SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA™

Partnering for real results.

Commercialization of Energy Storage Technologies

PECC International Project

Energy Transition and New Economic Models 2013-2014

Energy transition: Making the most out of available resources

Victoria, BC, Canada

November 08 2013

Presentation Agenda

- Introduction to SDTC's clean technology commercialization model
- Demand Drivers for Energy Storage (ES) and Renewable Energy (RE) Integration
- Technology Configurations and SDTC ES Portfolio Company Summary
- ES Market Size and Potential
- Regulatory Policy and Market Rules Support for ES

External Sources Acknowledgement

- Sandia National Labs
  - DOE/ EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA July 2013
  - Energy Storage for the Electicity Grid: Benefits and Market Potential Assessments Guide, A Study for the DOE Energy Storage System Program Feb 2010
- EPRI (Electric Power Research Institute)
  - Electricity Energy Storage Technology Options 23-Dec-2010
- Lux
  - Grid Storage Under the Microscope: Using Local Knowledge to Forecast Global Demand March 2012
- Roland Berger Strategy Consultants

SDTC Mission and Mandate

- SDTC is a policy delivery instrument of the Government of Canada to deliver environmental and economic benefits to Canadians.
- As a delivery agent, we foster the development and demonstration of technological solutions that address:
  - Clean Air
  - Clean Water
  - Climate Change
  - Clean Land
- Forge innovative partnerships and build a sustainable development technology infrastructure.
- Ensure timely diffusion - increase number and rate of uptake of technologies into the marketplace across Canada, providing national benefits.

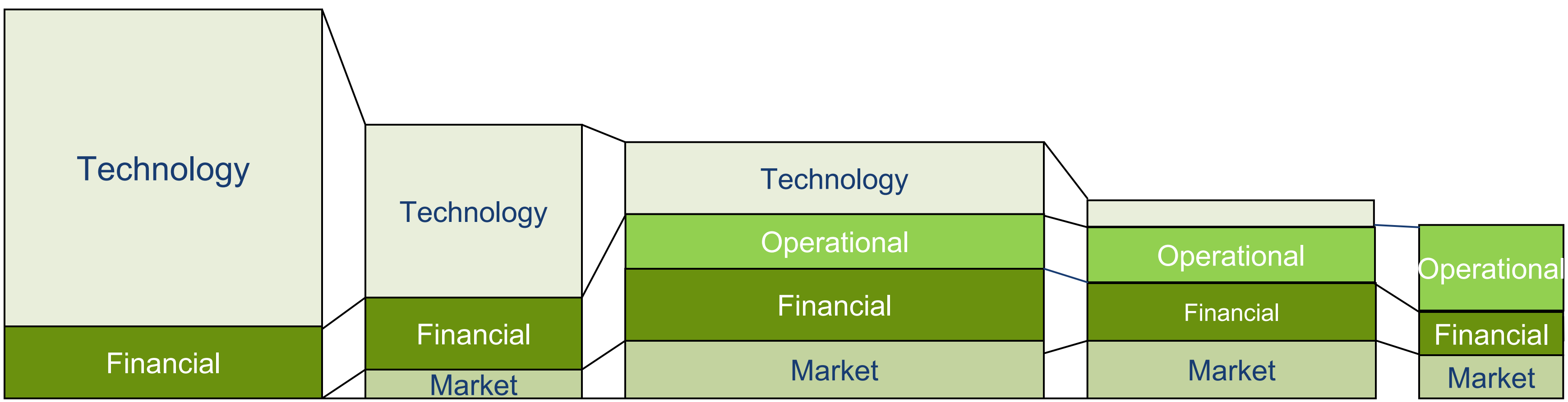
SDTC's Mission: "The Foundation will act as the primary catalyst in building a sustainable development technology infrastructure in Canada"

Cleantech Innovation Chain

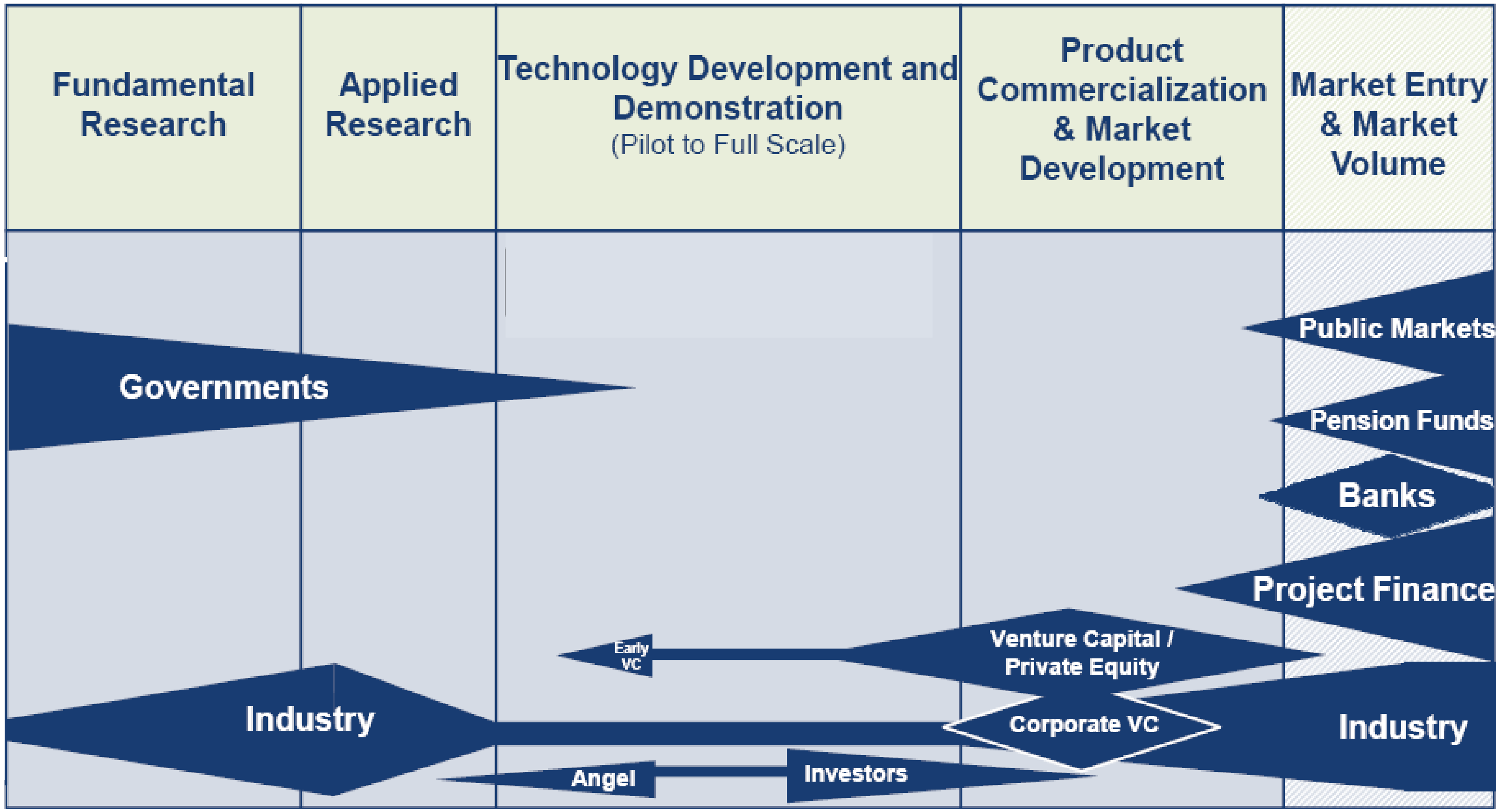
Stages of Technology Development

Fundamental Research → Applied Research → Technology Development & Demonstration *(Pilot to Full Scale)* → Product Commercialization & Market Development → Market Entry & Market Volume →

Risk Profile

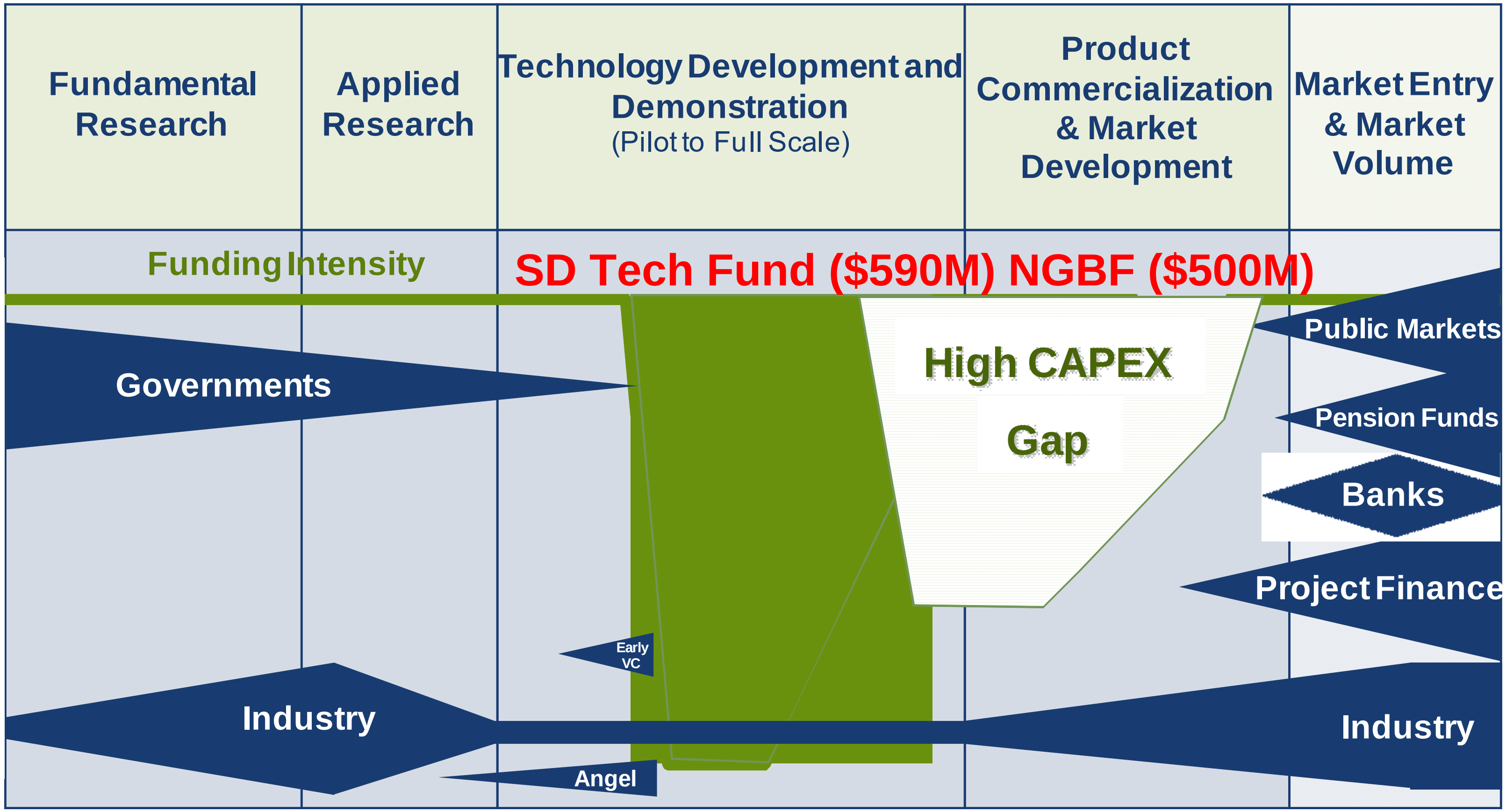


Gaps in Funding Cleantech Demonstration



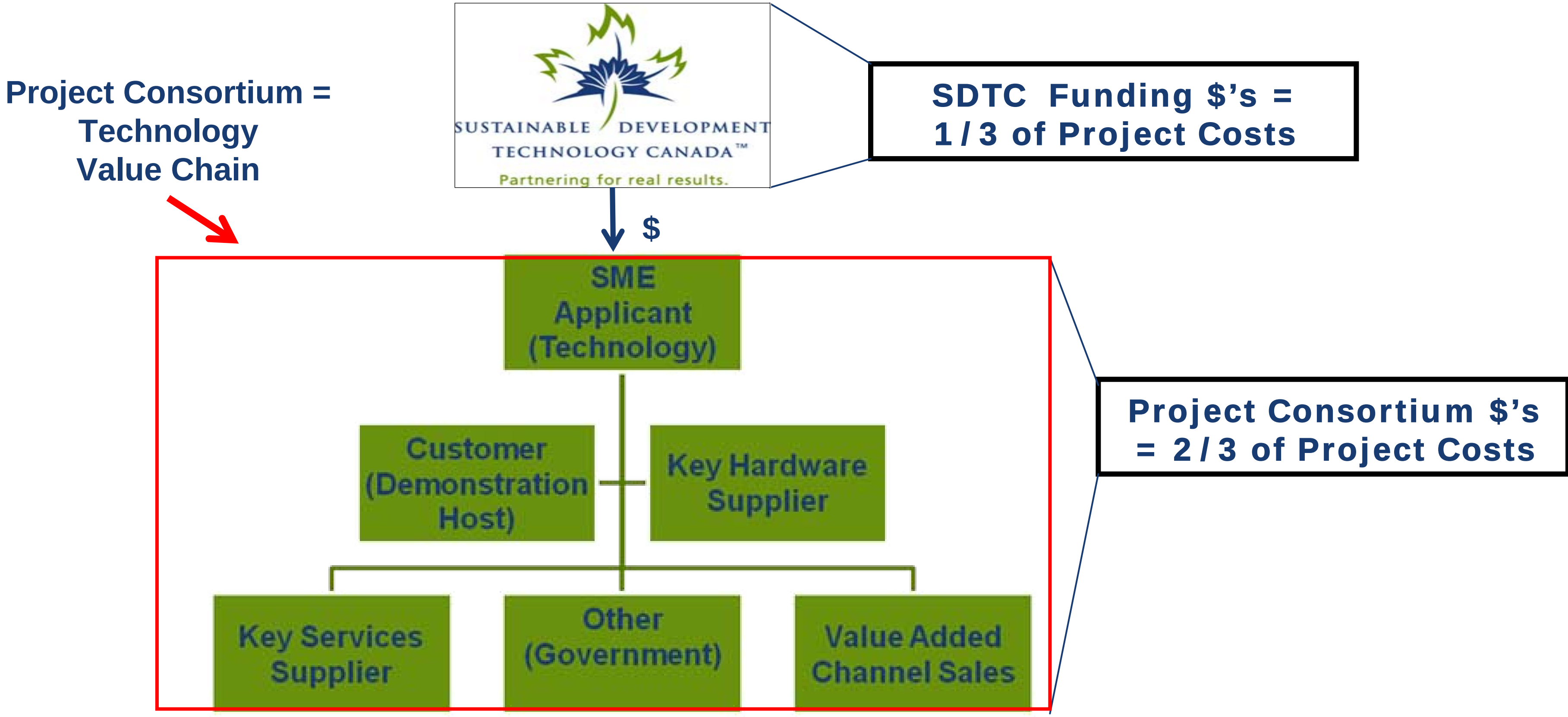
The sources of funding in the Innovation Chain are predominantly available for research and commercialization

SDTC funding address the pre-commercial funding gaps in the Innovation Chain



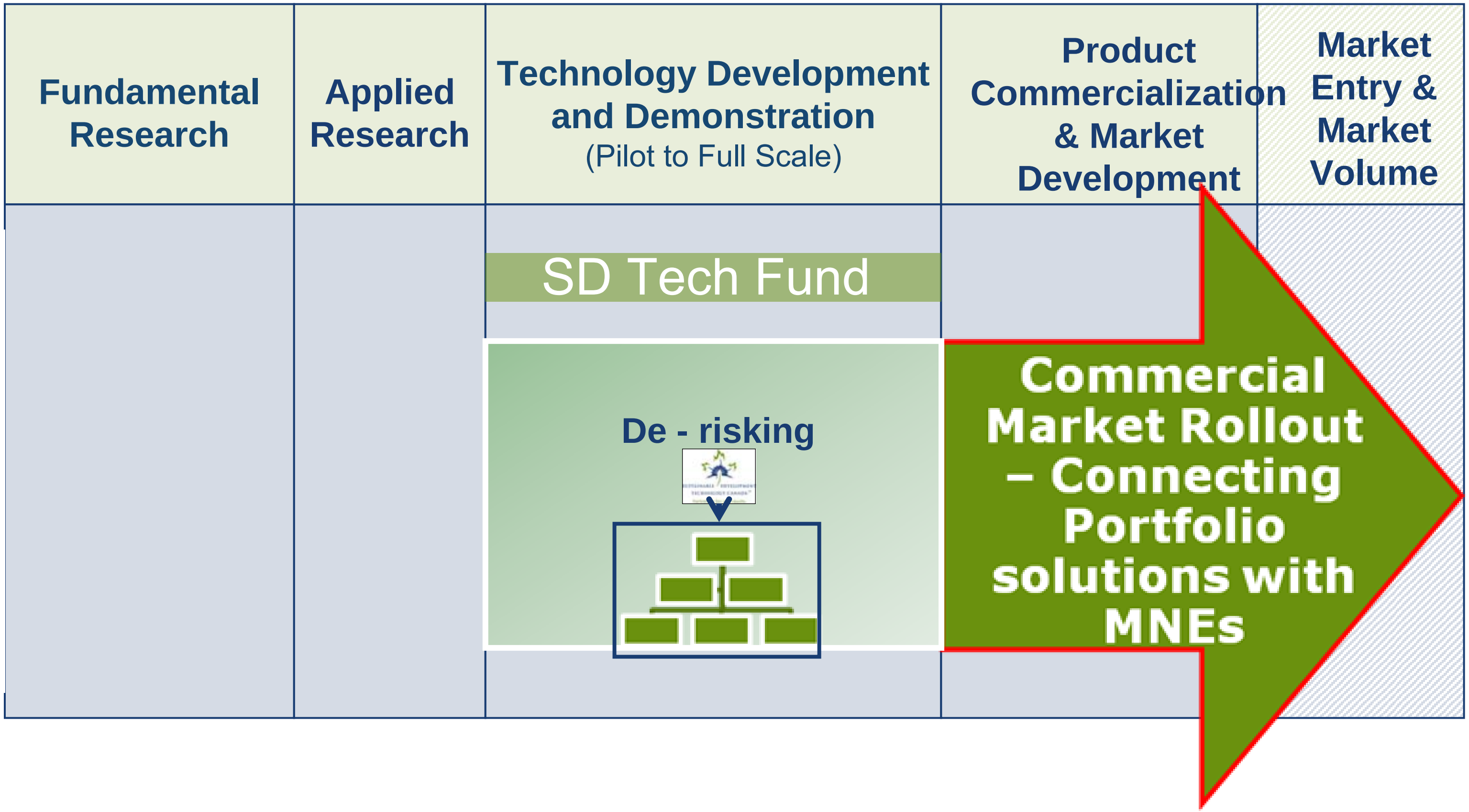
The SD Tech Fund is positioned to address the Pre-Commercial Gap in the Innovation Chain

Funding Model Ensures Market Relevancy



SDTC buys down risk associated with bringing new technologies to market enticing the private sector to co-invest

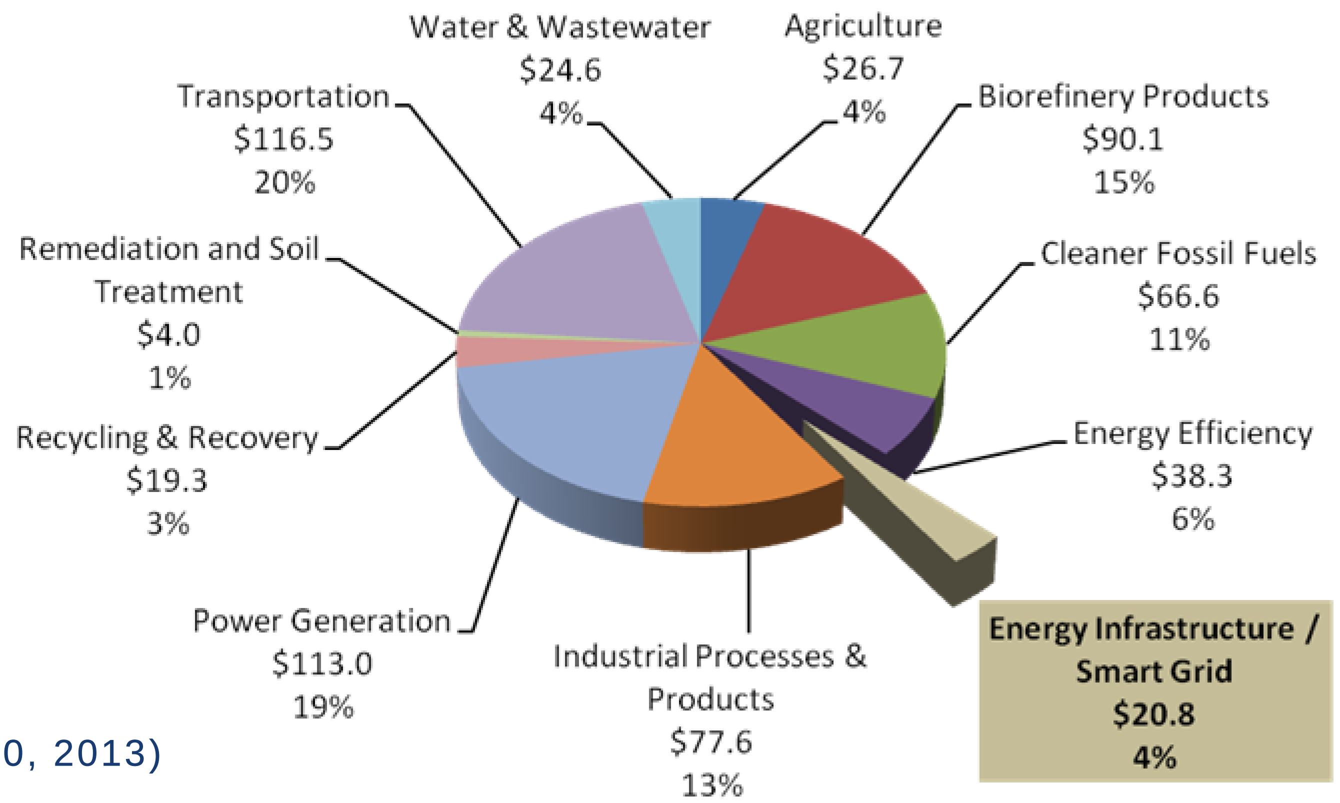
Commercialization: multi-step process



SDTC's value proposition is to provide a steady supply of field proven or plant proven technology for commercial sale or licensing to large multi-national enterprises (MNEs)

SDTC Portfolio Analysis by Dollars Invested

Funding by Industrial Sector ($M) 246 Projects - $589M total

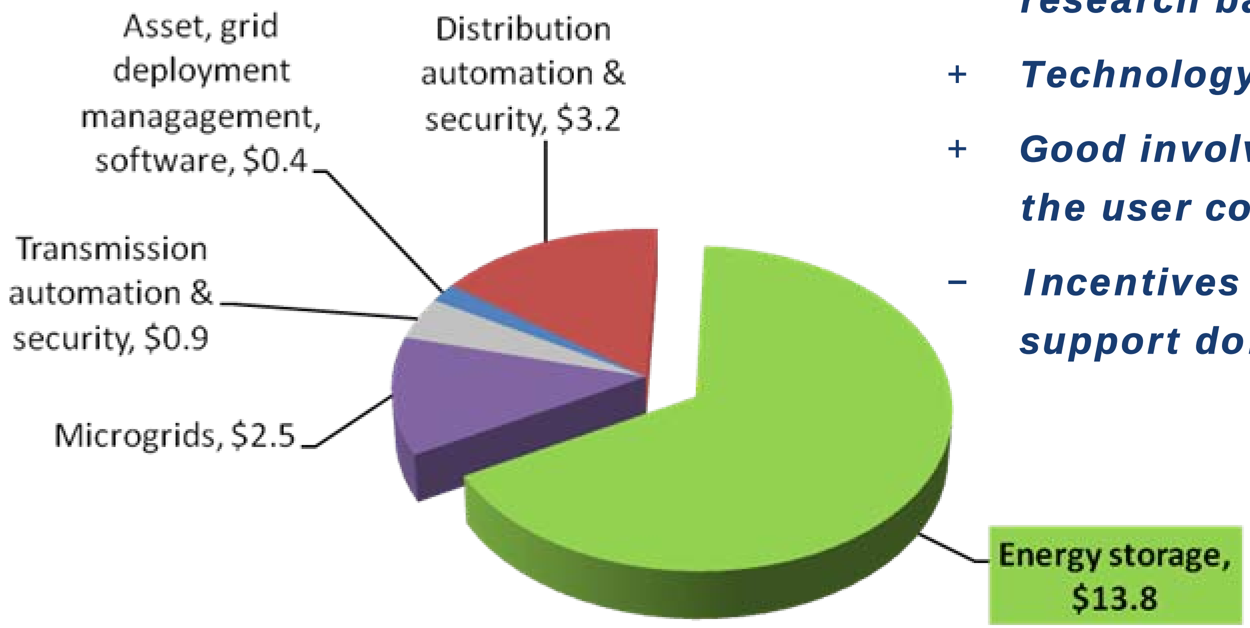


(June 30, 2013)

SDTC has backed a diverse group of technologies, with concentrations in key areas where Canada has a globally competitive position

SDTC Allocations Invested in Energy Infrastructure/Smart Grid

Energy Infrastructure / Smart Grid Sector ($M)



+ ***Strong materials science research base***
+ ***Technology leadership***
+ ***Good involvement with the user community***
− ***Incentives in US/Asia support domestic supply***

- ***6 grid storage companies***
- ***6 EV battery companies***
- ***2020 combined projected revenues: $700M***

(June 30, 2013)

Energy Storage related News Headlines

greentechmedia:

Grid-Scale Energy Storage to Support and Compete With Conventional Generation

New report outlines opportunities and challenges facing the North American energy storage market and details 150 companies active in the space.

Mike Munsell
October 17, 2013

CleanTechnica

Renewable Solar & Wind Energy Produced As Much As 60% Of Germany's Electricity October 3rd

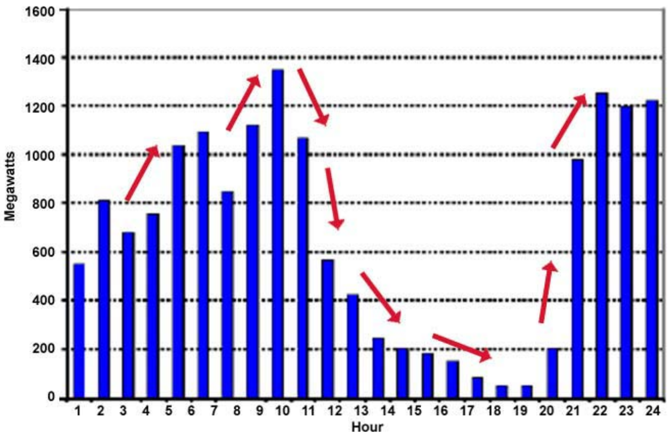
greentechmedia:

California Passes Huge Grid Energy Storage Mandate

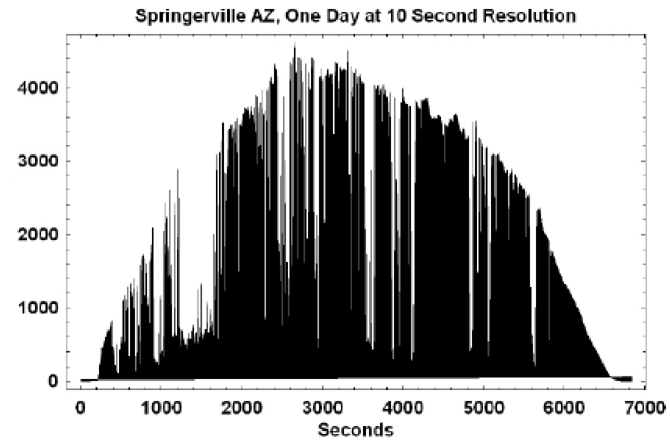
CPUC passes controversial mandate for 1.3 gigawatts of batteries, grid storage by 2020

Jeff St. John
October 17, 2013

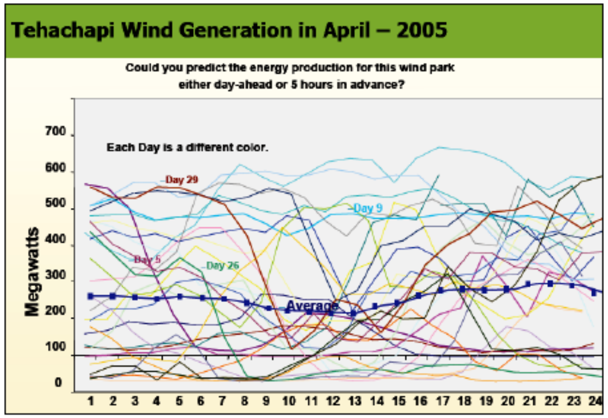
Intermittency of Renewable Energy (RE) demands ES for energy reliability, quality, time-shift, etc.



Sample Variability in Wind Farm Output over the Course of One Day (with arrows indicating ramp up and down)



Output of Large Photovoltaic Power Plant over One Day, with Rapid Variability Due to Clouds

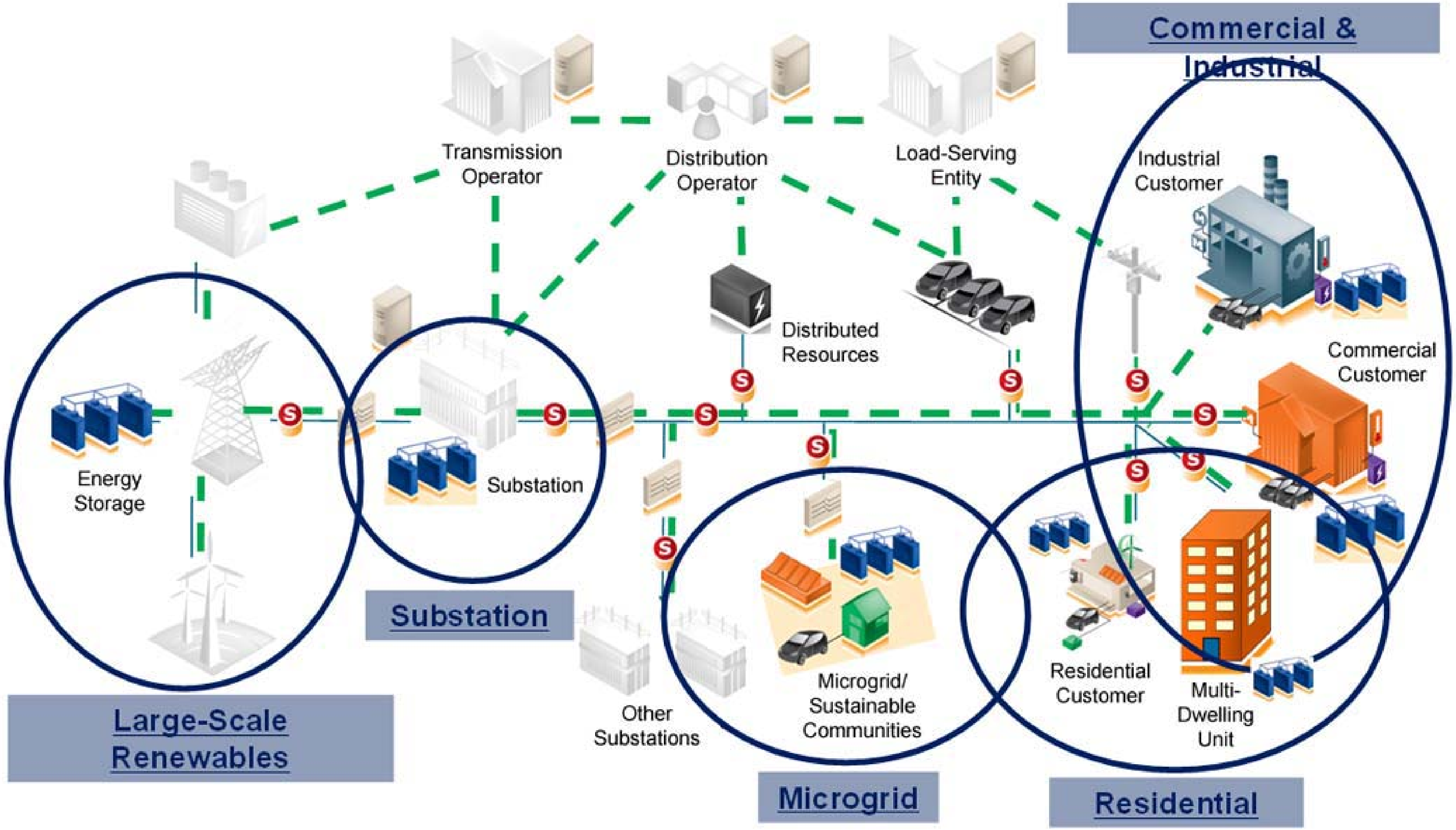


Source: EPRI

Day-to-Day Variability in Wind Farm Output over One Month, with Average Indicated.

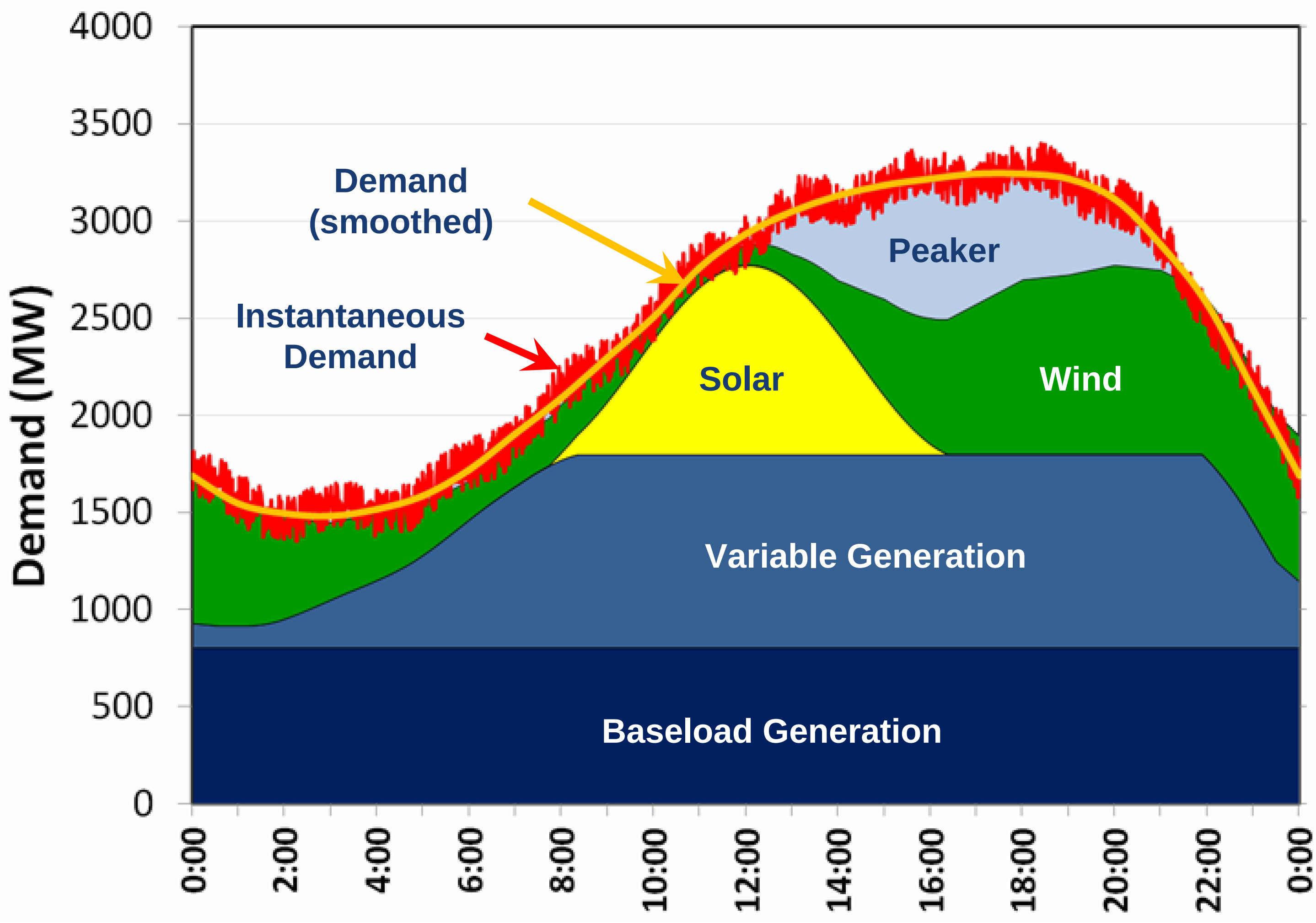
Energy Storage (ES) and Power Discharge Capacity

Multiple energy storage systems for multiple applications across the electric energy system



One ES technology solution does not fit all applications

Typical Daily Demand Profile



ES technology options

2 Primary <u>Technology</u> Options:	
1. Electrochemical	**2. Kinetic Energy**
Batteries	Pumped Water
Advanced Lead- Carbon	Compressed Air
Lithium - ion	Fly Wheels
Sodium Sulfur	
Flow	
Electrochemical Capacitors	

Performance Metrics and Costs drive Battery Technology Choices

Performance Metrics
Capacity - Energy Density
Charge Response Time - Power Density
Cycle Life - (# of times to charge)
Round trip efficiency
System Design
Materials Science
Device manufacturability, QC
Control Systems to communicate with Grid
Infrastructure or Ancilliary Equipment Required

ES technology costs and application benefits ($'s) are very sensitive to the ES Configuration

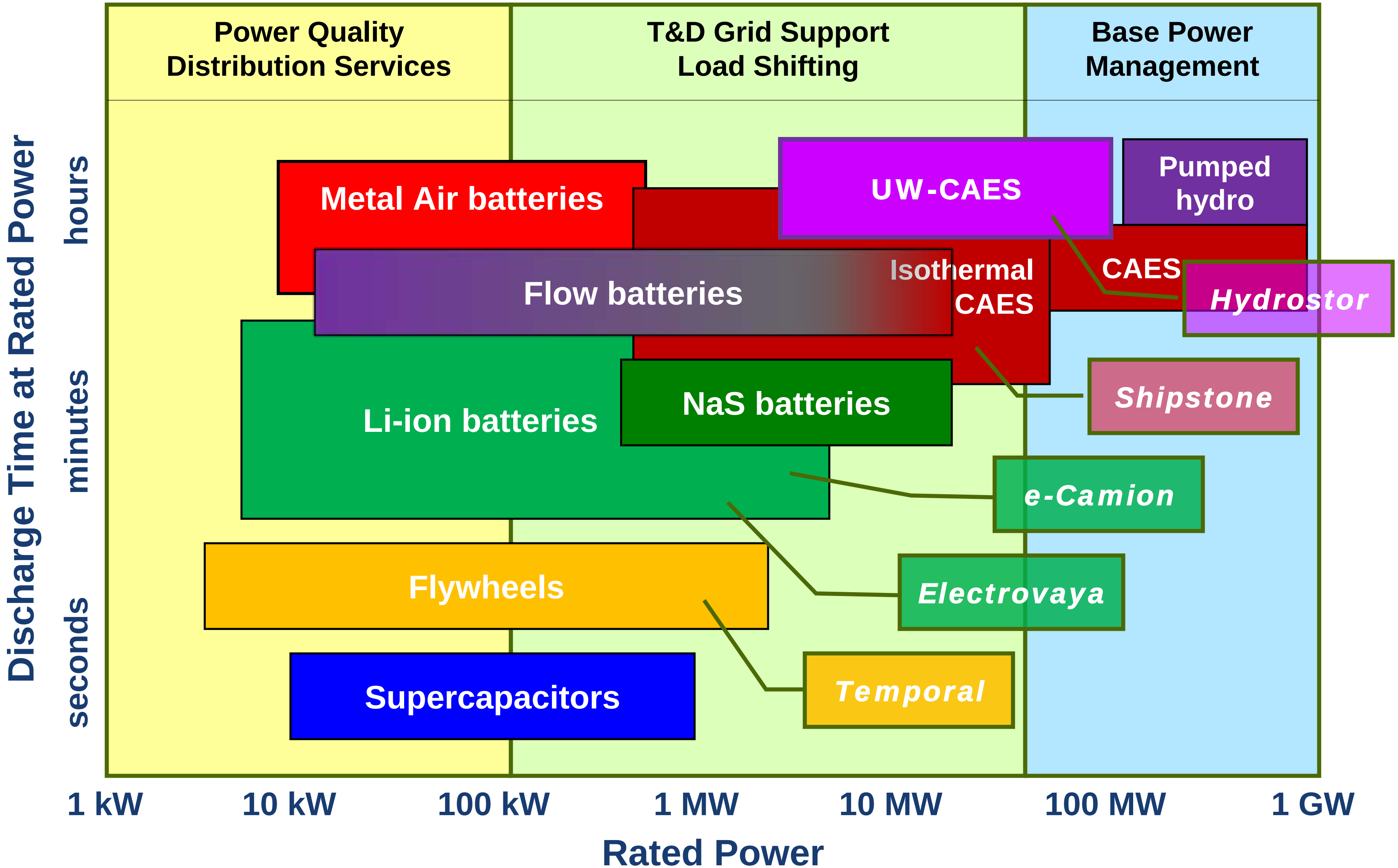
Performance Metrics and Costs define ES technology options

Primary **Technology** Options:	
1. Electrochemical	**2. Kinetic Energy**
Batteries	Pumped Water
Advanced Lead-Carbon	Compressed Air
Lithium - ion	Fly Wheels
Sodium Sulfur	
Flow	
Electrochemical Capacitors	

Performance Metrics
Cost Relative to Benefits of an Application
Cycle Life - (# of times can be charged)
Capacity - Energy Density
Charge Response Time – Power Density
Round Trip Efficiency
System Design
Materials Science
Device manufacturability, QC
Control Systems to communicate with Grid
Infrastructure or Ancillary Equipment Required

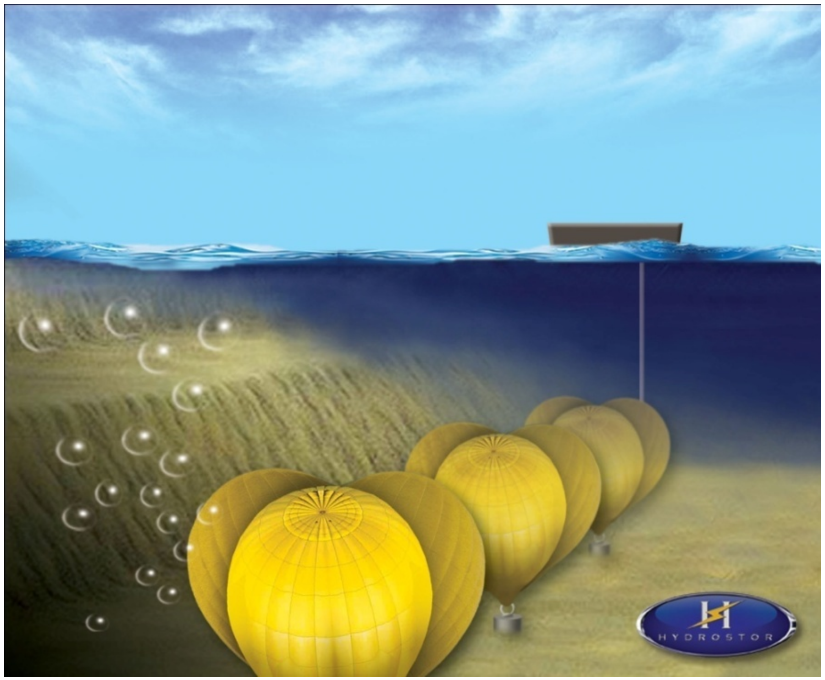
Storage Technologies	Main Advantages (relative)	Disadvantages (Relative)	Power Application	Energy Application
Pumped Storage	High Capacity, Low Cost	Special Site Requirement		●
CAES	High Capacity, Low Cost	Special Site Requirement, Need Gas Fuel		●
Flow Batteries: PSB VRB ZnBr	High Capacity, Independent Power and Energy Ratings	Low Energy Density	◐	●
Metal-Air	Very High Energy Density	Electric Charging is Difficult		●
NaS	High Power & Energy Densities, High Efficiency	Production Cost, Safety Concerns (addressed in design)	●	●
Li-ion	High Power & Energy Densities, High Efficiency	High Production Cost, Requires Special Charging Circuit	●	○
Ni-Cd	High Power & Energy Densities, Efficiency		●	◐
Other Advanced Batteries	High Power & Energy Densities, High Efficiency	High Production Cost	●	○
Lead-Acid	Low Capital Cost	Limited Cycle Life when Deeply Discharged	●	○
Flywheels	High Power	Low Energy density	●	○
SMES, DSMES	High Power	Low Energy Density, High Production Cost	●	
E.C. Capacitors	Long Cycle Life, High Efficiency	Low Energy Density	●	◐

SDTC Energy Storage Portfolio



Base Power Management:

Energy Storage



- Developing an Underwater Compressed Air Energy Storage System where excess electricity is converted to compressed air piped to flexible accumulators located off-shore.
  - >70% round trip efficiency for water deeper than 50m
  - 10-1000 MWh capacity
  - small on-shore footprint

Consortium Partners:

Toronto Hydro
McNally Construction
Baird Engineering
Virelec Ltd.
University of Windsor

2011

Power Generation:

Distributed Energy Storage

- Demonstrating a community electric storage (CES) unit to support distributed renewable electricity generation (PV) and improve local power quality.
  - 250 kWh/500kW capacity
  - 3 phase operation
  - pad mount / small footprint

Consortium Partners:

Toronto Hydro
Dow Kokam
University of Toronto

ecamion POWER OVER ENERGY

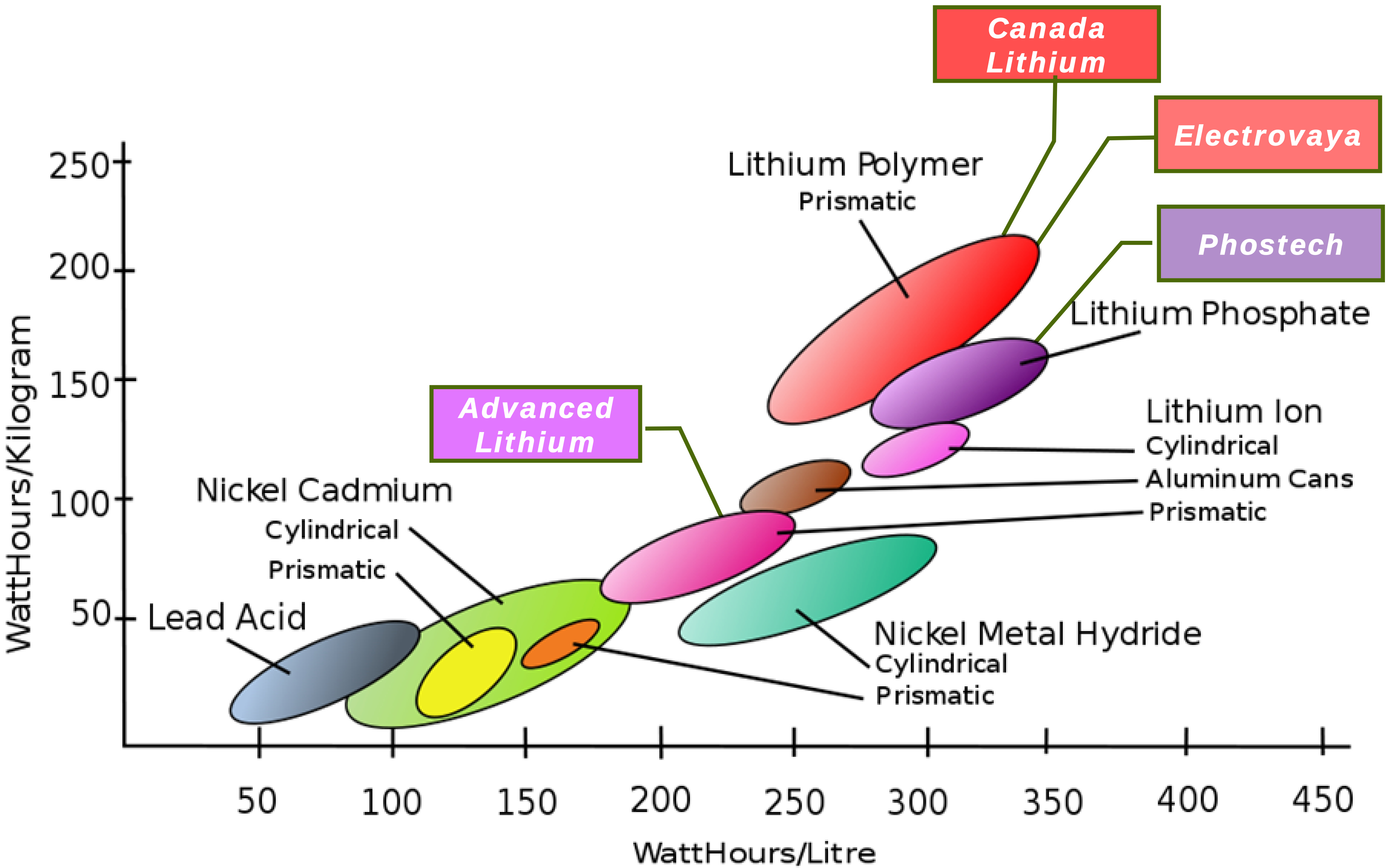
Wind Power Grid Integration Hardware

temporal POWER

Consortium partners:
Hydro One
Ryerson University

- Developed a low loss flywheel energy storage system to regulate voltages on distribution lines
- Have already demonstrated
  - 500 kW capability
  - retention of 95% of the energy stored for up to 10 hours
- An array of 10 flywheels will be used to reduce power fluctuations on a feeder line connected to a wind farm

SDTC Li-ion Battery Portfolio

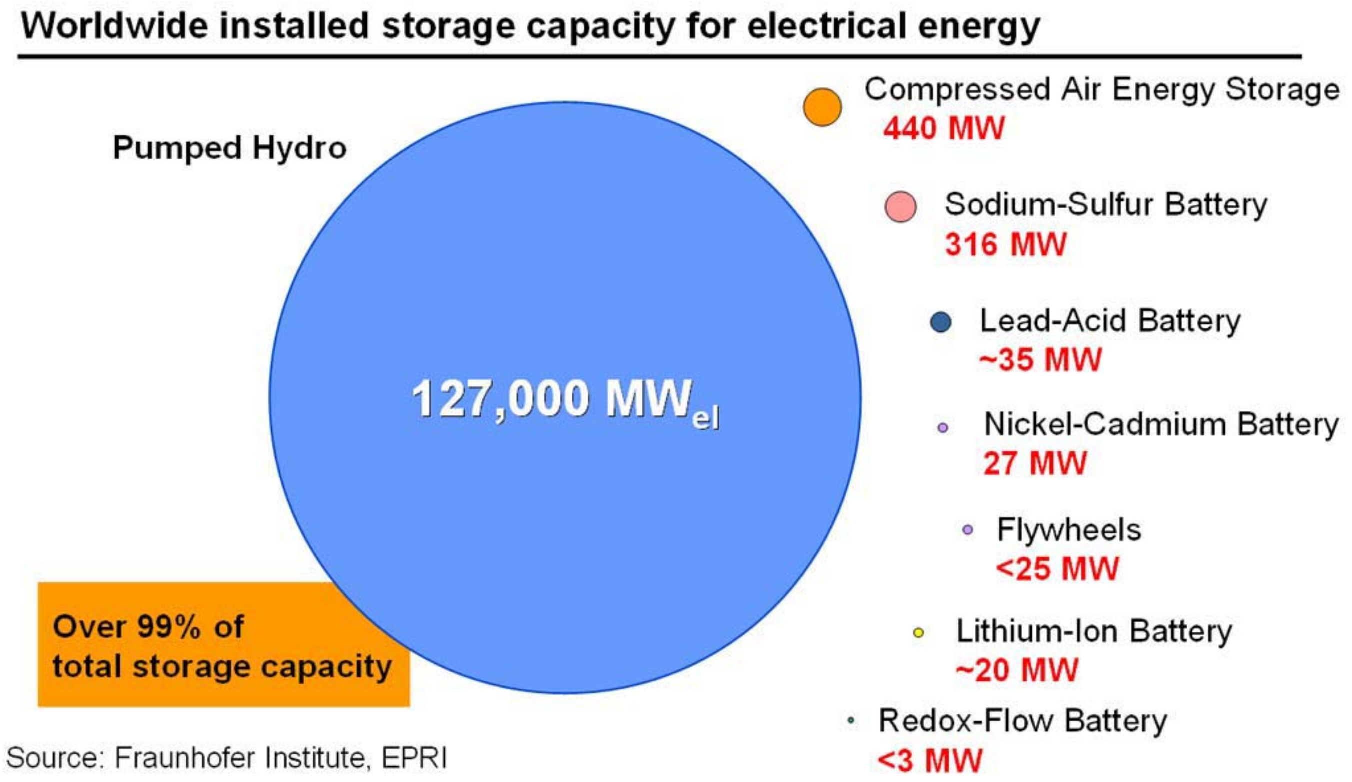


Market Size: Growing Rapidly but still tiny

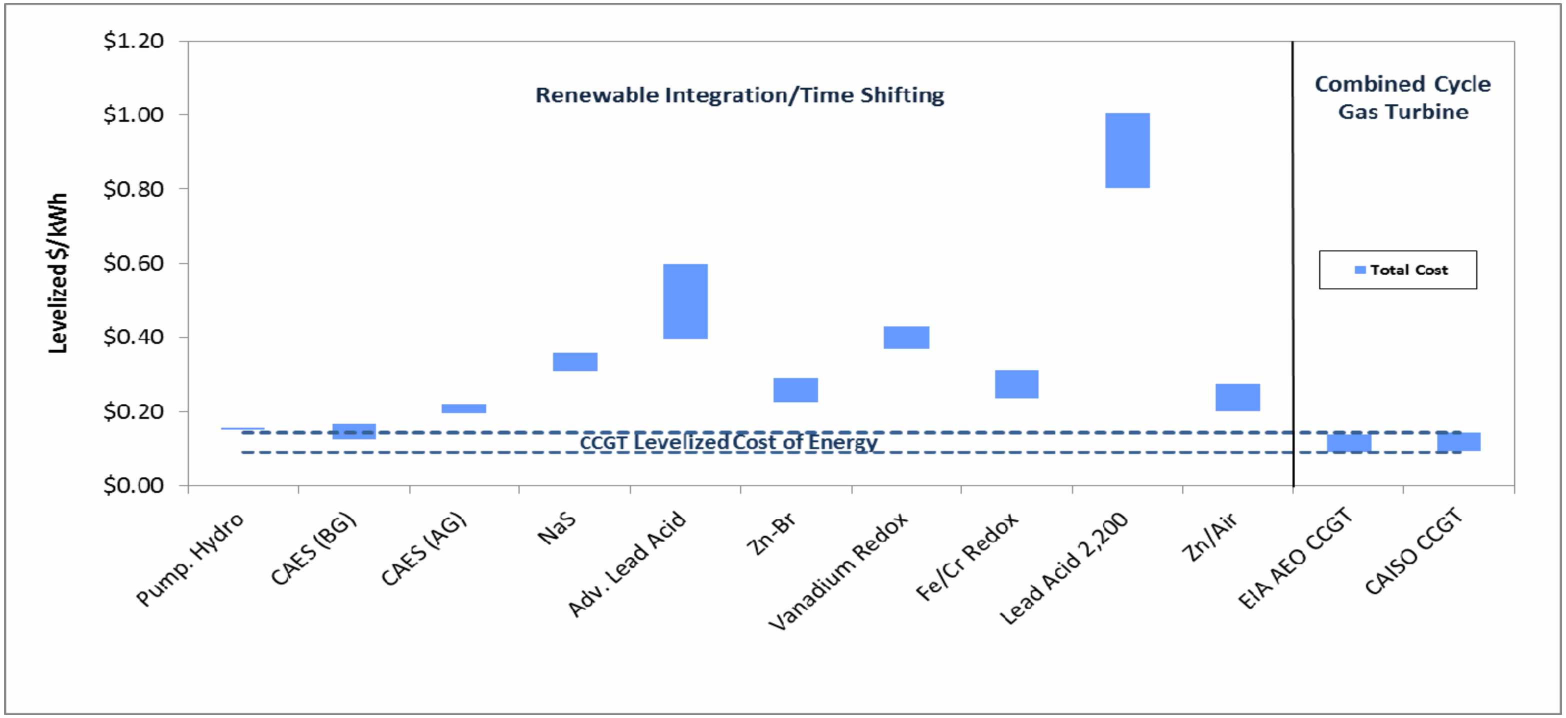
- As of 2011, 2.2% of electricity world wide was stored (mostly in pumped Hydro)

- Lux estimates that by 2017 the global potential for Grid storage is $117B accounting for 185 GWh (or 52 GW) of capacity.

- Despite rapid growth, grid storage capacity still represents only 0.79% of the 6,553 GW of global installed electricity capacity expected by 2017 (Lux)



Making the Business Case for ES



Levelized Cost of Delivered Energy for Energy Storage Technologies Compared to CCGT

Source: EPRI

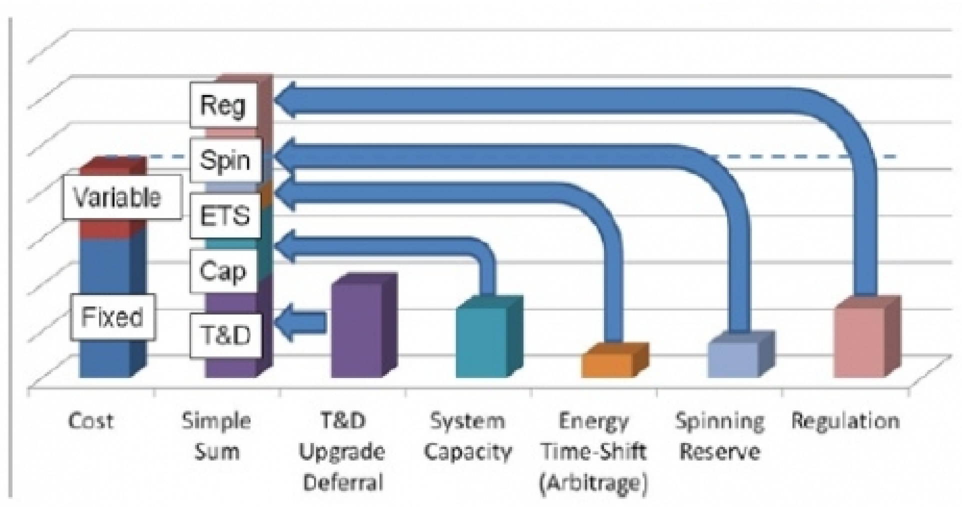
Capturing concurrent benefits is key to ES Project Economics

• There are a plethora of ES applications (~ 20) and multiple benefits ($) spread across the Energy generation, transmission and distribution, and end use system.

• Remote wind and photovoltaic (solar) power generation integration is one of the higher value ES applications

•Due to the high installed capital costs of most ES systems, applications of ES must be able to realize multiple operational uses across different parts of the energy value chain

•There are several ES applications that are natural allies in the goal for cleaner energy systems – comprehensive understanding and approach by new technology companies is required



Regulatory Support and Market Rule Changes for ES roll-out

Time of Use Pricing	Provides opportunity for price arbitrage
Pay for Performance Frequency Regulation	Payment for fast responding resources will likely exceed that for slower frequency regulation
Feed-in-Tariffs	Widespread intermittent renewable energy generation will required storage
Wholesale Rates for Battery Charging	Can make storage more cost effective due to the wider differential price between wholesale and retail electricity rates
RPS and RECs	Widespread intermittent renewable energy generation will require storage
Storage Mandates	Requirement for Storage guarantees market share
Direct Incentives and Subsidies	Reduction in capital costs can allow some grid storage technologies to be competitive with conventional grid assets
Emissions and Carbon Credits	Storage can act as a generation asset that produces no point-source emissions can have less emission per unit energy than peaking power plants
Defining an Asset Class for Storage	If storage can be defined as a new utility asset class, then its costs can be spread among a large rate base making projects more palatable

For More Information

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