Harvard Electricity Policy Group

Electricity Storage

as

Transmission and Generation

The Value of Lithium Ion Battery Deployment and Associated Policy Issues

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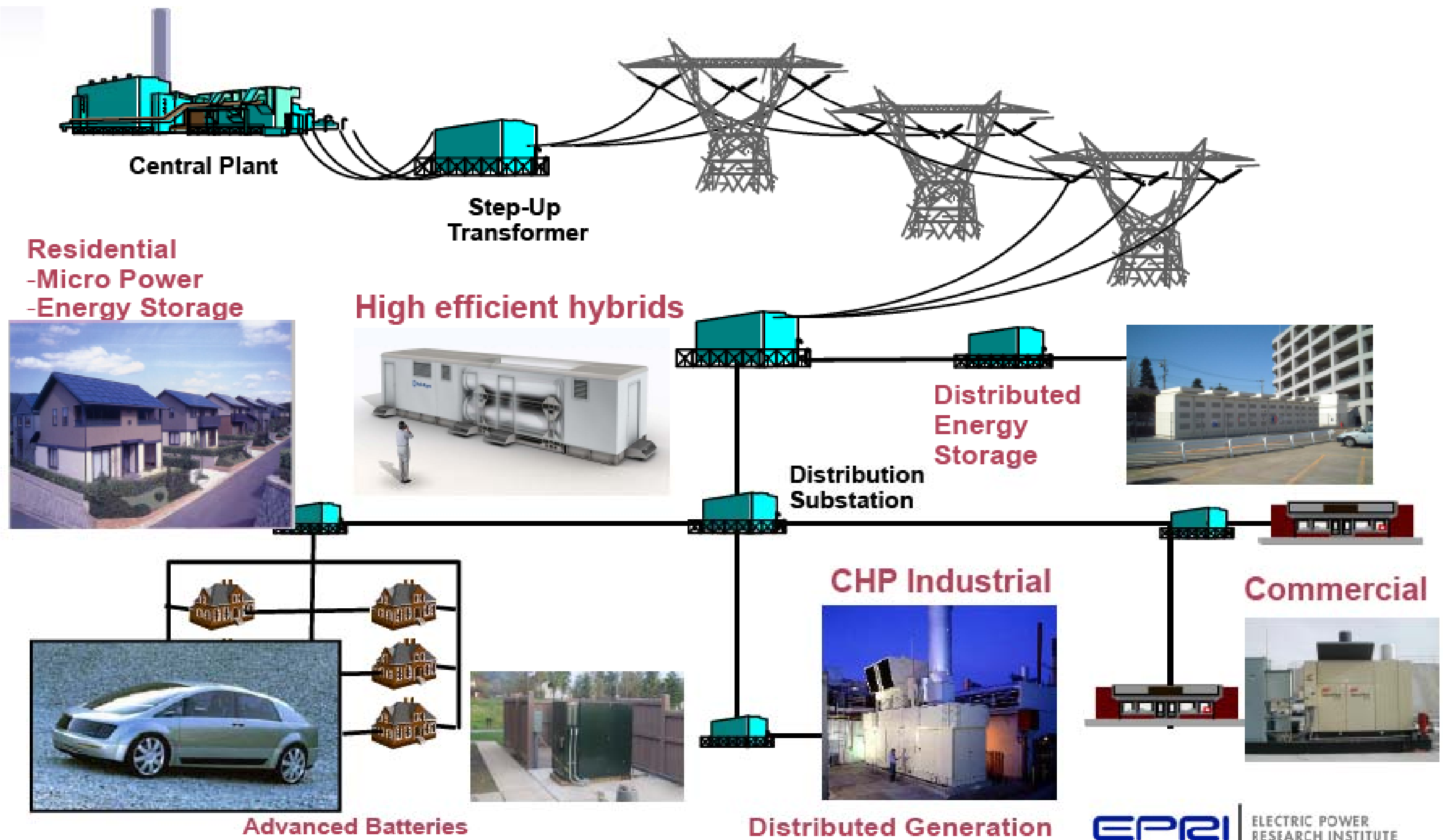
Overview Of Storage Types

- Pumped Storage
  - Approximately 2% of generation
  - Requires certain geologic structures or elevated tanks
- Compressed Air Storage
  - Promising new technology
  - Requires certain geologic structures
- Battery Storage
  - Can be widely deployed
  - Battery types include
    - Lead Acid
    - NaS
    - Li

Storage Throughout the Grid



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Focus on Battery Storage

- Safety: can drive site location and some battery chemistries are much safer than others.
- Round Trip Efficiency: varies greatly by battery type.
- Cycle Life: lives vary by at least an order of magnitude.
- Scalability: intelligent control can promote scalability.
- Maintenance and Support: from high and specialized to low.
- Size and Weight: new chemistries offer lighter weight and smaller size.

Substantial investments in recent years by the automotive industry provide new opportunities for cost-effective stationary storage.

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Focus on Lithium Ion Storage

- Lithium ion Iron Phosphate (LFP) chemistry is less volatile and designed for automotive use.
  - Water (not acid) is used as the solvent
  - Highly recyclable
- Li is a light weight metal and offer a high density of storage and deep discharge (80%) resulting in a relatively small footprint and light weight.
- Li cycle life can exceed 3,000 cycles or over 8 years if cycled daily.
- Current rate of charge and discharge good and substantial improvements will be commercialized in 3 to 5 years.

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Lithium Ion Round Trip Efficiency

- Battery 92%
  - Highest among battery chemistries
- Power Electronics 96.5%
  - Some improvements still possible
- Total Round-trip efficiency can approach 89%
  - Superior to most other types of storage
- Through providing measured output to the grid transmission and distribution efficiency gains can be realized.
  - Simulation modeling needs to be performed to quantify

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LFP Storage Costs

- We are currently driving down the cost of Li storage solutions below the critical $1,000/kWh threshold as identified by EPRI.
  - Utilizing large-format prismatic cells with advanced control as opposed to more expensive cylindrical cells.
- Long cycle life and low total cost of ownership provide long-term value.
  - Very low maintenance and does not require specialized technicians
- During the life of new generation assets currently being planned the cost of battery storage will continue to decline sharply.
  - Current generation planning needs to anticipate storage that will be available by the time the generation assets are commissioned.

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Centralized v Distributed Storage

- Depending on the application Li battery storage may be centralized or distributed
  - Solar or wind farm centralized
    - Can provide firm peak capacity
    - Reduces impact of intermittent generation on the grid
  - Peak load shifting can be distributed
    - Stores low-cost off-peak power
    - Reduces grid congestion
    - Can provide power when and where needed during peak
- Depending on the application storage may be viewed as a transmission or a generation asset.

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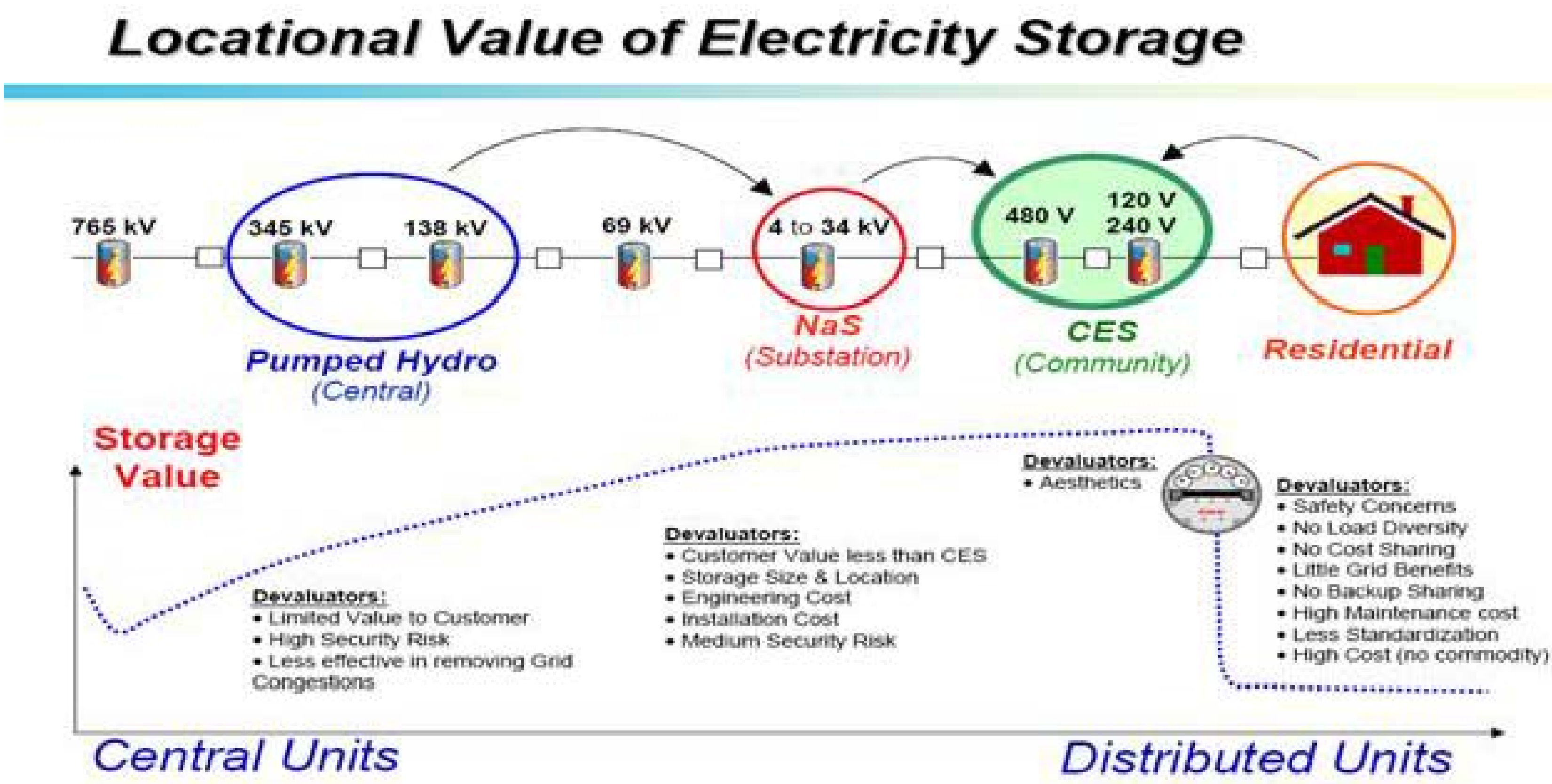
Value and Location of Storage



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Edge v. Center and Complexity

- Industry historically focused on centralized one directional control.
  - Existing control systems are dated.
- Distributed generation introduces control challenges that may overwhelm centralized control.
  - Smart Grid is intended to help but will be exceedingly complex.
- Complexity of control can be reduced through smart storage at the edge.
  - Reduction of complexity at the edge reduces control challenges at the center.

Enterprise Risk and Generation Assets

- The game is changing
  - No new coal states
  - Increased regulation
  - Carbon cap/tax
- Volatility of non-renewable fuel markets
  - Natural gas and oil (Carnegie Mellon—The Energy Journal)
  - Nuclear
- Will generation plants live out their planned economic life?

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How Storage Reduces Enterprise Risk

- Defers decisions on construction of traditional generation assets.
  - Allows time for new technologies to mature.
- Defers construction of some transmission assets.
  - Particularly valuable in constrained areas.
- Reduces capacity of transmission assets required for intermittent generation.
  - Smoothing delivery reduces transmission capacity requirements.
- Reduces investment required for peaking generation assets.
  - Eliminates GHG's generated by peaking assets.
- Improves economic efficiency of base and shoulder generation.
  - Enhances value of off-peak generation.

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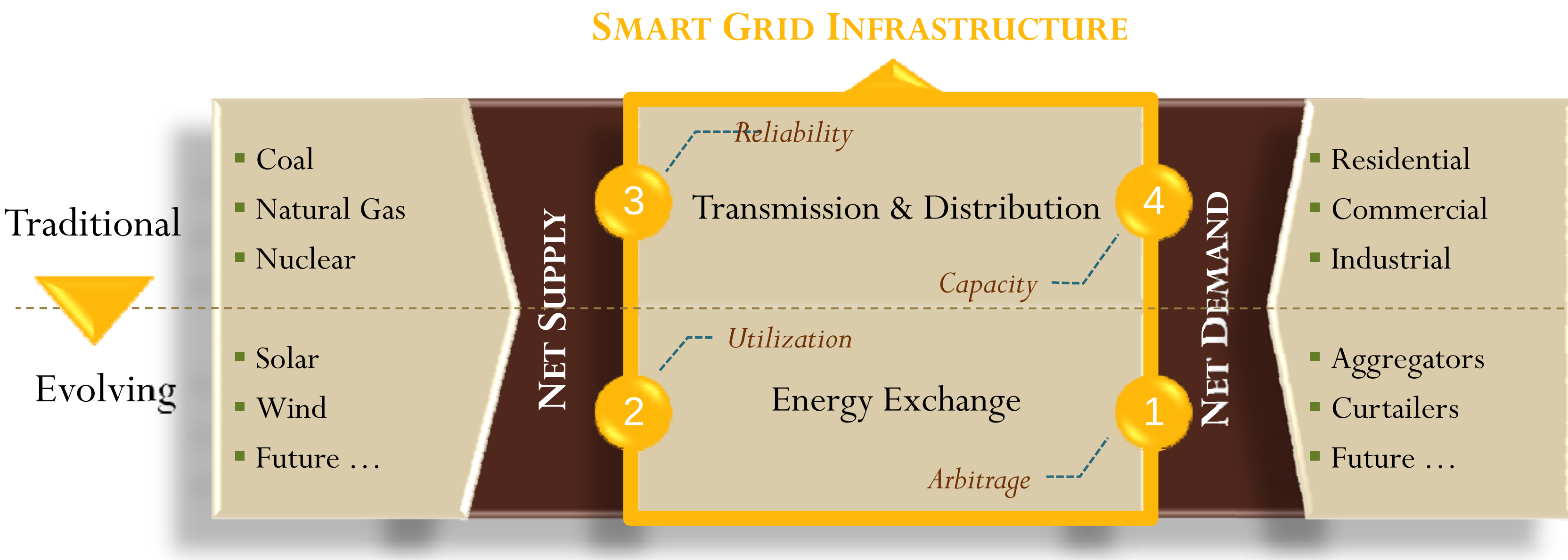
Storage Value Streams



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There are additional societal benefits including reliability of electrical supply and reduction of GHG's. and reduction of Enterprise Risk can have a significant value.

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Storage and Policy

- We have to get past categorizing storage
  - It may be transmission—it may be generation—or it may be both.
- Storage technologies need to be fully considered under pending and future legislation similar to renewable generation.
  - Clean Energy Act
  - Solar Technology Roadmap Act
- Pilots need to be encouraged through grants so storage can emerge as a powerful building block in utility strategy.
  - Facilitate creation of new economy clean-tech jobs and exportable technology.

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