CHANGING WHAT'S POSSIBLE

# ARPA-E University: Pathways to Success for ARPA-E Awardees

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Advanced Research Projects Agency-Energy

ARPA-E University
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# Introduction

- Program Director: 2010 – 2013
  - GRIDS, REACT, OPEN and SBIR
- Associate Professor, NC State University
  - Materials Science and Engineering
  - Semiconductor Materials and Device Research
  - FREEDM Systems Center
  - Technology, Entrepreneurship and Commercialization Prog.
- Entrepreneur
  - Nitronex (GaN/Si) [1999-01]
  - EPI / Veeco [1992-93]
  - QED / IQE [1989-91]

# Overview

- What Makes a Project and What is Success

- Activities Beyond the Technical Research
  - Techno-economic Modeling
  - Value Proposition
  - Team Building

- What After ARPA-E: Some Next Steps

# ARPA-E's creation and launch

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

**2006**
***Rising Above the Gathering Storm***
**(National Academies)**

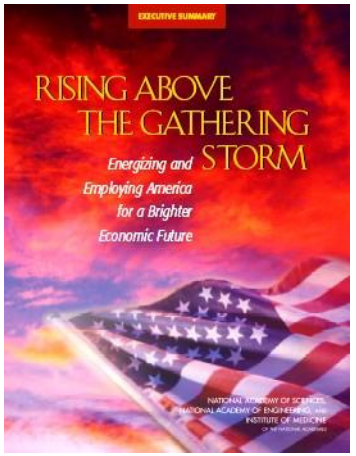
**2007**
**America COMPETES Act**

**2009**
**American Recovery and Reinvestment Act**
($400M)

**2011**
**FY2011 Budget**
($180M)

**2012**
**FY2012 Budget**
($275M)

**2013**
**FY2013 Budget**
($250M)

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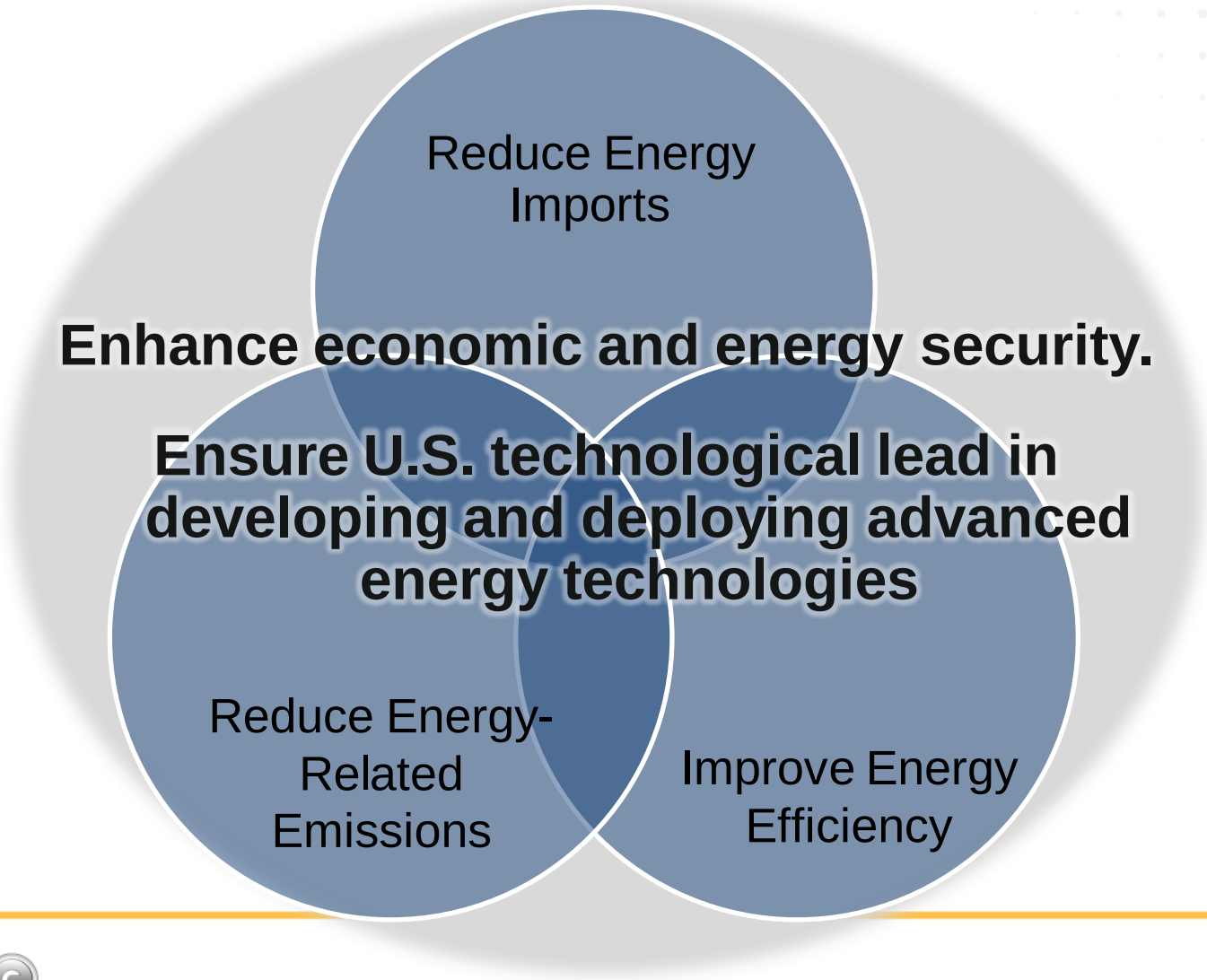
# Energy Challenges

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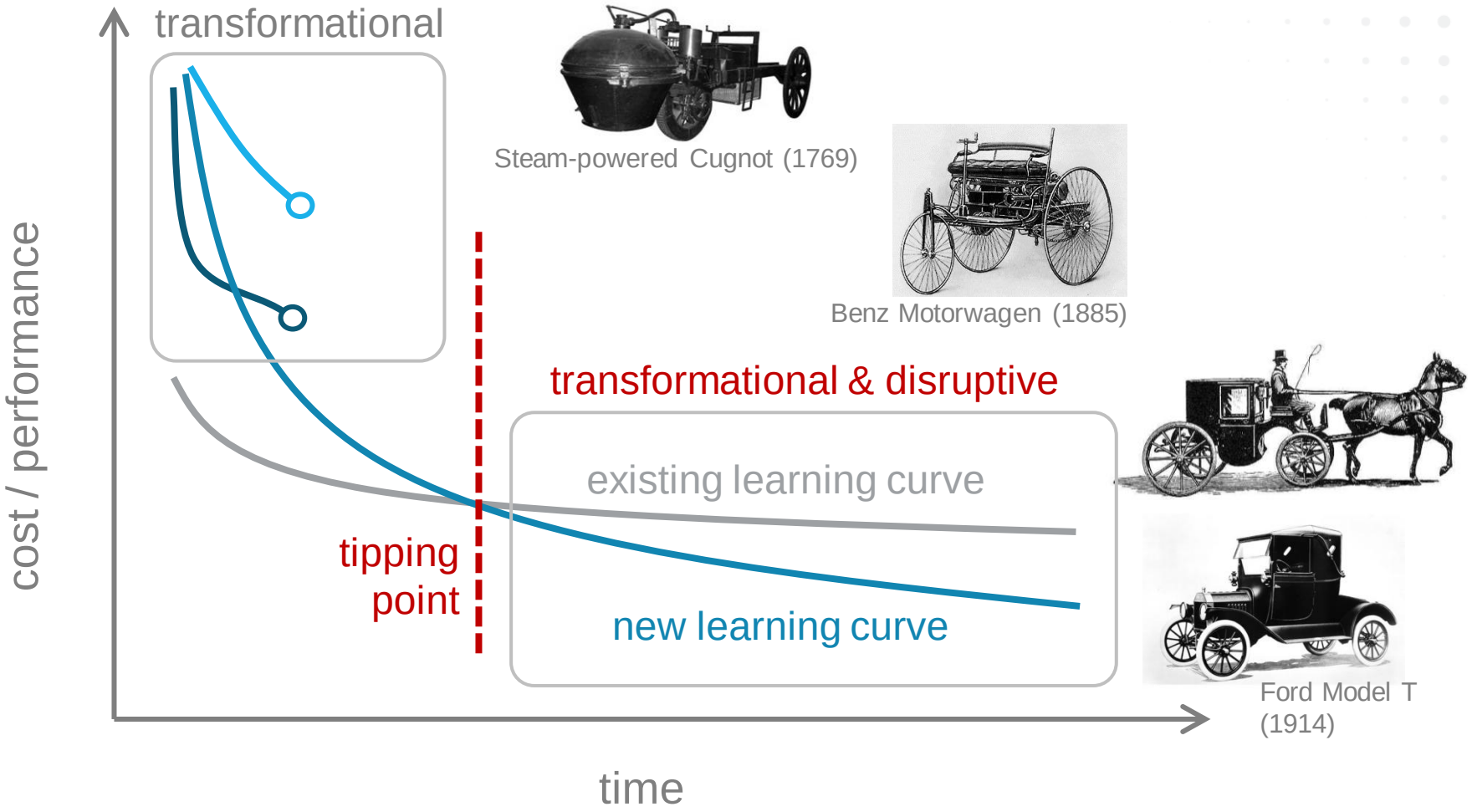
# Transformational & Disruptive Technologies Lead to New Learning Curves



# Basics of an ARPA-E Project

## 1. Impact

- High impact on 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

- Translate science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

## 4. Team

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

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# The ARPA Method

## Heilmeyer Questions

1) What are you trying to do?
   (Explain using no jargon)
2) How is it done today and what are the limitations?
3) What is the new approach and why might it be successful?
4) If successful, what difference will it make?
   (who cares?)
5) What are the risks and payoffs?
6) How much will it cost and how long will it take?
7) How will success be measured in the short, medium and long term?



Rising Above the Gathering Storm, NAS (2006)

# Three Outcomes in Technical Program

- Hard Applied Research Challenge →
  Success in Research Plan (Milestones Met)
  Move Technology Next Step to Market

- Hard Applied Research Challenge →
  Success not Possible in Research Plan
  (Milestones Definitively not Met)
  Publish and Move on / Fail Fast

- Hard Applied Research Challenge →
  Don't Know after Research Plan
  (Milestones Not Met or Incremental or Team or …)
  ARPA-E Execution Failure

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# Heilmeyer's "Seven Step No-Excuses to Technology Transfer"

1] Allocate capital and staff resources early in the research process [Build a Team]

2] Identify and involve possible users of the technology in research [Validate Value Proposition]

3] Wherever possible, use common equipment in the development lab and early manufacturing facilities [Techno-economic Connection]

4] Prove manufacturing methods in the lab [Prove out Techno-Economic Model]

5] Prove technology in the plant before trying to improve it [Execute without Getting Ahead of Critical Path]

6] Begin commercializing the technology immediately after demonstrating its feasibility [Identify Unknowns to Scaling]

7] Keep the lab involved through the completion of product development and product launch [Multiple Technical Challenges]



IEEE Spectrum (June 1994)

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# Techno-Economic Model

- Connector of Research Outcomes to
  Relevant Economic Factors

- More than a “Cost Model”
  (Not a ‘Business Plan’)

- Not to be Outsourced – Key PI Tool

- Inherently Challenging and Interdisciplinary

- Key Result: Reduce Technical Uncertainty Limits to Private Sector Investment

  Low/No Fidelity at Start of Project →
  Increasing Fidelity as Project Advances

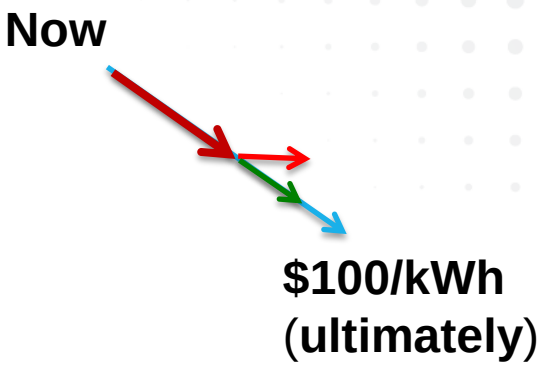
# Example: Energy Storage / Flow Battery

Key Metric: $/kWh (capex)

System Costs:

$/kWh (energy components) +

$/kW (power components) / duration




Unknowns:

Electrolye Composition / Concentration

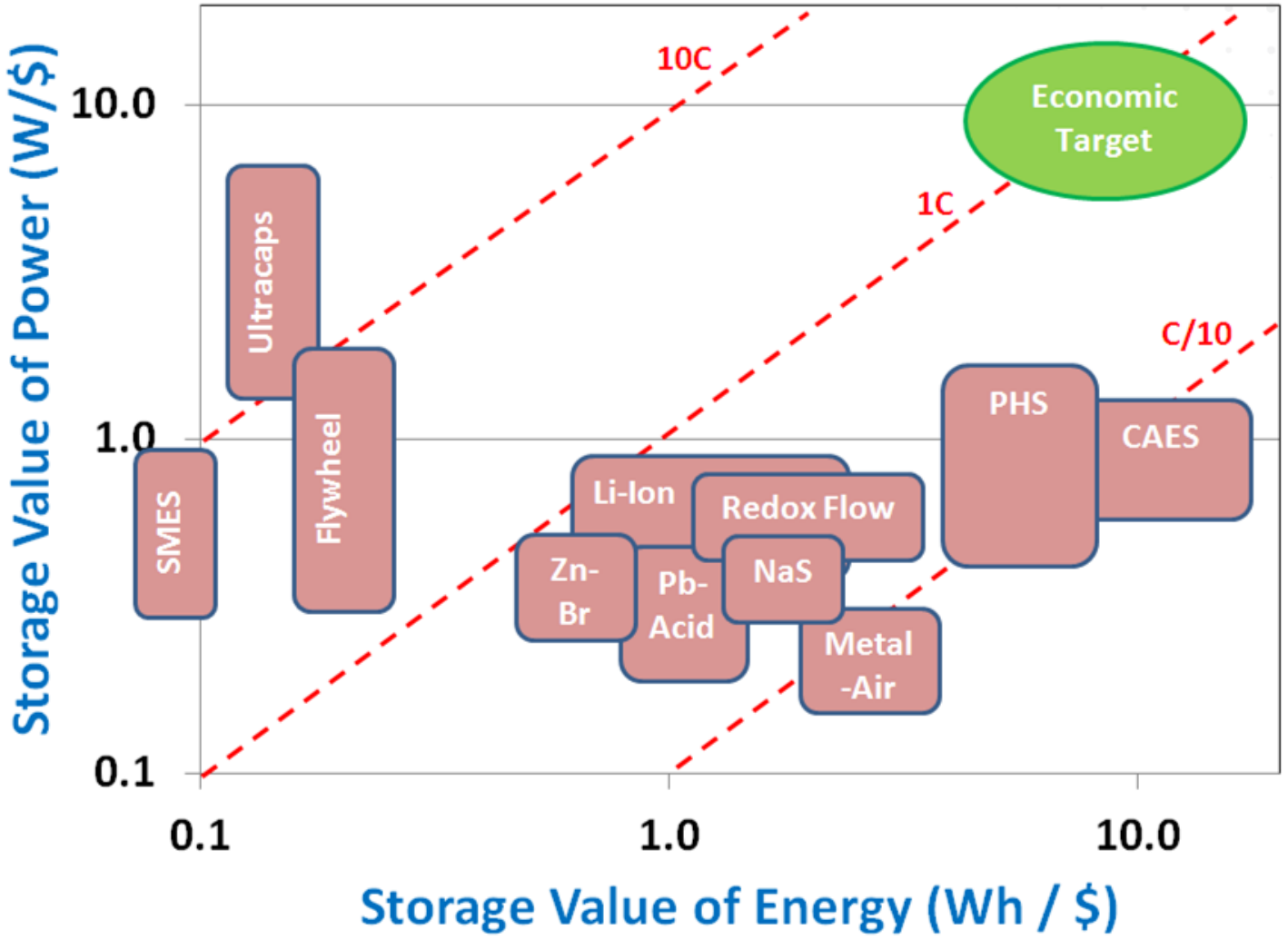
- Additives, Side Reactions, SoC Range, etc.

Power Density (Areal, Volume, etc)

- Current Density
- Reaction Rates + Mass Transfer + Resistance
- Cycle Life

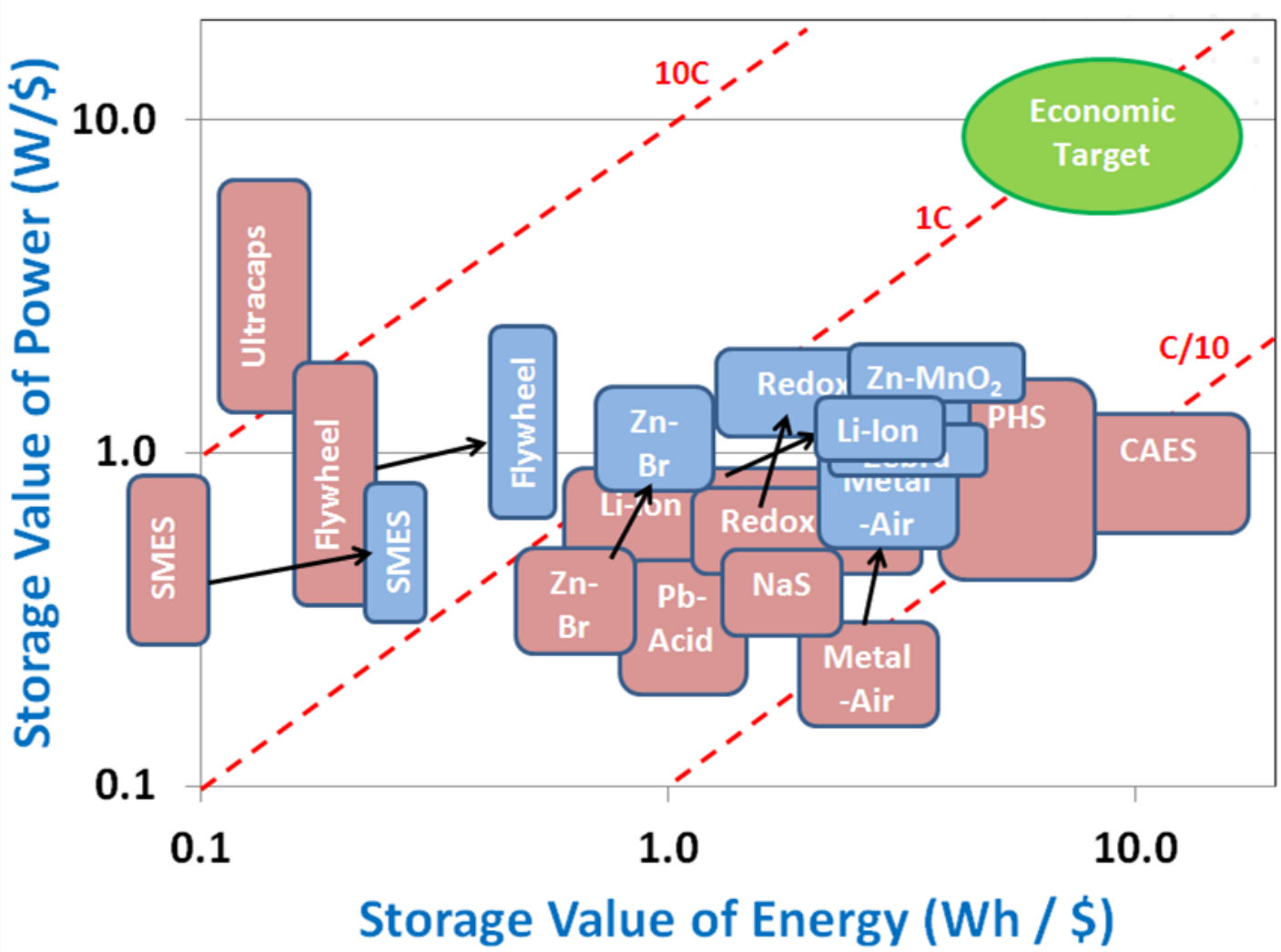
Cost of Raw Materials (and Labor) in System Model

# Economic Targets and SOA




Data: D. Rastler "Electical Energy Storage Technology Options" EPRI, 2010

# Technology Shifts

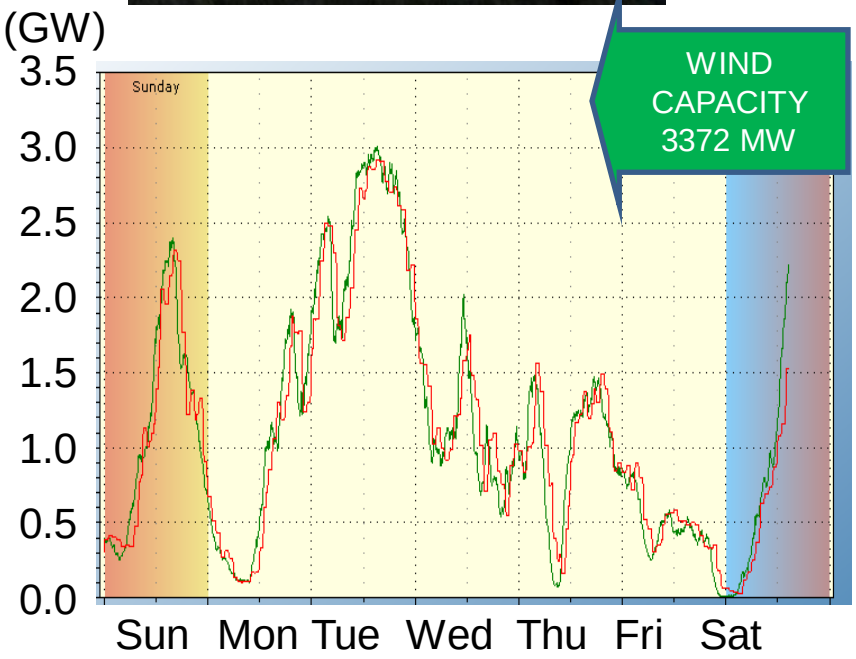



Data: D. Rastler "Electical Energy Storage Technology Options" EPRI, 2010 + Estimates Based on Technical Advances

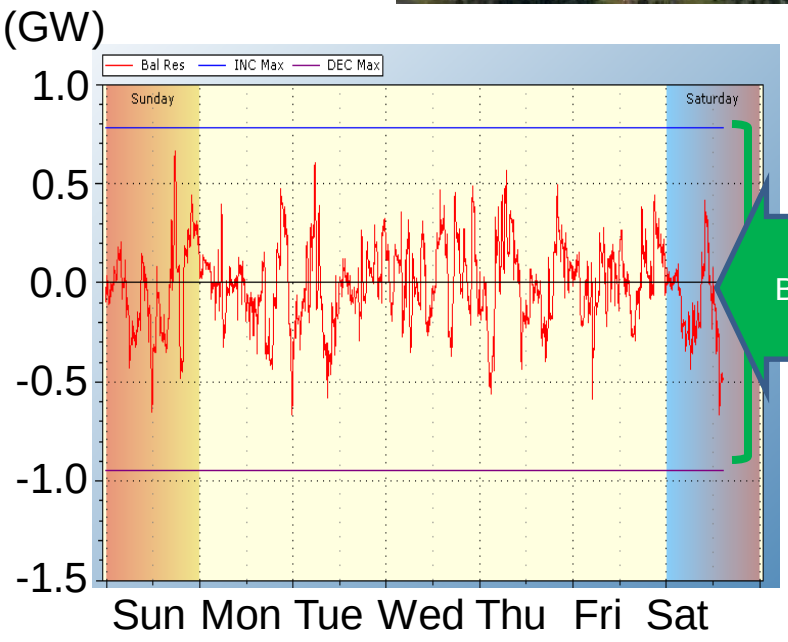
# Lessons

- Getting First Significant Digit Close is Challenge
- It is OK to say: we don't know 'X,Y,Z' at this time
- Techno-economic Models can Guide Changes of Work-plan or Translation Pathway
- Techno-Economic Modeling Can Be Where Teams Learn 'Bad News' - Which should not be 'bad news'.
- Discuss, Don't Argue - It is a FOA Target for a Reason
  - Many Potential First Market Opportunities before Ultimate Program Goal

# Balancing Reserves to Firm Wind Generation in High Renewable Penetration




WIND CAPACITY 3372 MW




HYDROPOWER BALANCE RANGE 1600-2000MW

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

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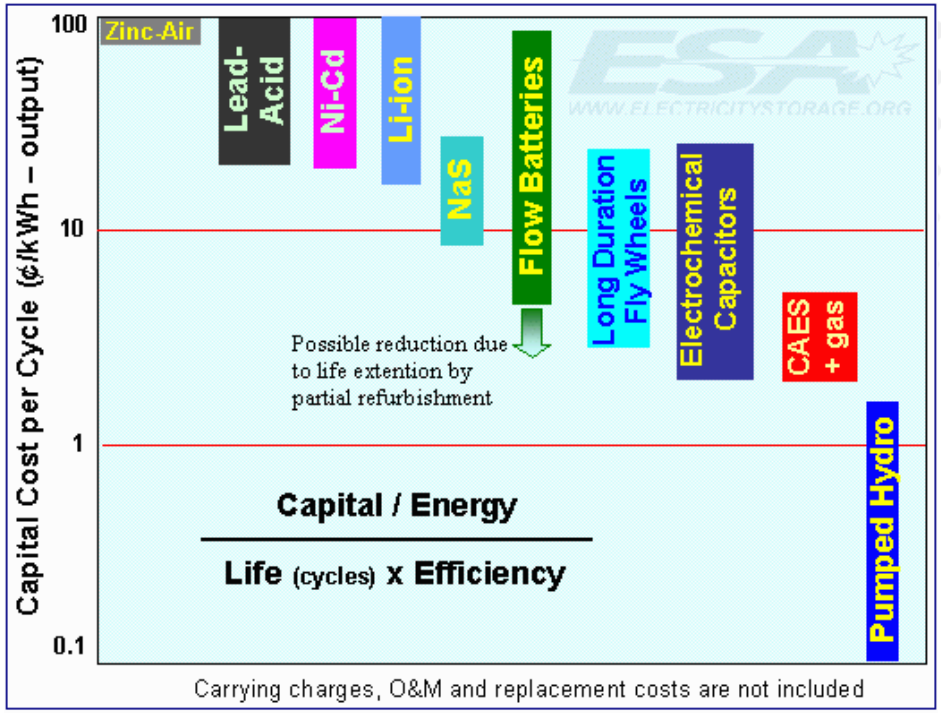
# Issues of Cost for Storage

'10X' Step Change

Needed in Technology




$$\$0.025 \text{ per kWh}_e = \frac{\$100 \text{ per kWh}}{5000 \text{ cycles} \bullet 80\% \text{ RTE}}$$

# Where Can Storage First Pay for Itself?

**DoD**

$0.25 - $25 / kWh$_e$

**Developing World**

$0.25 - $10 / kWh$_e$

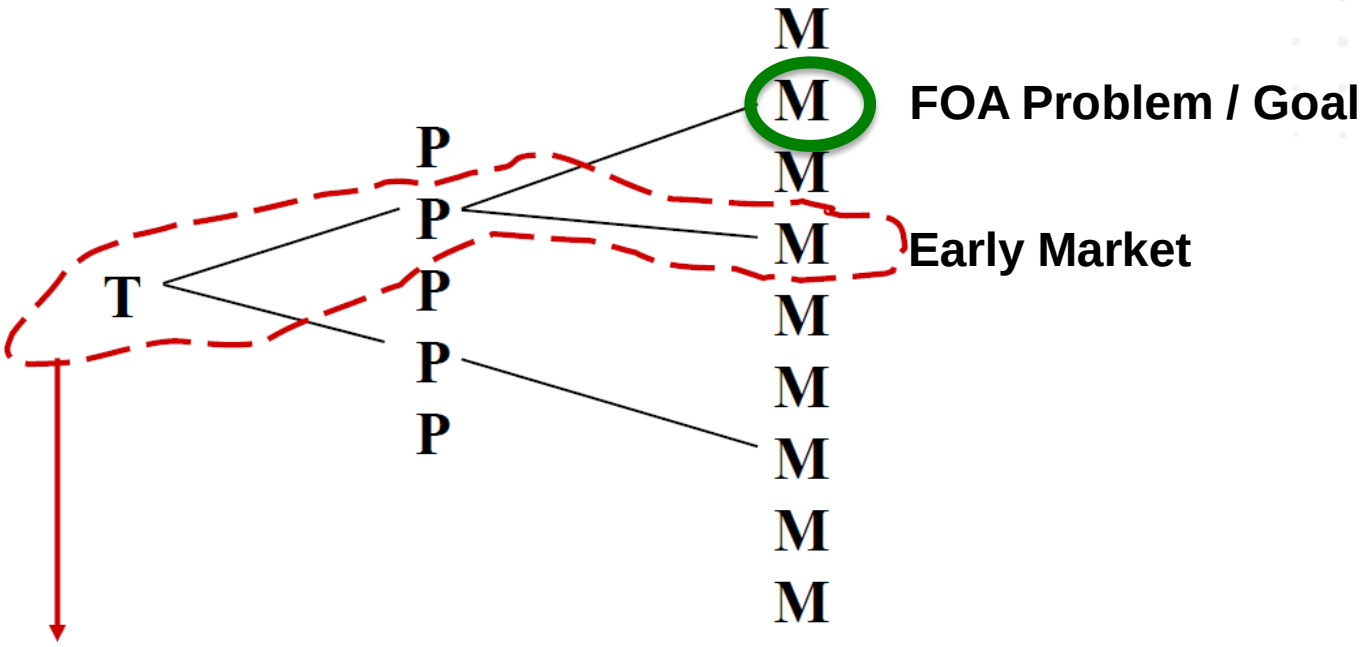
**Alaska & Hawaii**

$0.25 - $1.25 / kWh$_e$

**Lower 48 USA**

$0.07 - $0.15 / kWh$_e$

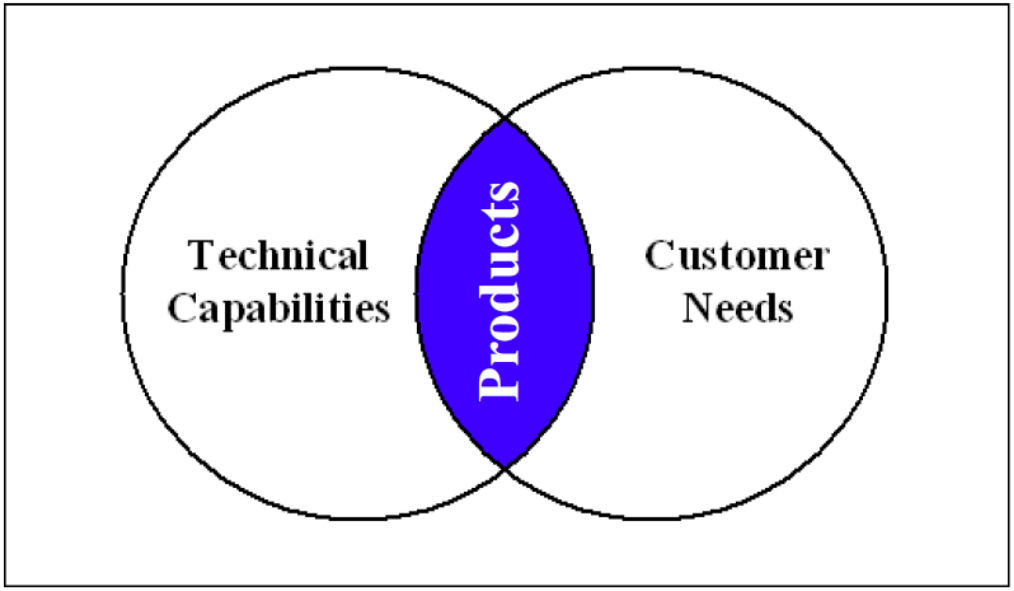
# Building a Value Proposition: Technology – Product – Market Linkage




The most basic building block of a Business Concept

From: NCSU Technology, Entrepreneurship, Commercialization Program (2009)

# Technology vs. Product




Need to Speak with Many, Many Potential Customers

Primary and Secondary Market Research, Voice of Customer, etc

Cyclic Process – Be Open to Change

***There is no product until customer needs and technical capabilities intersect***



**From: NCSU Technology, Entrepreneurship, Commercialization Program (2009)**

# The Value Proposition

A Value Proposition is a statement tying the customer needs to the benefits of using your product(s) (or business) in economic terms.



**From: NCSU Technology, Entrepreneurship, Commercialization Program (2009)**

# A Formulaic Value Proposition

First sentence:

- For (target customer)
- who (quantified statement of the need or opportunity)
- the (product/service name) is a (product/service category)
- that (statement of benefit)

Second sentence:

- Unlike (primary competitive alternative)
- Our product (statement of primary differentiation)

**From: NCSU Technology, Entrepreneurship, Commercialization Program (2009)**

# Made Up Example: Value Proposition

“For the Mobile Phone System Operators in Emerging Economies who Support 900,000 Mobile Towers with Electricity Using Diesel Generators, The ‘super new chemistry battery’ provides storage to increase uptime from 60% to 99% while reducing diesel fuel costs by 40%.

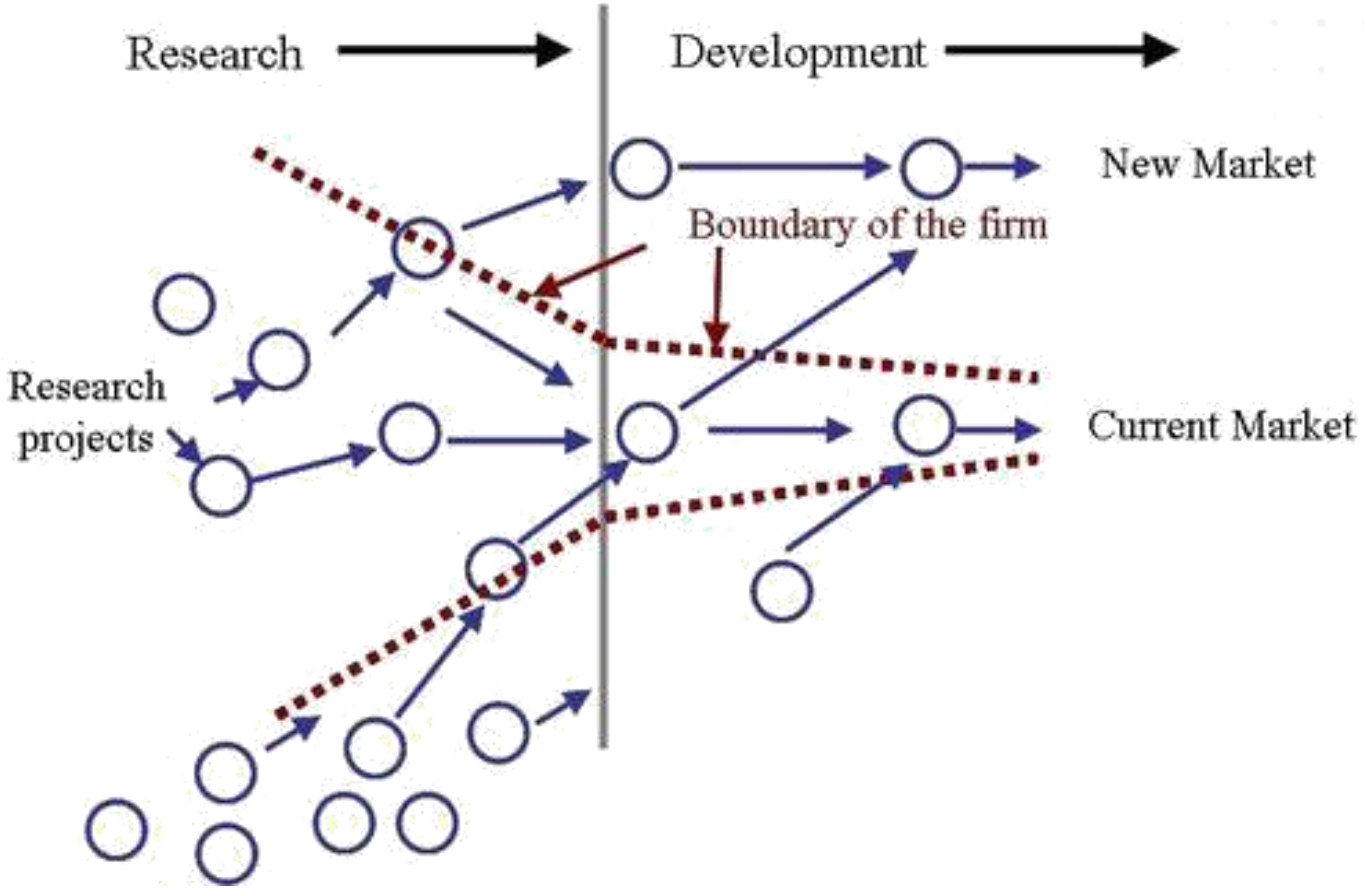
Unlike the existing approach of storing excess fuel on-site and building redundant generators, or the use of lead-acid batteries which are subject to theft, the ‘super new chemistry battery’ reduces capital expense by 70% while being inherently theft and tamper proof.“

# Comments on Value Propositions

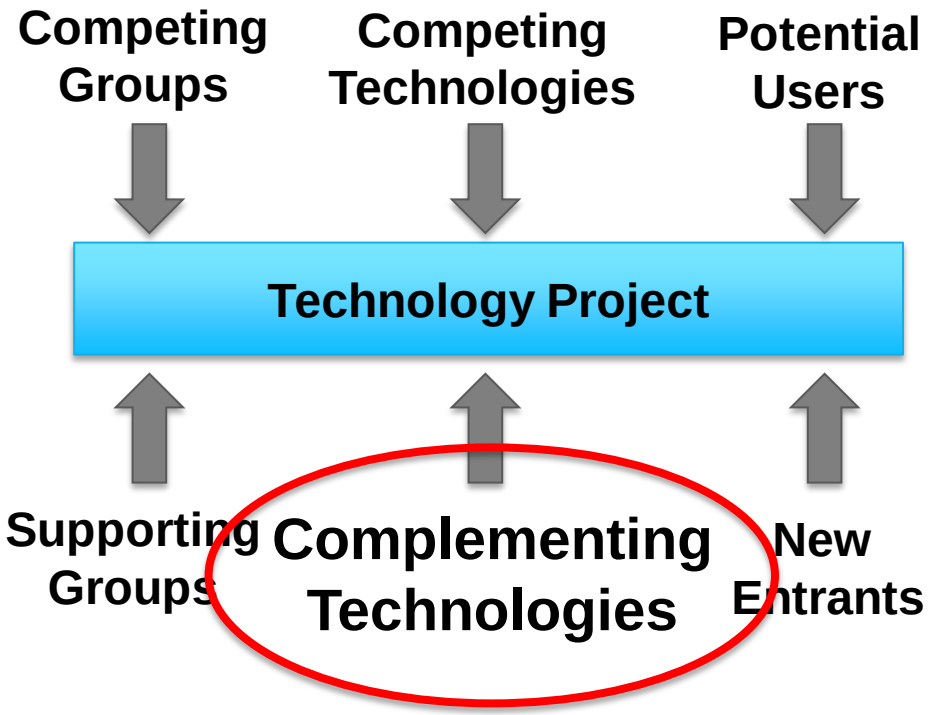
- A ‘Cool Technology’ is not a Value Proposition alone
- A Motivated Market is not a Value Proposition alone
- A FOA Target is not a Value Proposition alone
- Value Propositions:
  - Connect Technology Capability to Market Opportunity
  - Communicate Belief Underlying Effort: ‘So What’
  - Are Succinct and Brief

<u>Research Projects Quantitatively Validate a Value Proposition</u>

# Importance of Complimentary Technical Communities and Innovations



# Dynamics of Complementing and Competition in Market




Adapted From Andy Grove, Only the Paranoid Survive (1996)

# Note: For Existing Firms

**Value Proposition and Techno-Economic Modeling Best When Consistent with Existing Business Processes (Costing Models, New Product Definition, “Stage-Gating”)**

**Make T2M a Powerful Tool for Communicating with Stakeholders**

# Elements of an Energy Storage System

AMPED

ADEPT
SWITCHES
GENI

BMS

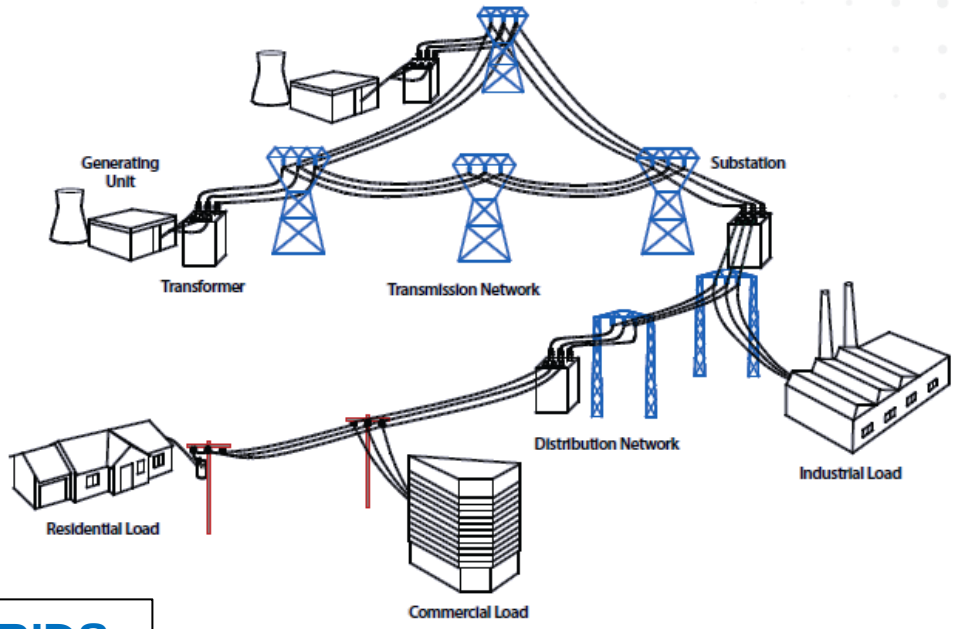
Controls

Grid Interface

Physical Energy Storage Element

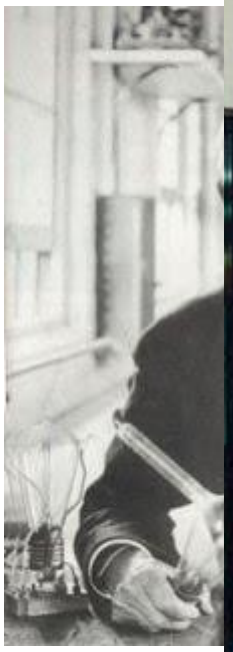
Balance of Plant

GRIDS
OPEN
BEEST
HEATS
RANGE



You Cannot Build an Industry Changing Firm and Succeed Economically all by Yourself

# Build a Team

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# Observations for Leaders of Translation Effort

- Know Your Self and Your Goals
- Where Do You Need To Build Yourself?
  Where Do You Need to Find Complimentors?
- Who Do You Trust?
  Who Gives You Bad News?
- Find a Mentor

**Important Attributes**
**- Openness to Ideas**
**- Contentious and Intellectually Honest**

- No Need to be 'Inventor' of Everything
  – Give Team Around you Opportunity for Buy-in

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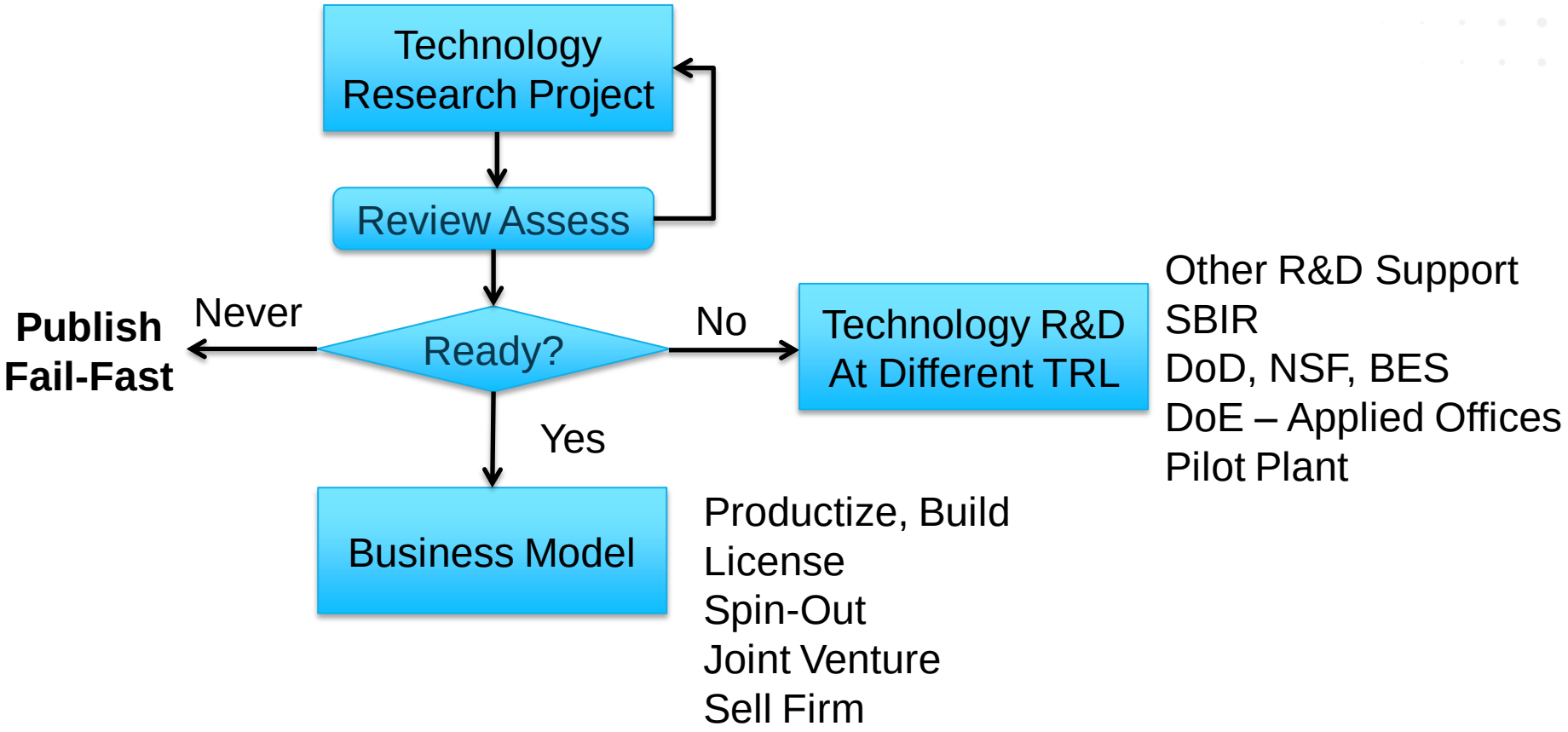
# My Research is Done, Now What?

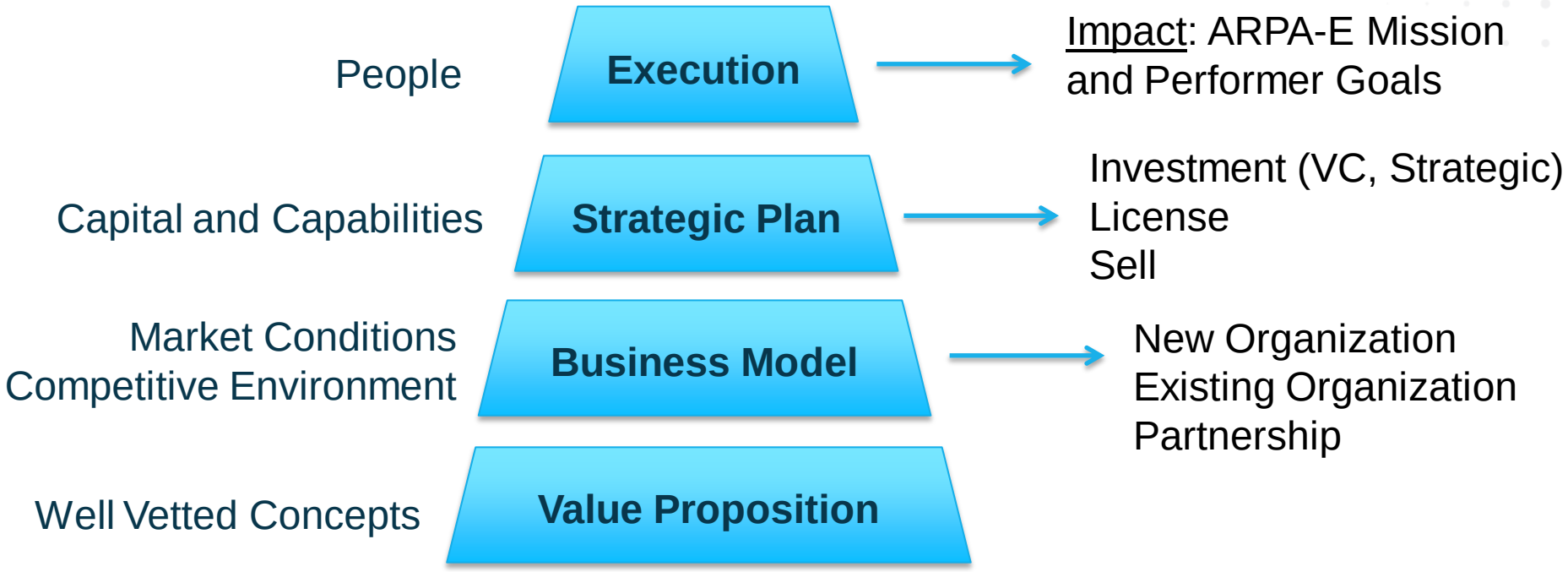
## (ie: can you extend my grant?)

If you are asking this question in month 36 of a project, you are 35 months late in asking.

# Simplified Technology Commercialization Decision Loop



# Foundations of Pathway to Market



# Comments On Pathway

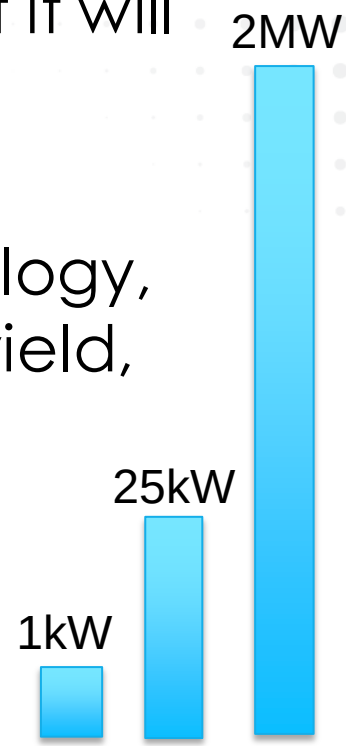
- Business Plan, Business Model and Fund-Raising is the Later Stage Question – need Foundational Information.
- Plan for Success, or Plan to Fail
- License Model: Why did you license it for that amount?
- VC Model: What is your expected ROI from those funds
- Corporate Model: How does this Opportunity Align with Overall Company?
- What is the 'Full Time Job' of the Leader, and why will Talented People follow the Leader?
- IP – A Topic of it's Own. It is a Necessary, but Not Sufficient Ingredient

# Common Next R&D Step

- "We know it works, we just don't yet know if it will scale" – Eric Toone, PD for Electrofuels

- New technical challenges in scaling: metrology, batch to continuous process, throughput, yield, etc…

- Value in building the Pilot Plant



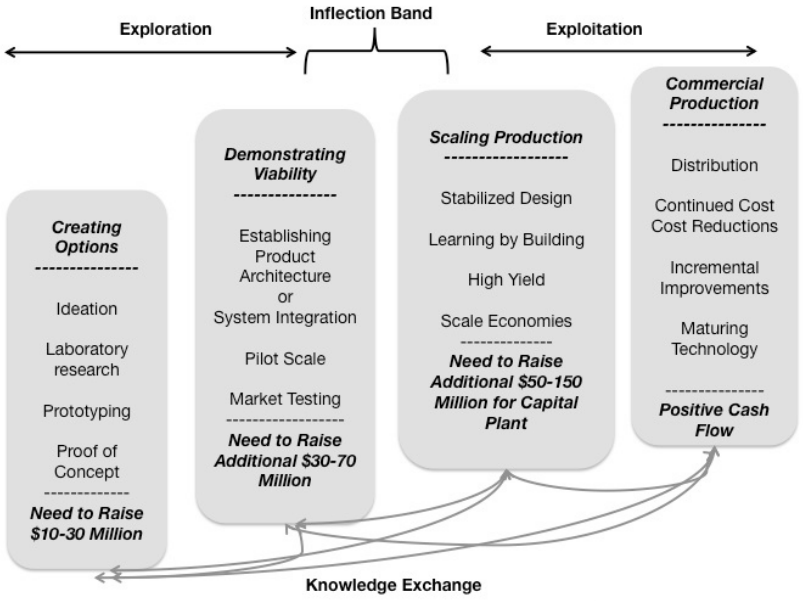

- Value in building nascent supply chain:

  Can the "Secret Sauce" be Made Competitively?

# A Positive Program Outcome / Goal: Tap Potential of US Manufacturing

"The U.S. as One of the Developed World's Lowest-Cost Manufacturers: Behind the American Export Surge" Boston Consulting Group (2013)

- Great Productivity Adjusted Skilled Labor
- Low Energy Cost
- Low Export Shipping Cost




Lester and Hart (MIT, 2011)

Importance of Clusters, Knowledge Growth and Scaling in Manufacturing – MIT Production in the Innovation Economy Group (2013)

# Thank You!

# Go Change What's Possible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