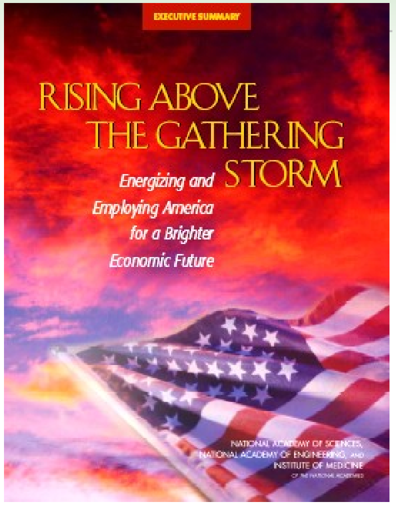
ARPA-E Storage Overview

Mark Johnson

September 26, 2012

DOE Energy Storage Review

A Brief History of of ARPA-E



FY12 Budget
($275M appropriated)

FY11 Budget CR
($180M appropriated)

2009 ARRA
($400M appropriated)

2007
America COMPETES Act

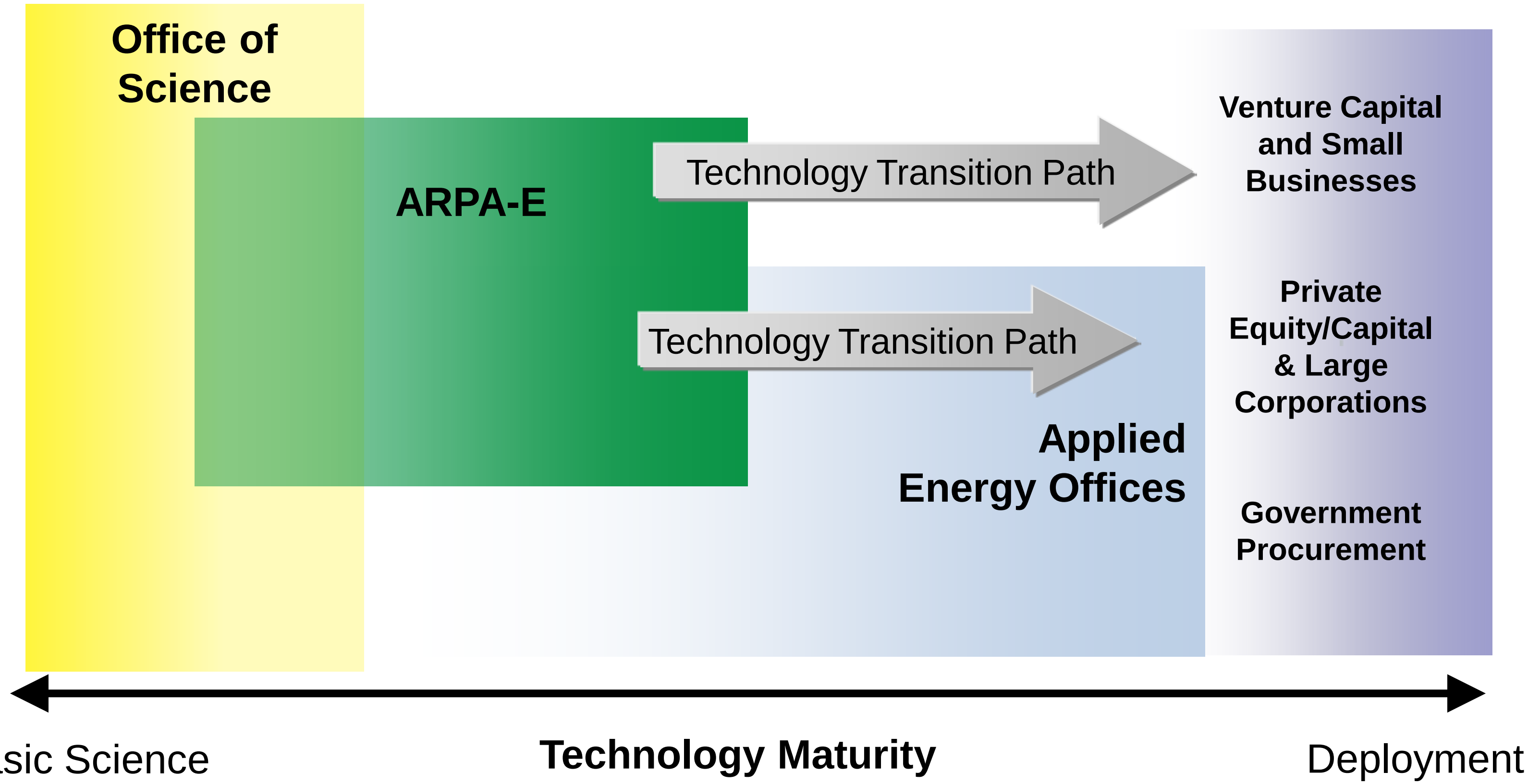
2006
Rising Above the Gathering Storm
(National Academies)

ARPA-E Launched at National Academies: April 27, 2009

First Funding Announcement: May 2, 2009

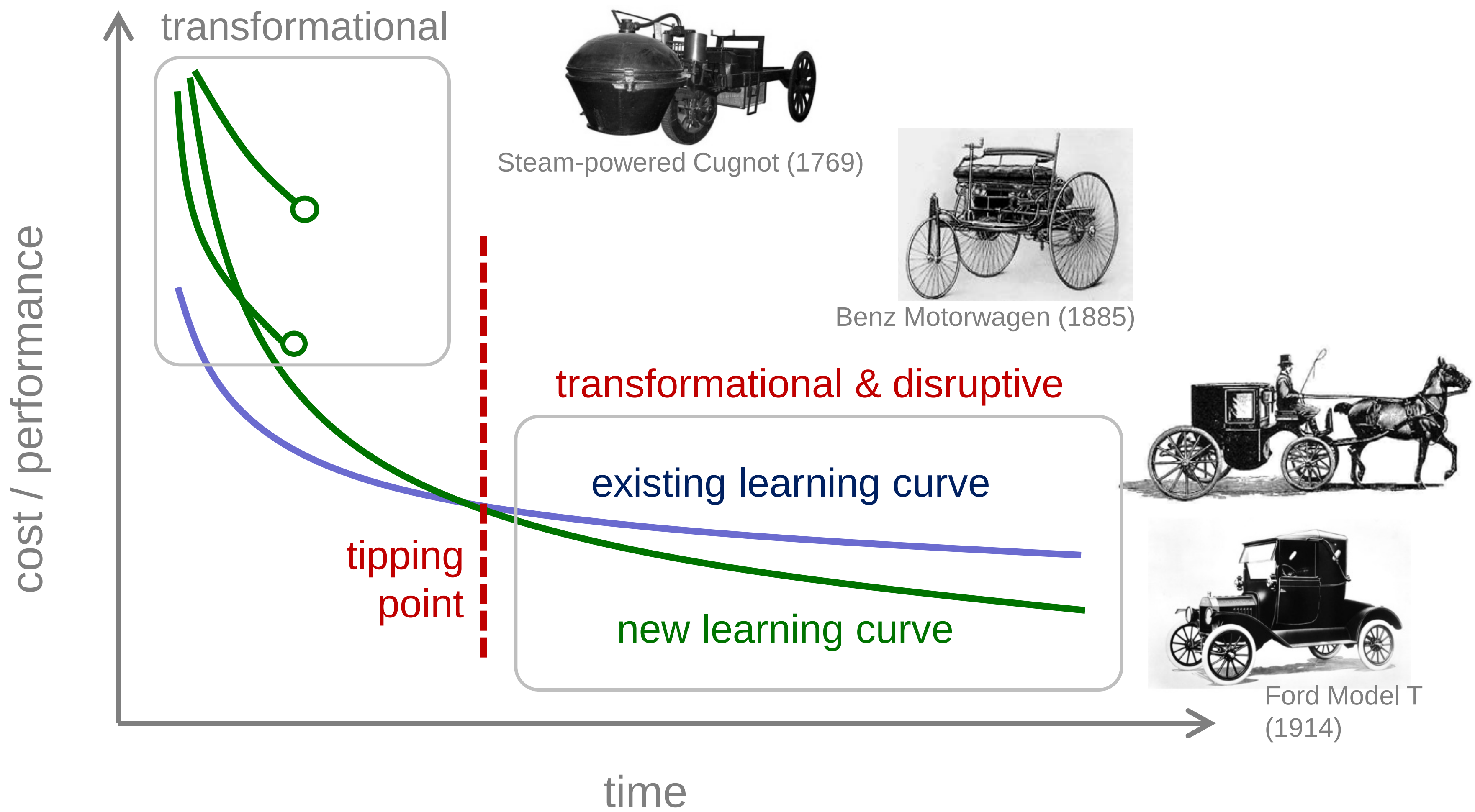
Innovation based on science and engineering will be primary driver of our future prosperity & security

Energy Innovation Pipeline

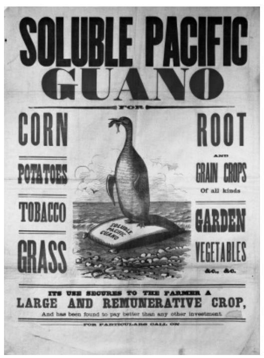


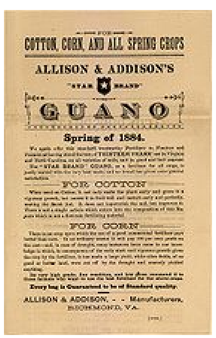
Progress of Disruptive Technologies

Transformational & disruptive technologies that lead to new learning curves



Societal Problem Driven Fundamental Research: Industrial Synthesis of Ammonia





Fertilizer

Gunpowder

Food Global Population, on Track to Exceed 2,000,000,000

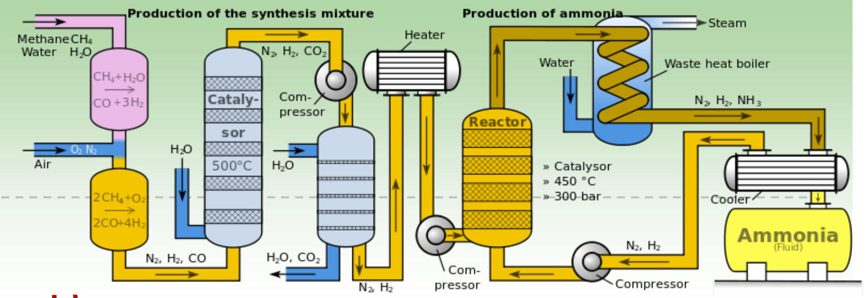
Food Production (Wheat) in Concentrated Locations (US)

$$N_2 + 3H_2 \rightarrow 2NH_3$$

"…the fixation of Nitrogen is vital to the progress of civilized humanity"

William Crookes (1898)

Ammonia R&D Timeline



Royal Academy "Wheat Problem"

Understanding Properties Of Ammonia

Academic Fight

Contract

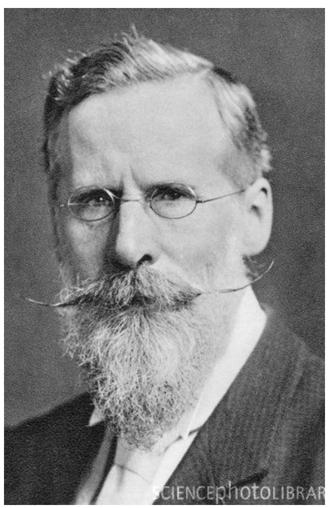
Lab Demo

Pilot Scale

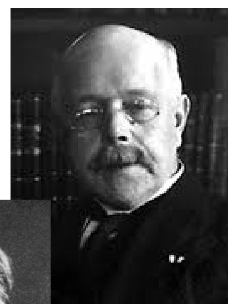
Production

"Grand Challenge" — **Basic Research** — **Break-Through** — **"Catalyst Genomics"**

1898	1900	1902	1904	1906	1908	1910	1912	1914



Crookes



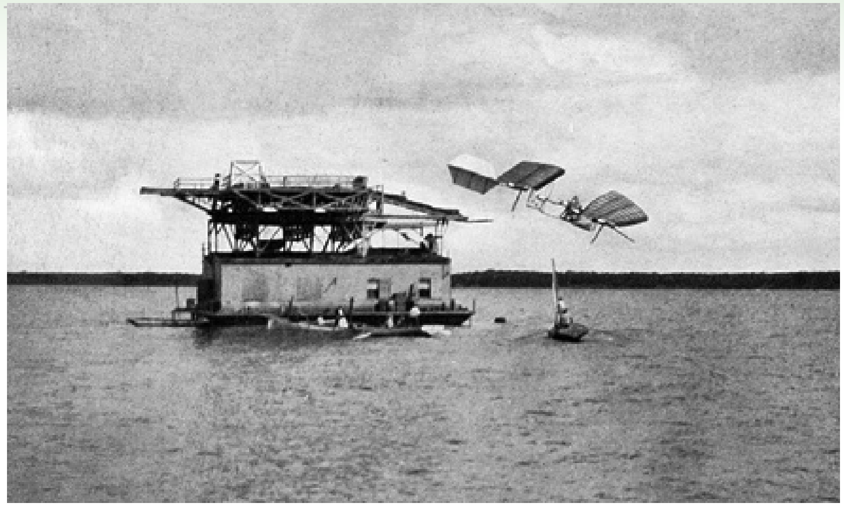
Ostwald & Nernst

Haber

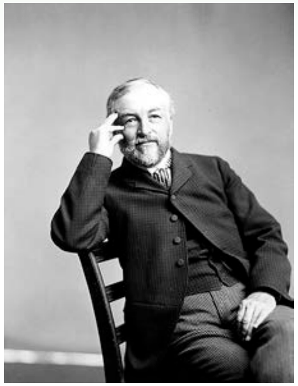
Bosch

Mittasch

Technology Innovators Might be Found in Unlikely Places



<u>Samuel Langley</u>
Ivy League Faculty
Smithsonian President
Well Funded



<u>Wright Brothers</u>
Little Education
Bicycle Mechanics
Boot-Strapped

What makes an ARPA-E project?

1. Impact

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

2. Transform

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

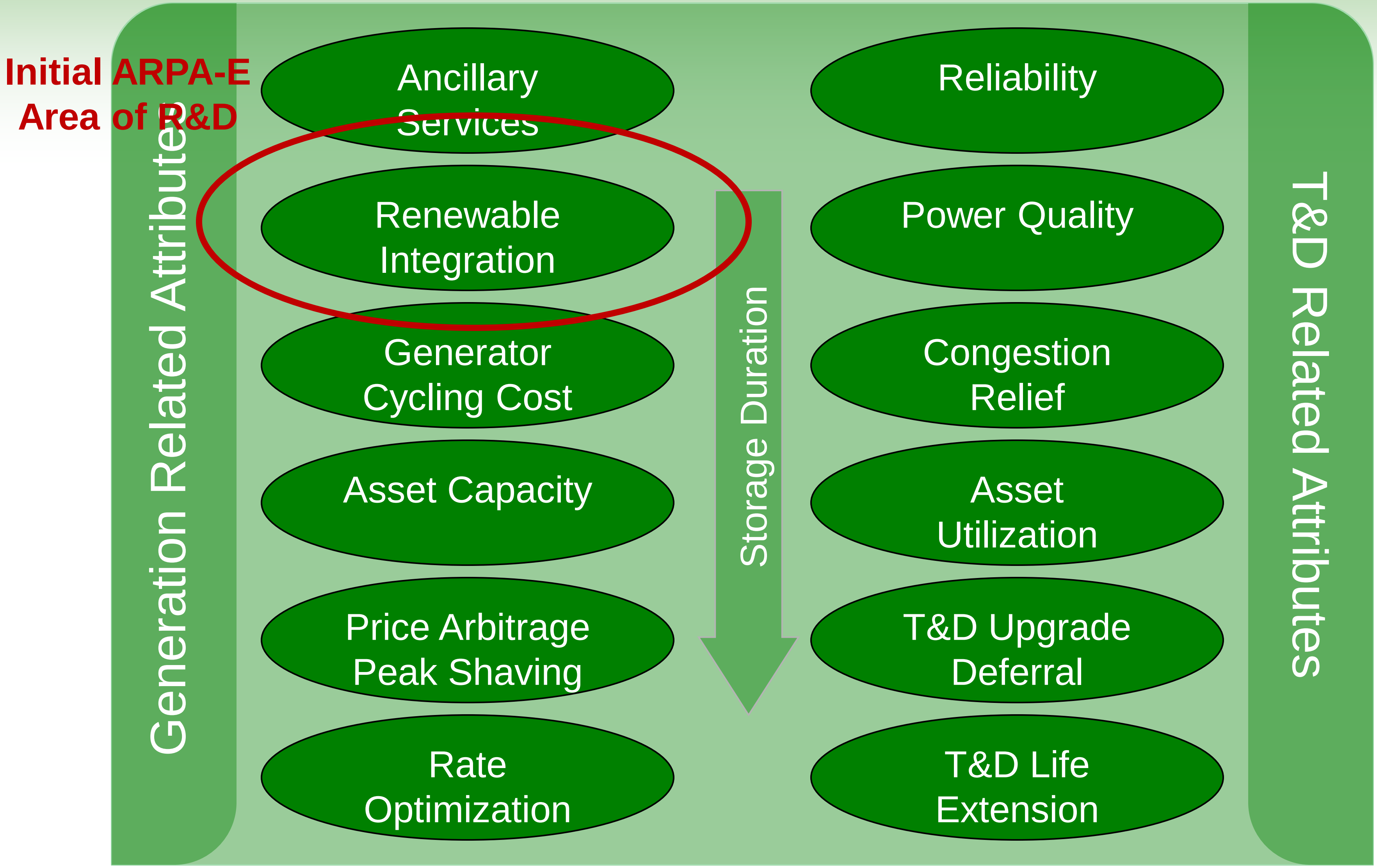
3. Bridge

- Between basic science and applied technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

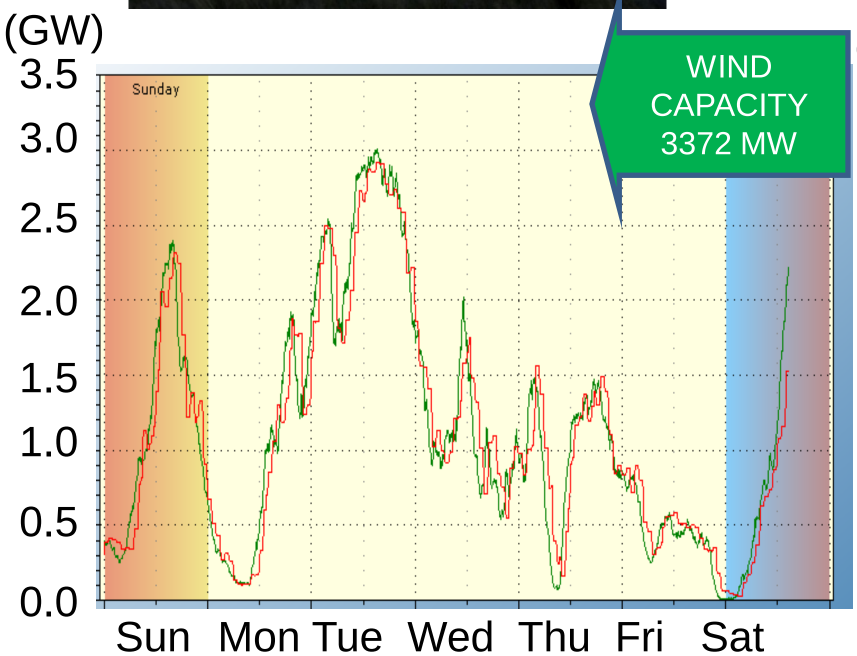
4. Team

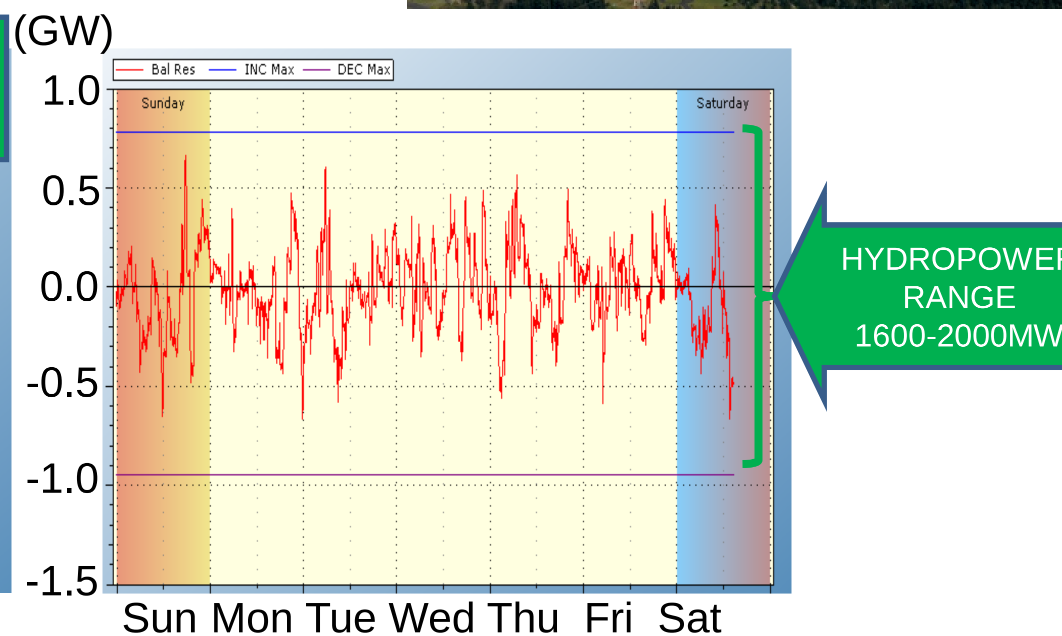
- Best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

Electric Grid Energy Storage



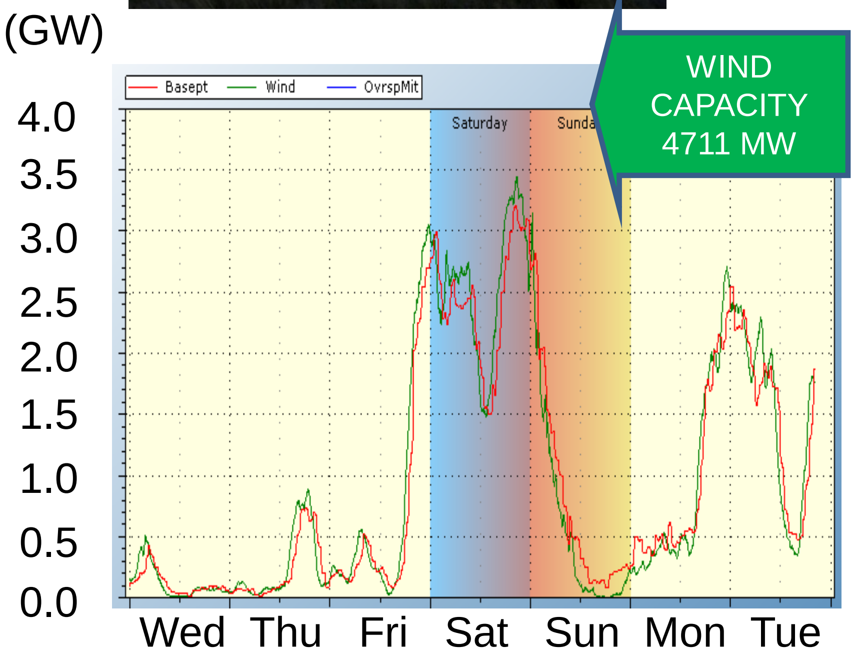
Characteristics of Renewable Electricity Balancing Reserves Firm Wind Generation for High Renewable Penetration.

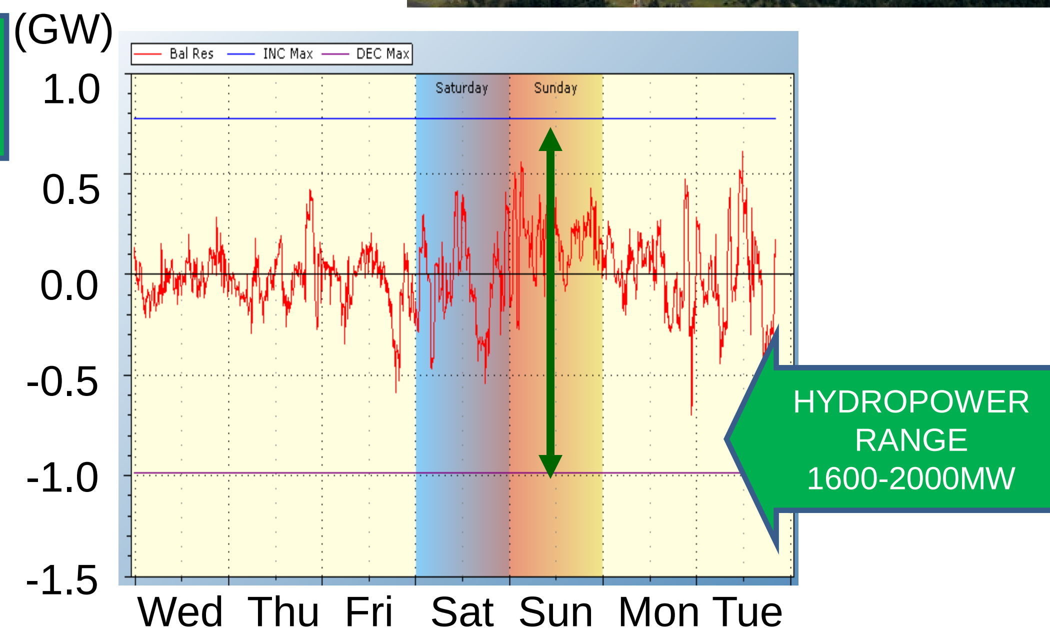




System Challenge: Efficient Energy Storage at Minutes to Hours Duration to Firm Ramping Balance

Balancing Wind and Load Has Gotten More Challenging





September 2012 Update Example

Externality

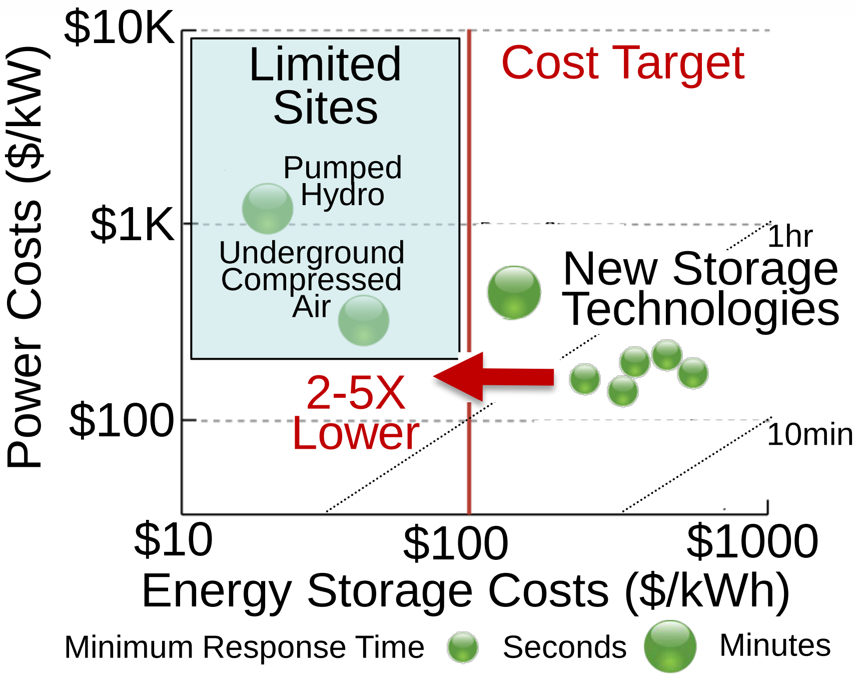
$2.50 / MBTU for Natural Gas

and $25-50 / MWh for Electricity

Storage Need to Be **Systems** Solutions

at **Low Cost**

Grid-scale Rampable Intermittent Dispatachable Storage (GRIDS) Program Metrics



Balancing Reserves at <$100/kWh

Greater than 5000 cycles and 80% RTE

Economics of Hydro / Deploy Anywhere

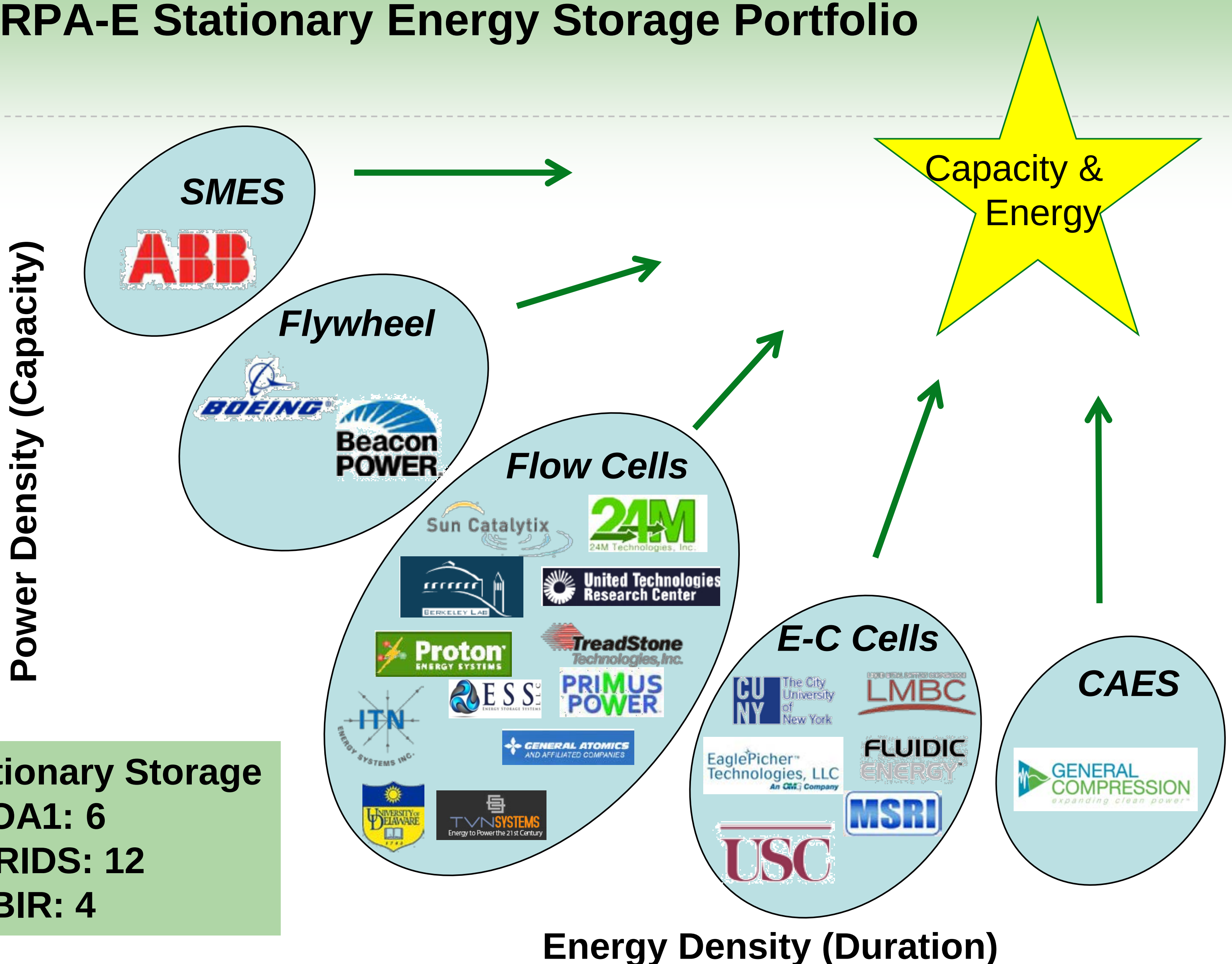
Technology Agnostic:
Chemical, Mechanical, Electromagnetic

Connect Across Industry for Handoffs

Focus: Transformational approaches to energy storage to enable low cost

New Technology Need: Low-Cost Energy Storage Solutions

ARPA-E Stationary Energy Storage Portfolio

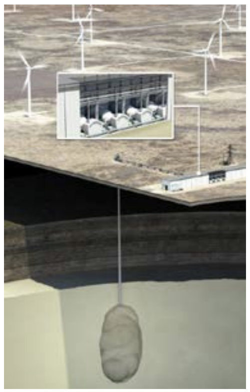


Stationary Storage
- **FOA1: 6**
- **GRIDS: 12**
- **SBIR: 4**

GRIDS: Sample Efforts

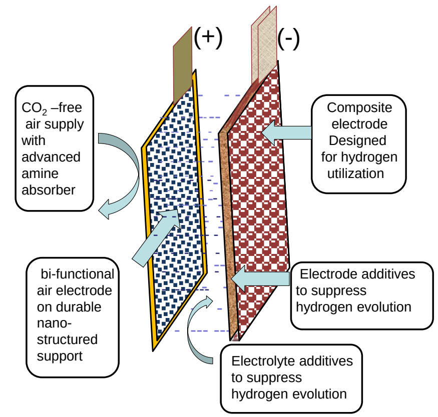
General Compression

Isothermal Compression: Technology Bridge to Commercial Follow-on



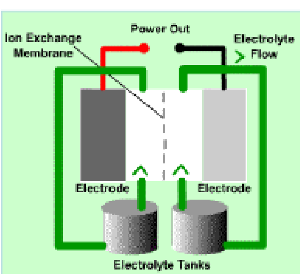
University of Southern California

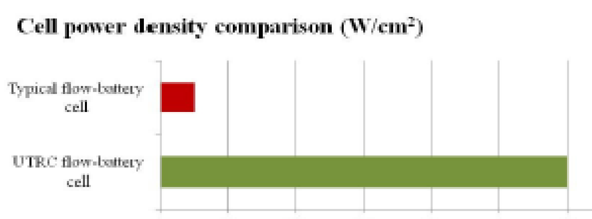
Iron-Air : Iron is Cheap & Air is Free



United Technologies

HIgh Current Density Flow Battery

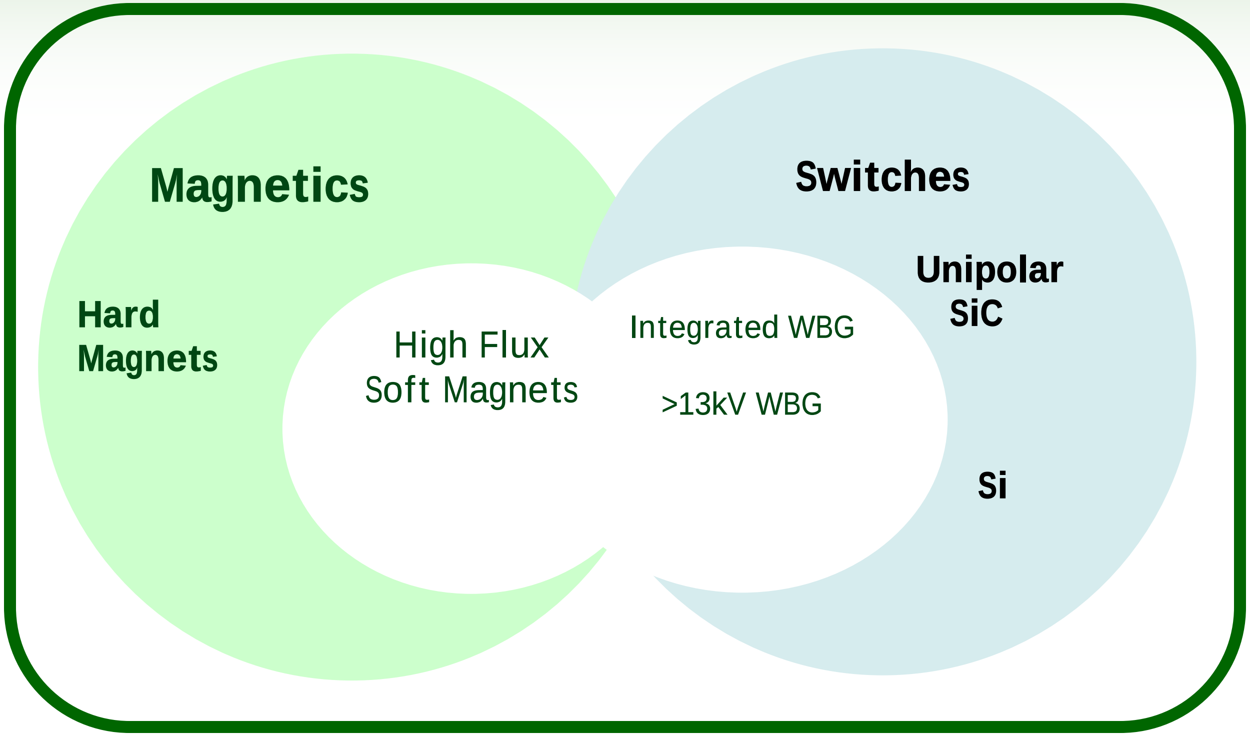




City University of New York

Cheap, Recyclable Alkaline Cell

ADEPT: Agile Delivery of Electrical Power Technologies



Integrated Circuits for Power Systems

- On-chip inductors and transformers
- High-voltage transistors (GaN and SiC)
- High-energy capacitors

Magnetics

– largest, most expensive part of a power converter

__>92% Dimmable LED Driver__ (comm. 37-50% of luminaire cost)

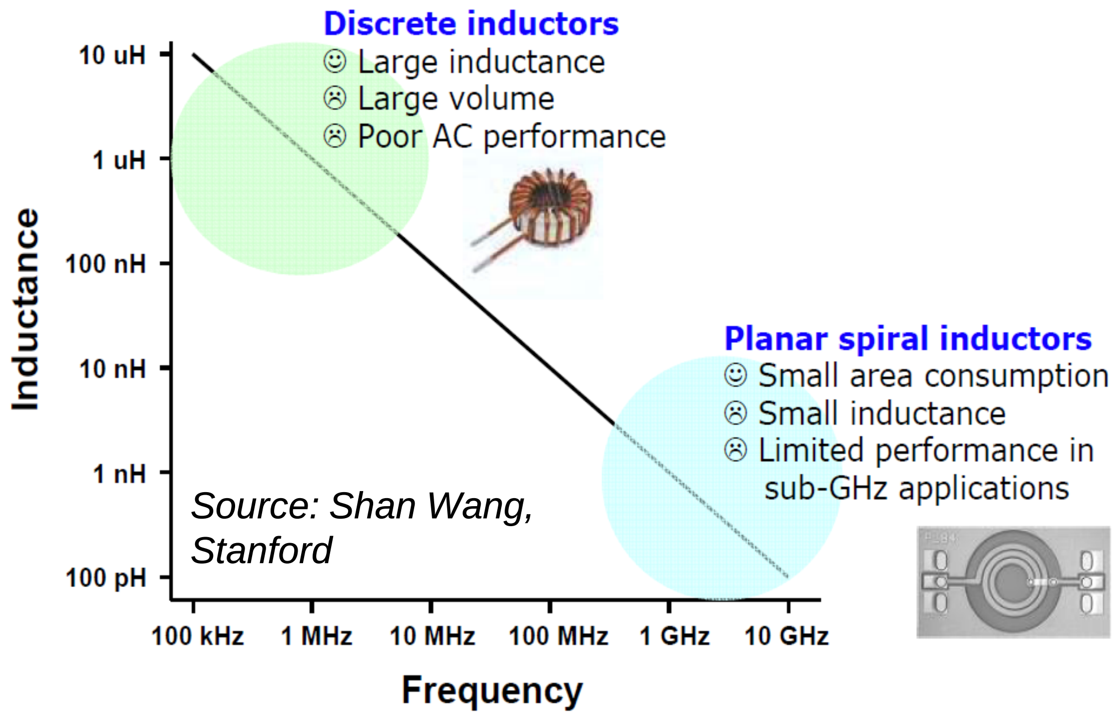
$$Z = j\omega L$$

AC/DC Converter

Magnetics

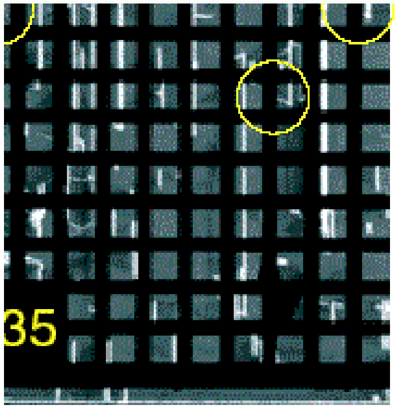
__1MW Photovoltaic Inverter__ ($0.2/W)

40% Magnetics



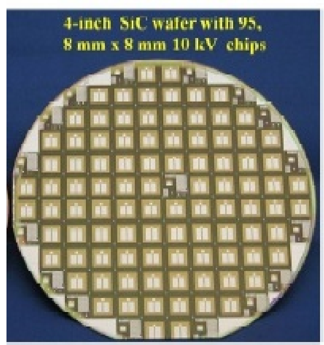
High Voltage Solid-State Devices

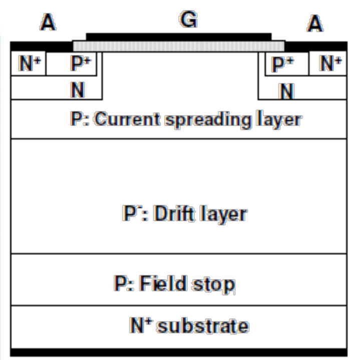
20kV & 1MW SiC Transistors



NRL

- **Significantly improved SiC IGBTs**
  - **High voltage (20kV)**
  - **Extremely efficient (>98%)**
  - **Fast switching (50kHz)**
  - **Higher minority carrier lifetimes, and blocking layers – improved reliability and lifetime**
  - **High device yields**



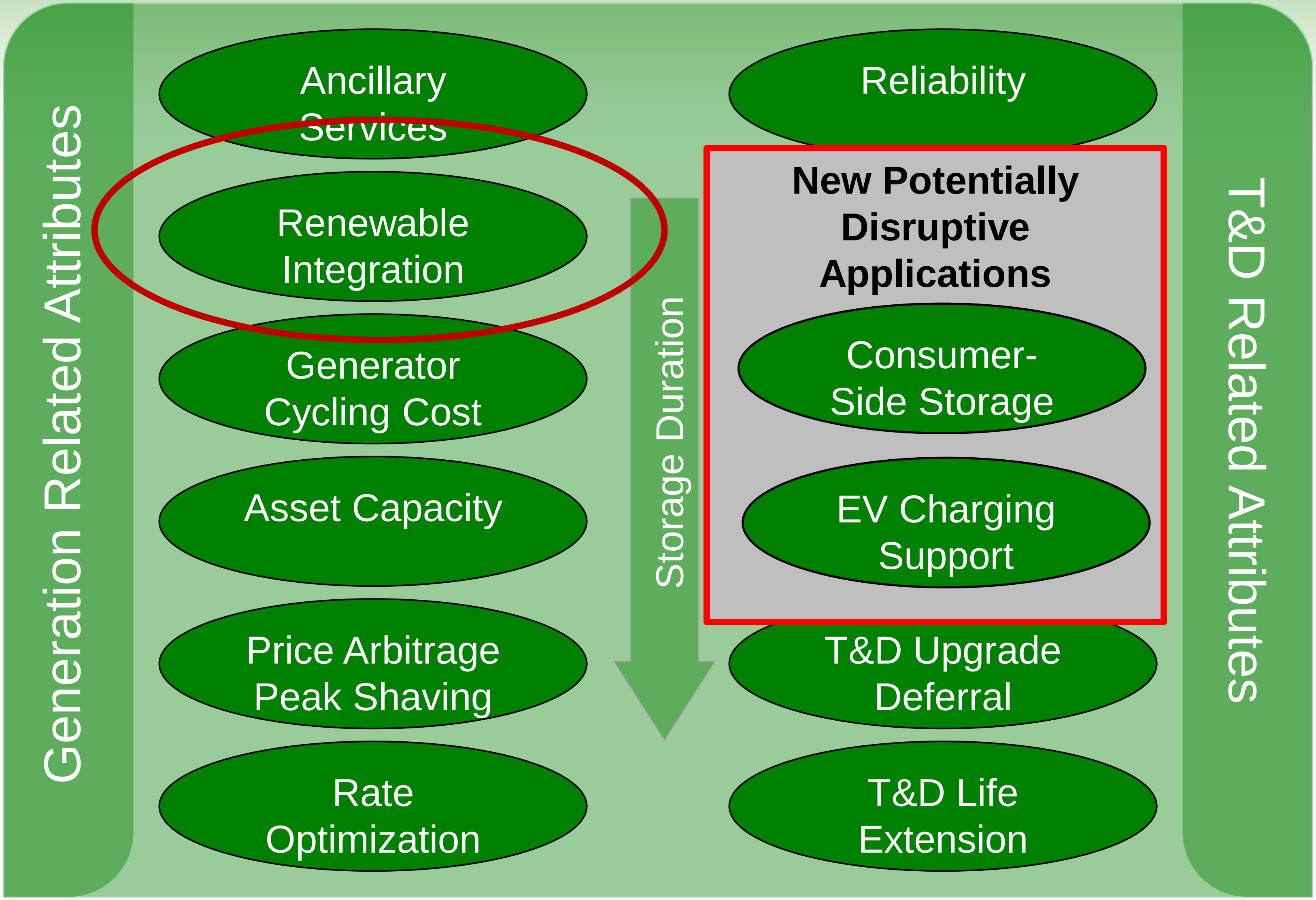


Cree

	Frequency	Mass	Volume
Today	60 Hz	8,160 lb	4.80m^3
Tomorrow	50 kHz	100 lb	0.14m^3

ABB

Electric Grid Energy Storage



Recent Opportunities

Energy Storage SBIR/STTR [7 new]

Advanced Management and Protection of Energy-Storage Devices (AMPED) [12 new]

Open FOA

https://arpa-e-foa.energy.gov/

Meet the ARPA-E Project Teams

at Poster Session this Afternoon

Thank You

Thanks to our conference sponsors

ESA
ELECTRICITY STORAGE ASSOCIATION

EAST PENN
manufacturing co., inc.

ecoult
energy storage solutions

AQUION ENERGY

Raytheon Ktech

A123 SYSTEMS

EnerVault
Safe, Reliable, Cost-Effective Energy Storage

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories