An anatomy of techno-scientific promise

The case of Li-ion batteries

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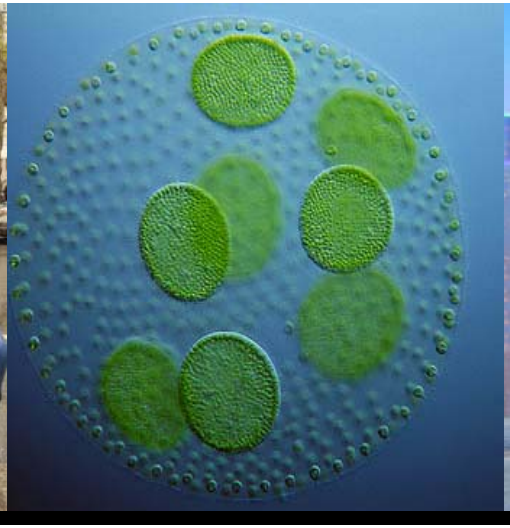
EV's and other cars of the future

- Competing visions & technologies
- Why do we 'believe' in some and not in others?
  - By definition: underperforming technologies
  - Belief in EV's relies on expected improvement of batteries
  - How are such expectations constructed?

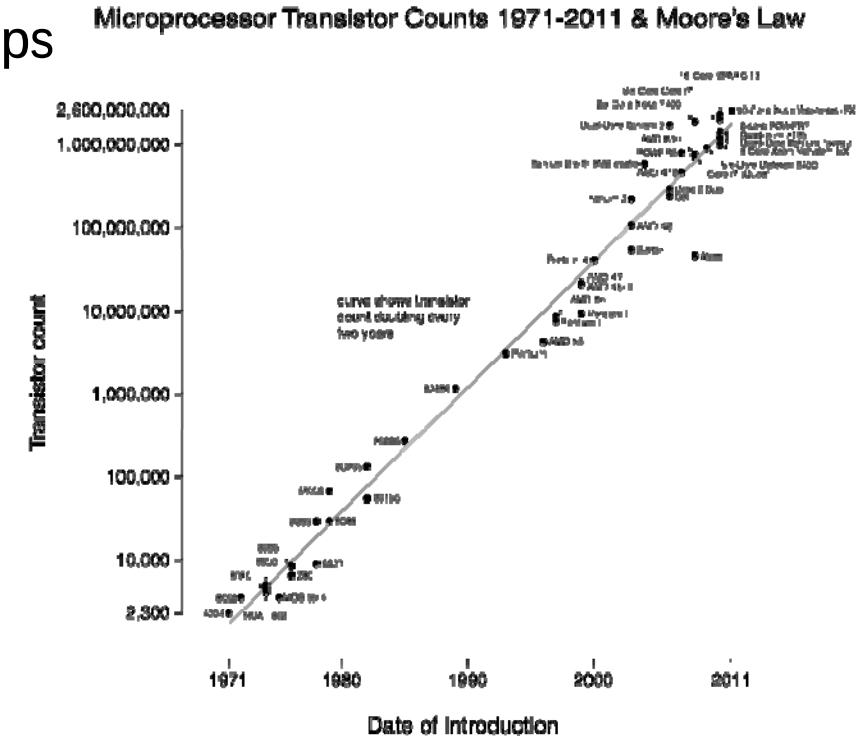

Innovation and expectations

- In general we expect technology to improve
  - ‘an endless frontier’
- Expectations of specific technological options:
  - Individually inspiring
  - Collective expectations coordinate efforts
  - Risk of “hype & disappointment”

- Expectations relate to:
  - Technology as such
  - Other stakeholders’ behavior
  - Contextual factors

Example: Moore's law

- "Density of computer chips will double every two years"
- Promise became requirement for industry



Expectations of Electric Vehicles

- Collective expectations positive
  - Mildly forcing stakeholders to move along
  - Some characteristics of hype?
- Collective ambiguity
  - Range, charging times, costs

- Much, if not all, depends on battery improvements?

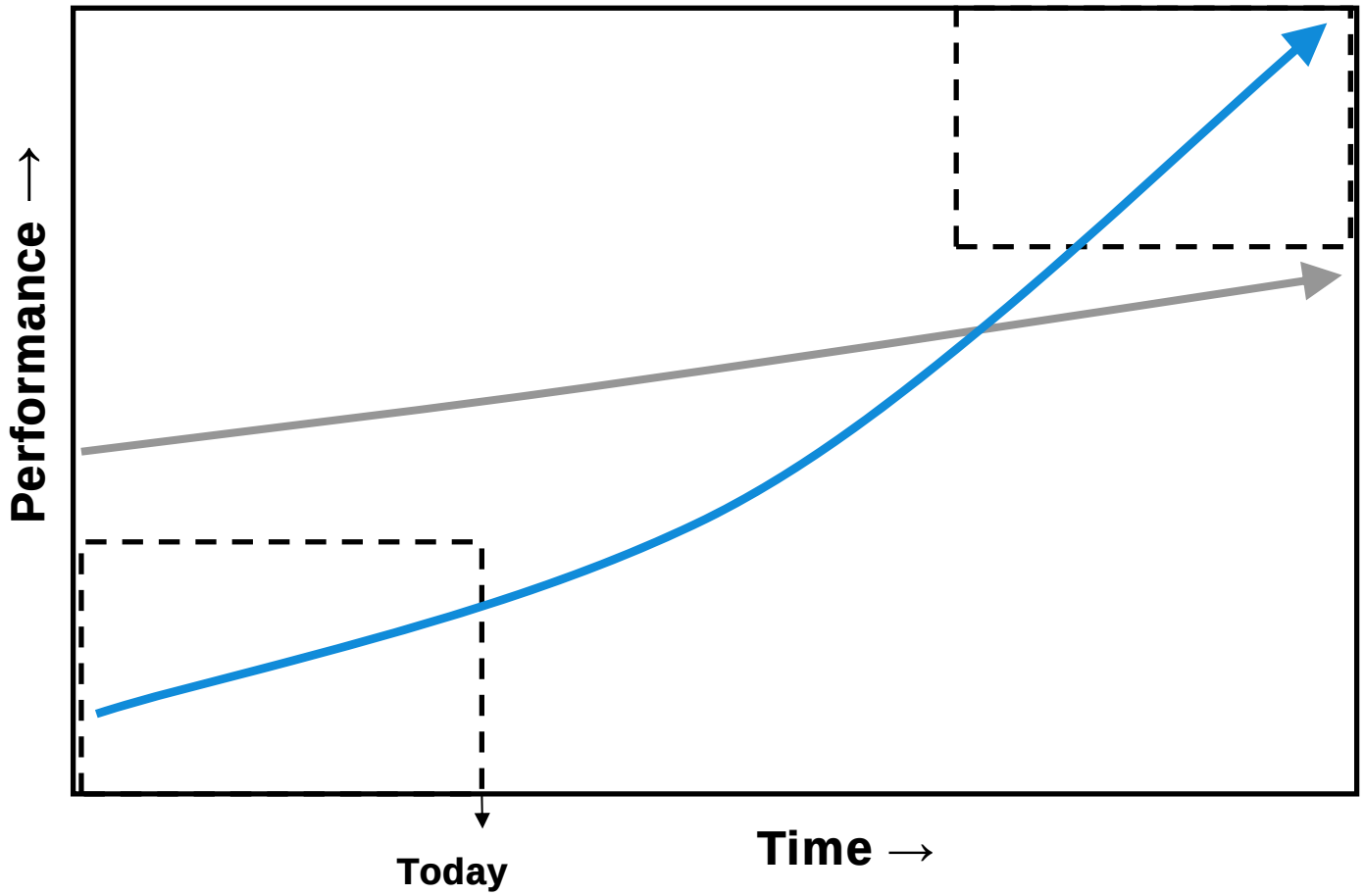
Consumer studies

- Meta study on consumer preferences:
  - Reduction of battery costs and the development of advanced battery technologies permitting longer range (Dimitropoulos 2011)
- Consumer survey in the Netherlands:
  - decisive factors are price, range and availability of fast charging facilities (Molin 2012)
- Pilot projects with mainstream consumers
  - “EV is not there yet”
  - Different from typical ‘early adopters’ (Graham-Rowe 2012)

Automotive industry statements

- Elon Musk (Tesla):
  - “a weak Moore’s Law” of 8% annual improvements in the price/performance of lithium-ion batteries
- Honda:
  - “vehicle electrification will accelerate only at the pace of battery innovation”
- Daimler:
  - “improvements on cost, safety and lifetime aspects have to be the main focus for the next generations of EV batteries”
- Volvo (last week):
  - Considering the lack of coordinated governmental incentives and the high battery system costs, the market share for electrified vehicles will struggle to pass the 1% mark by 2020

Constructions of expectations



Improving battery “performance”

- Many criteria to assess batteries:
  - Costs: cell/pack/system
  - Capacity: power & energy
  - Charging times
  - No. of charge and discharge cycles
  - Safety
  - Resource availability and recycling
- Priorities vary per application
- Trade-offs between characteristics

Extrapolating recent progress

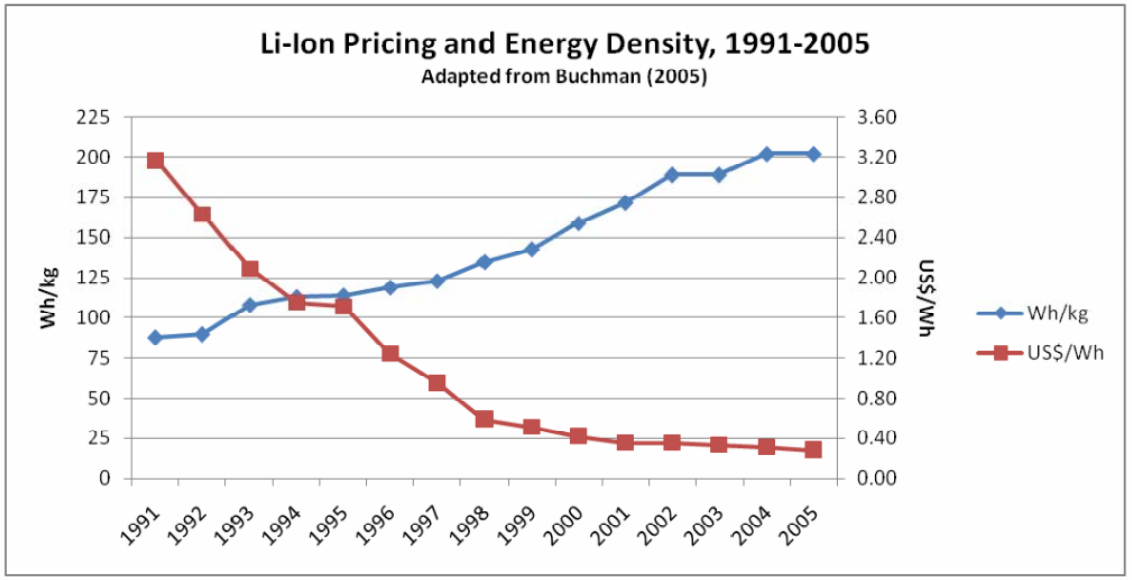
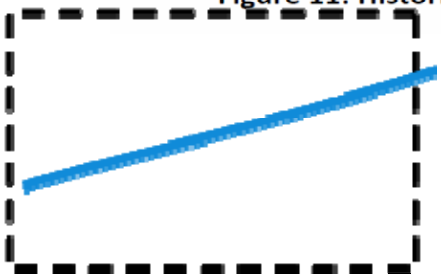


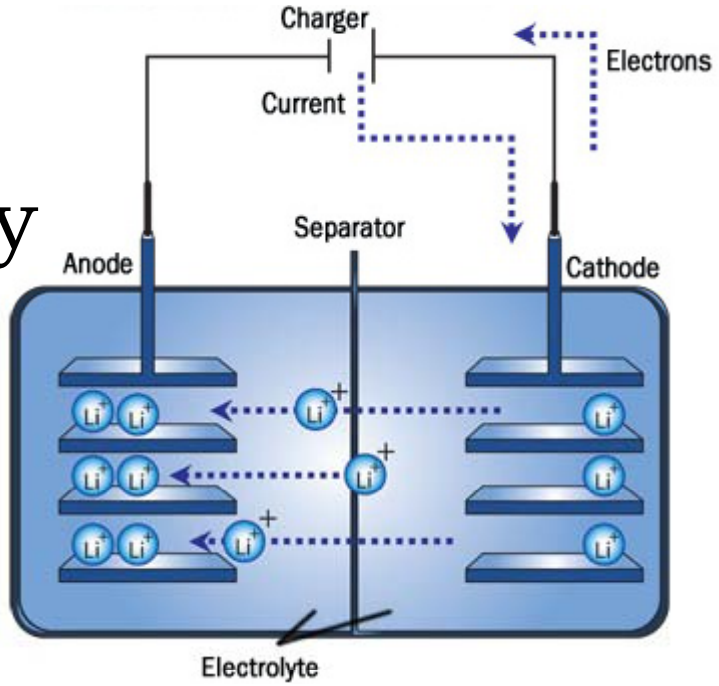
Figure 11: Historical Prices and Specific Energy Trends for Li-Ion Batteries



The paths forward: manufacturing

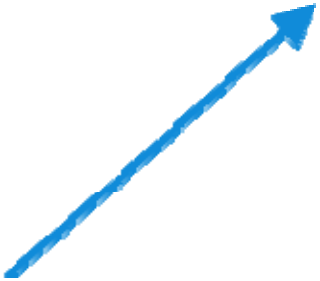
- Scale efficiency
  - Factory level
  - Supply chain optimization
- Increasing mining/production of raw materials
- More efficient packaging of cells
- Standardization
  - Standardized battery packs?
  - Quality and safety standards to enable competition
- *A123: Scale is not enough to bring down costs sufficiently*
- *BCG: 65% cost reduction towards 2020*
- *Roland Berger: 230→320 Wh/kg*

Path forward: chemistry



- Anode
  - Silicon, Tin
- Cathode
  - $LiFePo_4$ (safe, but low vol. density)
  - Manganese instead of Cobalt (expensive, from the Congo)
  - Sulfur
- Electrolyte
  - Solid state
- Generic sources of hope:
  - Engineering towards theoretical potential
  - Nanotech will safe the day
  - NASA

Path forward: beyond li-ion



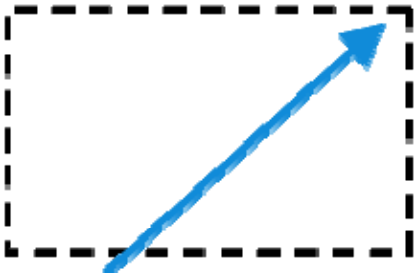
Current options

- Li-air!
  - Cycle issues
  - Potentially 5-10x energy density
- Zn-air
- “Re-inventing Lead Acid”

However

- “Not in 5yrs”
- “not commercial before 2025” (Volkswagen)

Defining an end-goal



Rare statements about end-goal

- “Sakichi” ultimate battery for Toyota > gasoline
- Nissan-NEC JV: “300 km range needed for mass market”
- “Car manufacturers ask for 5000 cycles”
- “1-2% market share for EV in automotive market is enough incentive for battery industry to invest”

Conclusions

- Rely on existing technologies coming 5-10 yrs at least
  - Incremental improvements in manufacturing and chemistry
- New battery types in lab/prototype
  - Step change improvements (price x performance) not promised
- EV in “valley of death” between R&D and true commercialization
  - Challenge: maintain momentum without actual big improvements
  - Promises of new batteries do help
- For now: focus on markets that make sense

- BMW:
  - “there are other promising technologies coming up and we do not know what the future will bring”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