



*... for a brighter future*

# *Lithium Ion Batteries*

## *Argonne's Approach to Technology Transfer*



U.S. Department  
of Energy

UChicago ►  
Argonne<sub>LLC</sub>

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# Outline

## ■ Overview of Lithium Ion Batteries

- Technology
- Developments at Argonne National Laboratory
- Market

## ■ ANL Technology Transfer Strategy

- Background
- Strategy
- Progress

## ■ Future Opportunities

- Materials scale-up engineering
- Batteries scale-up engineering

# *Performance areas*

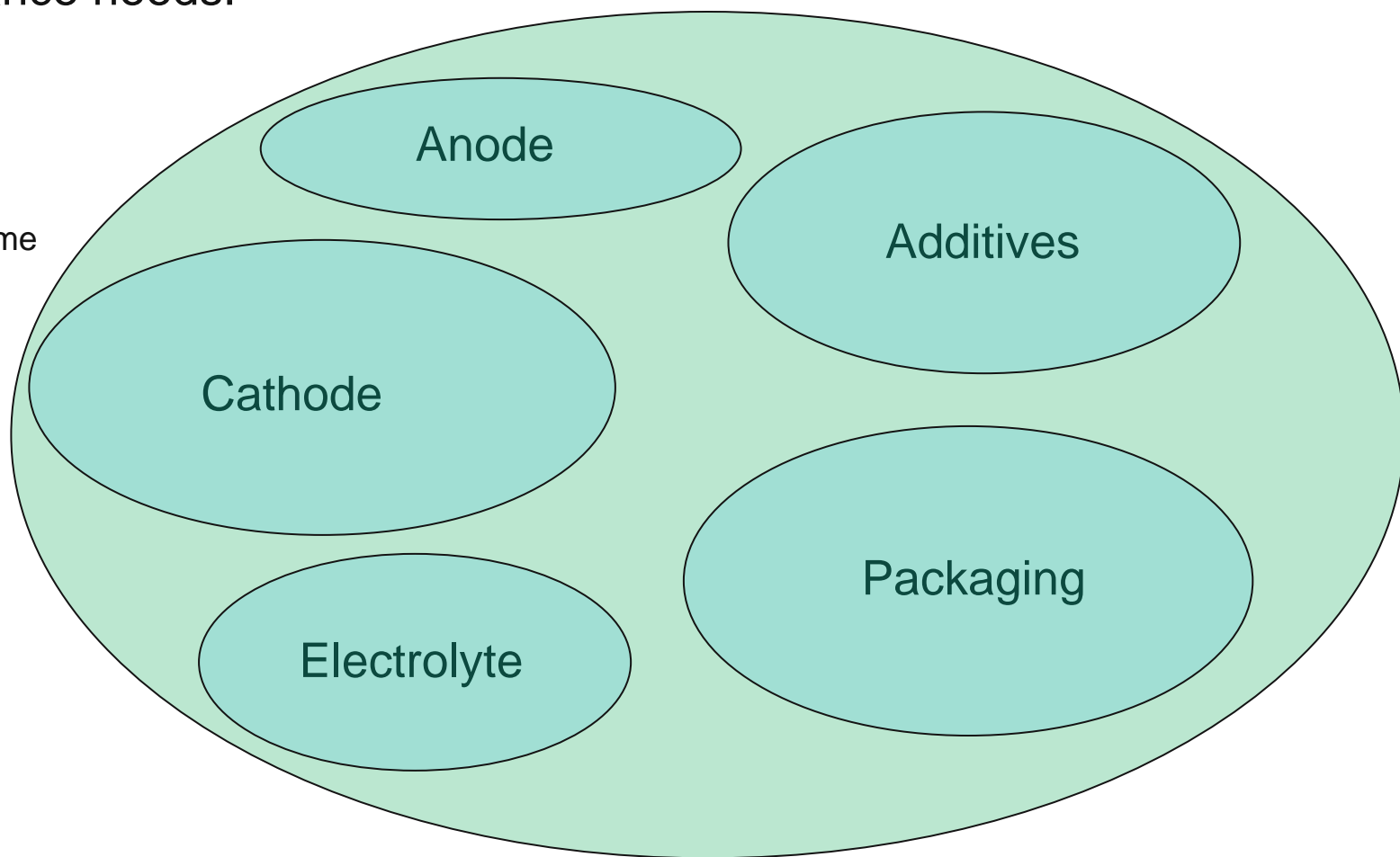
- Safety
- Power
- Energy
- Life
- Cycle time

# *Technology developed in several thrusts results in improved performance*

## ■ Performance needs:

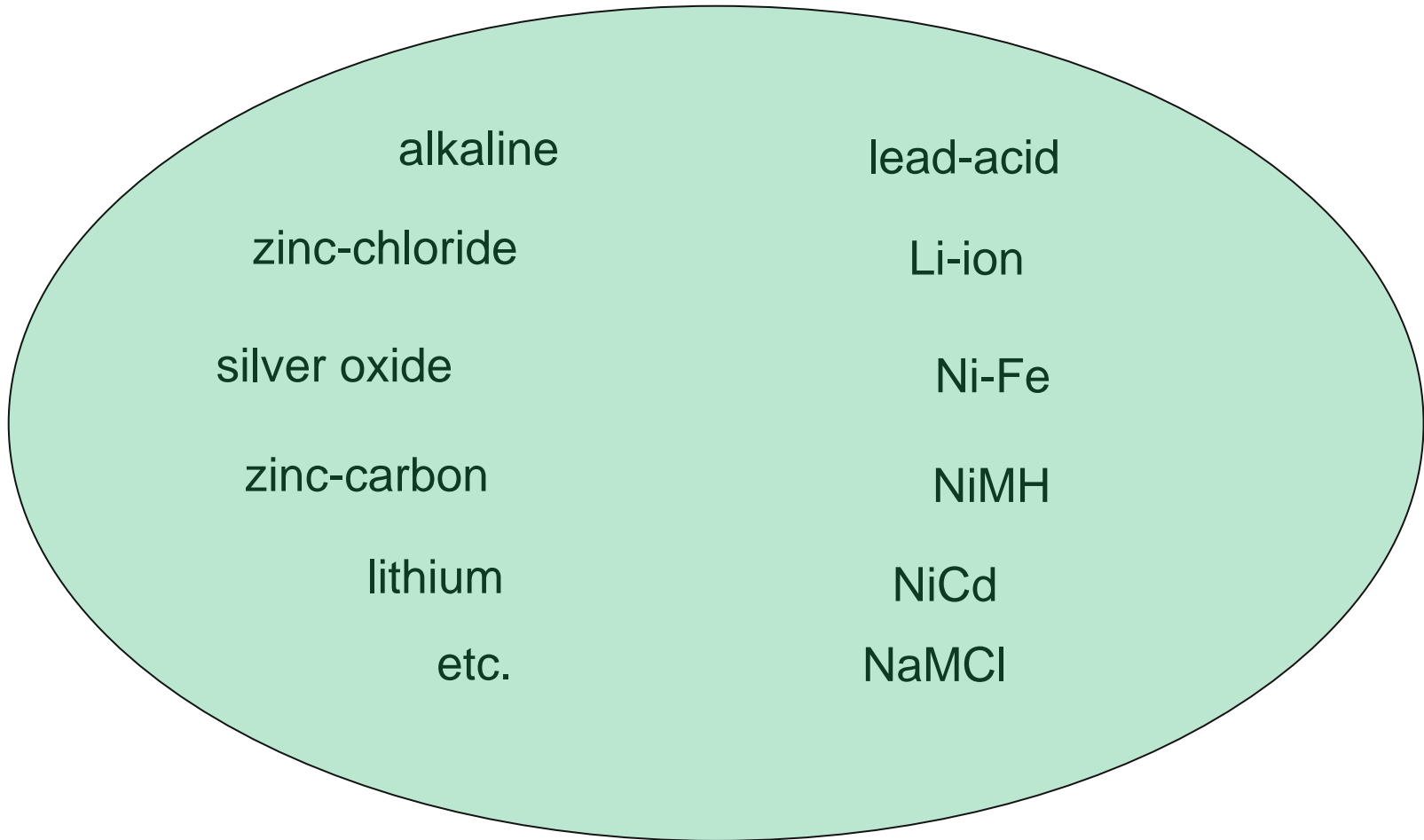
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## Technology areas for Li-ion:



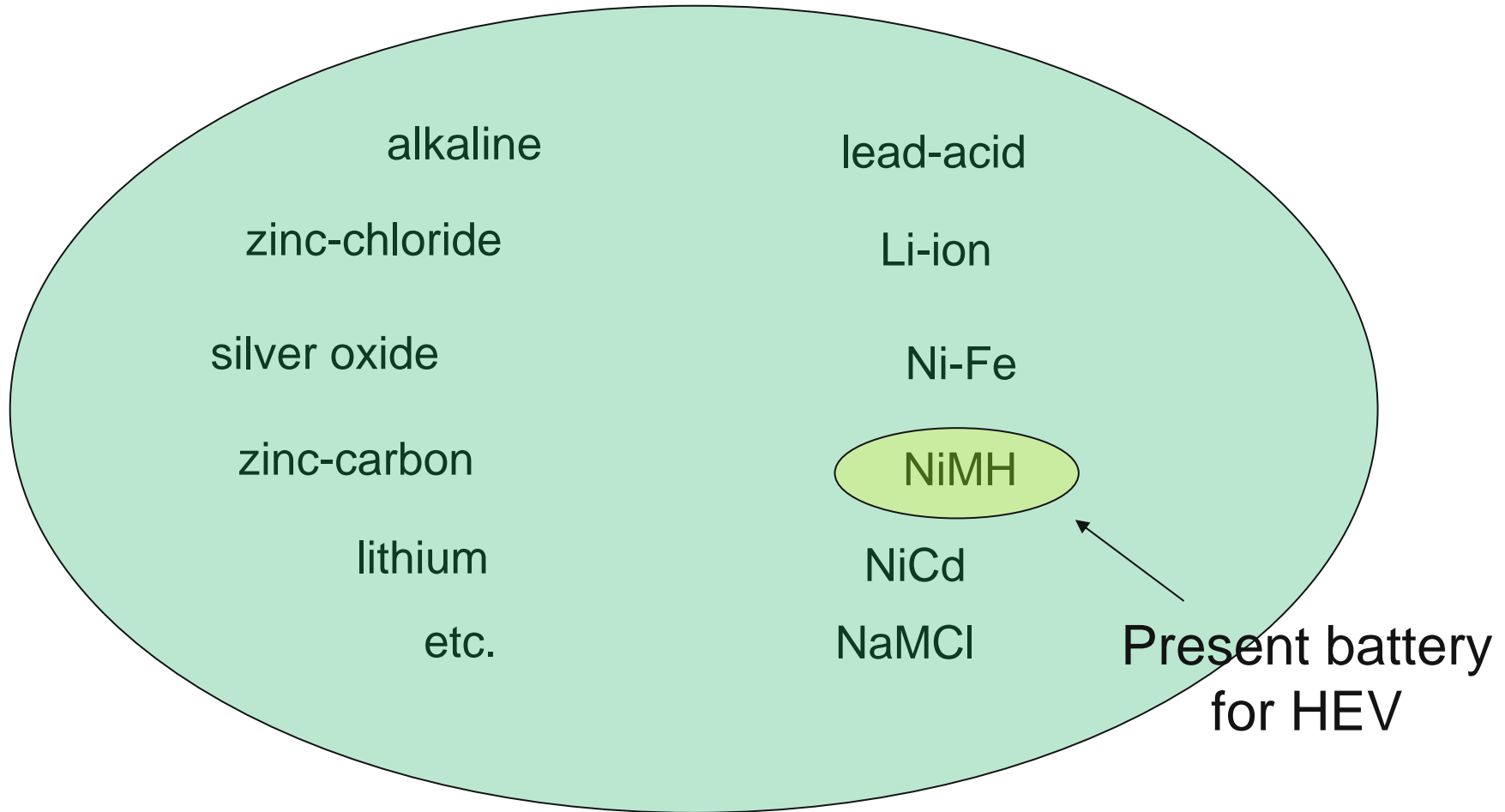
# *There are many types of batteries*

## Batteries:



# *There are many types of batteries*

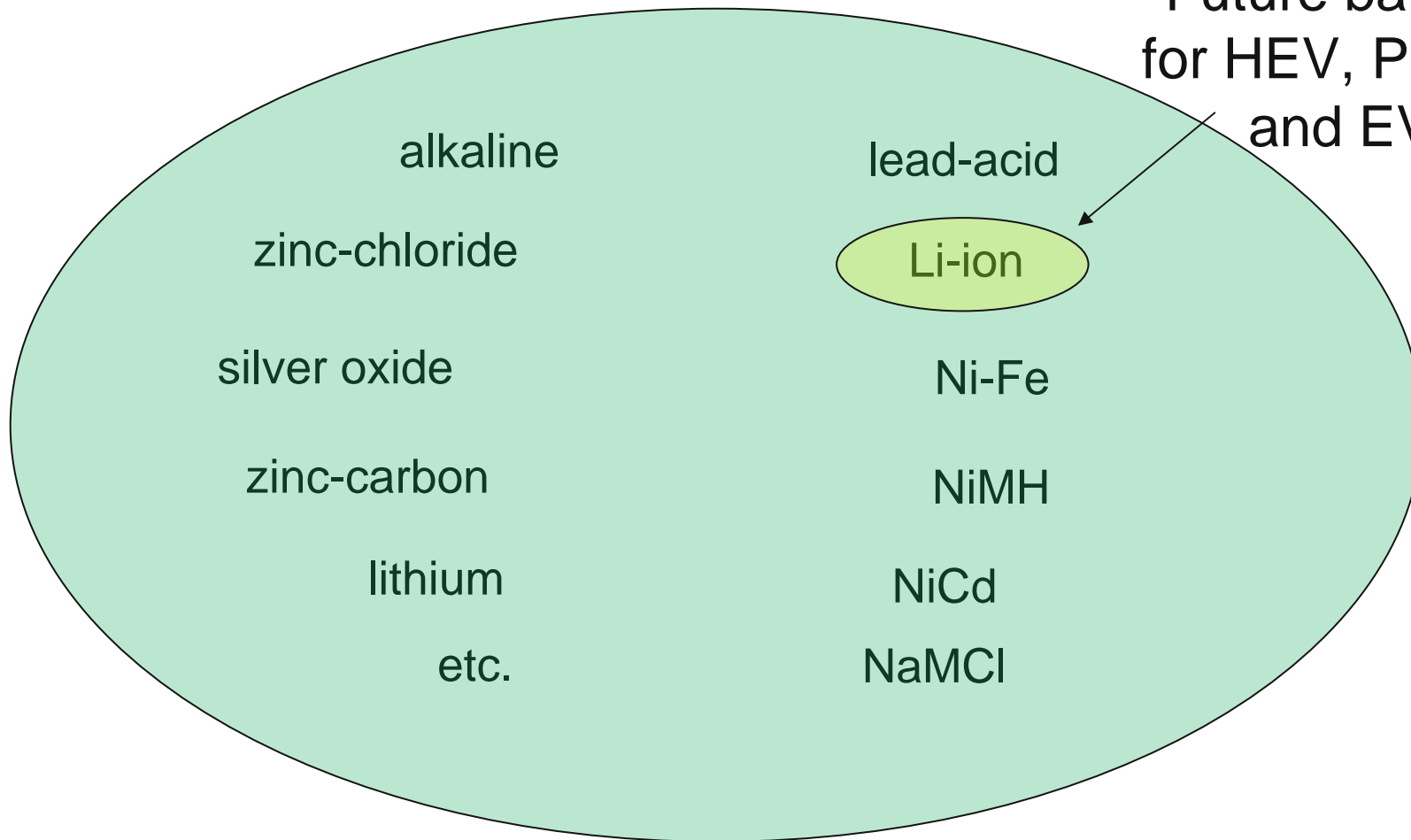
## Batteries:



# There are many types of batteries

Batteries:

Future battery  
for HEV, PHEV,  
and EV



# Overview of pertinent ANL inventions

These 33 patents have arisen from over 125 ANL inventions.

## Composite Cathode Structures

US Patent 6,677,082 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiMO}_2$  (M base = Ni; M' base = Mn)

US Patent 6,680,143 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiMO}_2$  (M base = Mn)

US Patent 7,135,252 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiMO}_2$  (CIP)

US Patent 7,205,072 – Fluorinated electrodes

US Patent Application 20060051673 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiM}_2\text{O}_4$  – layered-spinel (CIP)

US Patent Application 20060051671 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiM}_2\text{O}_4$  – layered-spinel (PCT)

US Patent Application 20060188781 – preconditioned electrodes (CIP)

US Patent Application 20060099508 –  $x\text{Li}_2\text{M}'\text{O}_3 \cdot (1-x)\text{LiMO}_2$  (CIP)

US Patent Application 20050026040 – preconditioned electrodes

US Patent Application 20030180616 –  $\text{Li}_2\text{MO}_2$  components

## Related and Other Cathode Materials

US Patent 7,041,414 –  $\text{Ag}_x\text{MnO}_2$

US Patent Application 20050058588 – F addition and spherical morphology

US Patent Application 20040091779 – F addition

US Patent Application 20040234854 – composition and method

US Patent Application 20040048156 –  $\text{Ag}_x\text{V}_3\text{O}_8$

US Patent Application 20040265696 –  $\text{LiNiTiPO}_4$

## Anode Materials

US Patent 6,221,531 – Doped  $\text{Li}_4\text{Ti}_5\text{O}_{12}$

US Patent 6,528,208 –  $\text{Cu}_6\text{Sn}_5$  etc

US Patent 6,730,429 –  $\text{Cu}_6\text{Sn}_5$  - method

US Patent 6,528,208 –  $\text{Cu}_6\text{Sn}_5$  etc

US Patent 6,855,460 –  $\text{Cu}_2\text{Sb}$  etc

US Patent Application 20040131941 –  $\text{SrLi}_2\text{Ti}_6\text{O}_{14}$

## Coated Electrodes

US Patent 7,049,031 – Protective coating for spinel electrodes

US Patent Application 20040191633 – colloidal coatings

US Patent Application 20040157126 – carbon coating method

## Electrolytes and Electrolyte Additives

US Patent 7,026,074 – Electrolyte additive

US Patent Application 20050019670

US Patent Application 20040151951

US Patent Application 20030157413

US Patent Application 20040151951

## Cell Design

US Patent 6,858,345 – Wound bipolar lithium battery

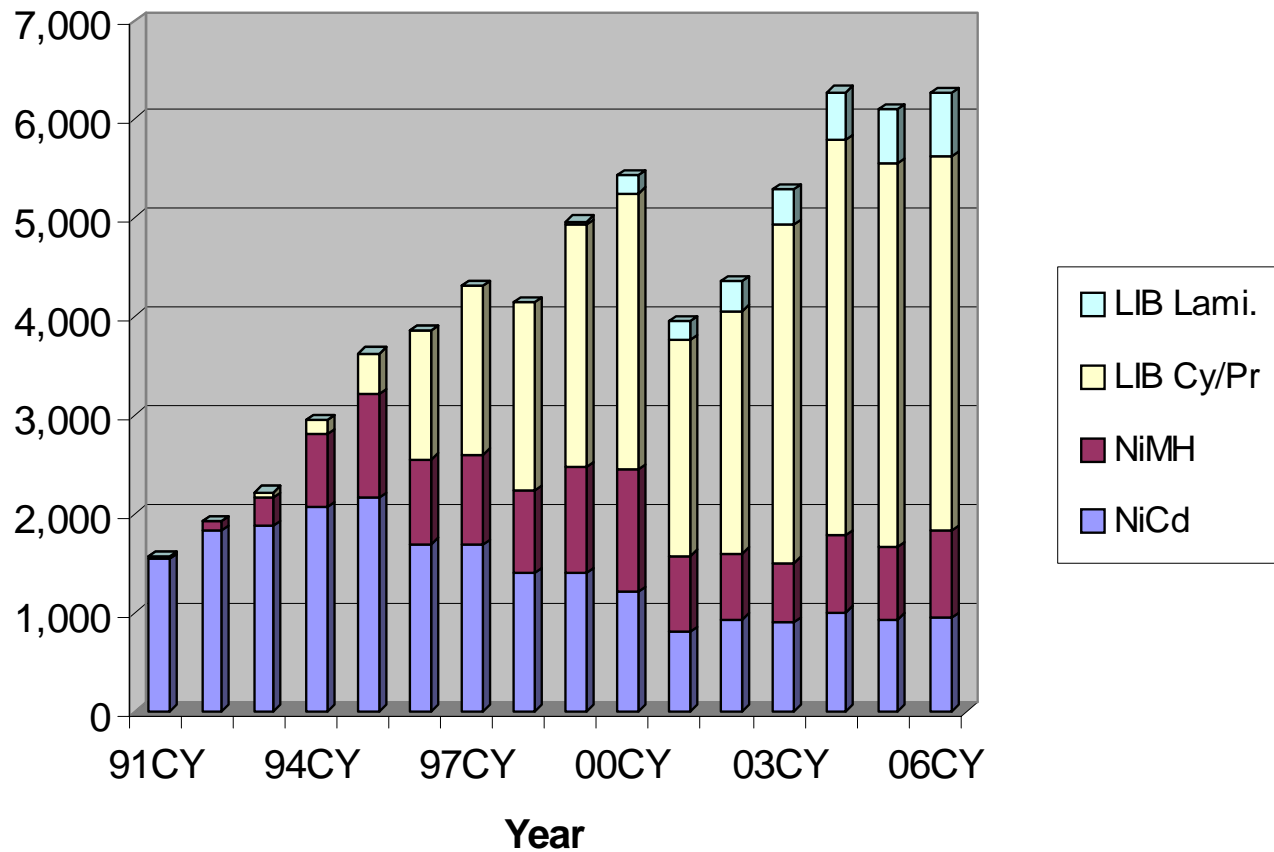
## Cell Packaging

US Patent Application 20020164441

US Patent Application 20050112461

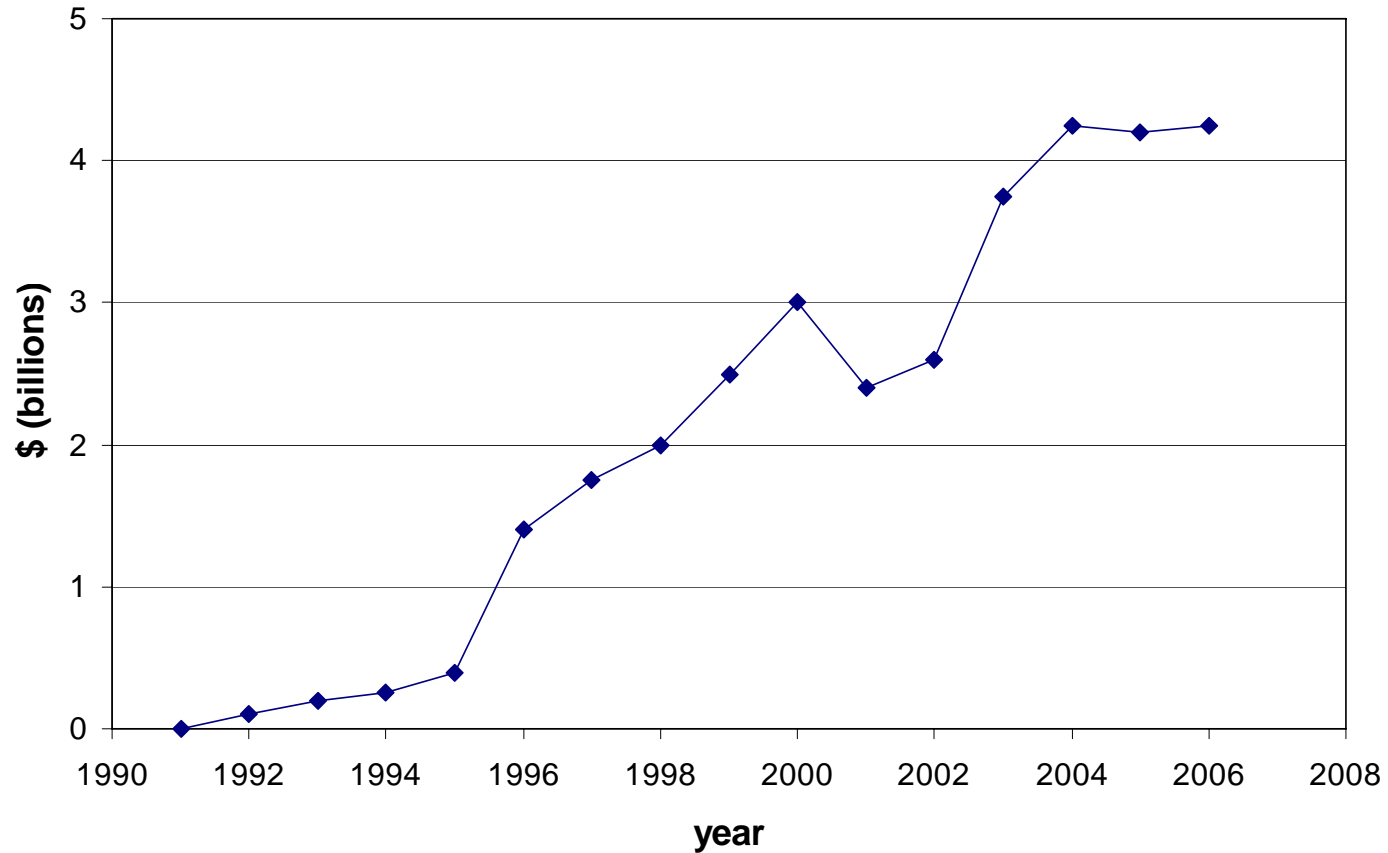
Source: Thackeray

# Battery market segmentation by technology



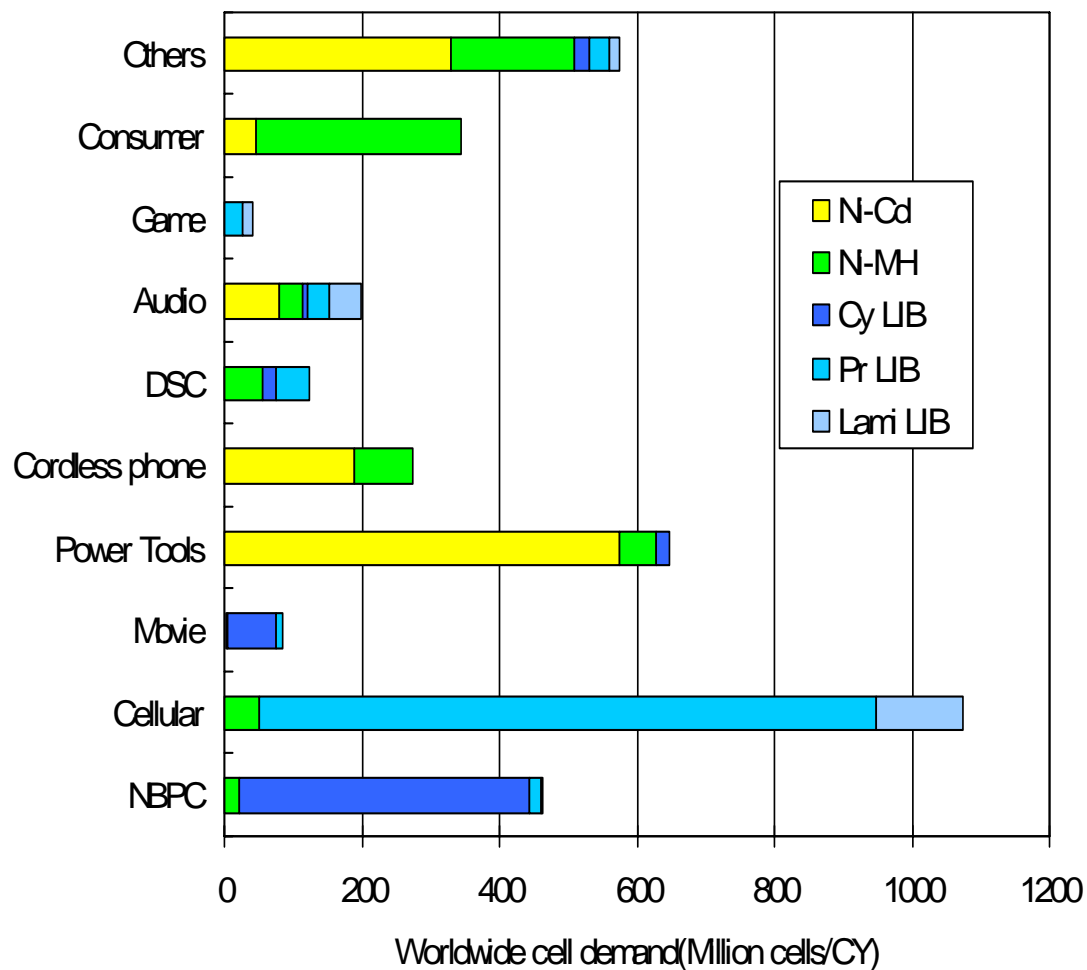
Source: Takeshita, 23rd International Battery Seminar

# Li-ion battery market size



Source data: Takeshita, 23rd International Battery Seminar

# Cell demand by application



Source: Takeshita, 23rd International Battery Seminar

# Overview of Technology/Market overlap

## ■ High Capacity

- Cell Phones
- Laptop computers
- DVD Players
- iPods
- Portable gaming
- ***PHEVs and EVs***

## ■ High Power

- Power Tools
- ***HEVs***

# Overview of Technology/Market overlap

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## ■ High Power

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- ***HEVs***

## ■ ANL Technology Innovation

- Aimed at transportation
- Can be used in consumer electronics, power tools

## ■ Strategy of Commercial Entities

- Develop revenue with existing markets (consumer electronics, power tools)
- Ultimate goal: transportation

# Argonne Technology Transfer Strategy

## ■ Background

- ANL IP portfolio is large, varied, and potentially highly impactful on American society and the U.S. economy.
- ANL team is world-class.
- U.S. Government has a vested interest in finding viable commercial entities to bring the technology to market.
- ***Decision is to license the technology as broadly as possible, non-exclusively in major markets.***

# Argonne Technology Transfer Strategy

## Commercialization Landscape

### ■ Battery Manufacturers

- Want access to the technology
- Fear investing in the substantial commercialization effort without a qualified materials supplier already in manufacturing stage

### ■ Materials Suppliers

- Want access to the technology
- Want to supply to the battery manufacturers
- Fear taking the capital risk when the license is purely non-exclusive

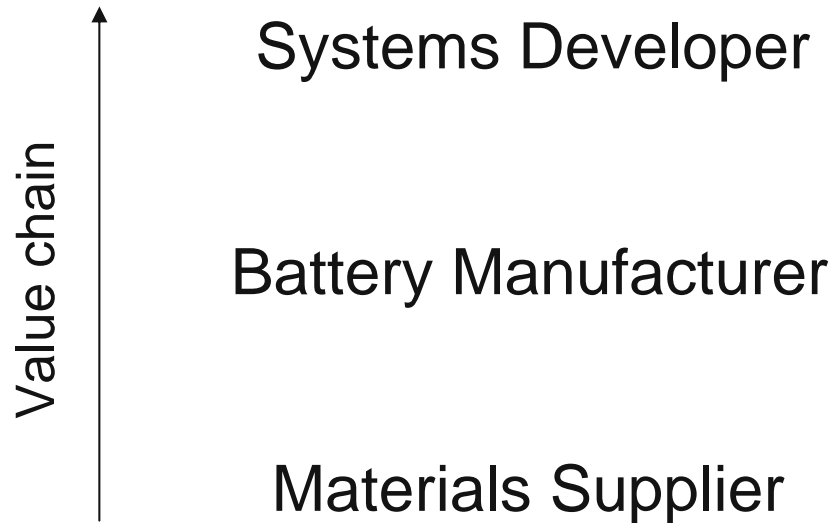
### ■ Battery Startups

- Want access to the technology
- Will develop batteries and make materials themselves if required
- High risk tolerance

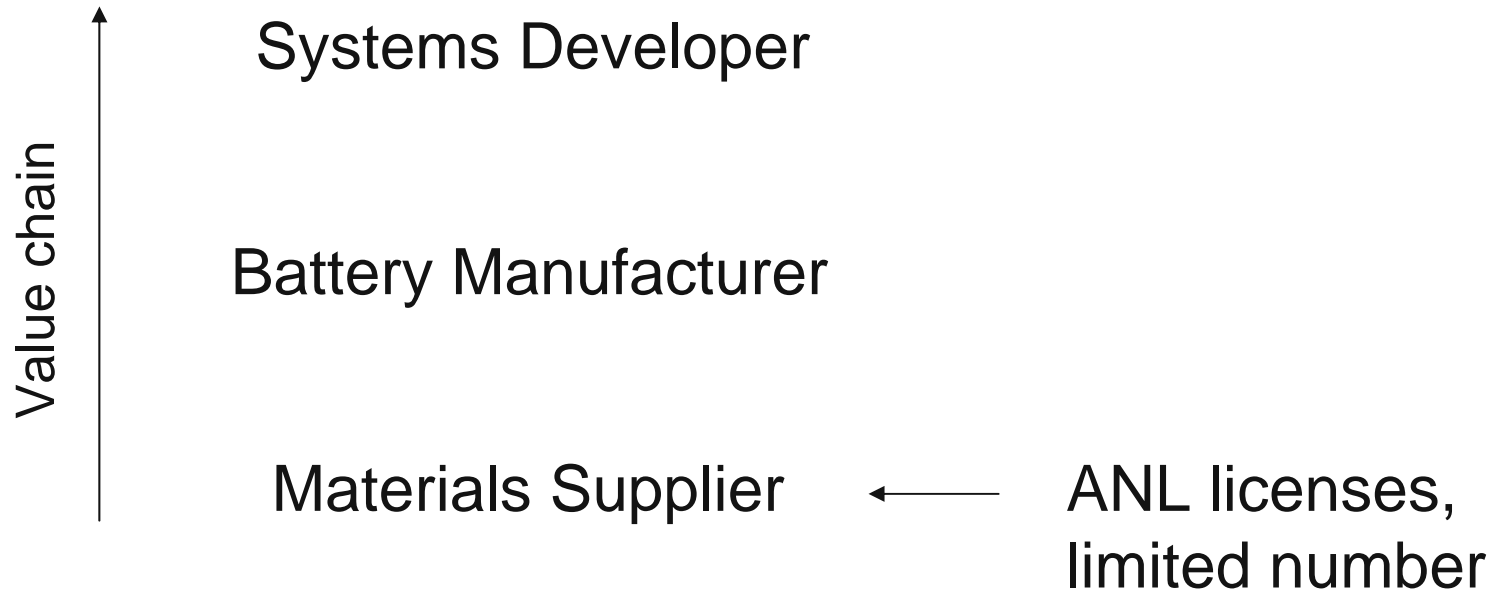
# *Argonne Licensing Strategy: Enable Device Manufacturers*

- ANL approach to technology transfer, given the commercialization landscape:
  - License a limited number of established materials suppliers.
  - Enable broad commercialization of technology by battery makers via the supplier license.
  - Maintain the right to license battery makers individually.

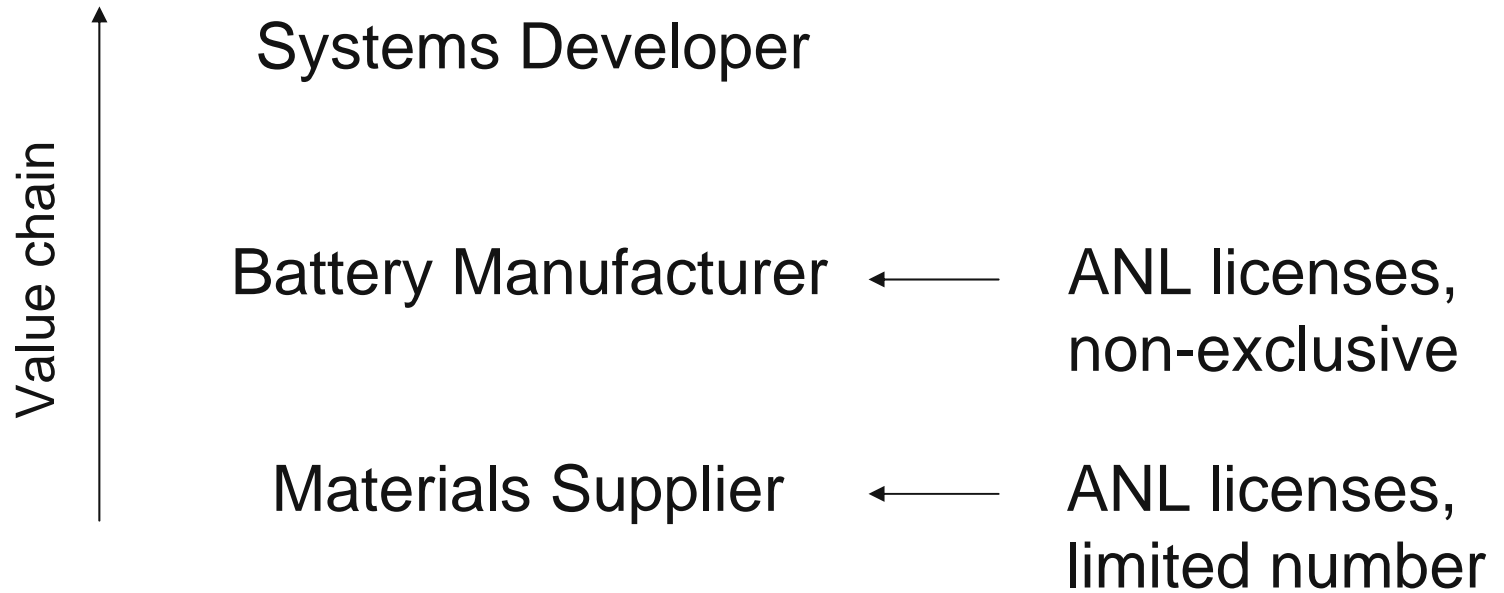
# Argonne Licensing Strategy



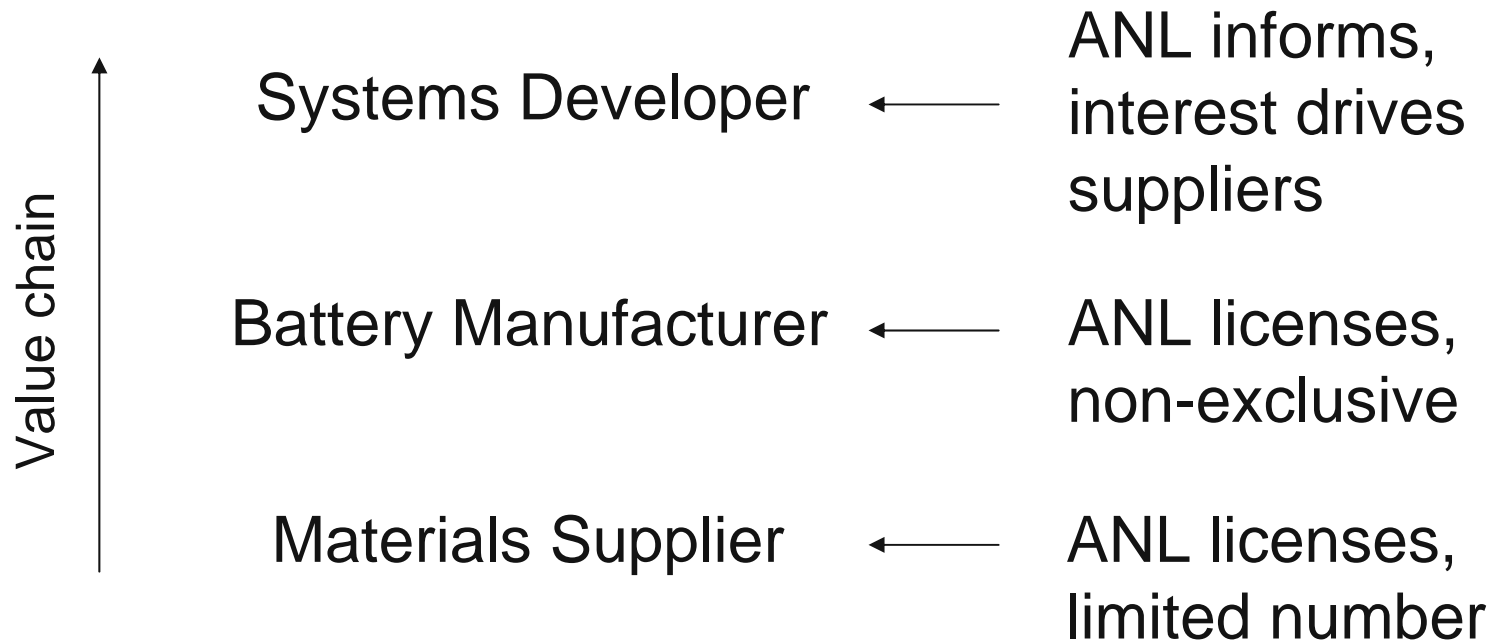
# Argonne Licensing Strategy



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# *Argonne Technology Transfer: Progress Report*

## ■ Materials suppliers

- Toda Kogyo (Japanese). **Licensed** cathode technology.
- 10 other entities, from the largest chemical companies in the world, to startups.

# Argonne Technology Transfer: Progress Report

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*Toda took 3 years to negotiate.*

# Argonne Technology Transfer: Progress Report

## ■ Materials suppliers

- Toda Kogyo (Japanese). **Licensed** cathode technology.
- 10 other entities, from the largest chemical companies in the world, to startups.

## ■ Device Manufacturers

- NanoeXa (U.S., startup). **Licensed** cathode and electrolyte additive technology.
- 12 other entities.

## ■ Systems Developers

- Motorola (U.S.). Want ANL cathode technology for cell phones.
- MicroSun (U.S.). Want ANL cathode technology for multiple applications.

# What are the future opportunities?

## ■ Excellent progress Transferring Lithium Ion Battery Technology

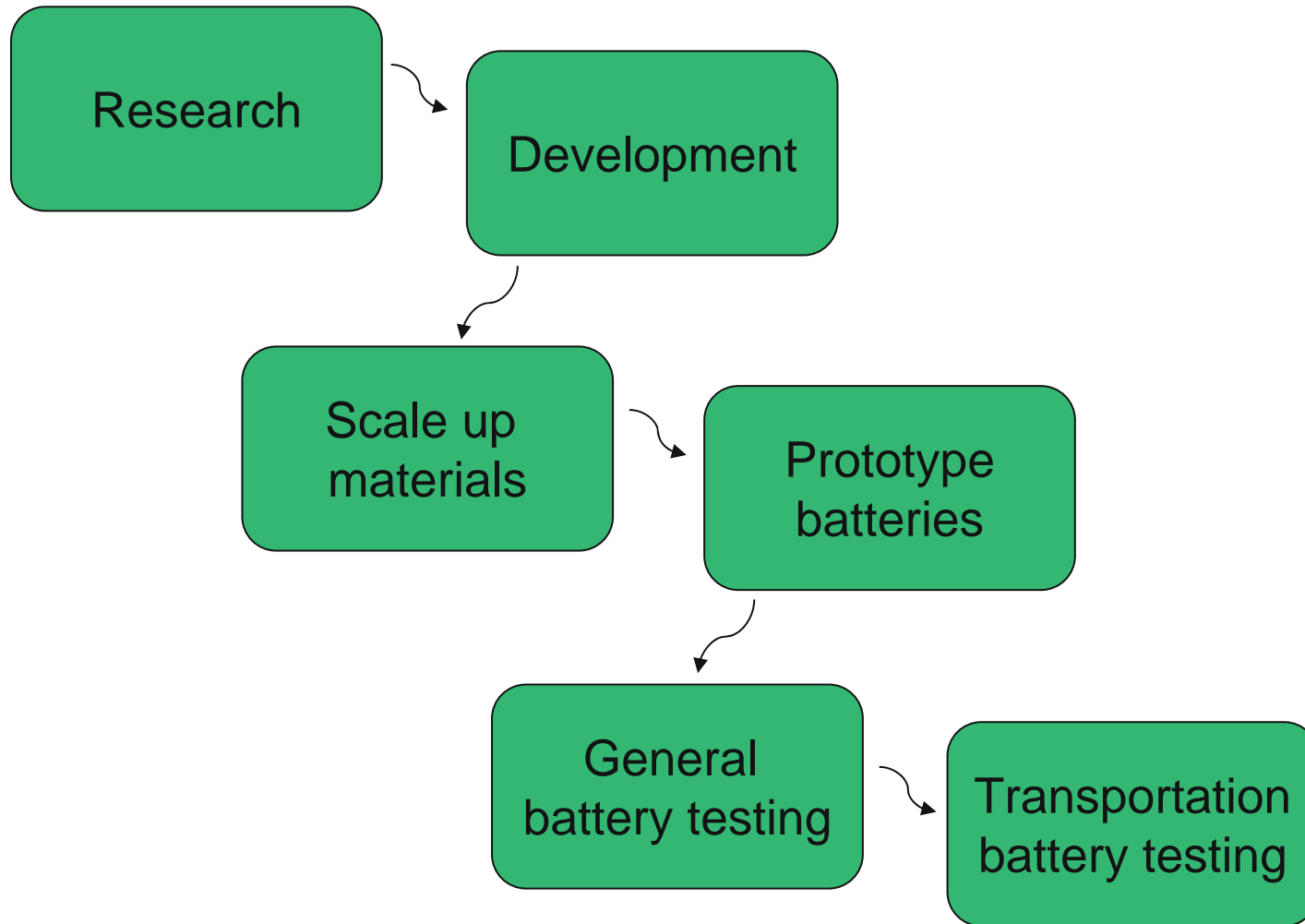
- Technology will be transferred into commercial realm via licenses both to well-known and startup companies
  - *In discussions with over 30 companies around the world*
  - *One major materials suppliers licensed, another in substantive negotiation*
  - *One battery startup licensed, three in substantive negotiation*
  - *One capacitor manufacturer in substantive negotiation*
- Sum total up-front fees for contracts currently being negotiated > \$4M

## ■ Technology Transfer process could be improved

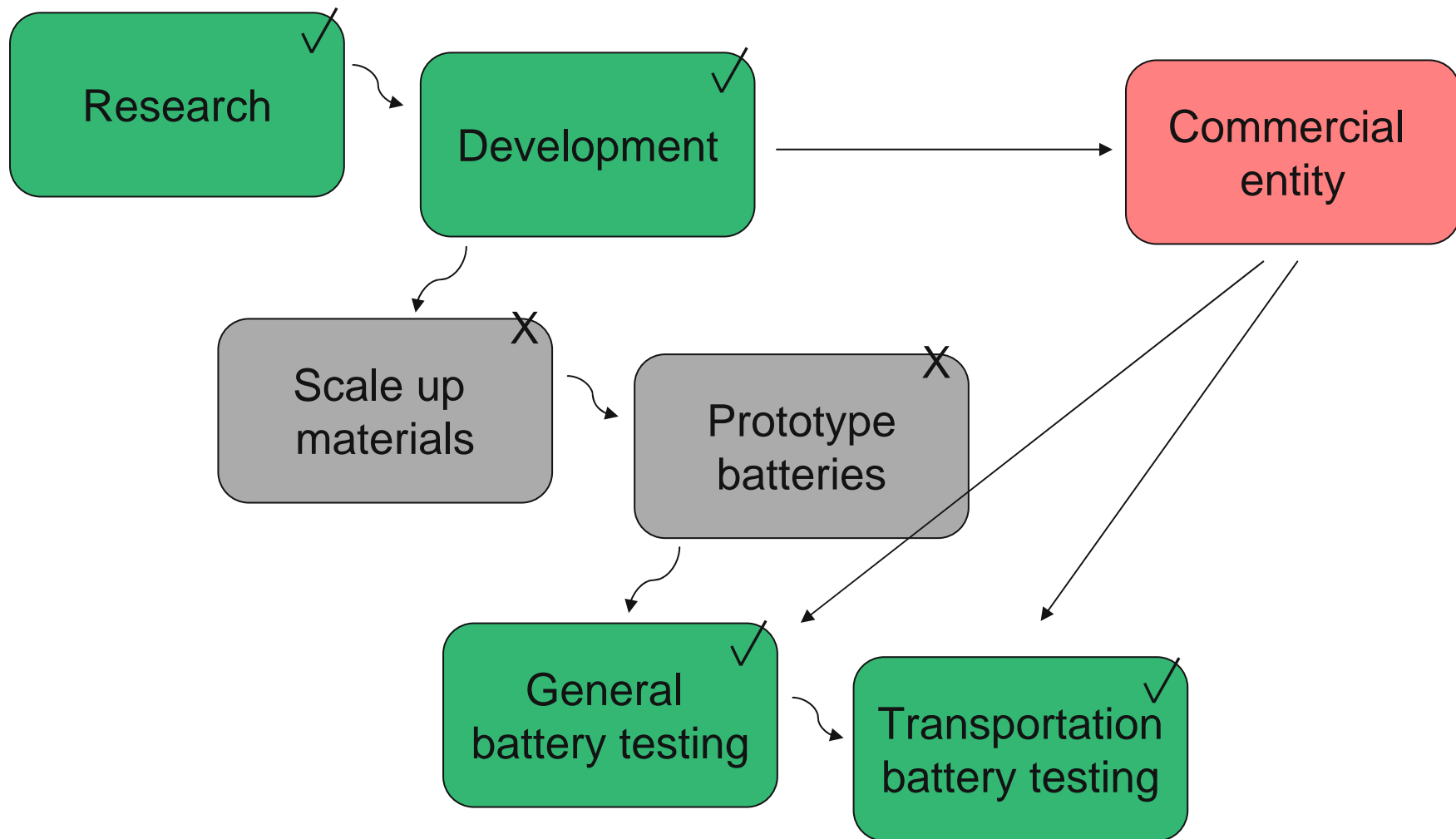
- There is a gap in knowledge and innovation around scale-up engineering
- As a result, infrastructure is being developed outside the U.S.

# *The two gaps can be filled with one change...*

## *Develop Process Expertise for Batteries*



# Flow chart for today's process in ANL



# *There is a unique opportunity for an even greater strategic step to be taken.*

- In the 1980s, it was recognized that Japanese industry was dominating the microchip industry, in both design and manufacturing.
- A consortium was formed, called Sematech, to solve manufacturing technology issues. It was funded both by the U.S. government and U.S. corporations, and run by U.S. corporations. Within 5 years, the U.S. put itself back into the lead position semiconductor technology. (Think Intel, AMD, Micron, IBM.)
- In the 2000s, we need to recognize that Asian industry (Japan, Korea, China) have taken the dominating position in supplying the world in lithium-ion portable power. (Think Sony, Samsung, etc.)
- An analogous consortium could be formed, funded both by the U.S. government and commercial interested to put the U.S. back in the lead in this important technology area.

# *Summary of ANL's approach to commercializing Li-ion battery technology*

- Lithium-ion portable energy is already an important market, with potentially exponential growth as applications in transportation mature
- ANL has an excellent group of scientists and engineers developing cutting edge technology
- That technology is being licensed successfully
- There is great opportunity for a strategic shift in the U.S. approach to portable power via lithium-ion technology