum on Summer Days



Summer

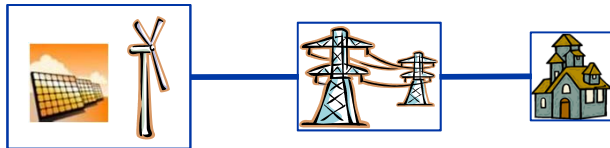
Winter



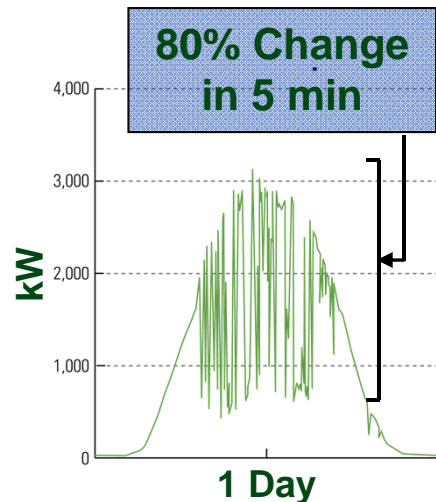
# DoE ARPA-E Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)



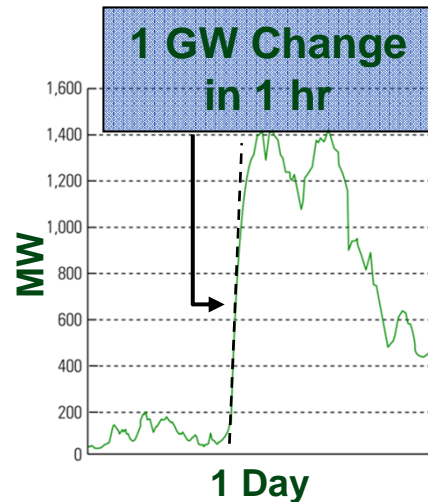
## Renewables Today



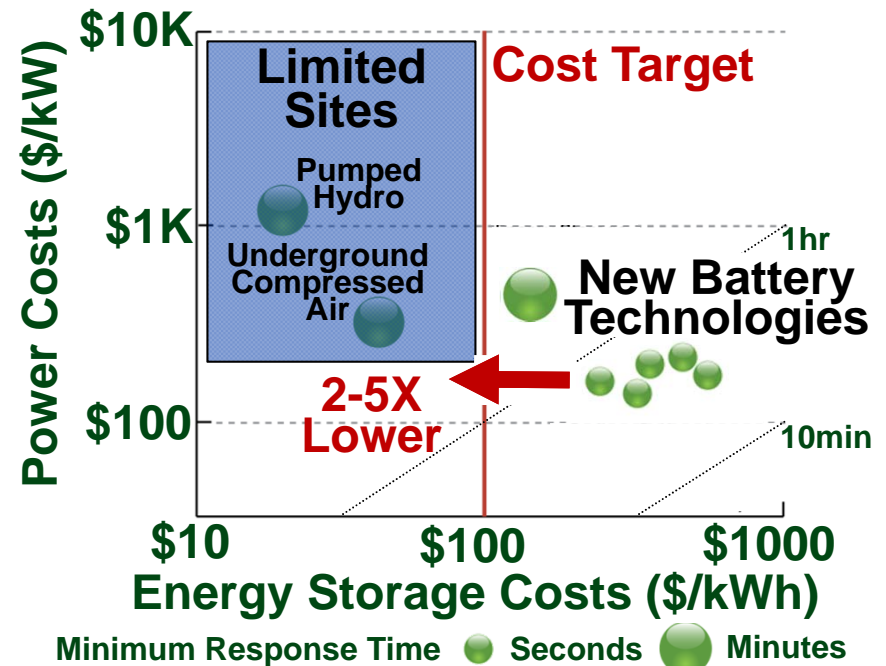
Solar PV in AZ (TEP)



Wind in OR (BPA)



**Problem:**  
Minutes-to-Hours Changes in Power



**Need:** Innovative Technologies for  
Cost-Effective Energy Storage

**ARPA-E Focus:** Transformational approaches to energy storage to enable wide deployment at very low cost



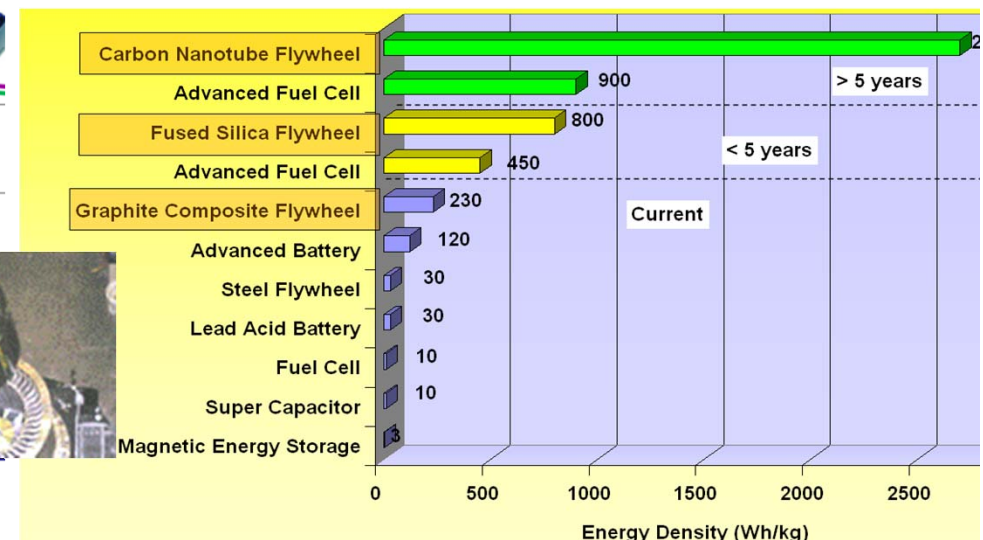
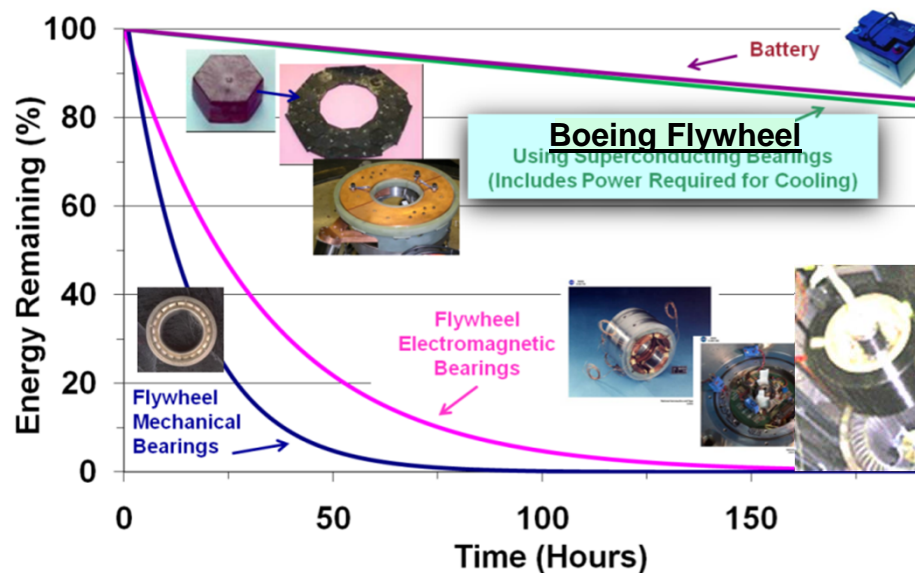
# Boeing's Low Cost, High Energy Density Flywheel Storage Grid Demonstration for ARPA-E

## Why Pursue Flywheel Energy Storage?

- Non-toxic and low maintenance
- Potential for high power density (W/kg)
- Potential for high energy density (W-Hr/kg)
- Fast charge / discharge times possible
- Cycle life times of >25 years
- Broad operating temperature range

## Why Use Superconducting Bearings?

- Simple passive system
- Very low frictional loss = Very long lifetime
- Low cost and maintenance
- Tolerance for balancing dynamic structure
- High speed capability (> 500,000 RPM)
- Adjustable stiffness & damping



**Boeing Superconducting Bearings Offer Many Design and Operational Benefits Over Conventional Bearing Systems**

# Southern California Edison Smart Grid Activity: Vision for a Cleaner, Smarter Energy Future

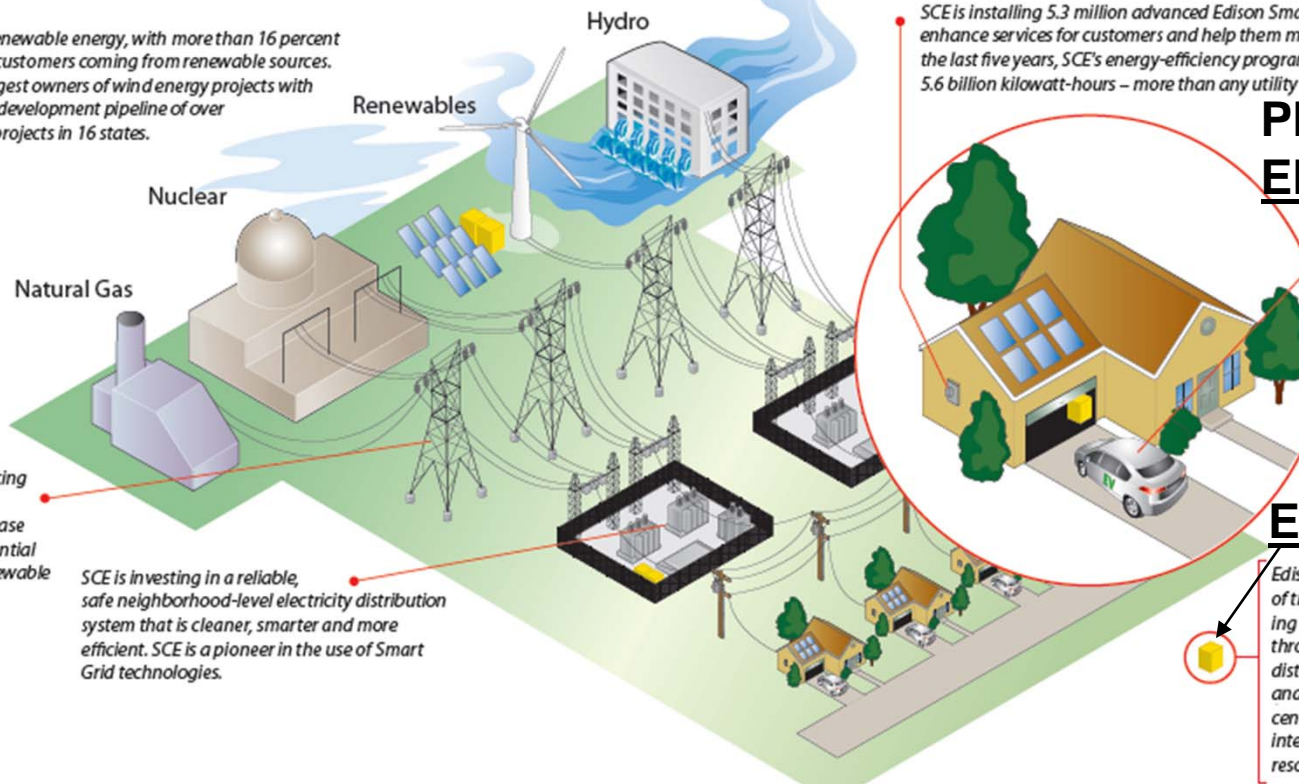
**Mission statement:** Demonstrate the integration of disparate smart grid technologies (supply, transmission, distribution, and in-home) into a holistic “Integrated System of the Future.”

SCE is the nation's leader in renewable energy, with more than 16 percent of the electricity delivered to customers coming from renewable sources. EMG is one of the nation's largest owners of wind energy projects with 1,185 MW in 10 states, and a development pipeline of over 5,000 MW of wind and solar projects in 16 states.

EMG is one of the nation's most experienced operators of cogeneration facilities, which use clean-burning natural gas to produce electricity and steam through combined heat and power systems.

SCE is expanding and enhancing the transmission system to maintain reliability and increase access to areas rich with potential for wind, solar and other renewable power generation.

SCE is investing in a reliable, safe neighborhood-level electricity distribution system that is cleaner, smarter and more efficient. SCE is a pioneer in the use of Smart Grid technologies.



SCE is installing 5.3 million advanced Edison SmartConnect™ electricity meters to enhance services for customers and help them manage energy use wisely. Over the last five years, SCE's energy-efficiency programs have helped customers save 5.6 billion kilowatt-hours – more than any utility in the nation.

## Plug-In Hybrid/Electric Vehicle

Plug-in vehicles will connect and communicate with the Smart Grid, allowing Edison and its customers to manage the demand on the system and the costs associated with using electricity to fuel transportation.

## Energy Storage

Edison International believes the grid of the future will feature new emerging energy storage technologies throughout the system from small distributed applications for homes and local communities up to large central plant applications that help integrate intermittent renewable resources such as wind and solar.

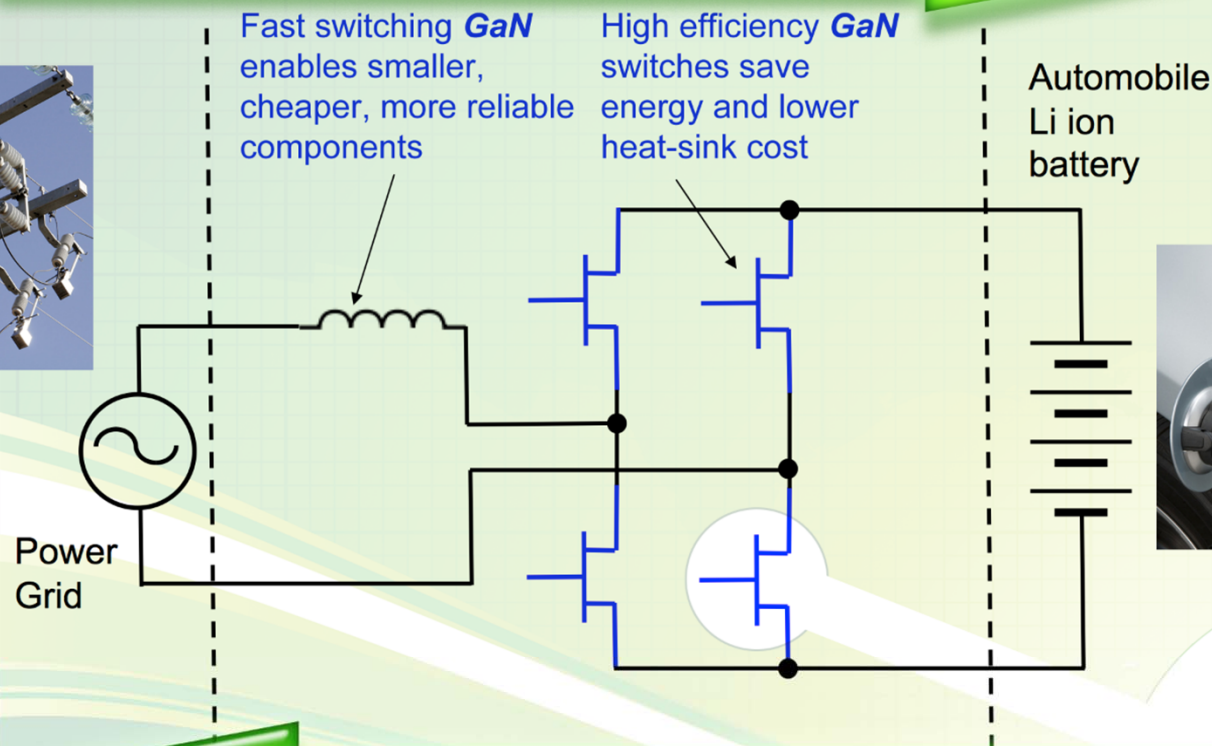
## Plug-In Hybrid/Electric Vehicles Key to Energy Storage

- 1) Grid → Vehicle Charging (mostly at Night)
- 2) Potential Vehicle → Grid Charging (back-up)



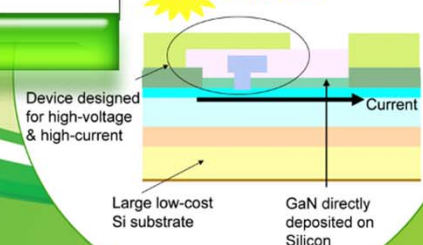
# GaN Switch Technology for Bi-Directional Battery-to-Grid Charger

Enabling  
a  
**Smarter  
Grid**



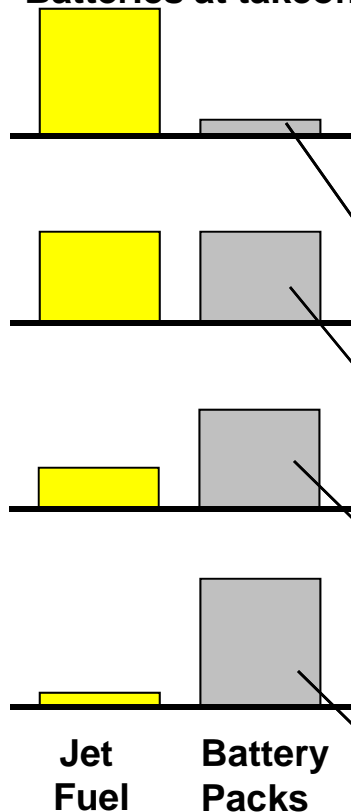
Low Cost  
High Efficiency  
GaN Switches

Same Price as Si



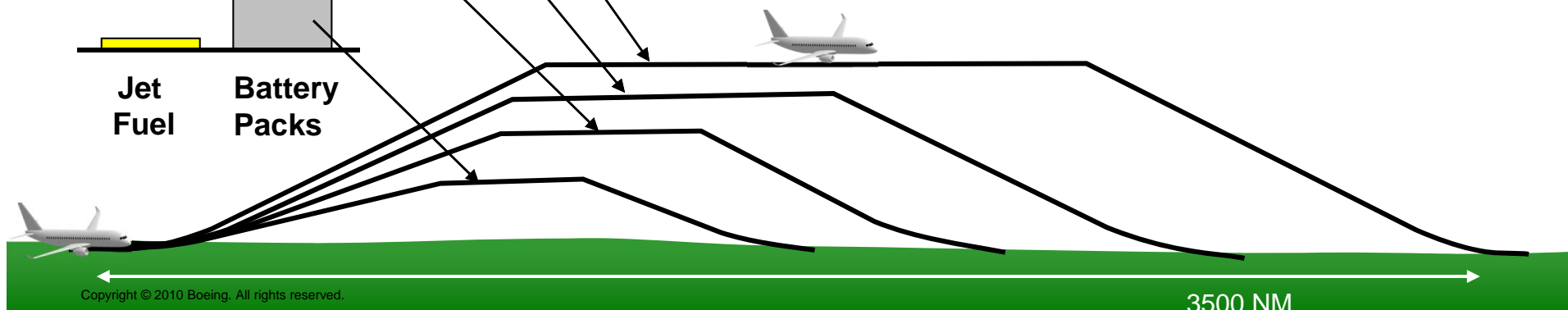
# Future Hybrid Aircraft May Reduce Fuel & Emissions by Storing Energy from the Grid During Off-Hours

Weight of Jet Fuel and Batteries at takeoff



## Subsonic Ultra-Green Aircraft Research “SUGAR-Volt” Hybrid Aircraft Concept

- Both electric motor + conventional gas turbine for take-off & climb
- Either system used for cruise
- Hybrid propulsion allows for ratio of jet fuel and batteries to vary depending on the mission
  - Long ranges fly mostly on jet fuel
  - Short missions fly mostly on electric power



# Summary



## ■ **Energy storage will reduce costs and increase security**

- Increases grid independence, relieving stress on transmission infrastructure
  - Storage is one means (of many) to advance microgrids (campuses, bases, communities)
  - Plug-In Hybrid/Electric Vehicles may help store power in off-hours
- Reduces pollution and energy losses due to untimely generation
- Enables renewable energy system integration
  - Firms variable energy generation (wind, solar) without adding/stressing gas-turbines
  - Transmission system upgrades needed for renewables include storage (siting)

## ■ **Boeing Energy's key efforts:**

- 6 projects with DOE, including 3 Smart Grid Demonstrations
- GaN Switch Technology for Bi-Directional Battery-To-Grid Charging (HRL/ARPA-E)
  - Enables Next Generation of Plug-In Hybrid/Electric Vehicles
- Superconducting Flywheel kinetic energy storage (ARPA-E & Sandia Nat'l Lab)
  - Actual spinning reserve: Rapid charge/discharge without degrading system life
  - High number of cycles & nearly full depth of discharge
  - Longer life (>25 years) and lower maintenance than batteries (or other flywheels)
  - Wide range of operating temperature, from extreme desert to extreme cold
  - Safe: No risk of explosion, fire, or hazardous waste (clean, non-toxic)
  - No rare commodities (e.g. lithium, fossil fuels)
  - Level of charge is known exactly