Economics/Emerging Business Opportunities in Energy Storage

McKinsey & Company

Dickon Pinner

October 23, 2008

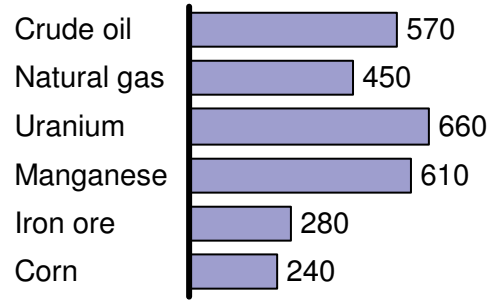
Overview

1. Why is it different this time?
2. Have we seen this before?
3. What barriers remain?
4. The Product Manager's dilemma
5. Who wins?

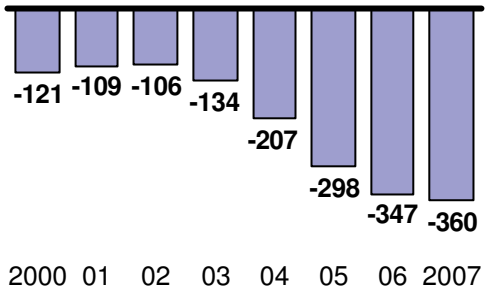
1. Why is it different this time?

Four major discontinuities are driving interest in storage

Cumulative price increase since 2002
Percent



US Trade balance due to petroleum imports
Billions, USD



Storage enables applications by decoupling generation from consumption

1. Government attention

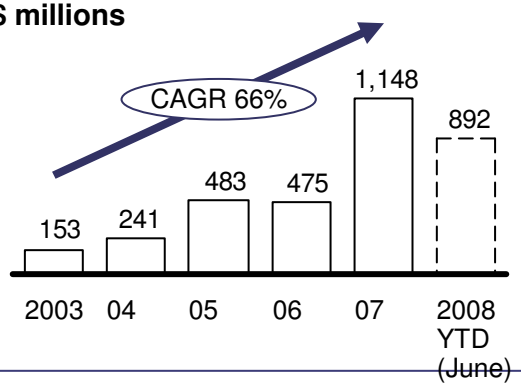
2. New technologies and innovation

3. End user enablement

4. Commodity price increases

- Utility asset utilization
- Distributed power generation
- Reduced losses from power interruptions
- Renewables intermittency
- Mobility
- Superior driving performance

VC investment in batteries
$ millions



Source: McKinsey Analysis; IIT, EAI, Platts, Capital IQ

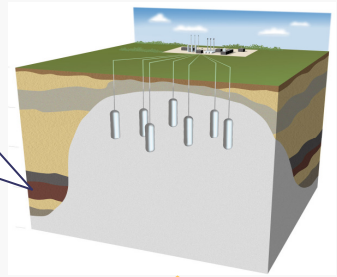
2. Have we seen this before?

Natural gas storage: Price and value transparency of gas storage provided users with greater optionality

Storage played a critical role in the development of the unregulated natural gas market…

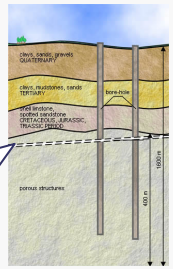
Transit storage

Storage connected to distribution pipe permits balancing



- Storage has allowed 50% of transmission system upgrade costs to be avoided
- Average utilization of natural gas assets is 90% vs. ~60% for electricity assets
  - Part of the efficiency came by penalizing fluctuating demand and making the cost/benefit of salt dome storage transparent

Natural gas distribution pipeline

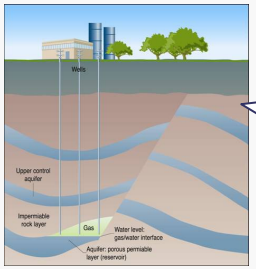


Storage at/near wellhead

Storage uncouples supply from demand allowing for lower-cost production from fewer, more profitable wells

Storage with different properties selected by cost/ end use application

- Aquifers and depleted reservoirs
- Salt domes

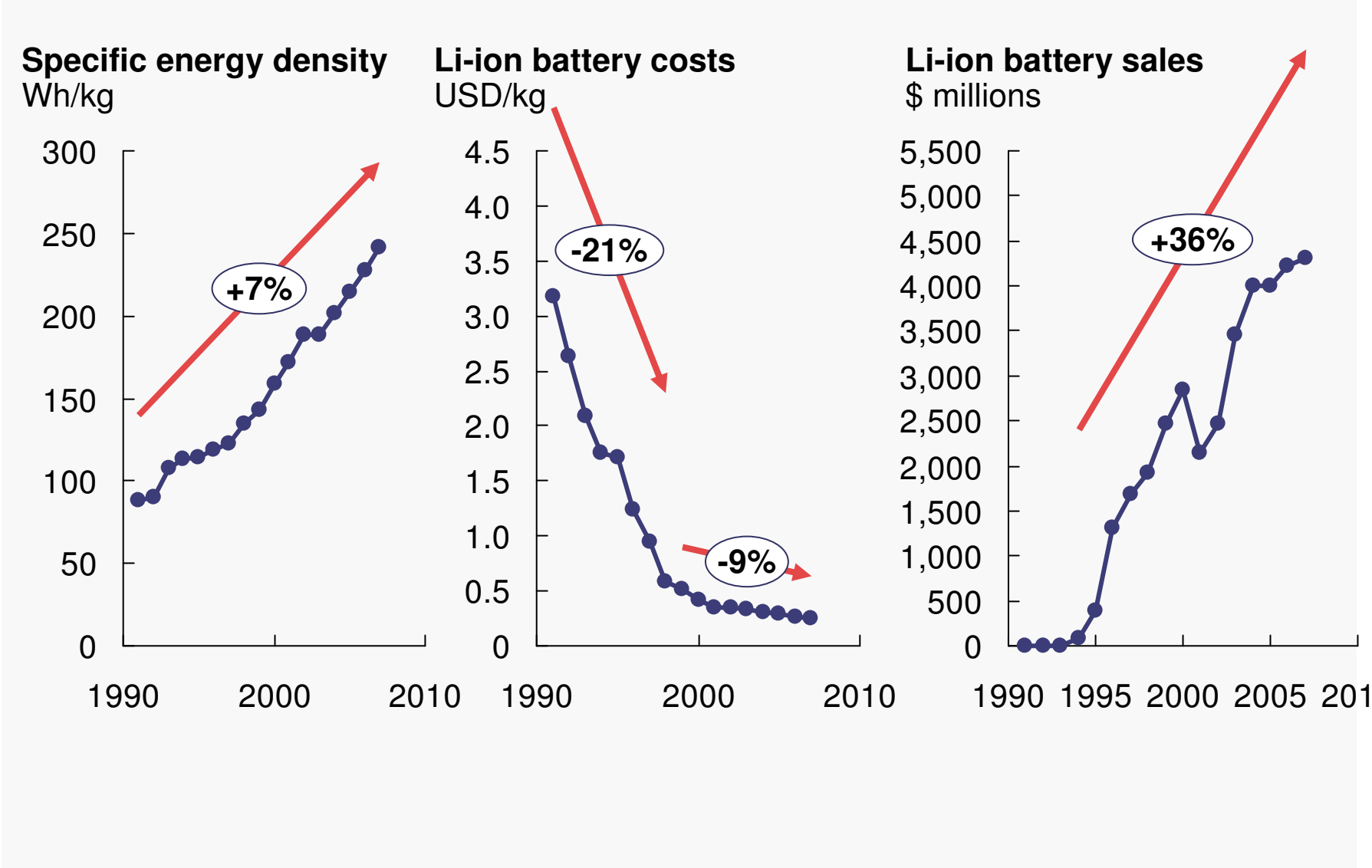


Storage at/near end user

Storage permits arbitrage/trading

Source: McKinsey Analysis; DOE, FERC Order 636, 1992, "Energy Storage" – Richard Baxter

Battery performance, cost and sales have come a long way



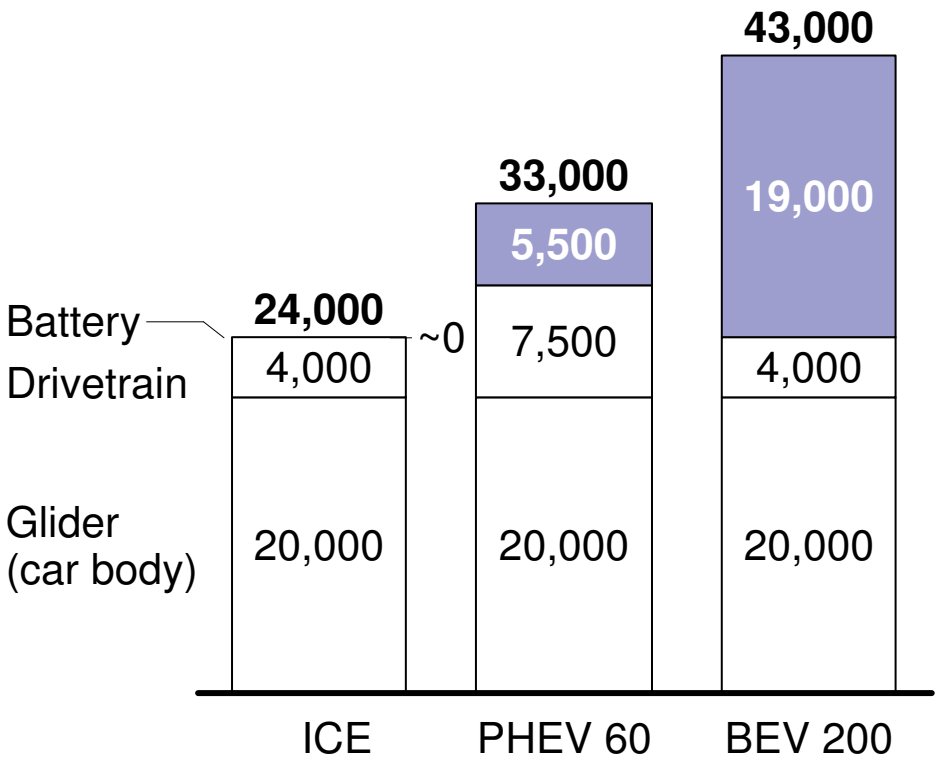
Source: IIT

3. What barriers remain?

High upfront cost for EV batteries will be a barrier to adoption which, in turn, creates business opportunities

Cost breakdown for VW Golf equivalent in 2013

U.S. Dollars



Possible solutions*

1. **Decouple battery** from car purchase
2. **Sell mobility, not just a vehicle**; bundle car lease, battery lease, and electricity consumption into one usage charge

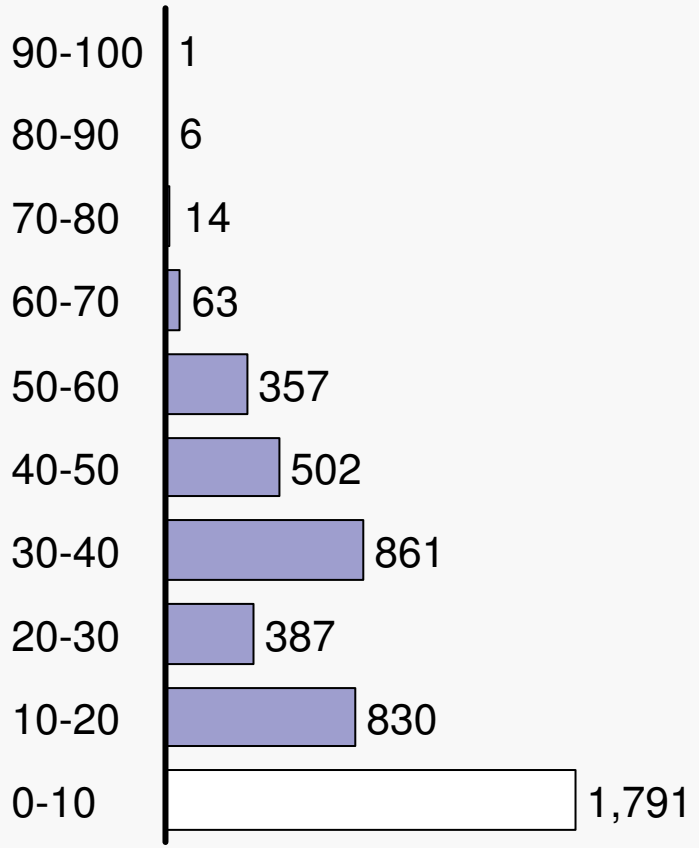
* In addition, ICE sales taxes (e.g., Israel, Denmark) or EV subsidies (e.g., California) reduce upfront price differential for consumer

Source: Rocky Mountain Institute, McKinsey analysis

Innovation cycles can be very long

Asset more than 10 years old

Number of US gas-fired power plants
By age, 2007



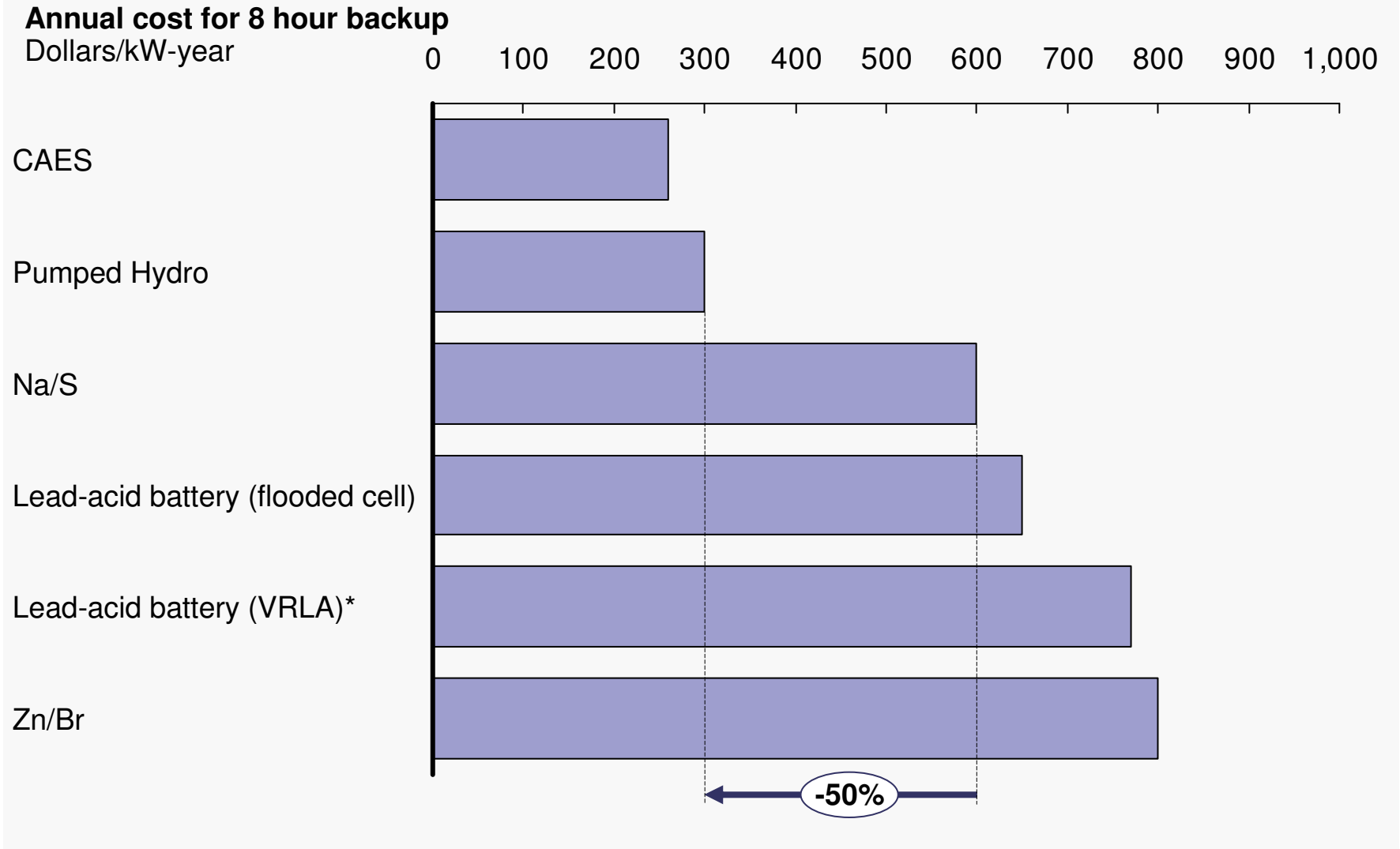
Summer generation
(MW)

0.5	
41	
104	
490	
10,785	
33,813	
58,916	
12,567	
45,657	
238,116	

- Many of the assets that storage might compete with can be operated for many decades
- 40% of plants (by generation capacity) are 10 years or older, implying that the **60% of generation capacity built within the last decade will last for many years**

Source: Energy Velocity

Depending on the segment, storage costs still need to come down significantly

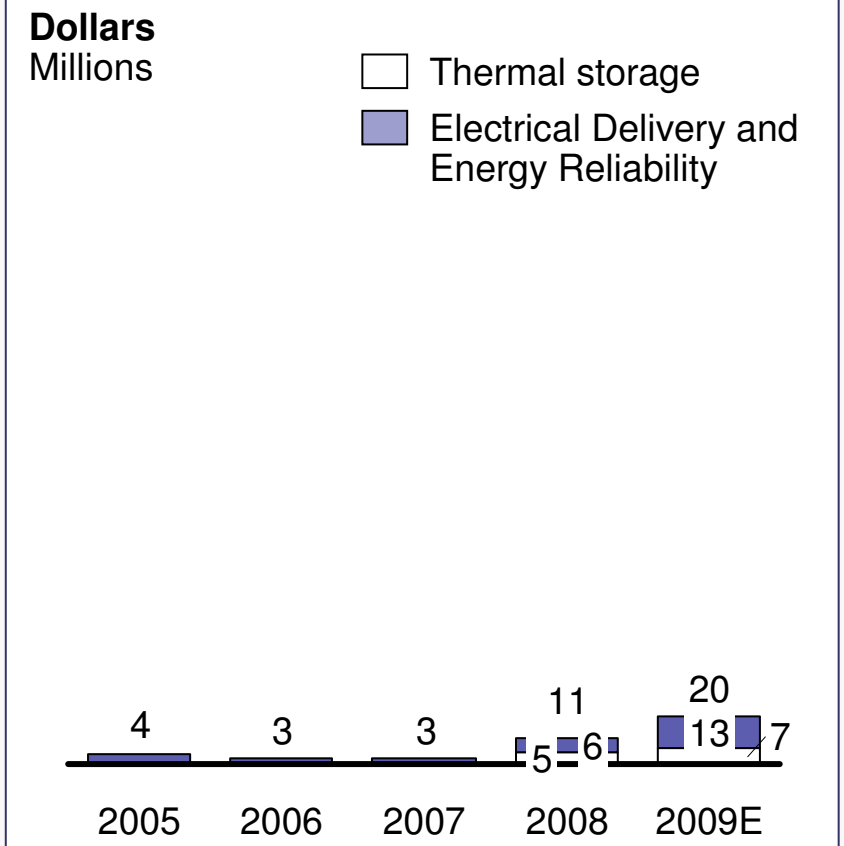


* Valve regulated lead acid batteries (sealed)

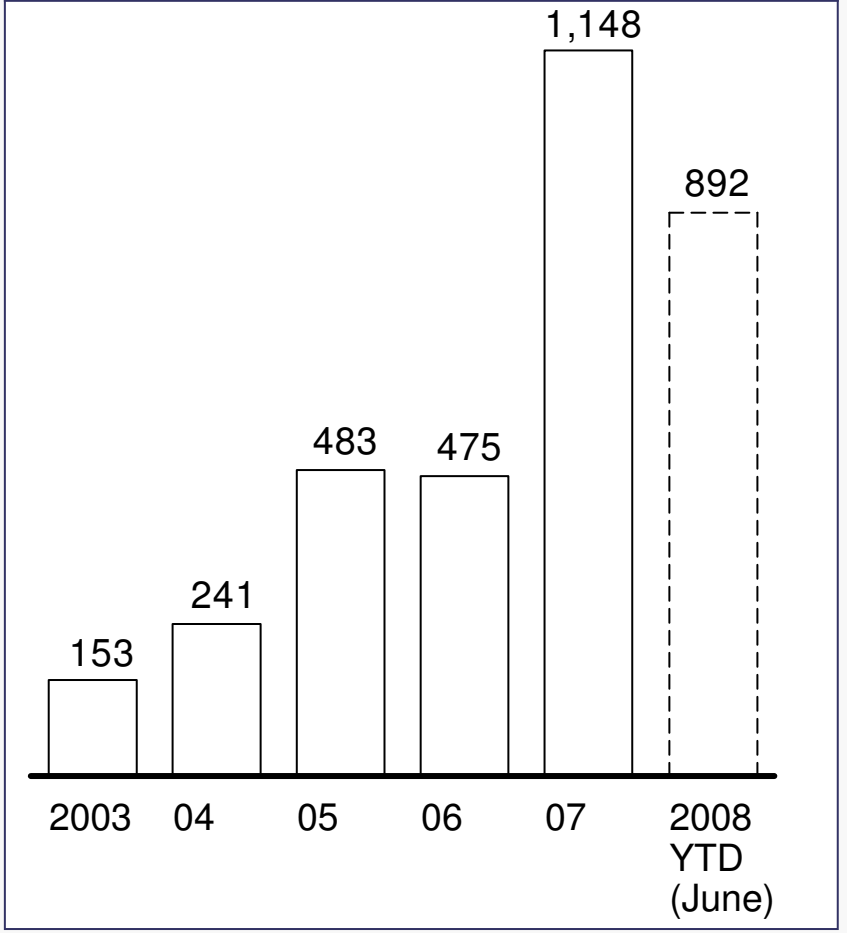
Source: Sandia National Laboratory

US government funding is low, but private sector is very active

Electrical Delivery and Energy Reliability



VC investment in battery technologies



Government funding was ~1% invested thus far in 2008 by VC investors

Source: US Department of Energy; Energy Independence and Security Act 2007

3. What barriers remain?

We are also not completely done with the safety issue yet

Fire damaged PHEV Prius…

Fire damaged Li-ion cells…

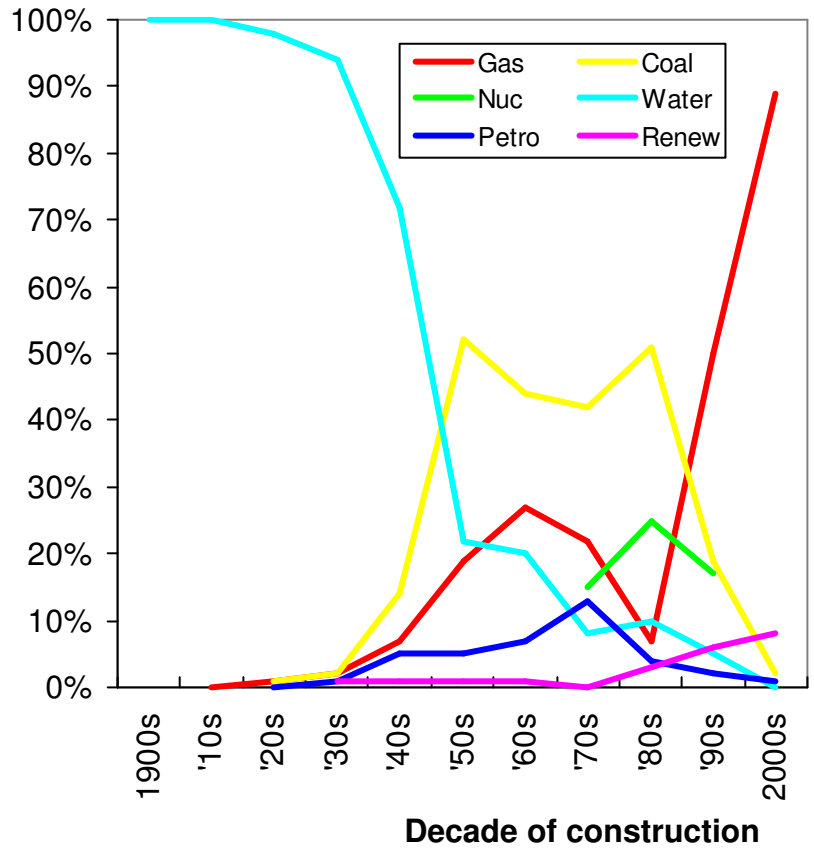
"… the driver opened the windows and began to pull over. When the windows were opened, a significant amount of smoke was pulled forward to the driver's area. The driver ***exited the vehicle and noted a fire at the right side in the rear (cargo) compartment of the vehicle which eventually consumed the vehicle****…"*

Source: Press clippings

Adoption cycles can be long… depending on the segment

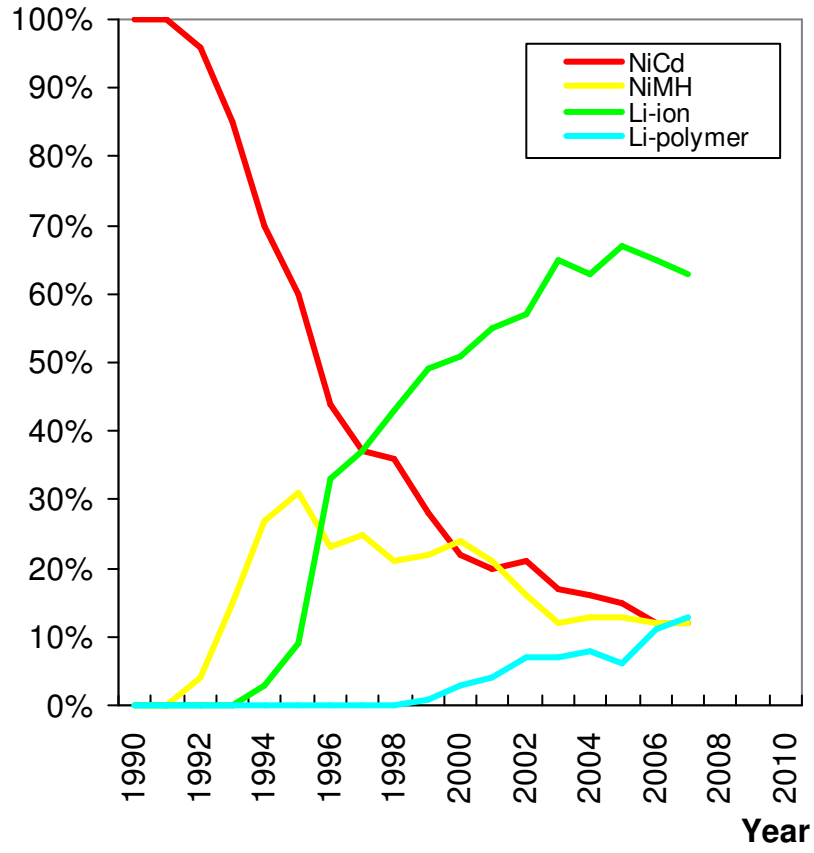
Utility sector

New generation capacity by technology
Percent summer generation capacity



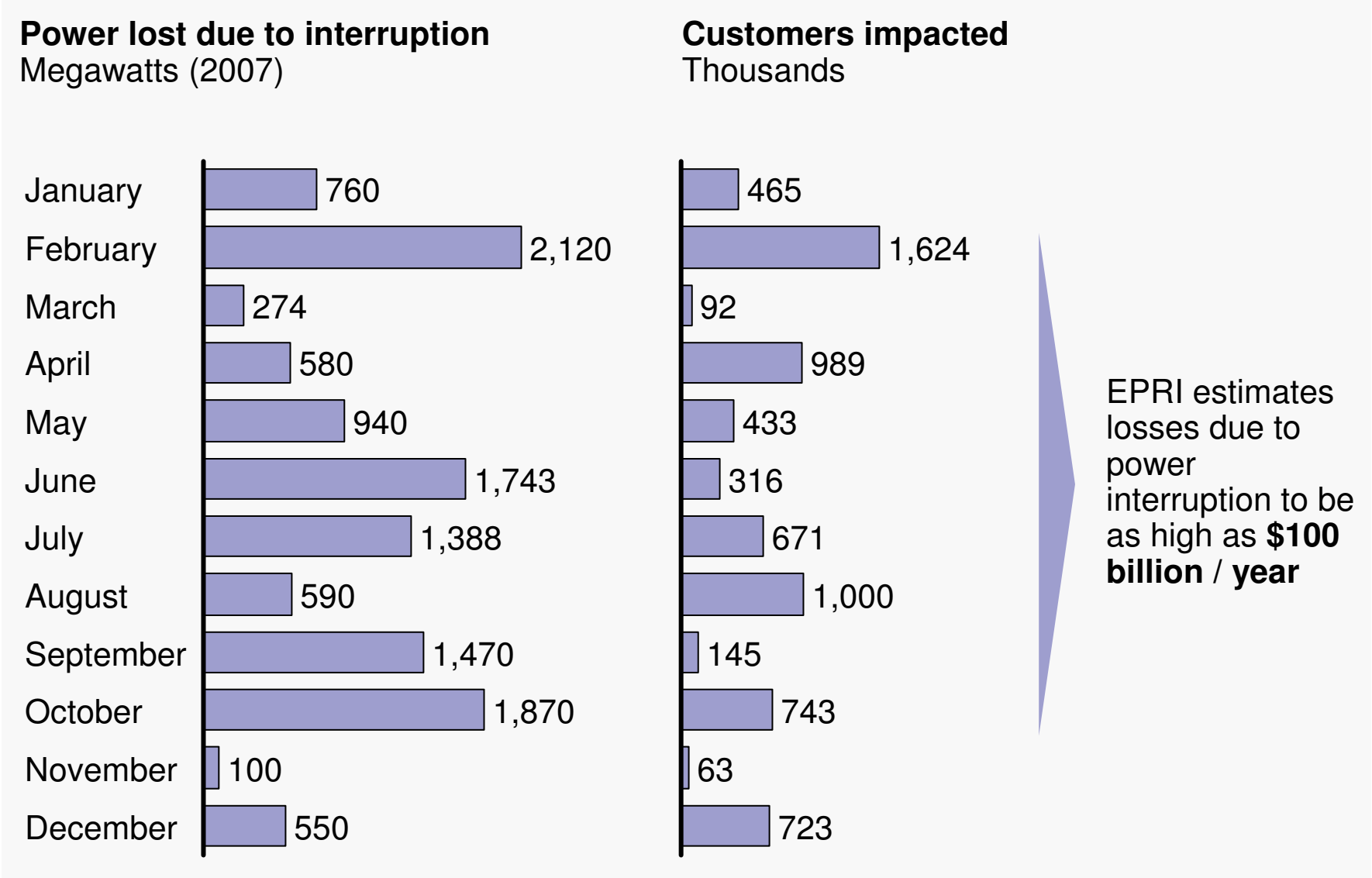
Consumer electronic sector

Battery sales by technology
Percent



Source: McKinsey analysis; Energy Velocity; IIT

Value from storage – reduced losses from power interruptions



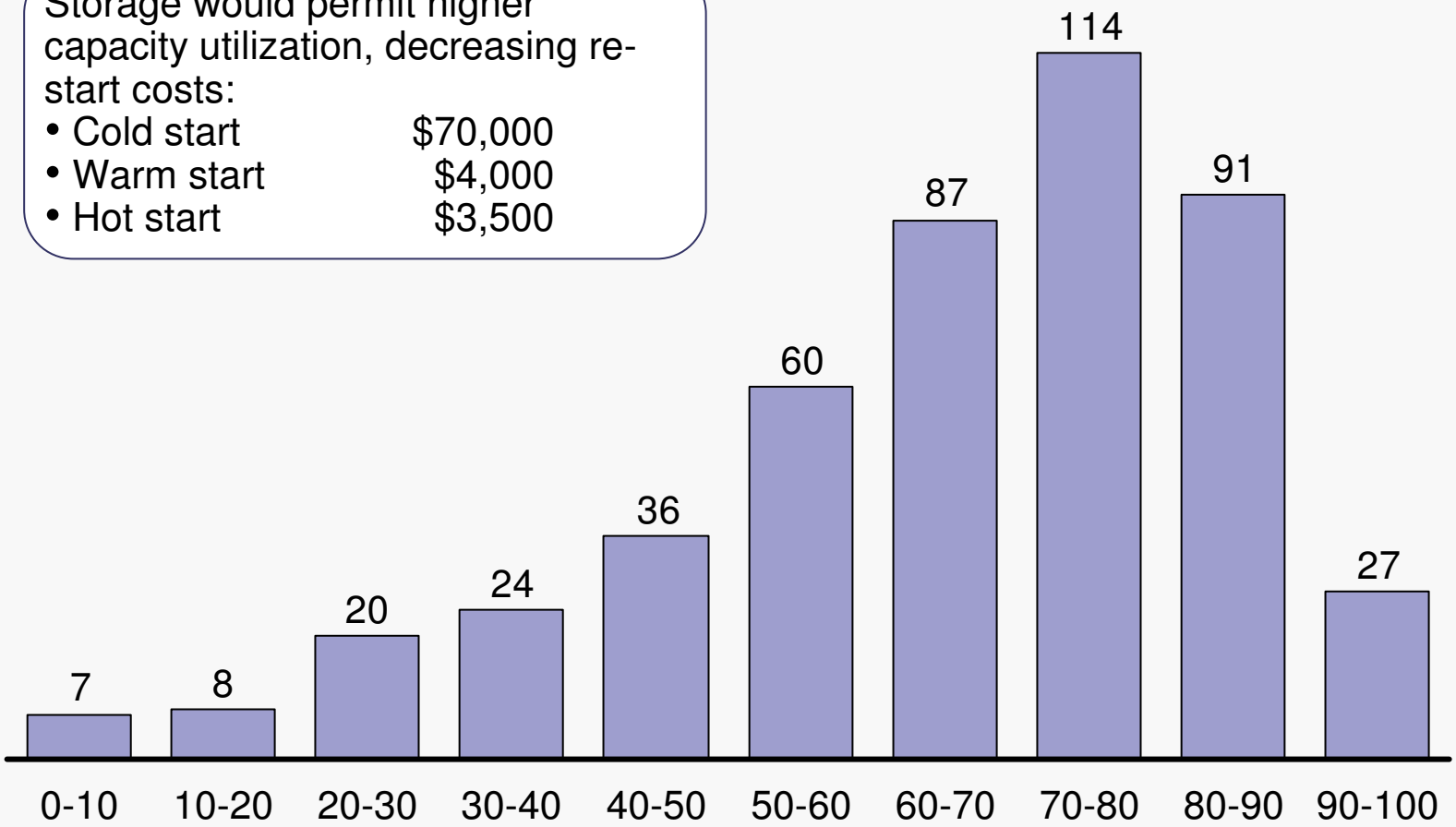
Source: EIA

Value from storage – better power generation asset utilization

Capacity utilization of US coal plants
Percent utilization, number

Storage would permit higher capacity utilization, decreasing re-start costs:

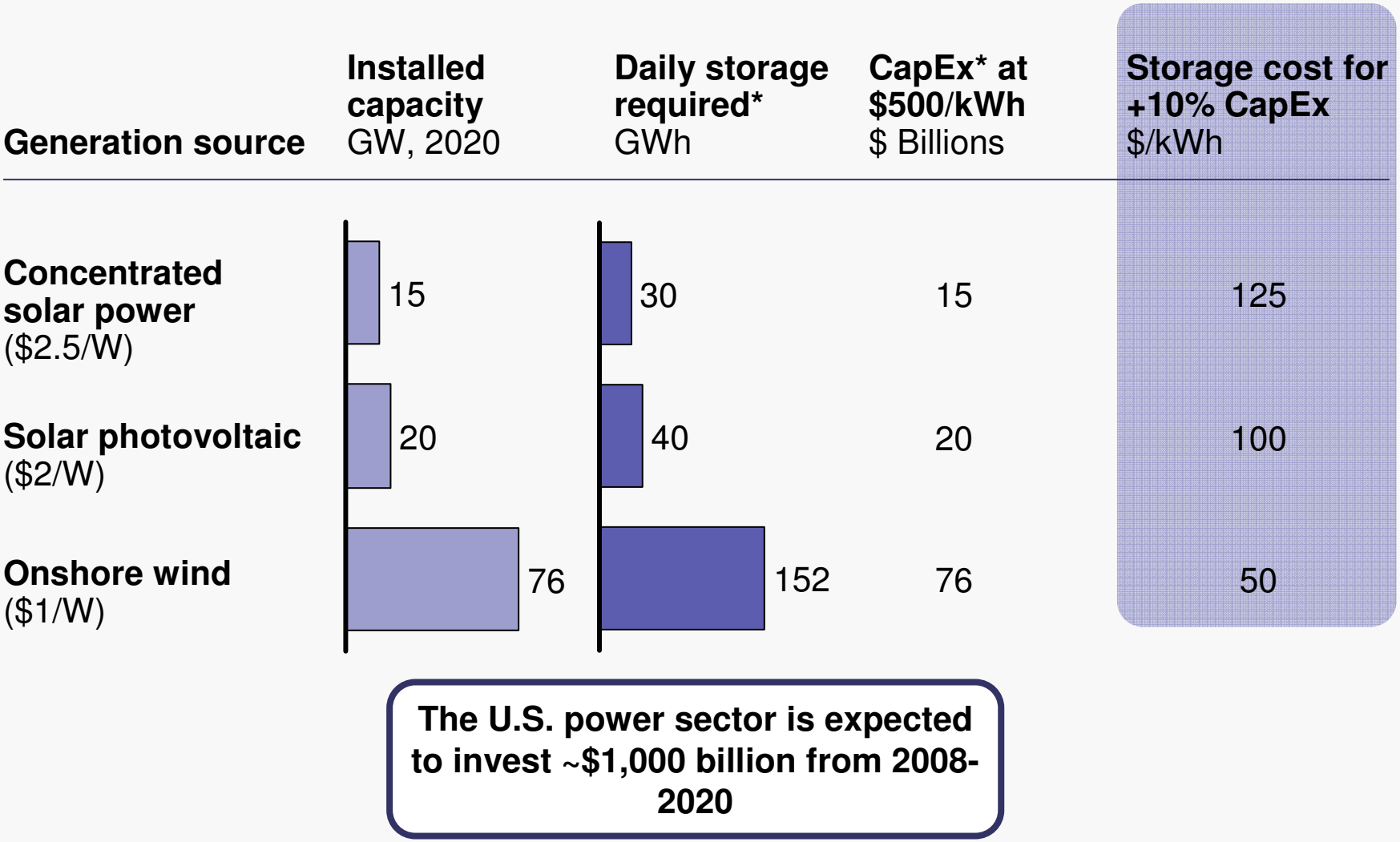
• Cold start	$70,000
• Warm start	$4,000
• Hot start	$3,500



Source: EIA; Platts

Most market size estimates assume relatively little near-term penetration, suggesting there is significant upside

U.S. UTILITY MARKET 2020



* Assuming $500/kWh; 2 hours/day renewable storage; does not include cost of energy storage replacement (if needed)

Source: McKinsey analysis

Successful adoption of individual technologies depends on alignment across three dimensions and overcoming agency issues

1. Functionality… broadly defined, e.g.,

- Power density (specific, volumetric)
- Energy density (specific, volumetric)
- Discharge rate
- Shelf life
- # of cycles
- Form factor
- Noise
- Safety
- Thermal range
- etc…

2. Cost… also broadly defined across title lifecycle

- Capex
- Opex
- End of life

3. Product lifecycle & switching costs

Each end user segment has very different requirements across these dimensions

NOT EXHAUSTIVE

Functionality – need to match choice of technology to segment functionality requirements

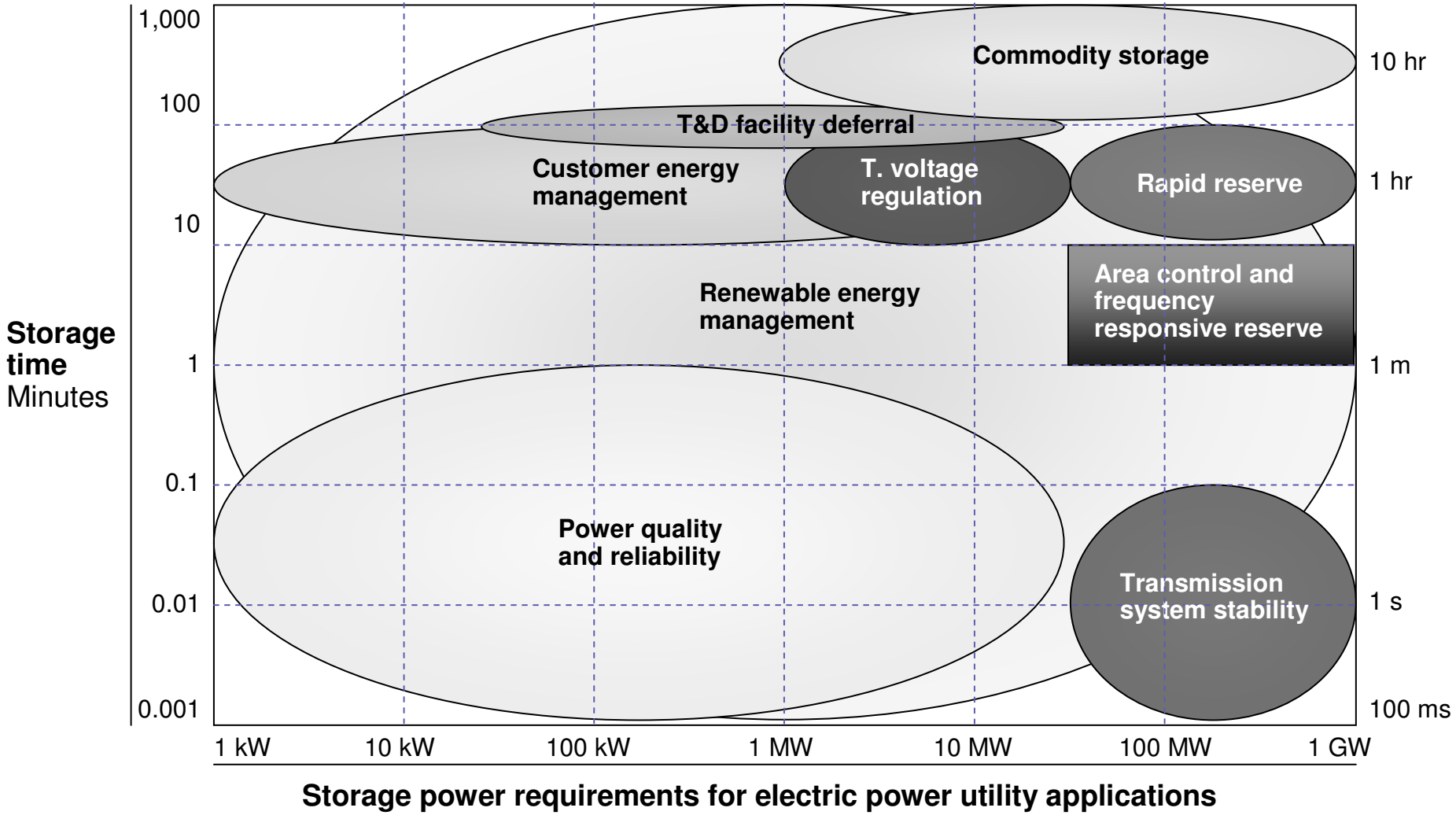
✓ Central importance

Metric of functionality	Example end user segment: Utilities (Frequency response)	Stationary power (UPS)	Portable Power (Forklift)	Micro Power (Med. device)	Consumer electronics (Smartphone)	Transportation (EV)
Power ρ*			✓			
Energy ρ		✓				
Spec. power*			✓			
Spec. energy					✓	✓
Discharge rate	✓					
Shelf life		✓		✓		
# of cycles	✓		✓			✓
Form factor				✓	✓	
Capital costs						✓
O&M costs	✓	✓				
Noise		✓				
Safety				✓		✓
Thermal range						

* Density is per unit volume; specificity is per unit mass

Source: McKinsey

…and combine to create the map of technologies functionally suited to various applications



Source: McKinsey; Sandia National Laboratory; ESA

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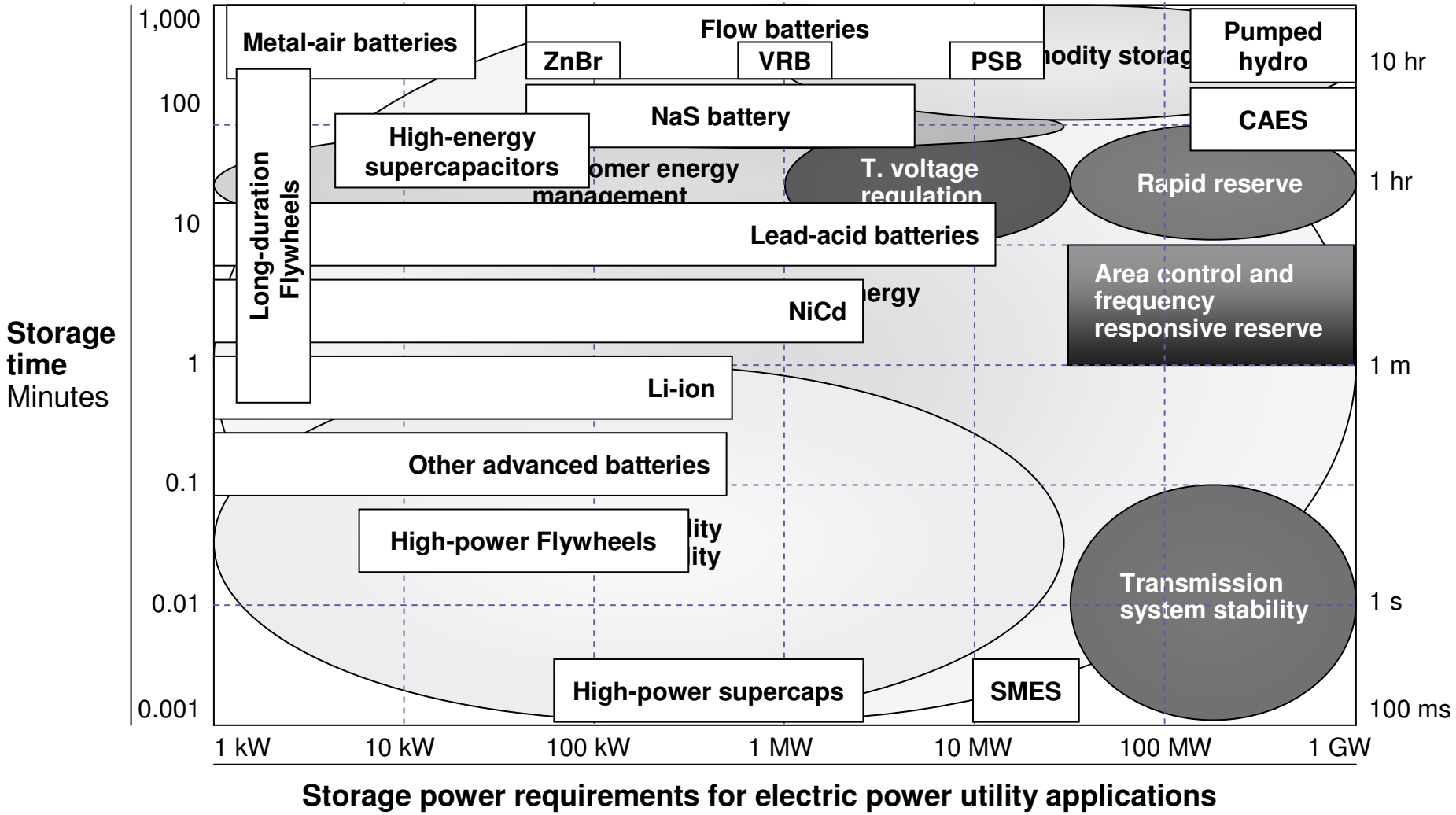
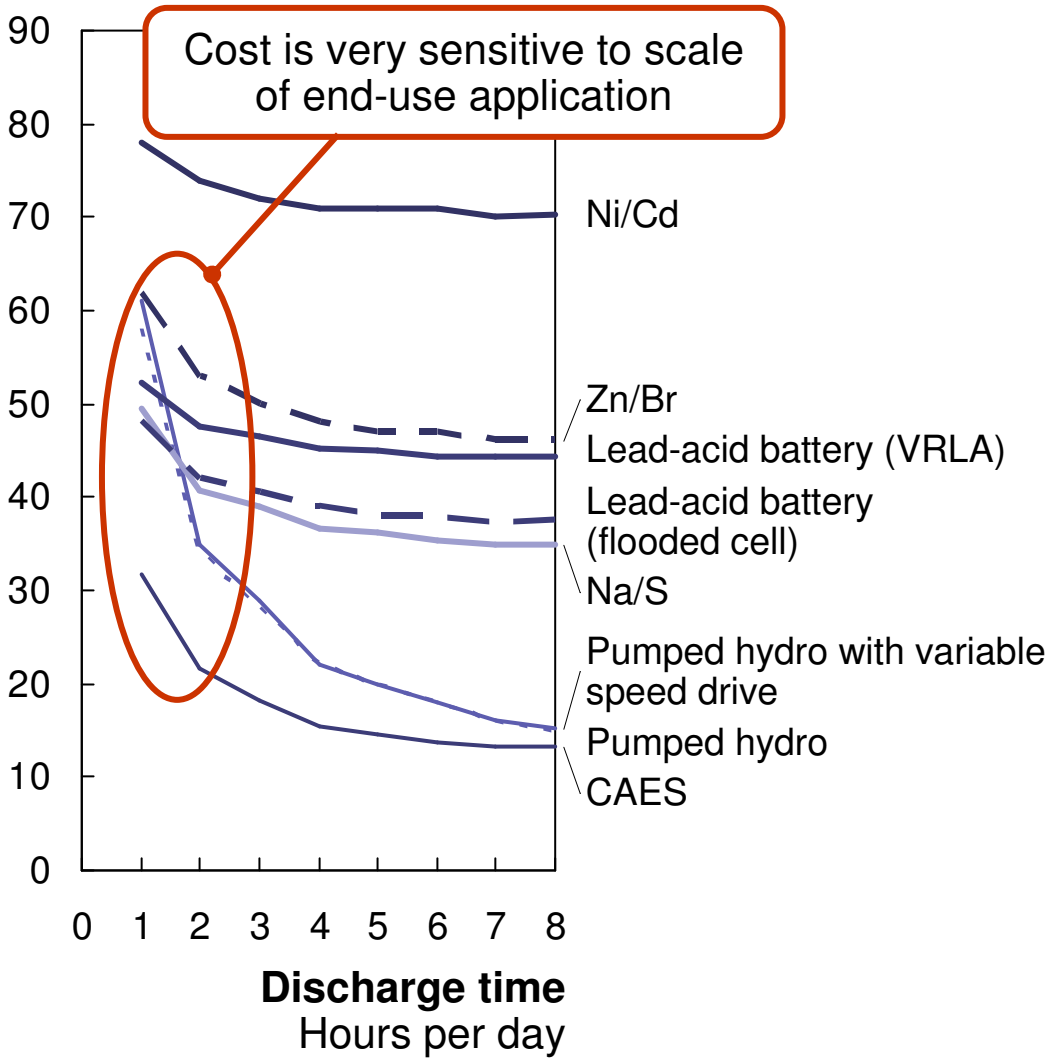


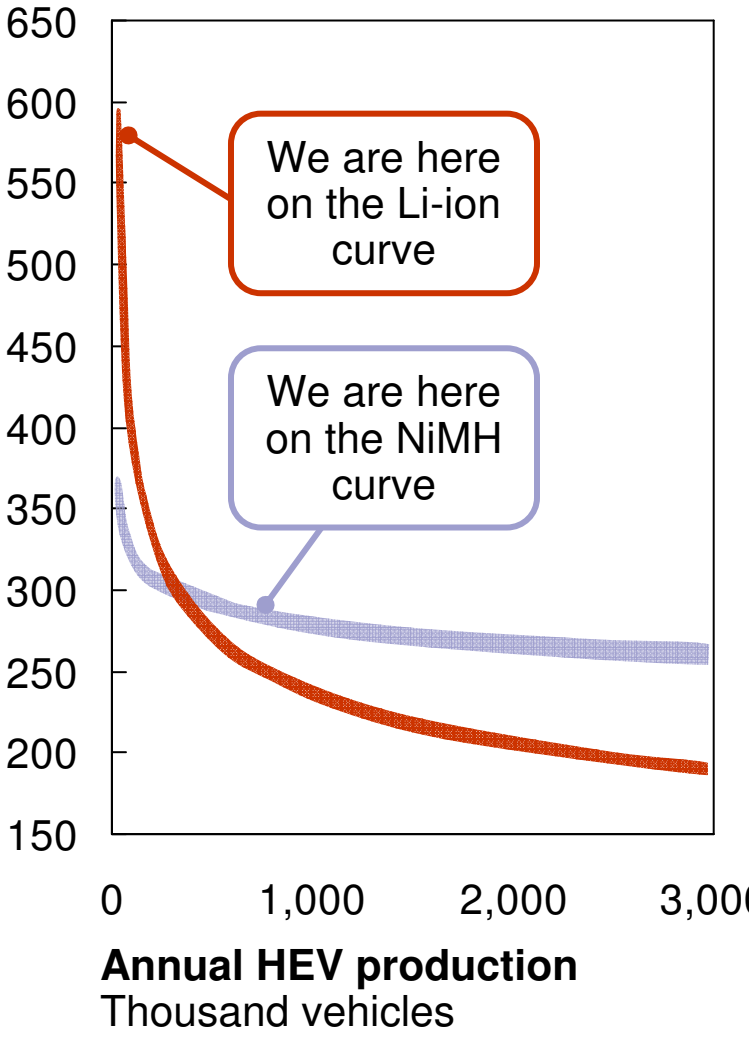
Source: McKinsey; Sandia National Laboratory; ESA

Cost is also very important

Revenue requirement
Cents/kWh



Estimated cost per kWh (cell-level)
Dollars

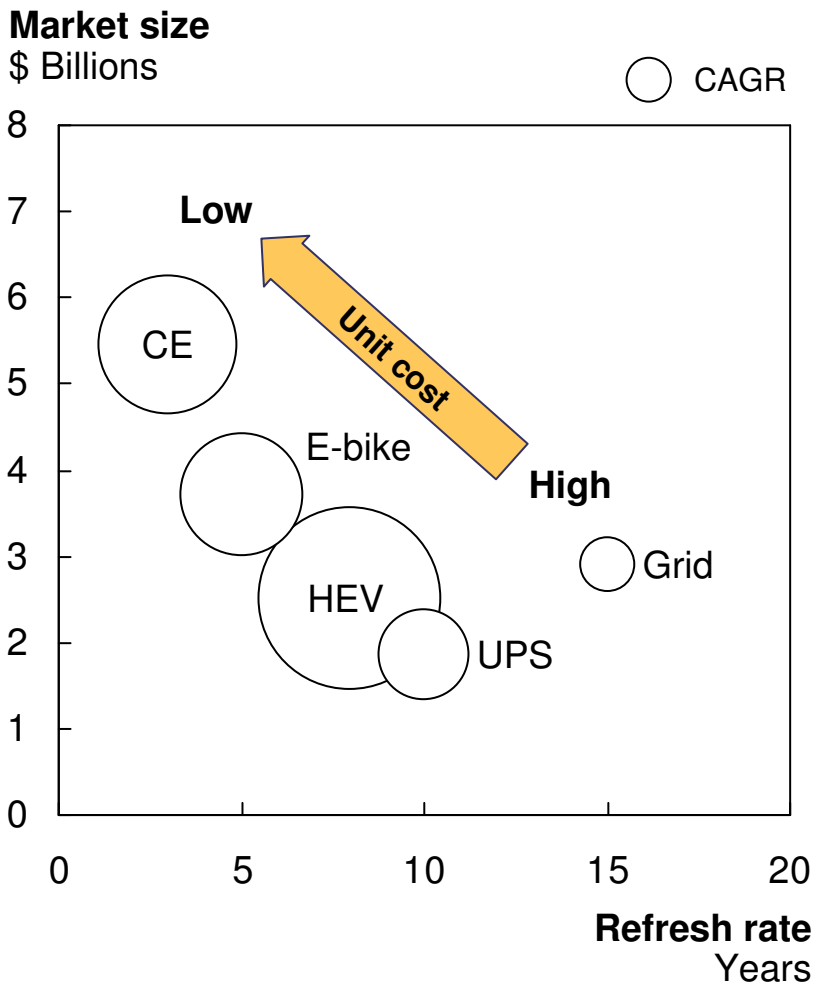


Source: Sandia National laboratory

2012

And product lifecycle must also be considered . . .

Market size, refresh rate and technological adoption



Rapid turnover facilitates adoption rate

Application	Refresh	Technology
CE	3 yr.	• **95% Li-ion** • **5% AgZn**
E-bike	5 yr.	• 95% Pb acid • **5% Li-ion**
HEV	8-10 yr.	• 67% NiMH • **27% Li-ion** • **6% Zn-Air**
UPS	10+ yr.	• 80% Pb acid • **20% flywheel**
Grid	15+ yr.	• 98% Pb acid • 2% other

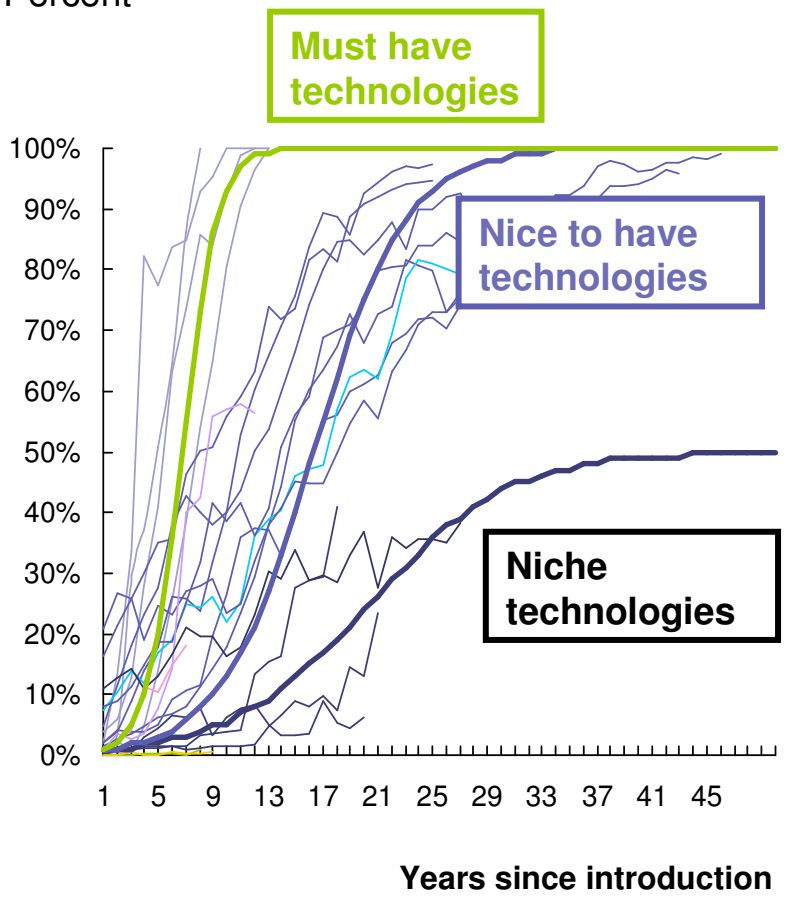
Source: McKinsey analysis; Lux reserach

EXAMPLE FROM AUTOMOTIVE INDUSTRY

. . . as does regulation . . .

Automotive sector…

New generation capacity by technology
Percent

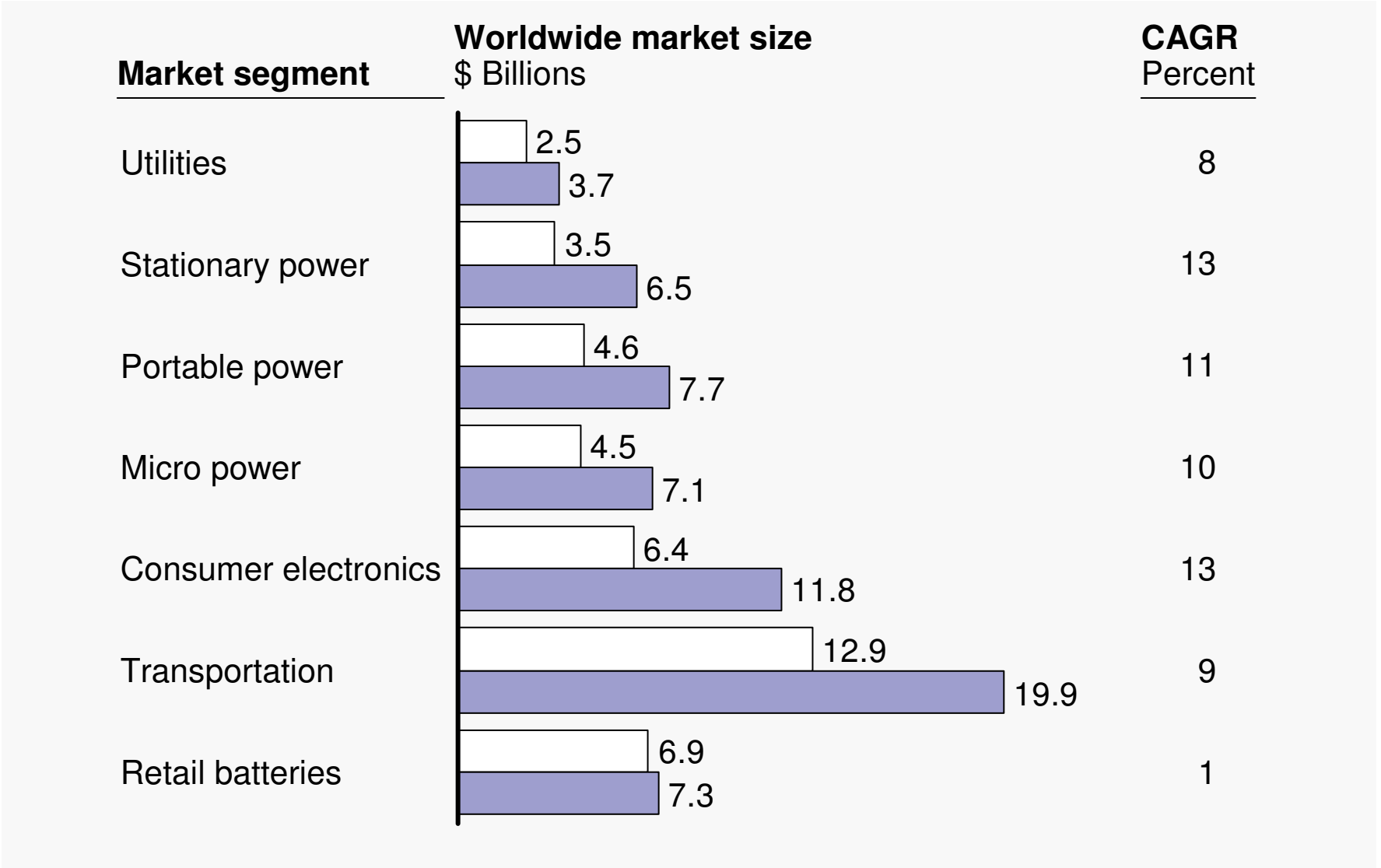


- Of more than 20 automotive technologies examined, only 4 were adopted in less than a decade
- The most rapidly adopted technologies were motivated by **safety or by regulatory pressure** (e.g., radial tires (fuel efficiency, safety) or fuel injection (fuel efficiency)

Source: McKinsey analysis

5. Who wins?

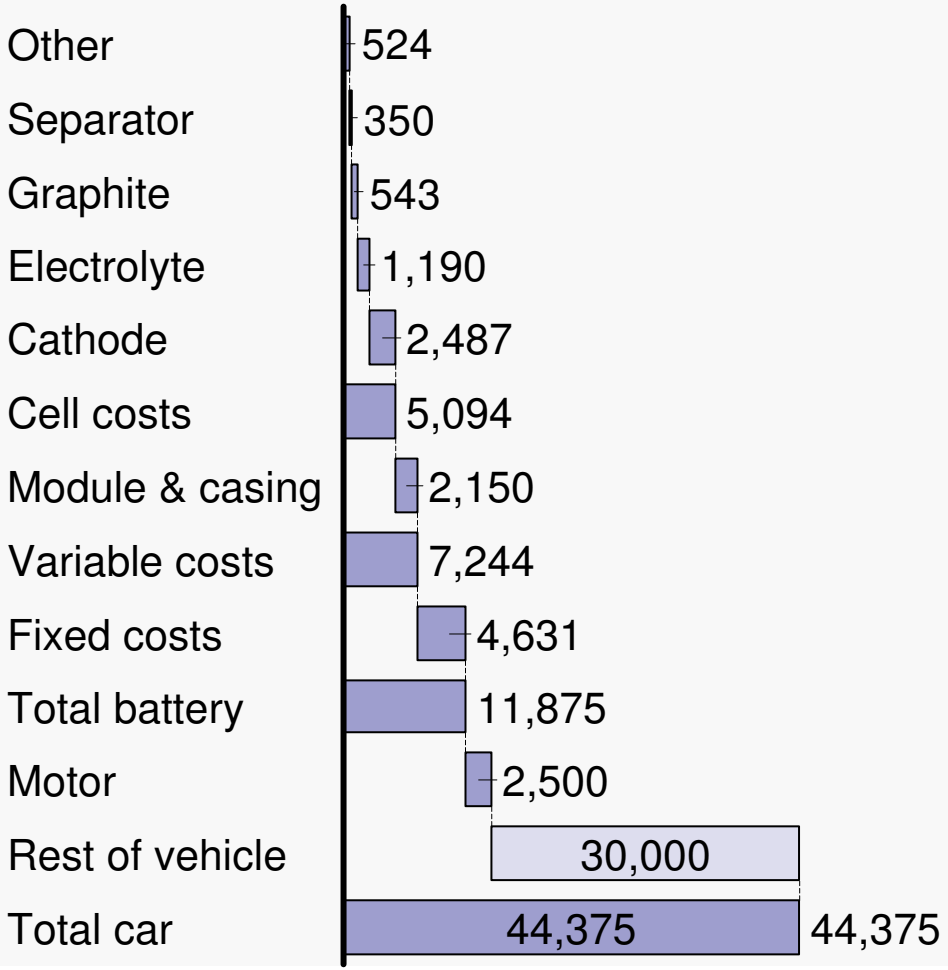
Energy storage market (conservatively) should grow to $60-70 billion by 2012



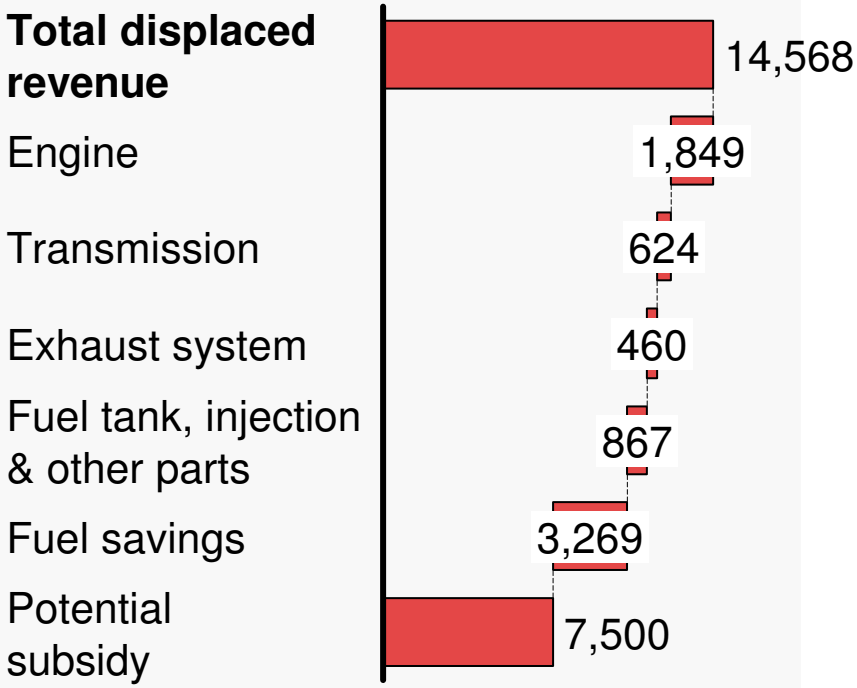
Source: Lux Research

What's at stake? Large transfers of value across several industries

Cost breakdown of a hypothetical EV powered by a Li-ion battery
Dollars per unit



"Displaced" revenue due to use of a Li-ion battery
Dollars per unit



Could shift between established OEMs, attackers, utilities, infrastructure players

Source: McKinsey analysis

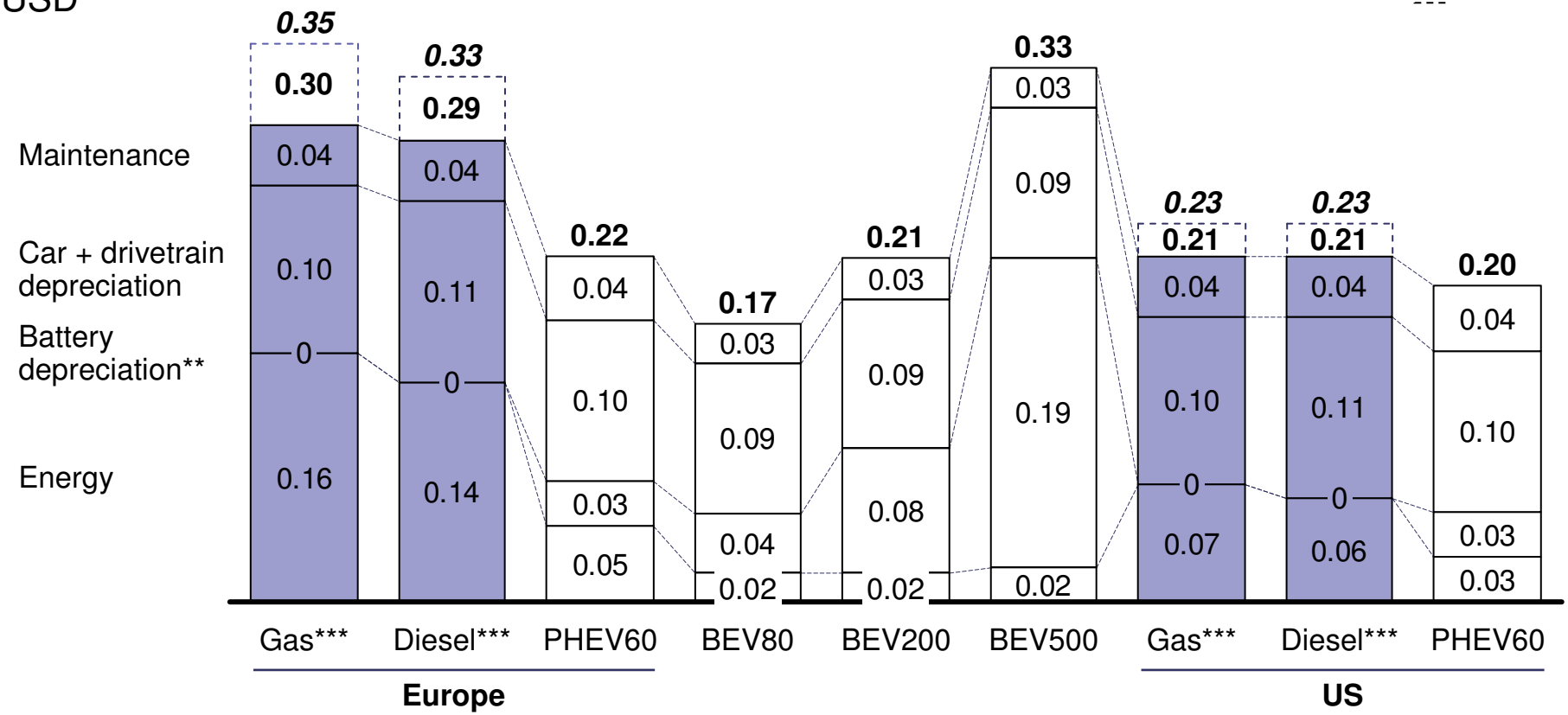
EV EXAMPLE

PHEVs and low-range BEVs with lower total cost of ownership, especially in Europe due to high fuel taxes

2013 MEDIUM CASE

Total cost per kilometer of operation*

USD



- Results **heavily dependent on tax regulation** (fuel taxes, sales taxes on ICE)
- Could change substantially through **business model innovators**, e.g., Better Place

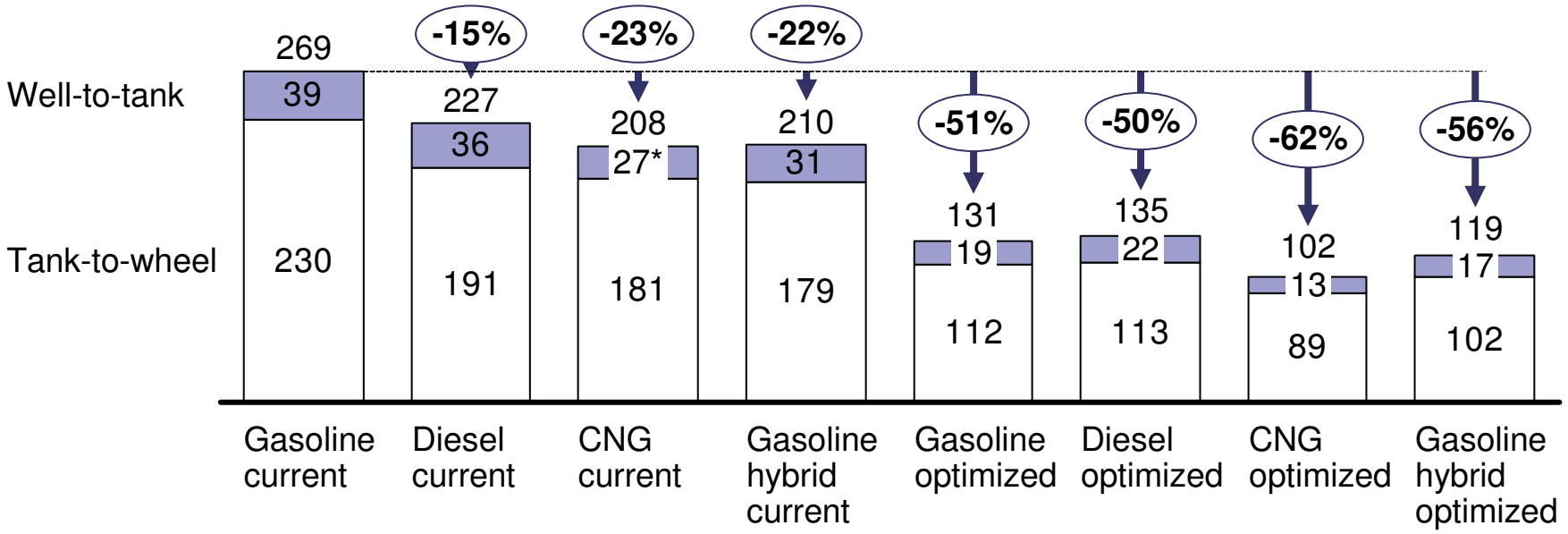
* Model analyses first 10 years of ownership (16 year life of car) for standard segment car, e.g., VW Golf
** Depreciation modeled separately from vehicle
*** Improved ICE with fuel reduction packages 1 + 2
Source: McKinsey analysis

EV EXAMPLE

Abatement potential and costs of technologies (1/2)

STANDARD SEGMENT
EUROPE, 2030

"Well-to-wheel" emissions
g CO_2/km (real, not driving cycle)



Investment cost (consumer) EUR	0	650	1,400	1,800	1,950	2,050	3,400	3,750
Payback period (consumer) Years	0	1.0	1.6	4.7	2.2	1.9	2.5	3.3

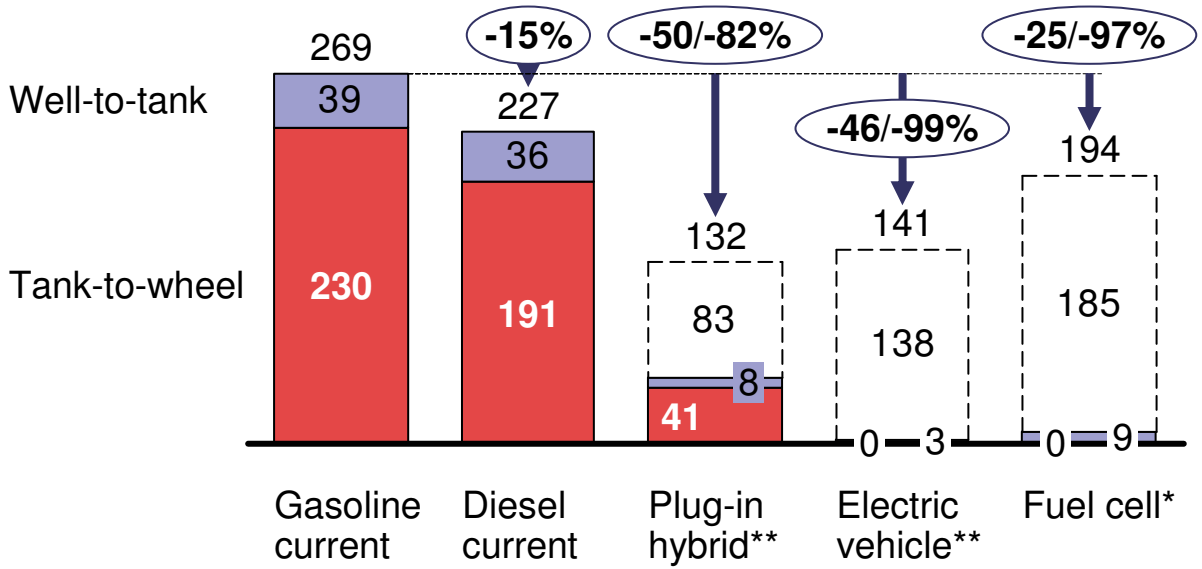
* Assuming EU Mix for CNG

Source: McKinsey

Abatement potential and costs of technologies (2/2)

STANDARD SEGMENT
EUROPE, 2030

"Well-to-wheel" emissions
g CO_2/km (real, not driving cycle)



	Gasoline current	Diesel current	Plug-in hybrid**	Electric vehicle**	Fuel cell*
Investment cost (consumer) EUR	0	650	5,750	7,050	> 10,000
Payback period (consumer) Years	0	1.0	4.2	5.2	–

* Hydrogen generated using electrolysis**

** Emissions depend on type of electricity used, range shown between nuclear (low emision value) and CNG EU mix (high emission value)

Source: McKinsey

Tremendous amount of recent activity, e.g., auto OEMs

Chrysler announces several "production intent" electric vehicles including a new Lotus-based pure EV sports car, and a PHEV minivan and Jeep Wrangler

Hyundai announces intent to build and sell EV version of Hyundai Getz with 120 km range in New Zealand

Berkshire Hathaway buys 10% of Chinese electric car-maker **BYD** and announces partner-ship with US utility **Mid-American Energy** to create dealerships and charge stations

General Motors officially unveils the 2011 Chevy Volt

Renault/Nissan unveils electrified version of renault Megane, Kangoo, and another new all-electric design to be sold in 2012

Source: EVWorld.com; Business Week; company information; press search

EV EXAMPLE

New alliances between automotive OEMs and utilities

Mitsubishi to partner with **Tokyo Electric** on new electric vehicles

– Green Car Congress

General Motors teams with **35 U.S. utilities** on plug-in cars

– Wall Street Journal

Tesla and **PG&E** partner on "smart charging"

– AutoblogGreen

Subaru will partner with **New York Power Authority** to evaluate the company's R1e electric vehicle

– Green Car Congress

E.ON, Volkswagen and **GAYA** team in a project aiming to demonstrate the use of electricity generated by renewable energy such as wind and solar for powering up PHEV's under real-time conditions

– EV World

RWE and **Daimler** teaming up for electric car project in Berlin

– Financial Times

Toyota and **EDF** are starting trials of a range-extended plug-in hybrid in the UK

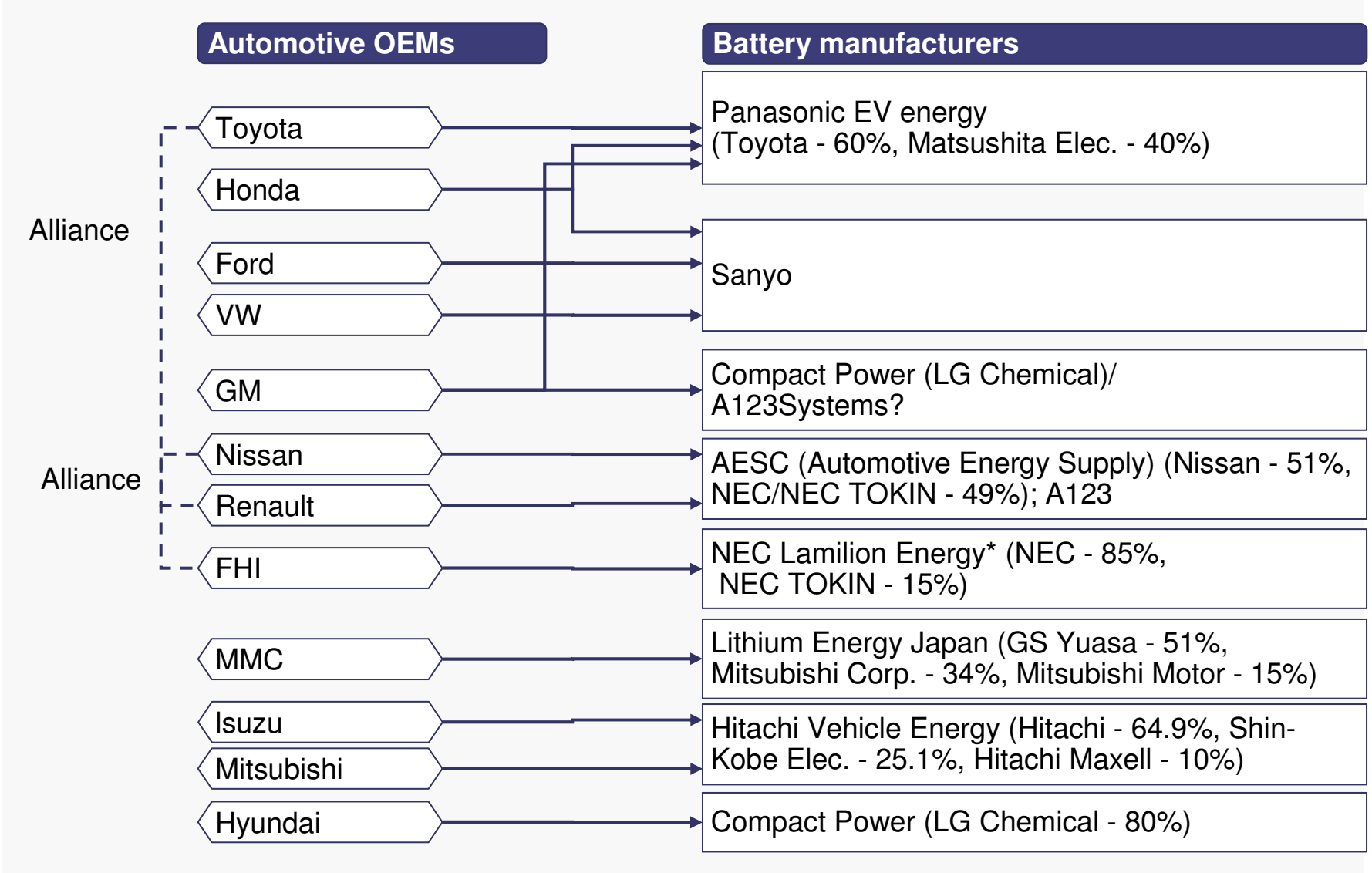
– Channel 4

Mitsubishi to provide i MiEV electric vehicles to **Southern California Edison's** technical center for joint testing and evaluation

– Mitsubishi Motors

Source: Press clippings

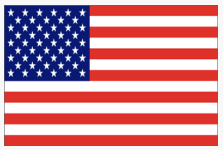
Alliances between automotive OEMs and battery manufacturers



* Integrated into AESC in 2008

Source: Company data; Sanyo Electric; automotive technology

Governments are announcing targets / plans to support EV adoption

Country	Year
 **Israel**	2011
 **Denmark**	~ 2011
 **Portugal**	2011
 **Spain**	2014
 **Australia**	2012
 **California**	–

Source: Press search, Time magazine, Haaretz, Wired, msnbc.com, Renault press releases, autoobserver.com, ENN, New York Times, drive.com, The Australian, CNN.com

5. Who wins?

EV EXAMPLE
● Positive
○ Negative

How will new technology impact "rents" in value chain?

			Overall impact of EVs	Opportunity	Threat
Established players		Utilities		●	• Additional power sales • Ability to rate base asset • Driver of smart grid • V2G – ancillary services	• Stress on legacy grid
		Oil companies		◔	• Battery fast charging at gas stations • Own the battery	• Reduced demand for gasoline/diesel
	New entrants	Car OEMs		◑	• Early adopters may gain significant market share and set standards others must follow	• Electric motor further commoditizes OEM offering
		Car suppliers		◑	• Opportunities for new suppliers (e.g., electric motors manufacturers) to enter	• Companies will need to adapt to offer new parts
		Battery OEMs		◕	• EVs drive huge demand • Drive value migration to software and thermal mgmt	• Maintaining R&D roadmap • Car OEMs develop batteries
		Biz model innovators		●	• Use EVs as basis of new business model	• Response from incumbents • Access to capital

Concluding thoughts

- Storage opportunity is clear, but barriers remain
- Storage is an enabler with multiple benefits to many people; therefore hard to sell
- Regulation could potentially play a role in making value visible to different users
- Storage will enable some huge disruptions.
  - Will be big winners and losers
  - New structures and industry leaders will emerge
- Emerging leaders will act now to shape future industry structures