

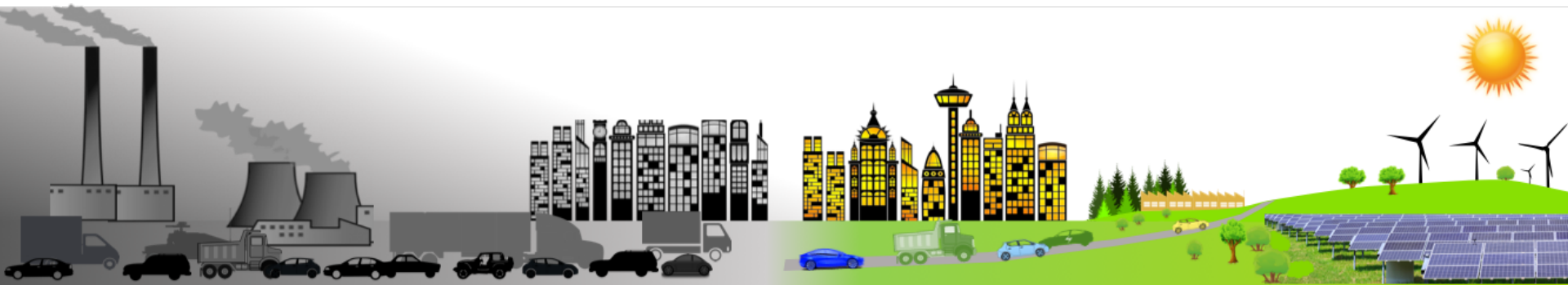
Technology Disruptions in Clean Energy

Eric Strid

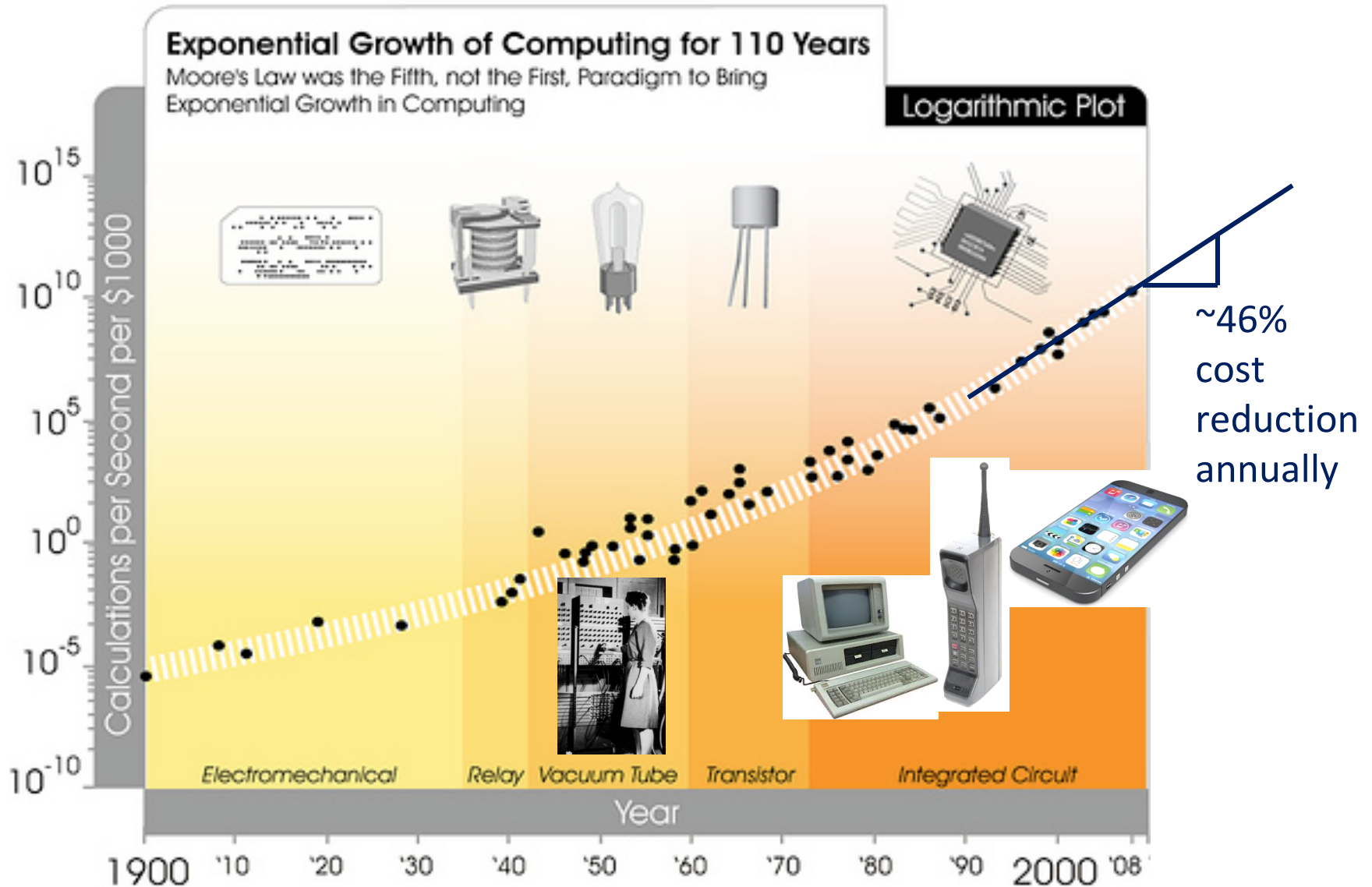
Gorge Technology Alliance Geek Lunch April 21, 2020

Recording: <https://www.youtube.com/watch?v=JhLg2u4uV1I&feature=youtu.be>

- Disruption 101
- Crossing chasms
- What's coming in clean tech
- So what



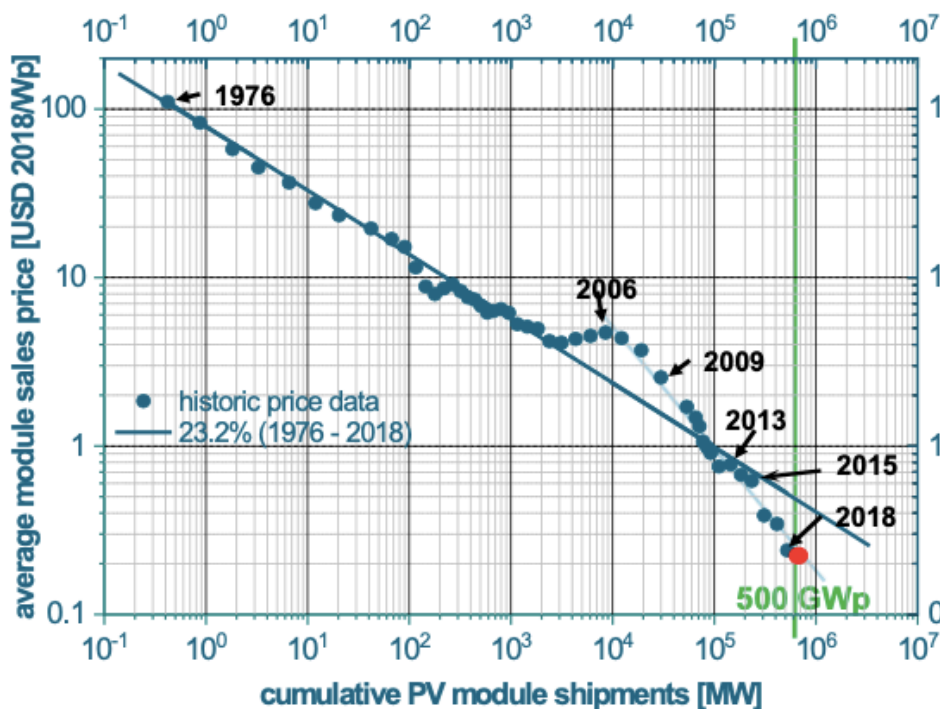
Semiconductors: application disruptions amid continuous scaling disruptions



Disruption 101

- Exponential mindsets
- Learning rates
- Technology roadmaps

PV learning curve – Module



Shipments / avg. price at years end:

2017: 105 GWp / 0.35US\$/Wp
 2018: 109 GWp / 0.24 US\$/Wp
 2019: ≥120 GWp est.

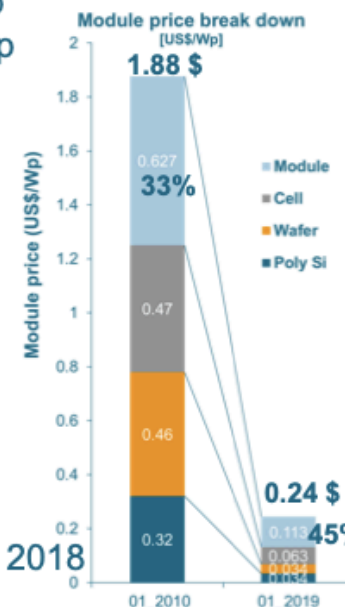
2018 o/a shipment: ≈ 523 GWp
 o/a installation: ≈ 504 GWp

0.5 TWp milestone passed!

LR ≈23 % (1976 2018)
 LR ≈40 % (2006 2018)

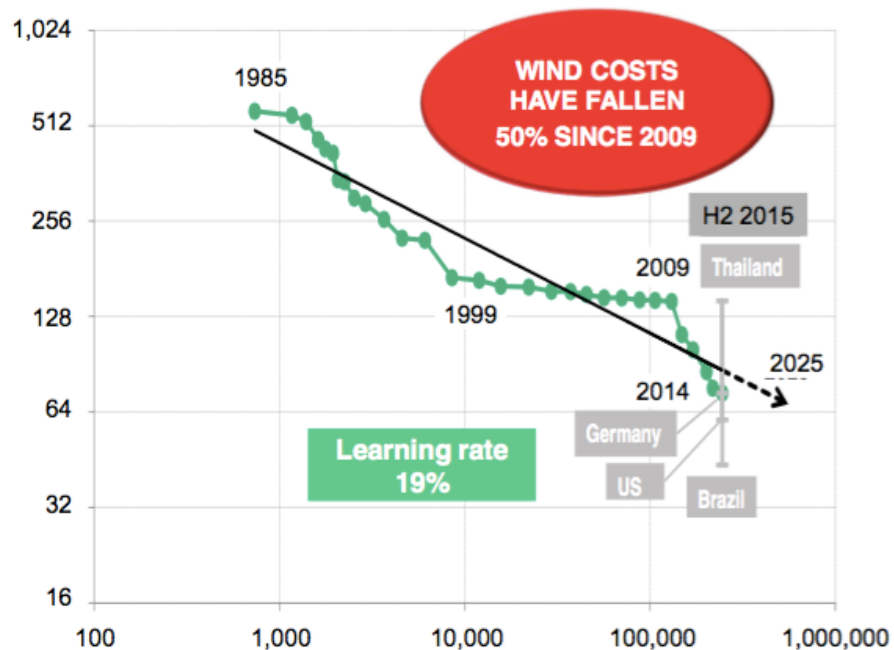
→ ≈90% price reduction 2009 → 2018

→ High volume shipped with **huge** price reductions



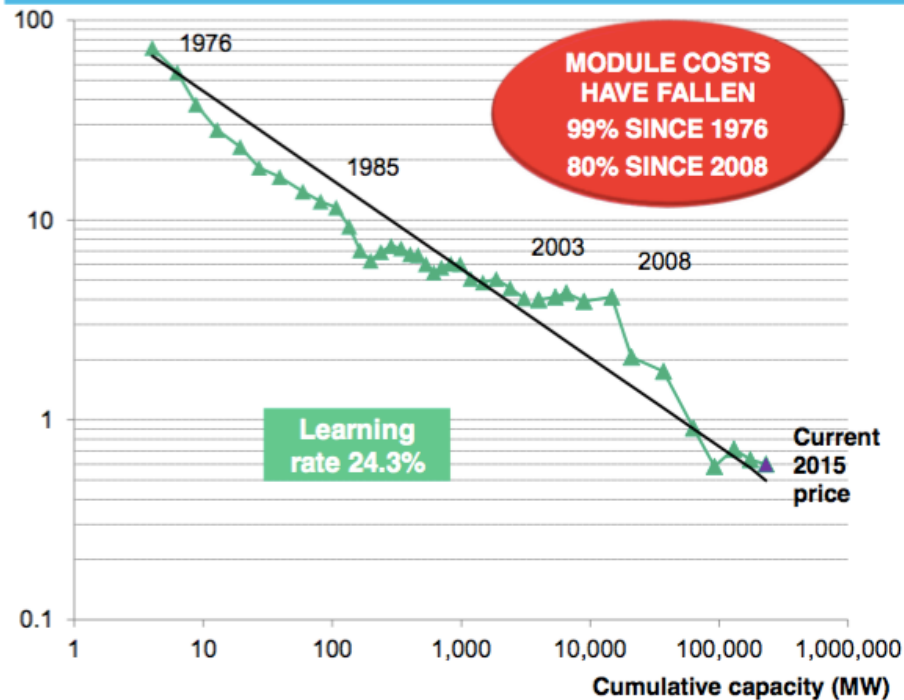
Clean energy “breakthroughs” are all production learning rates

ONSHORE WIND LEVELISED COST (\$/MWh)



Note: Pricing data has been inflation corrected to 2014. We assume the debt ratio of 70%, cost of debt (bps to LIBOR) of 175, cost of equity of 8% Source: Bloomberg New Energy Finance

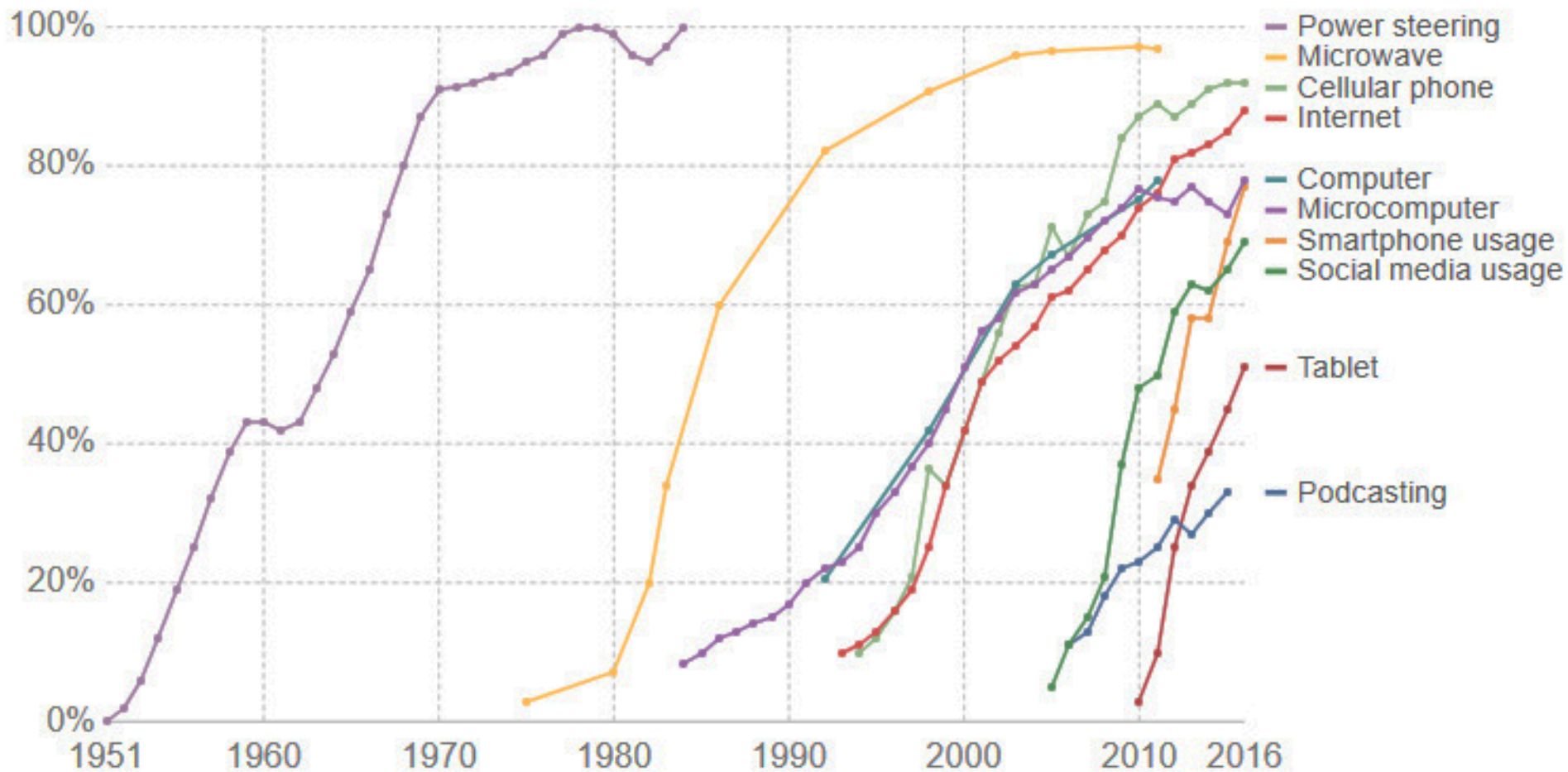
SOLAR PV MODULE COST (\$/W)



Note: Prices are in real (2015) USD. 'Current price' is \$0.61/W Source: Bloomberg New Energy Finance, Maycock

- *Learning rates derive from increasing efficiencies as we build more*
- *No technology breakthroughs needed to extrapolate*

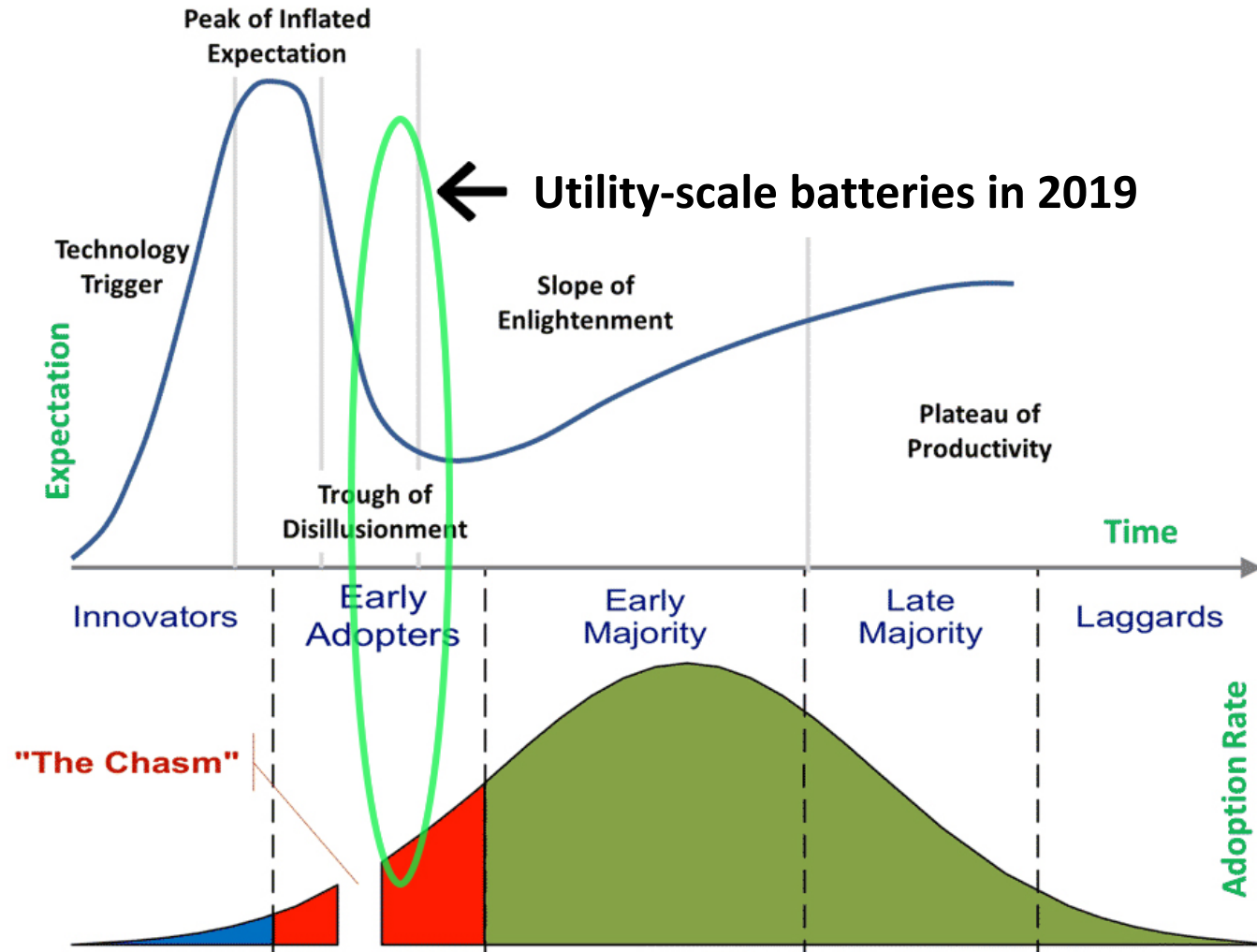
Technology adoption examples



- Adoption S curve typically modeled as a logistic function
- E.g., solar PV now ~3% of global energy used
- **Market shares all reset to zero**

Microeconomics of disruption

- Opportunity: creatively destroy the status quo with superior cost-performance
- Challenge: new technologies must cross the chasm



Organizational behaviors in the chasm

Department	In the chasm	In the early majority
R&D	It works--just sell it	I told you so
Marketing & Sales	The dogs aren't eating the dog food	We finally figured out how to sell it
Operations	This stuff is weird and it has bad yields	Wow, how do we scale up fast enough?
Finance	This is not looking good	I like it!

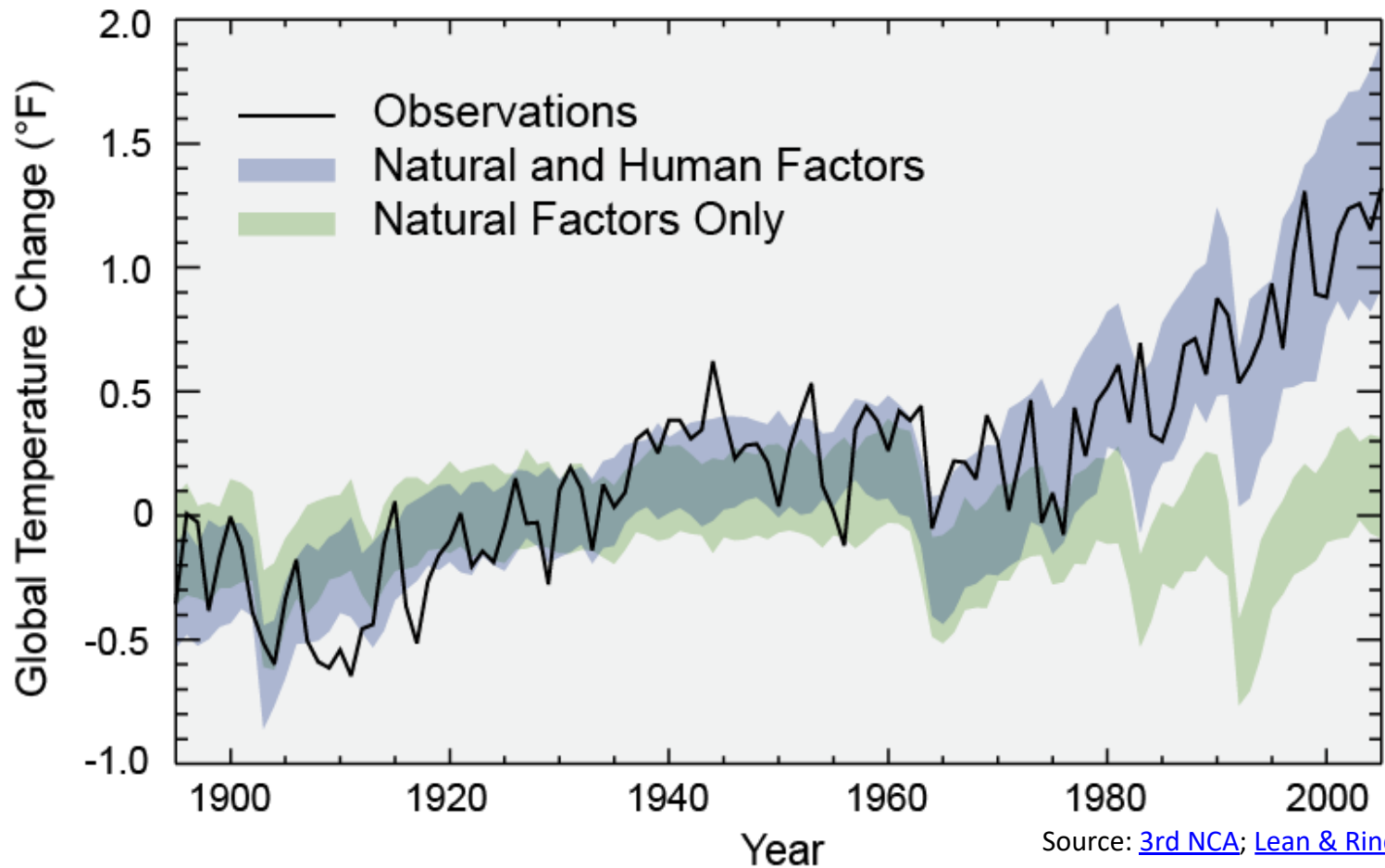
Small companies crossing chasms

- Add larger, defensible platforms of profitability
- New segments require money, patience, luck
- Market research is key



Climate data has been clear for decades

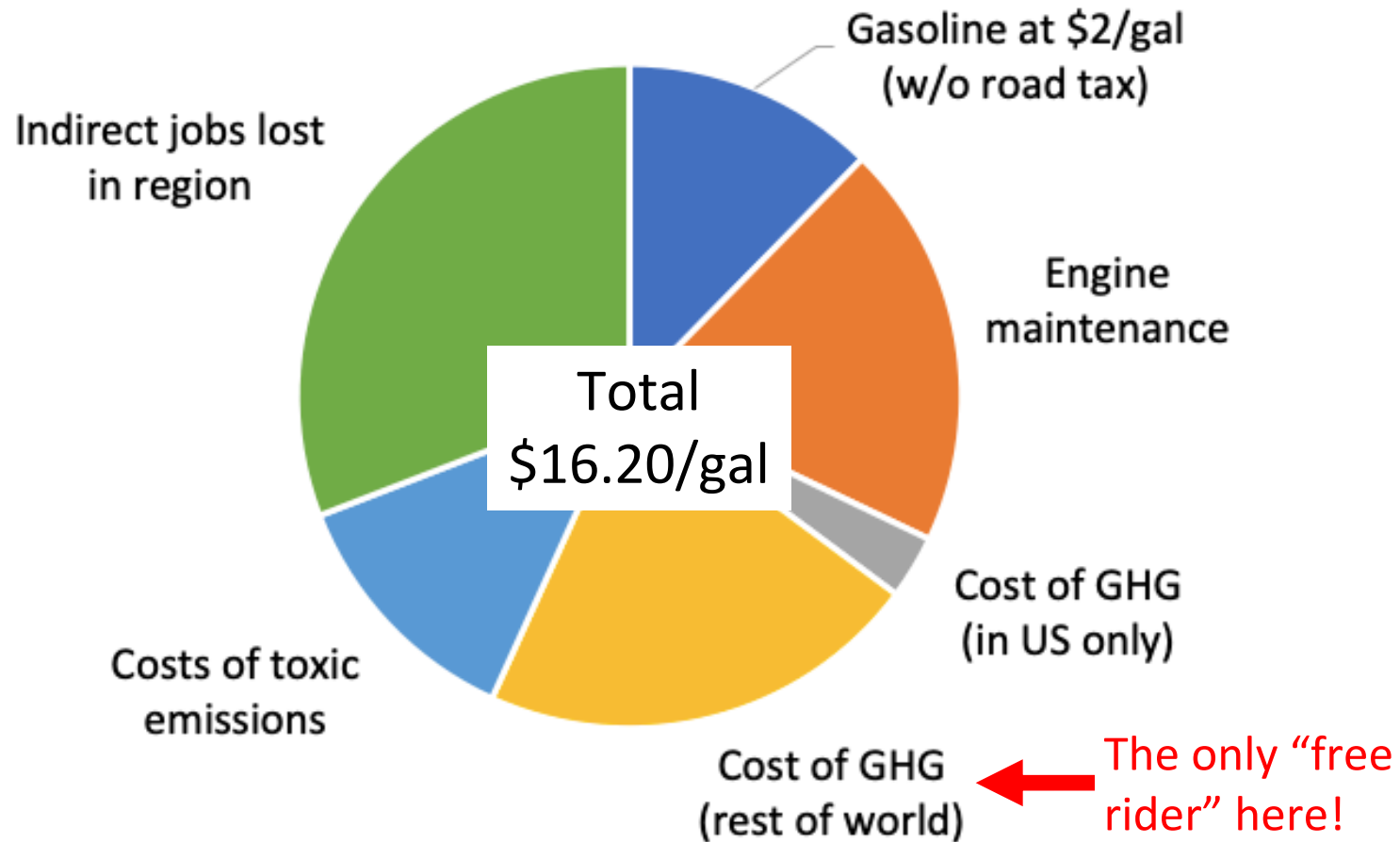
Separating Human and Natural Influences on Climate



1982: [Exxon predicted](#) today's CO₂ levels and warming

2018: Five oil majors [agree with climate scientists in court](#)

Fossil fuel cost example: gasoline in OR

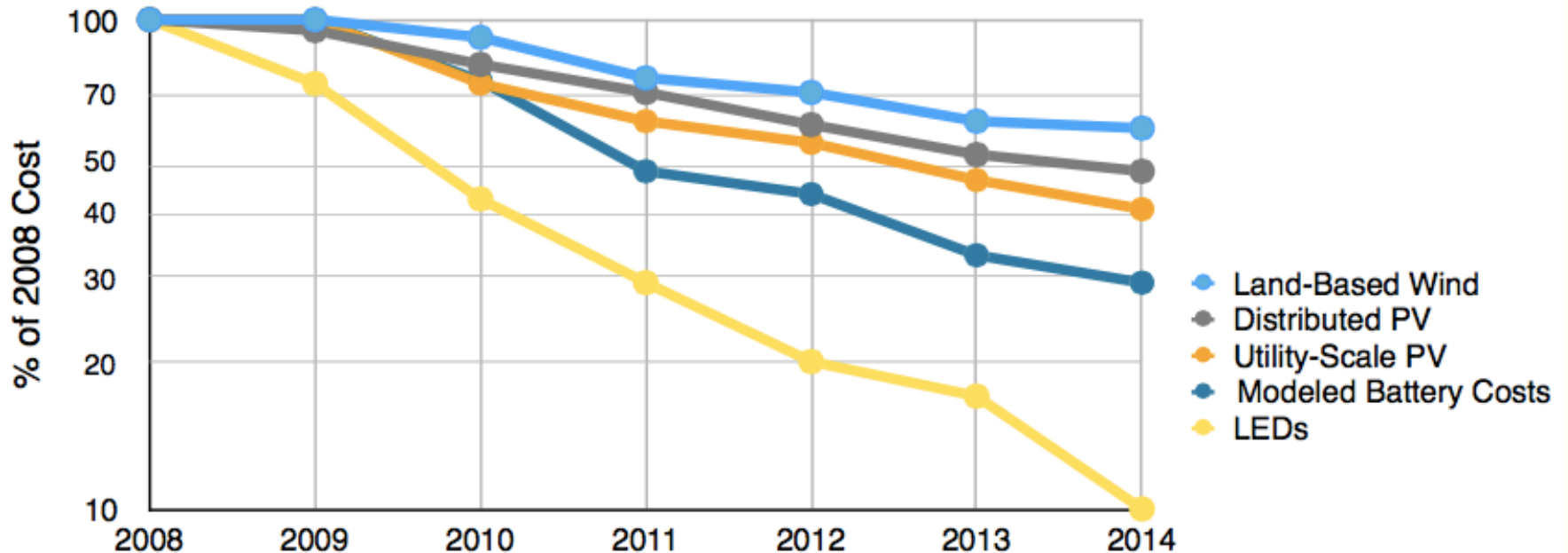


- EV equivalent: fuel ~\$1/gal + maintenance ~\$0.20/gal
- No need to hype the dangers of a gas we exhale...

The information technology industry meets the energy industry

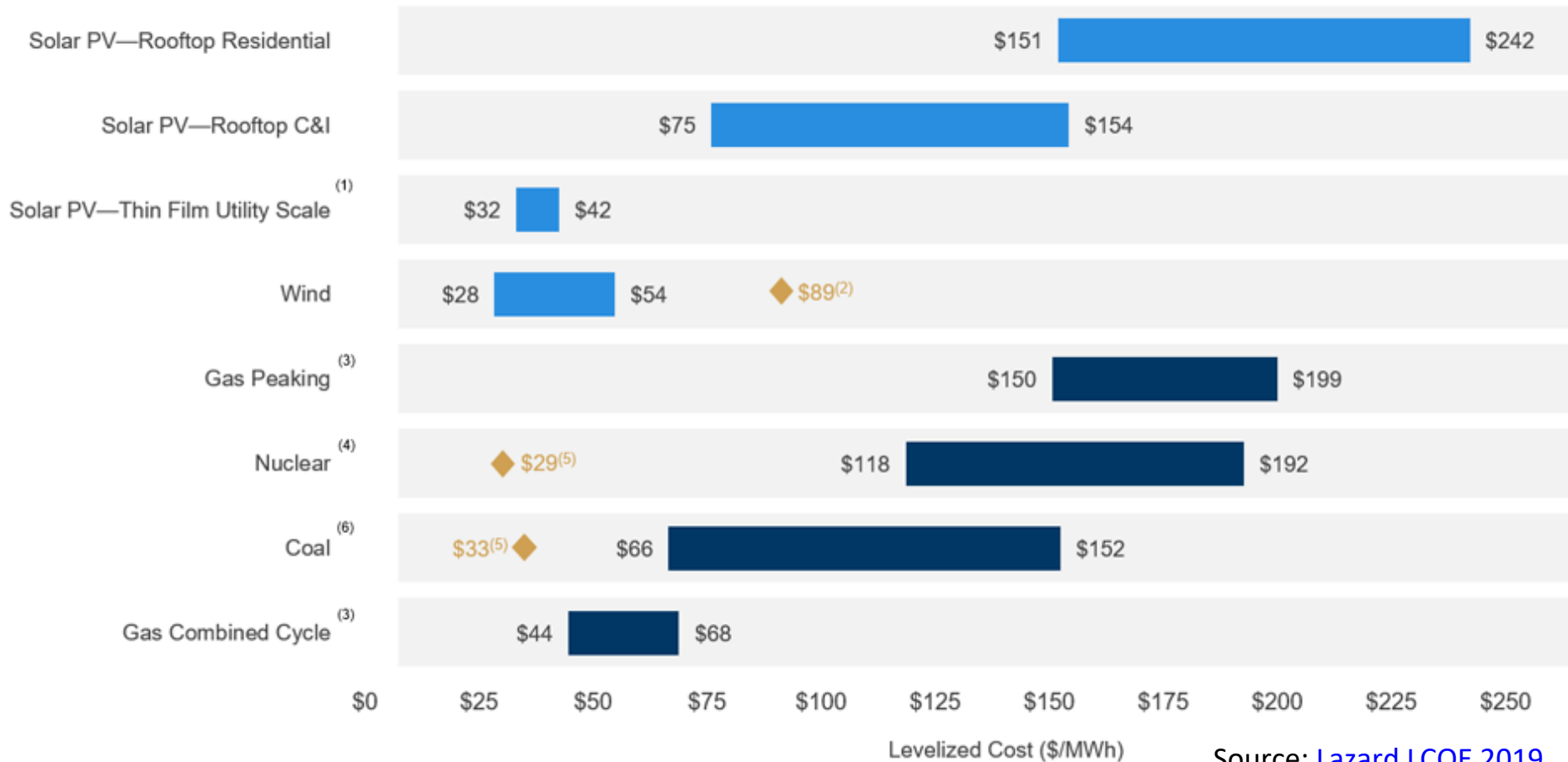
Learning curves, exponential expectations, technology roadmaps...

Falling Costs for Clean Energies Technologies



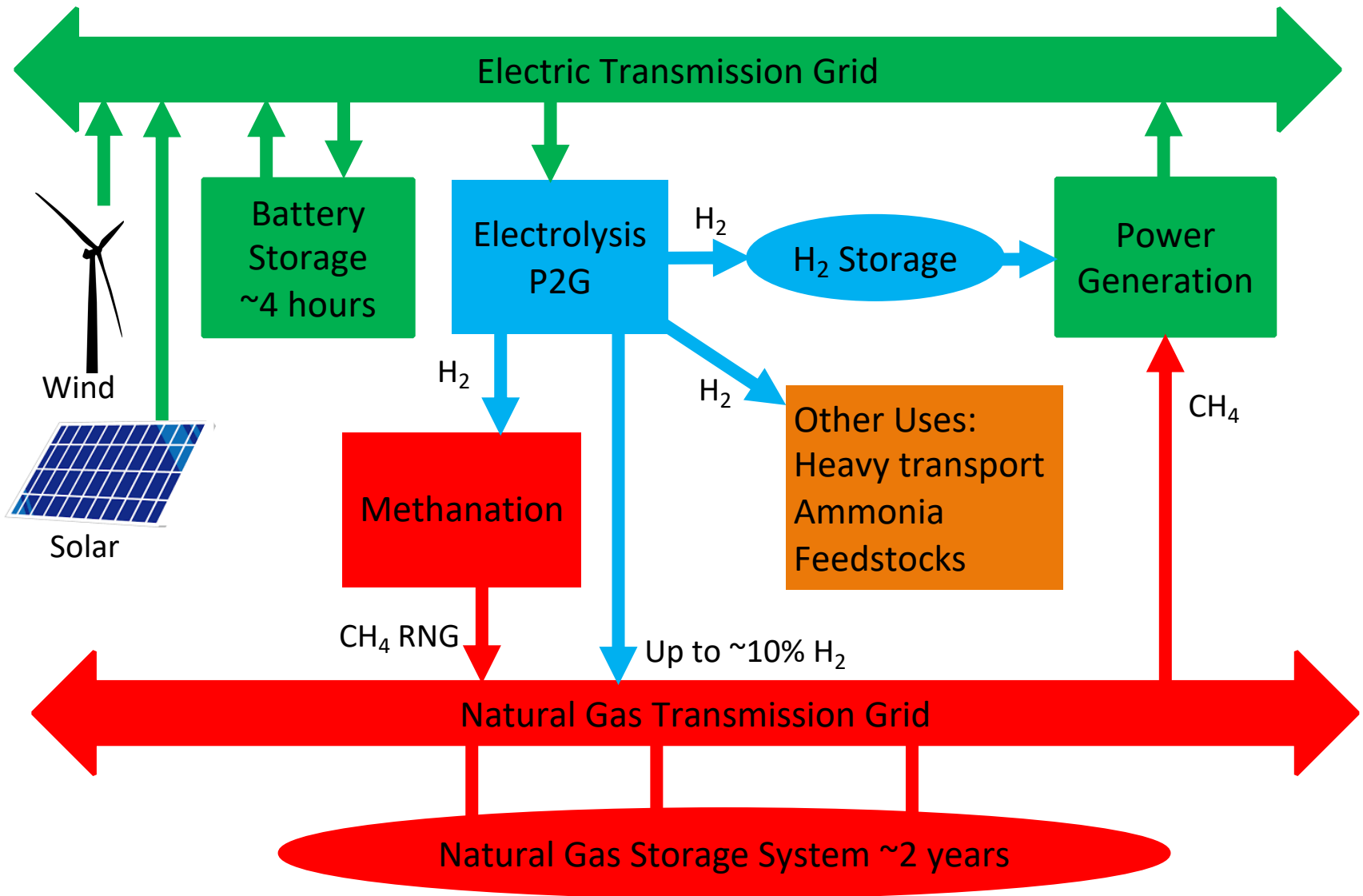
Source: US DOE 2015 Report *The Energy Revolution is Here*

Levelized Cost of Energy (\$/MWh)



- Unsubsidized, global averages in 2019
- Cheaper to build and operate wind or solar farm than to operate a coal plant
- Wind, solar, and storage will disrupt even more with better cost-performance

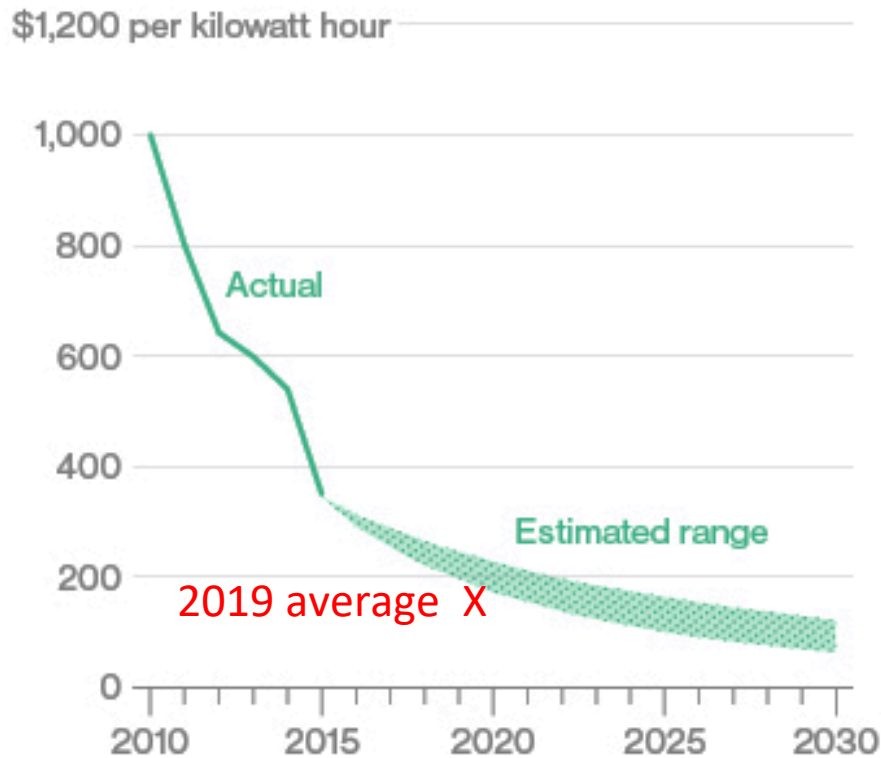
Need: two months of seasonal storage



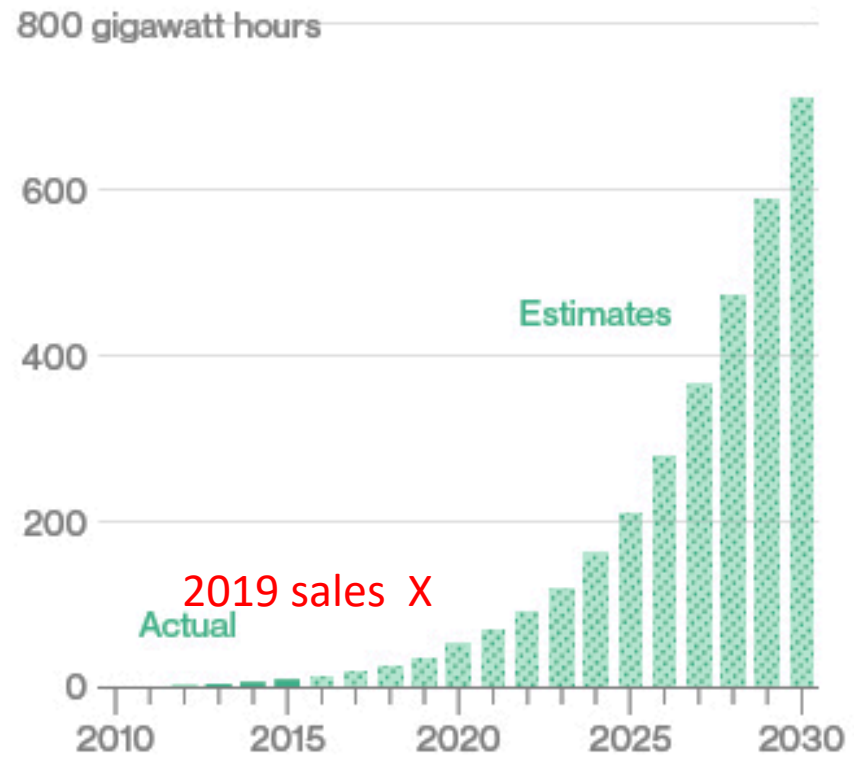
EVs are all about the batteries

Batteries make up a third of the cost of an electric vehicle. As battery costs continue to fall, demand for EVs will rise.

Cost for lithium-ion battery packs



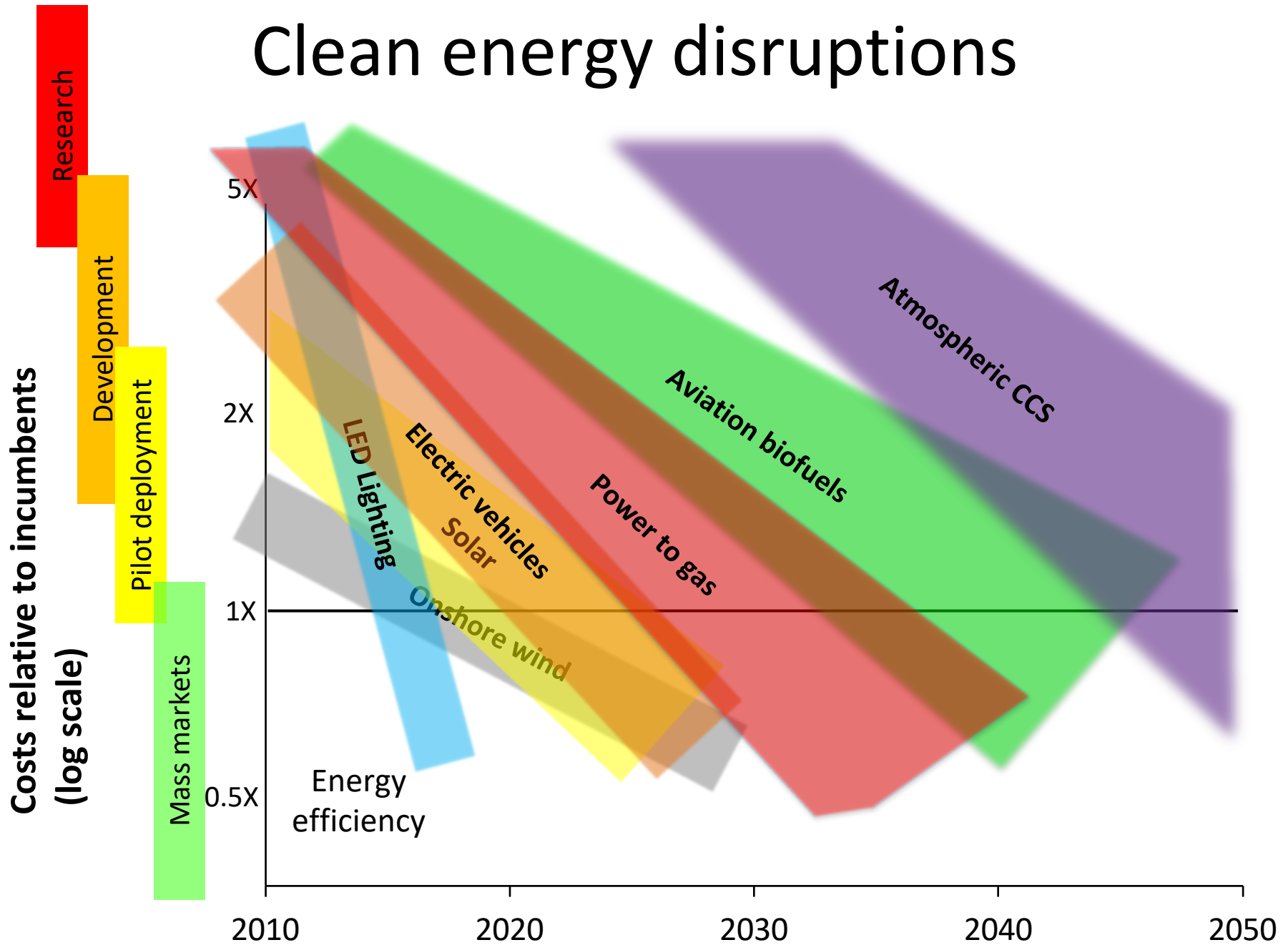
Yearly demand for EV battery power



Source: Data compiled by Bloomberg New Energy Finance



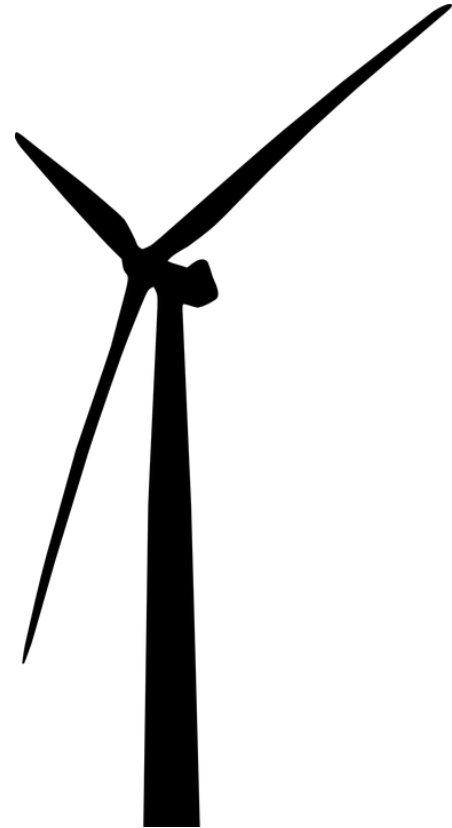
Clean energy disruptions



P2G, biofuels, and A-CCS are guesstimates; all others extrapolated from learning rates.

Energy stakeholders

- Utilities, managers, engineers
- Policy makers and 3000 regulating bodies
- Incumbent companies
- Disruptive companies
- Investors
- All are threatened
- All should embrace the new forces instead of denying them



Implications to the grid

- ~50% increase in load from EVs in OR/WA
 - By far the largest growth opportunity for utilities
- Clean-energy transitions will save, not cost
 - Op costs, healthcare costs, keep spending in region,...
- More complex grid planning
 - Intermittent renewables vs. storage vs. controllable loads
 - Cost trajectories and new tech vs. useful life
 - Value of resilience
- OPUC must push new technologies, business models
- Natural gas grid must also rapidly decarbonize
- Investor opportunities—it comes down to financing

Implications for planners

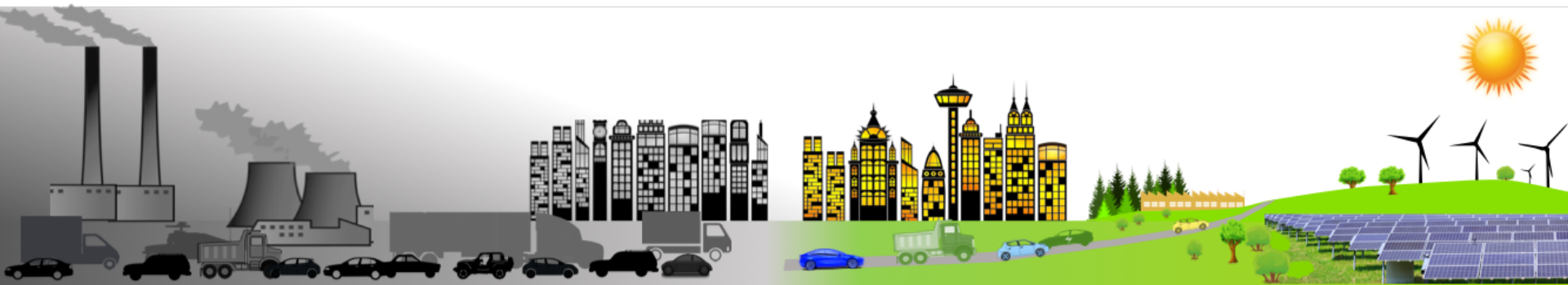
- Clean tech cost trajectories
 - Fossil fuels increasingly uneconomic in all sectors
 - Huge opportunities for entrepreneurs
- Optimism: new tech necessary, though not sufficient
 - We have the technologies to achieve 45% reduction by 2030
- Policy makers must rapidly
 - Accelerate decarbonization by selling its co-benefits
 - Unite business-environment, rural-urban, Rep-Dem
- Households: only a few key infrastructure decisions lock in the major emissions
 - Your housing
 - Your transportation

Paradigm shifts

- It's too late for incremental changes
 - Countries and companies that move fast will benefit
- Storage replaces peak generation and wires
 - T&D will eventually become uneconomic...
- Regulation useful before the chasm, too slow after
- Sector-specific challenges and opportunities
 - Generation and EVs need mandates
 - Buildings need stricter codes
 - Aircraft, cement, P2G, shipping are in R&D phases
 - Int'l Maritime Organization: collect fees for industry RD&D
 - Financing opportunities in each

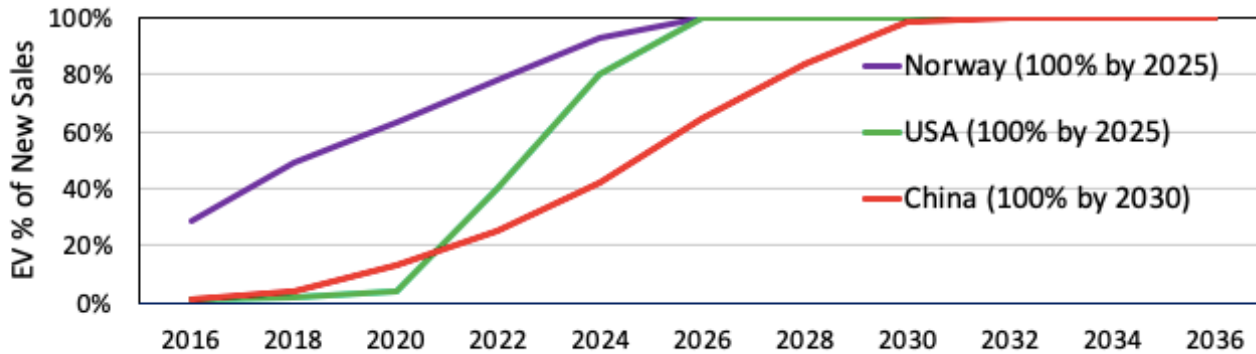
Summary

- Classic technology disruptions are evolving in energy generation and storage and transportation
- Creative destruction will decrease energy costs and affect all stakeholders
- Policymakers will struggle to keep pace
- Vote with your infrastructure purchases



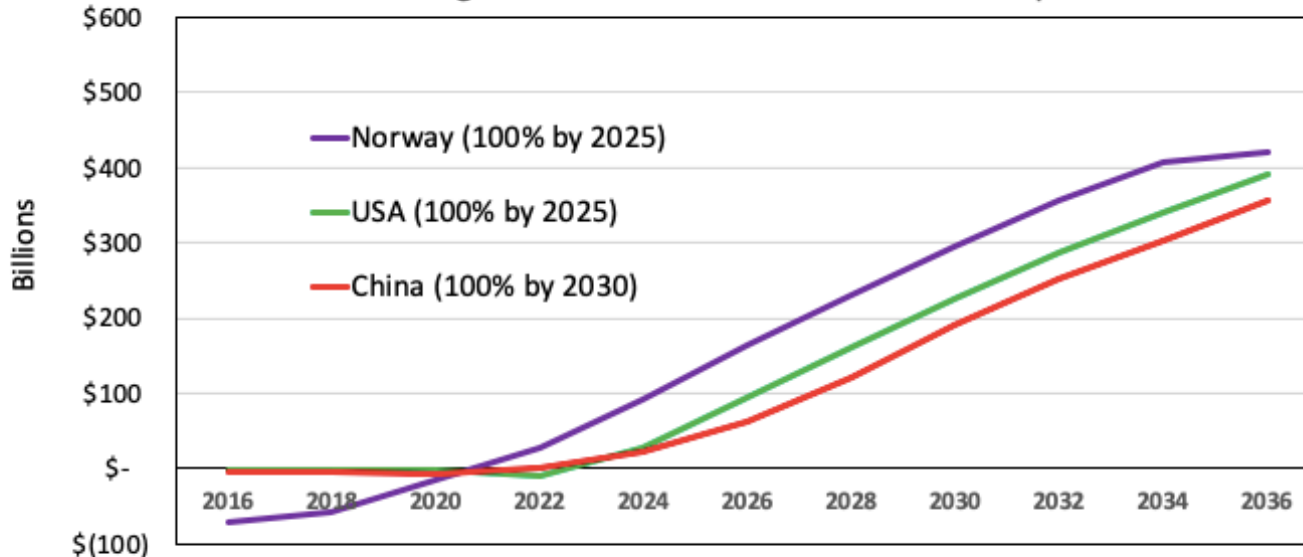
100% EV sales by 2025 achieves IPCC 2030 target and saves the US trillions

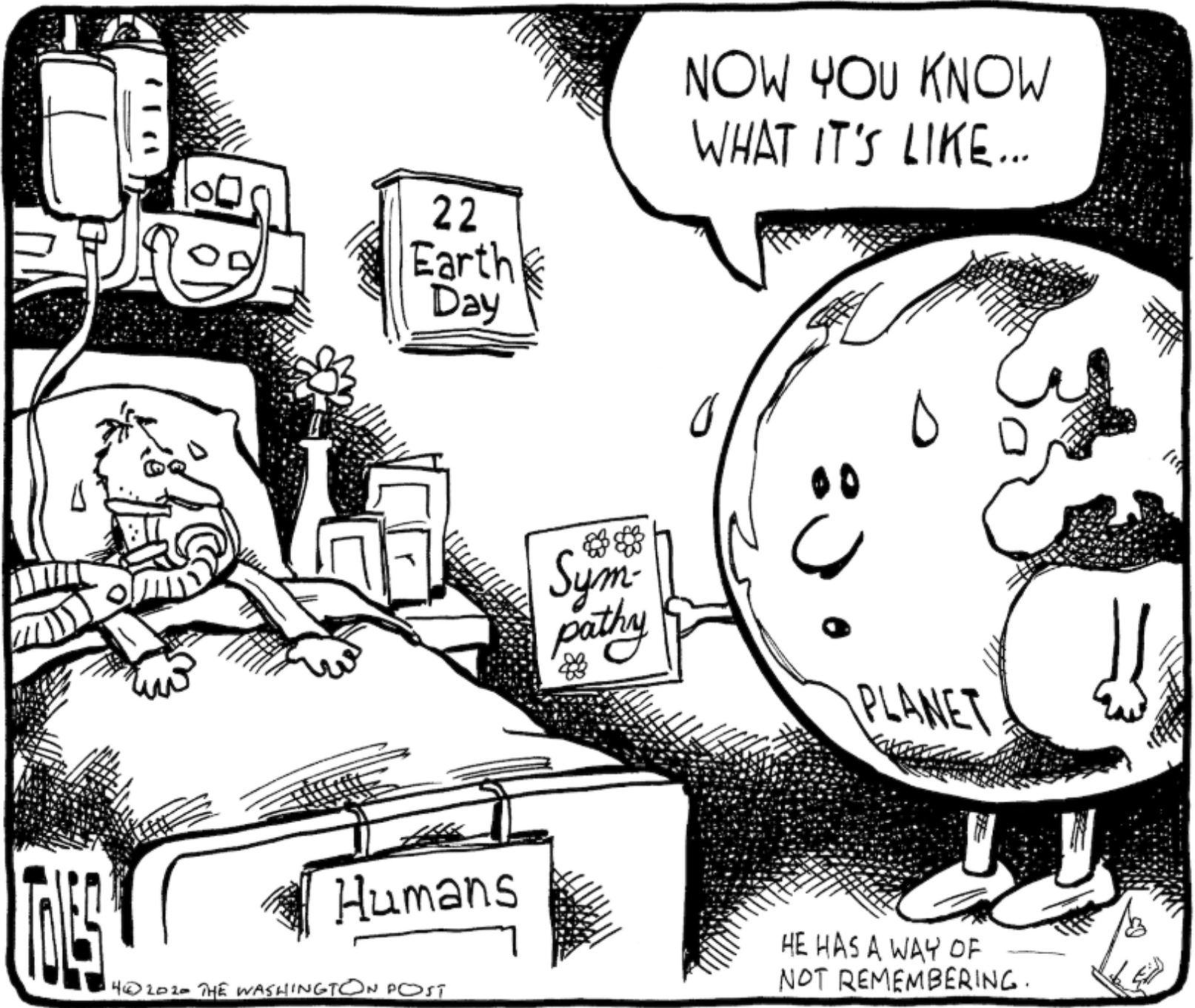
EV Adoption Cases for New Light-Duty Vehicles



- Norway is the only country on track
- The faster we adopt, the more money saved
- US replacement rate has been 6% annually for LDVs
- The race for EV market share will exceed most forecasts

US Annual Savings: Total EV Price + Fuel for Various Adoption Rates





NOW YOU KNOW
WHAT IT'S LIKE...

22
Earth
Day

Sym-
pathy

PLANET

Humans

HE HAS A WAY OF
NOT REMEMBERING.