

The Joy of Clean Energy

How the clean energy revolution will enhance our businesses and communities



Eric Strid, April 26, 2017

Columbia Gorge Climate Action Network and Power Oregon

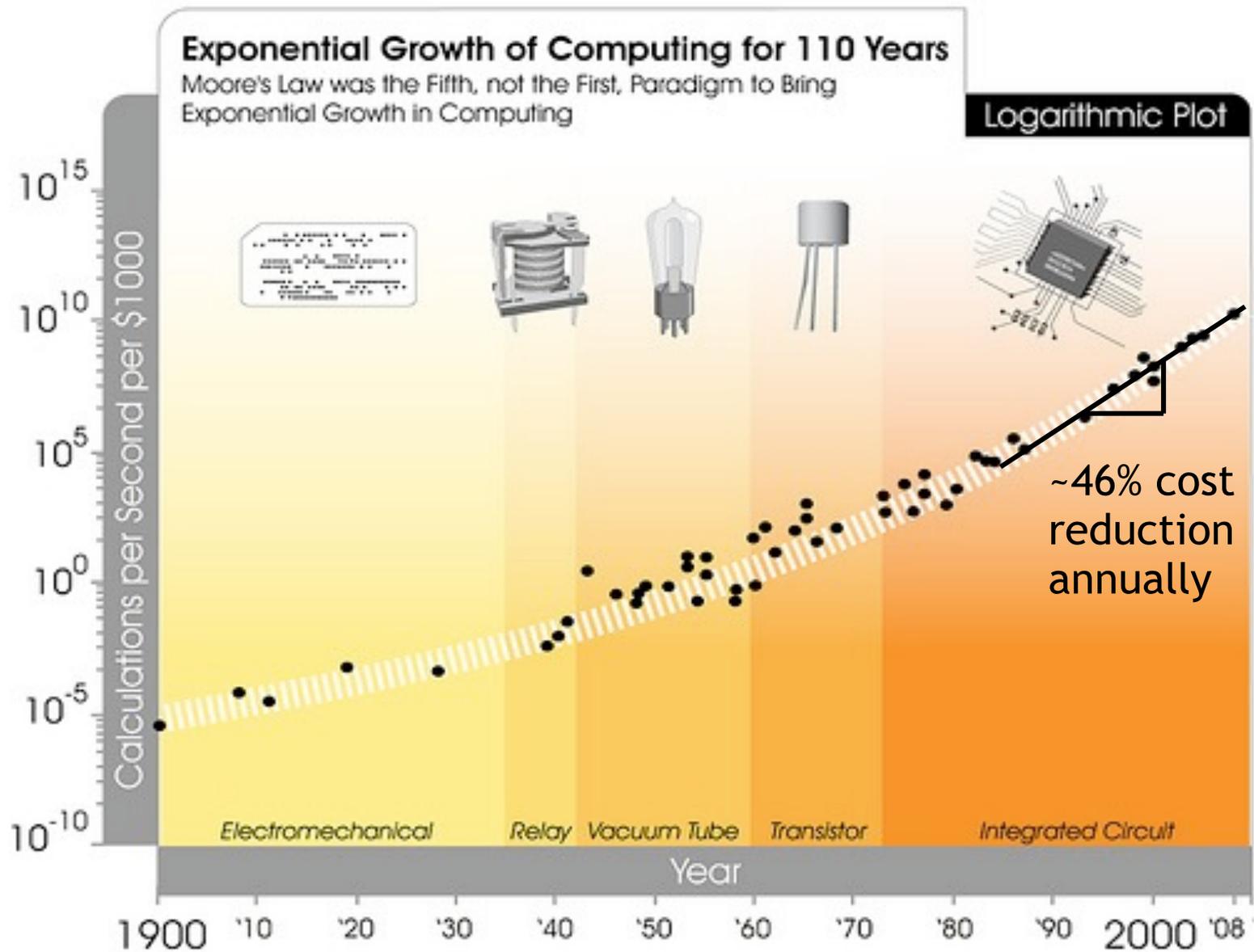
This presentation is posted at cgcan.org/event/the-joy-of-clean-energy/

The Joy of Clean Energy

- **The new realities**
 - Experience curves
 - Cost crossovers in clean energy
 - Energy abundance
- **So what?**
 - Your household
 - Your business
 - Oregon

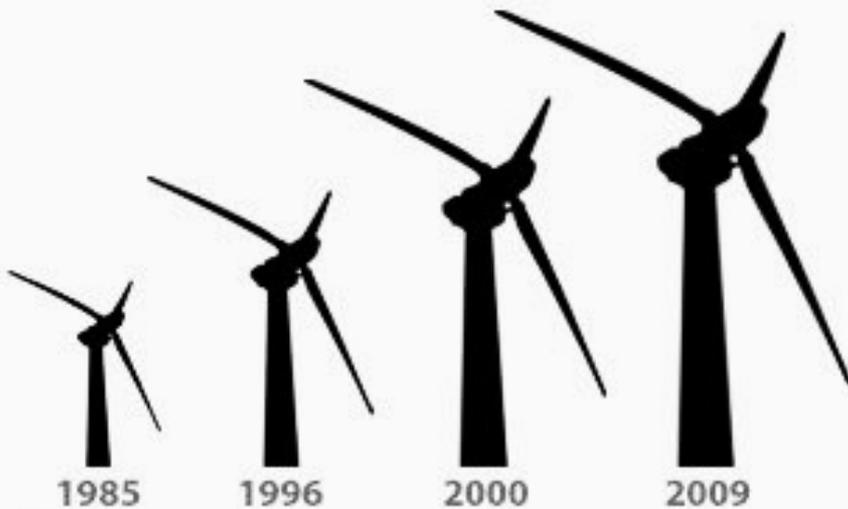


Exponential Cost Reductions in Computing



“Breakthroughs” in Clean Energy

Wind turbine evolution

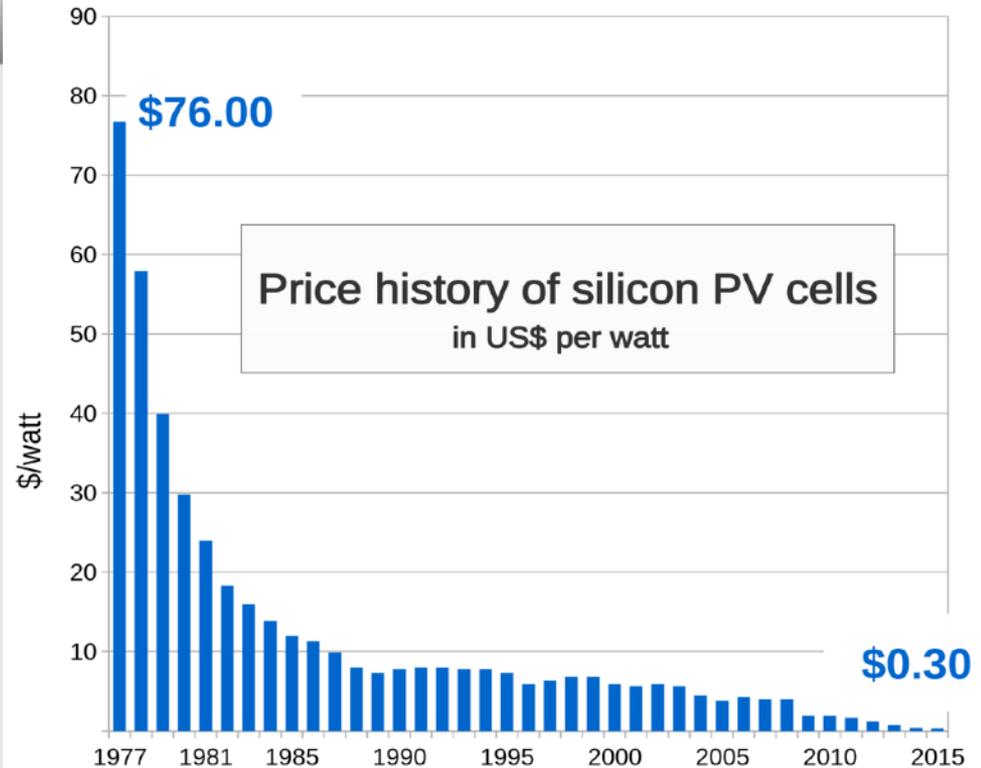


Rotor (yards)

18	44	78	110
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Rating (KW)

100	550	1,650	2,500
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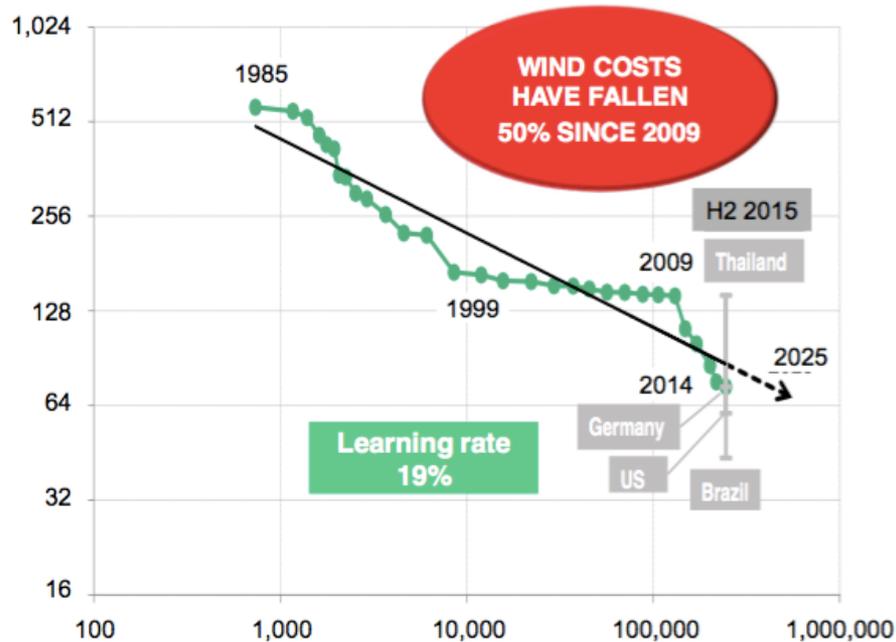
Source: Bloomberg New Energy Finance & pv.energytrend.com

<https://www.youtube.com/watch?v=mmyrbKBZ6SU>

0:33 to 1:33

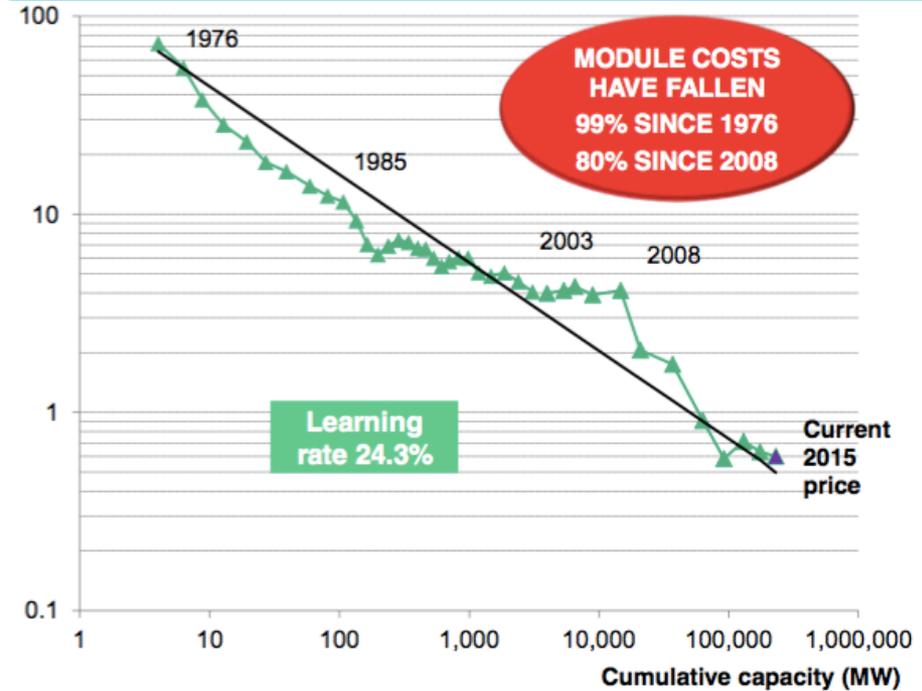
Clean Energy “Breakthroughs” *Predictable for Decades*

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

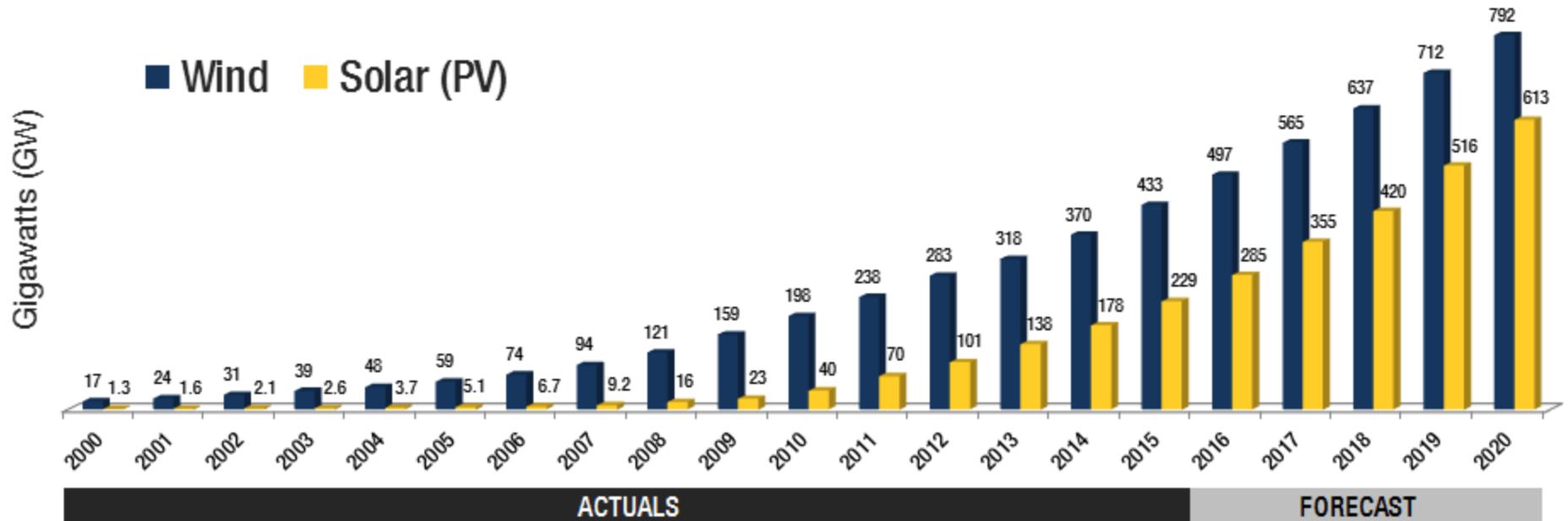
SOLAR PV MODULE COST (\$/W)



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*

Adoption is exponential when prices fall

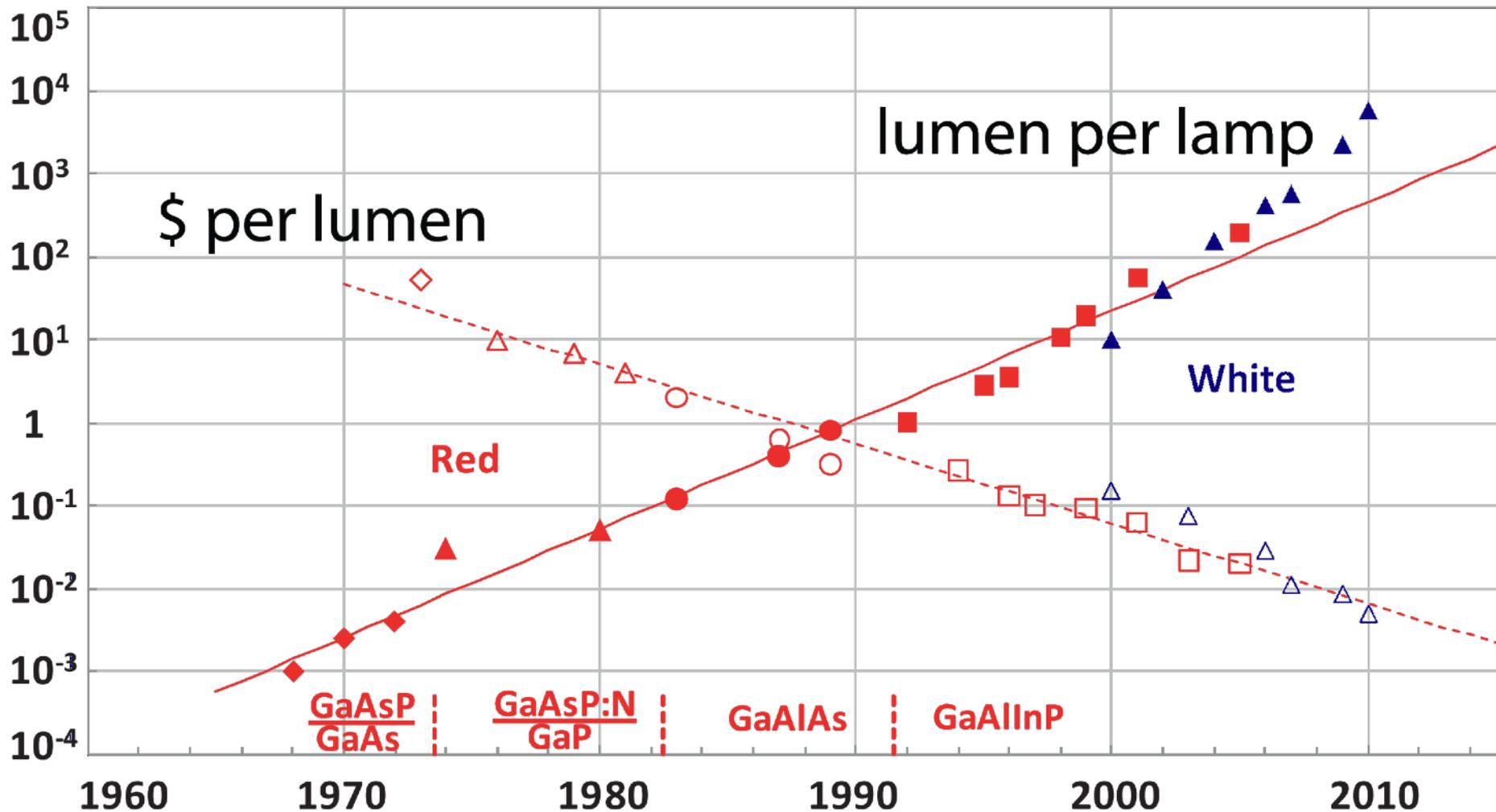


Cumulative global installations through 2015 + forecast.

Source: fi-powerweb.com

Rapid progress in LEDs

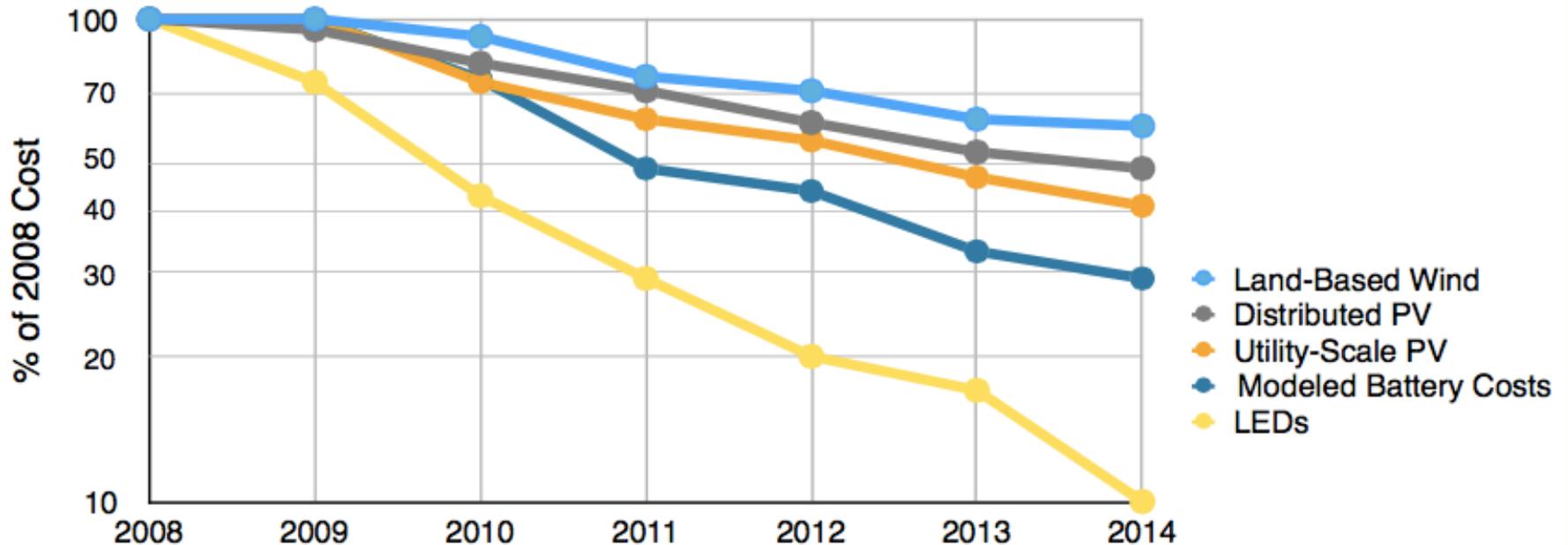
Exponential improvement in cost and light output



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*

When will Electric Vehicles be affordable?

EV MASS MARKET: \$30,000 + 200 MILES RANGE

Bloomberg
NEW ENERGY FINANCE



Tesla Model 3

BMW i3

VW e-Golf

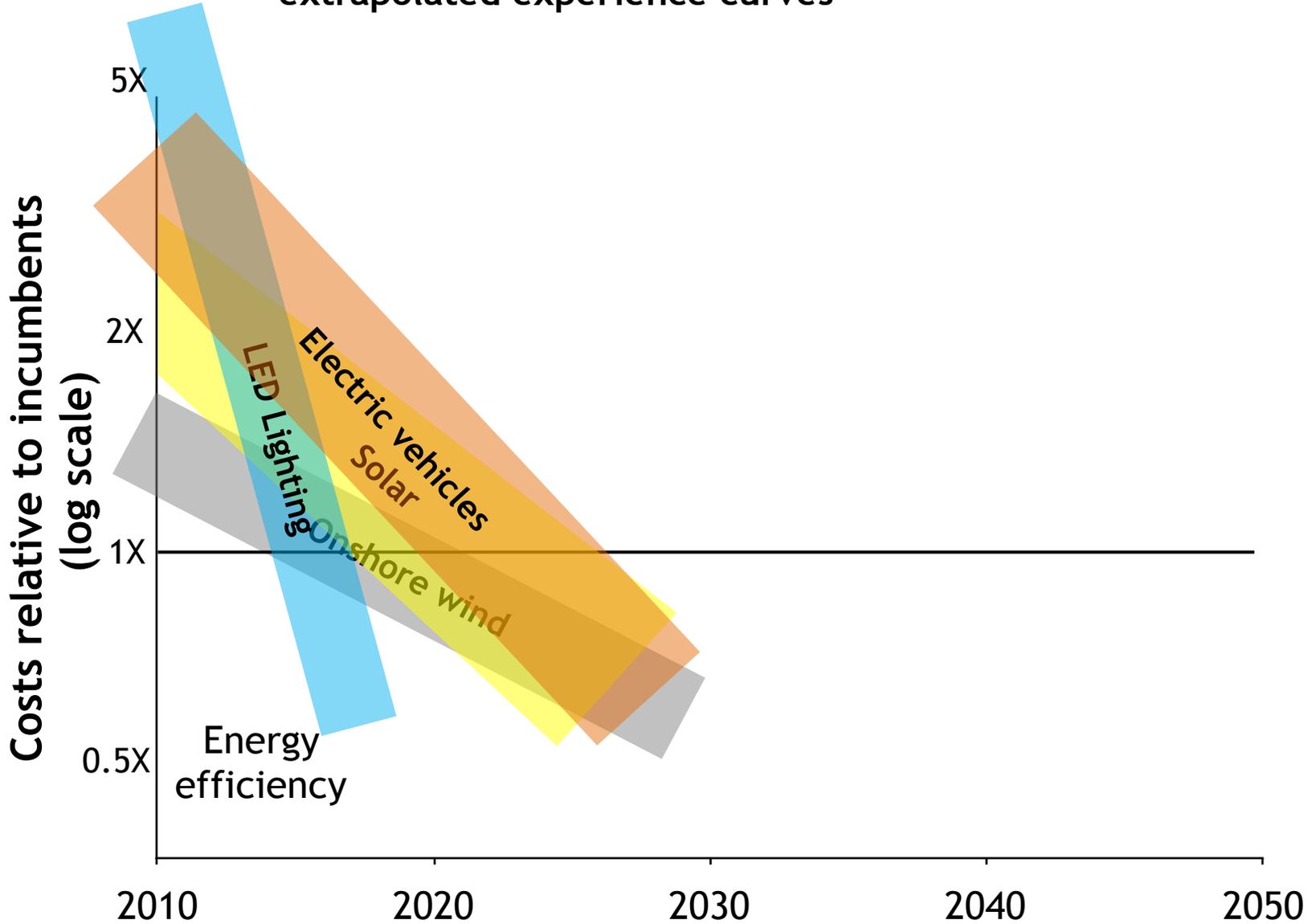
Chevy Bolt

Nissan Leaf

Images: Tesla GM; VW; Nissan; Wikimedia Commons

Clean-Energy Cost Trajectories

extrapolated experience curves



Increasing Energy Abundance

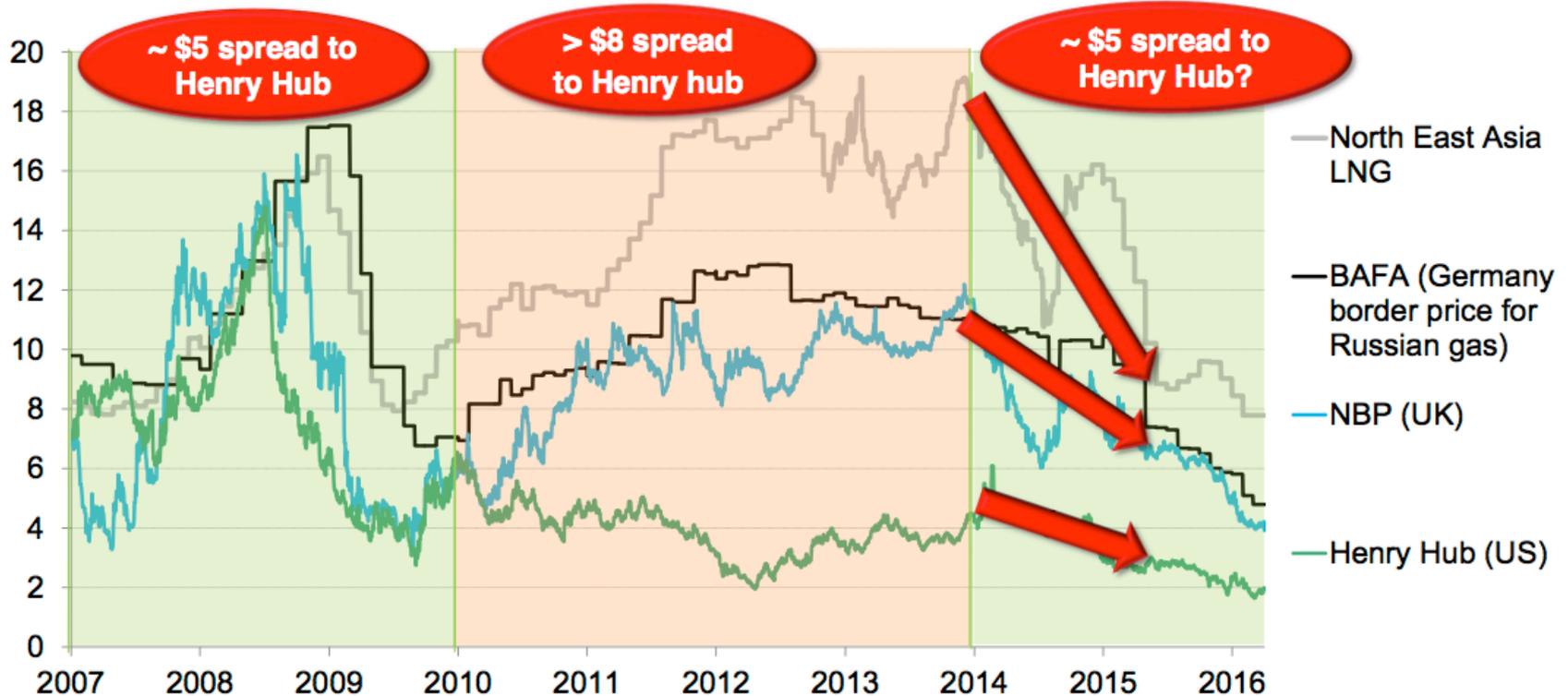
- Renewable sources favored due to zero fuel cost
- Peak demand for coal, then oil, then fossil gas
- Solar and wind get even cheaper

“There’s something like \$130 trillion of capital in institutional investors... They now complain that there aren’t enough green investments for them.”—Mike Eckhart, Citigroup

Coal, Oil, Gas Prices All Declining

GLOBAL NATURAL GAS PRICES (\$/MMBTU REAL 2016\$)

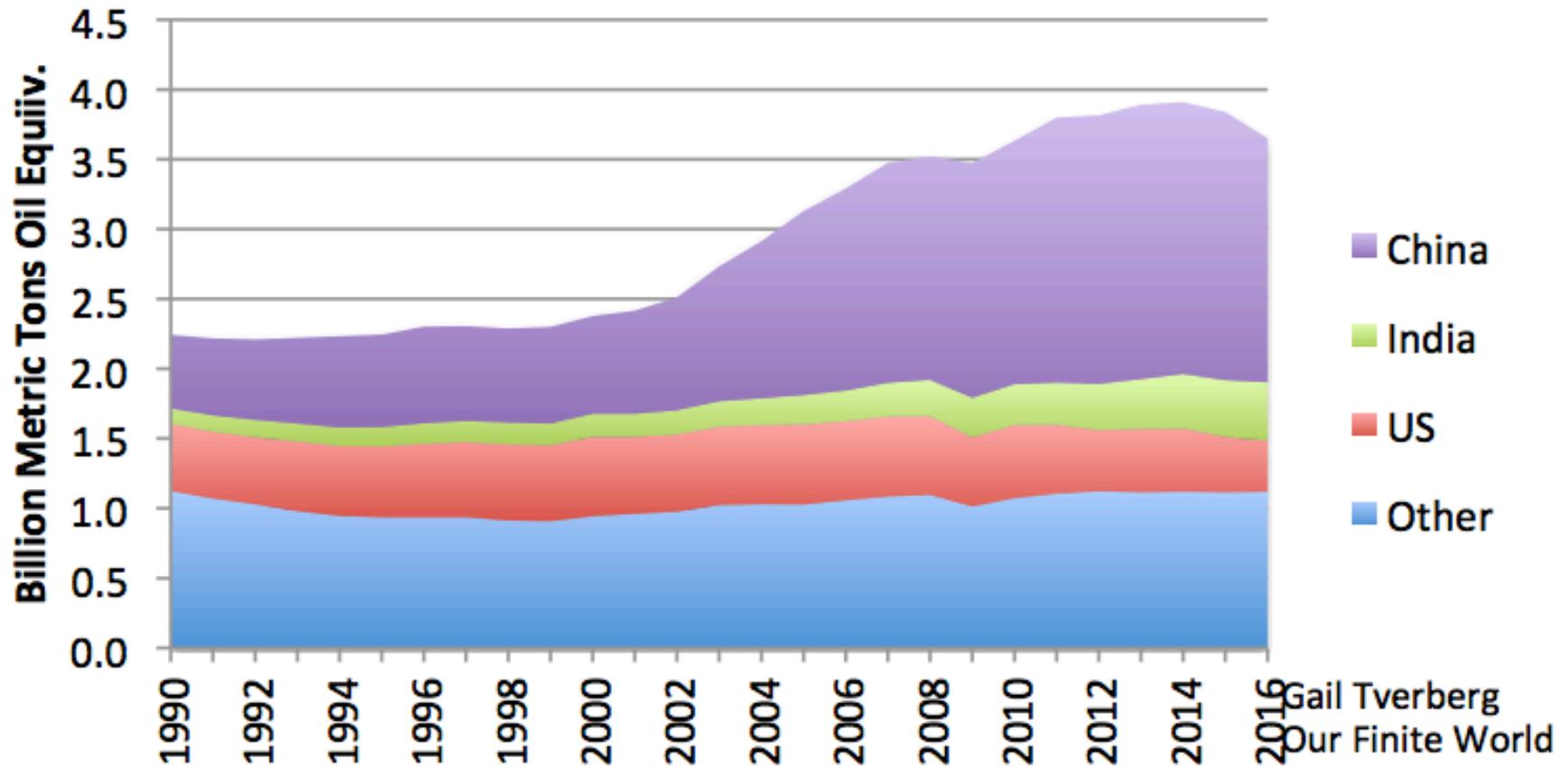
Bloomberg
NEW ENERGY FINANCE



Source: Bloomberg New Energy Finance

Coal demand peaked due to gas, RE

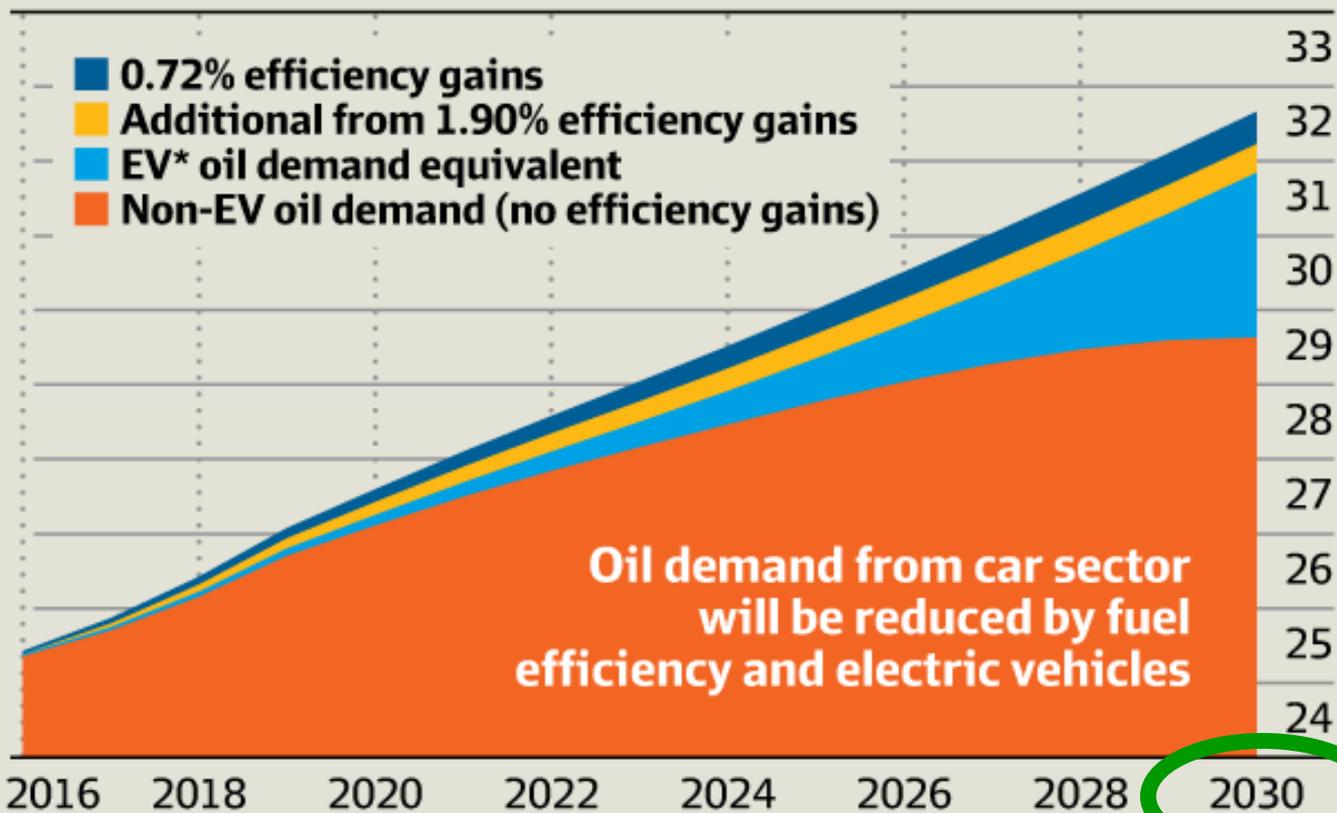
World Coal Consumption - 2016 estimated



Oil demand depends on EV adoptions

Over the hill

Passenger vehicle oil demand (million barrels/day)

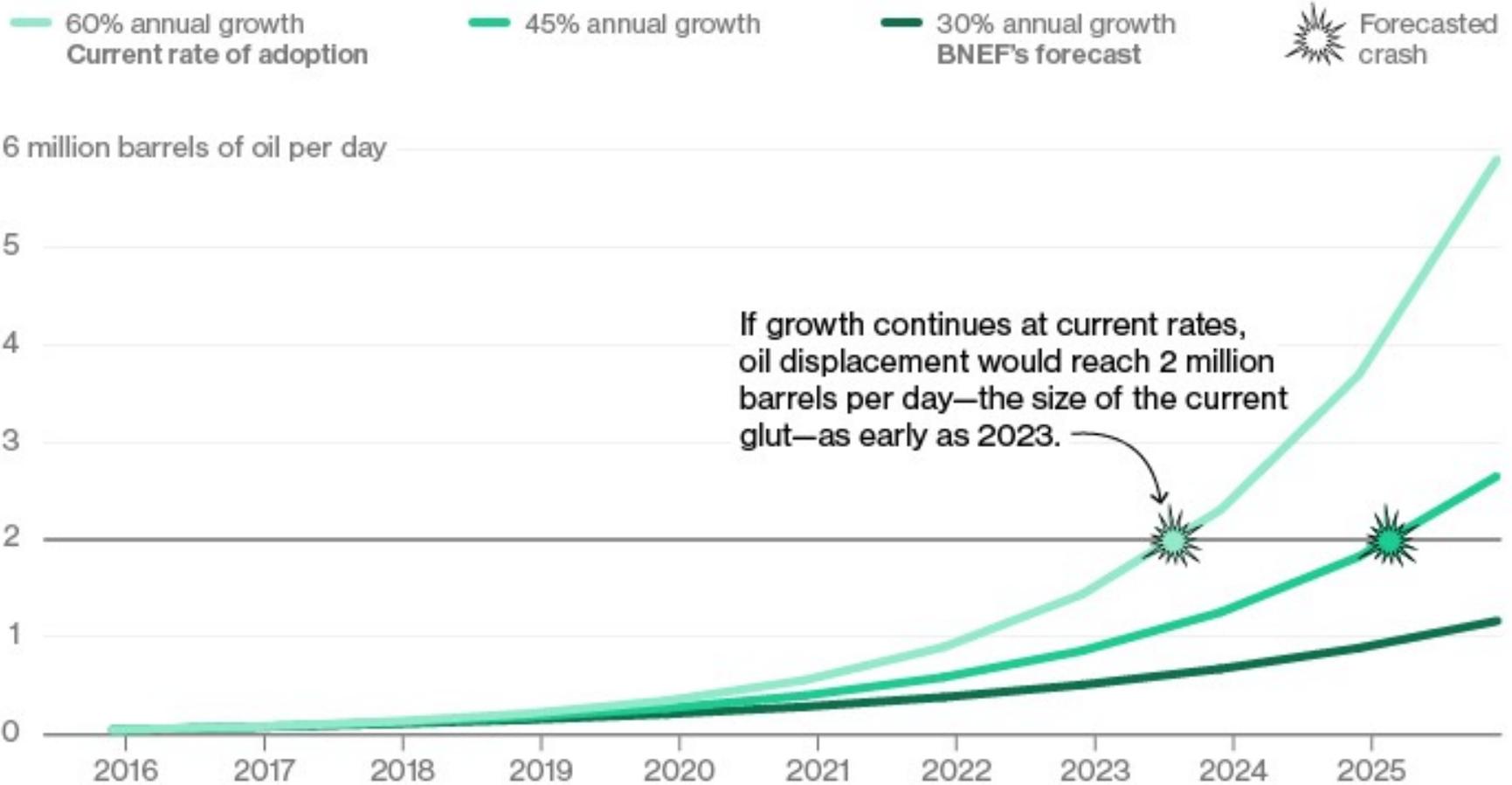


*Electric vehicle 32.5% CAGR

SOURCE: OPEC, IEA, OICA, CITI RESEARCH

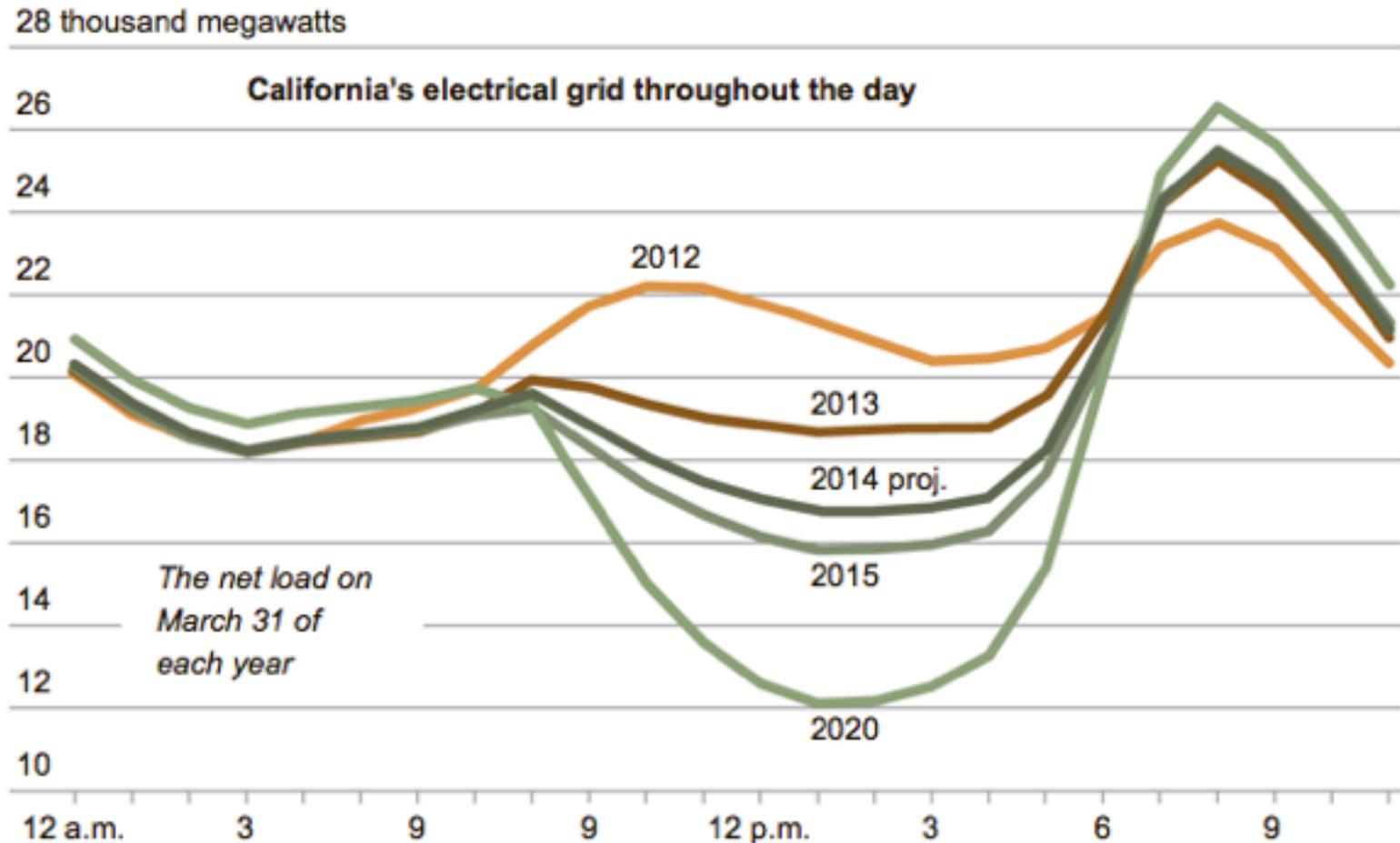
Forecasting the next big oil slump

The amount of oil displaced by electric cars depends on when vehicle sales take off. Here are three scenarios for rising EV sales.



Wind and solar buildouts will be paced by additional resources to stabilize the grid

Baseload vs storage vs transmission vs demand response...



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Implications for households and communities

- Save money on utility bills
- Save money on transportation fuels
- Save time on auto maintenance
- Divest your fossil fuel investments
- *Experience the joy of being part of the solution instead of part of the problem*

[Net-zero retrofit](#)



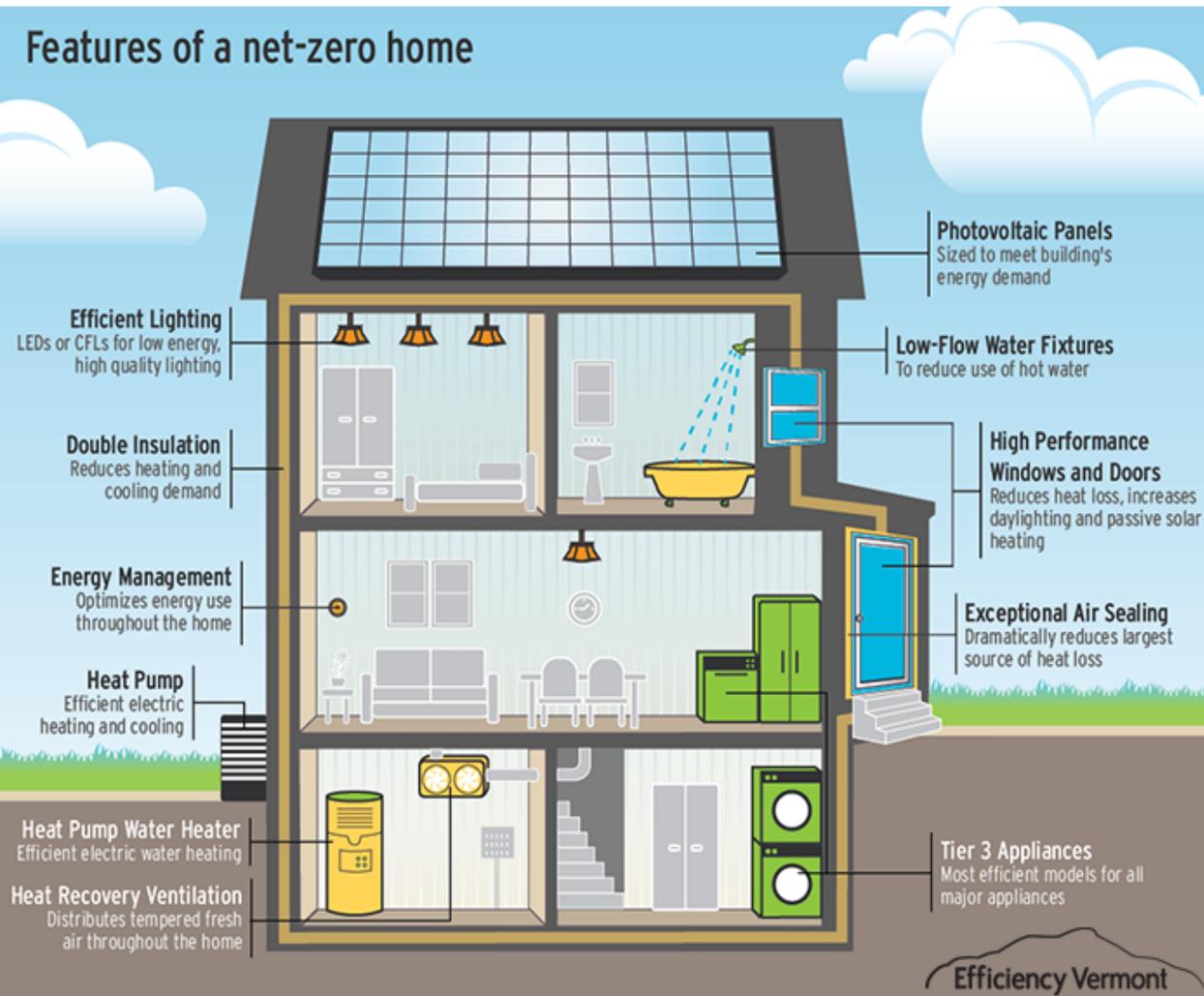
Implications for your household

The 12-step plan for carbon addicts

1. Admit that we all directly or indirectly cause far too much toxic and greenhouse gas emissions due to our fossil-fuel addictions.
2. [Calculate your carbon footprint](#) (about one hour) and sign up for the Gorge Footprint Challenge
3. Create a plan to halve your household footprint while saving money, within 10 years (or less)
4. [Change your driving and home energy consumption habits](#) (~10% emission reduction immediately for an average household)
5. [Buy or lease a zero-emission vehicle](#) (ZEV) to replace one car (~10% reduction)
6. [Cut your air travel](#) in half (1% to 20% or more)
7. [Upgrade your house envelope](#) (better insulation, doors, windows; ~3-10%)
8. [Buy or lease another ZEV](#) to replace the other car (~10%)
9. [Install an electric heat pump](#) and a heat-pump water heater (~5-10%)
10. [Install solar panels](#) or buy green electricity (~10%)
11. [Eat less red meat](#). (~5-10%)
12. At [CGCAN.org](#) and at CGCAN action meetings continuously share support with others. Celebrate that you're incrementally killing Big Coal, Big Oil and Big Gas, while decreasing your household emissions faster than most countries!

<http://cgcan.org/trump-antidote-kick-your-carbon-addiction/>

Decisions in your ten-year plan

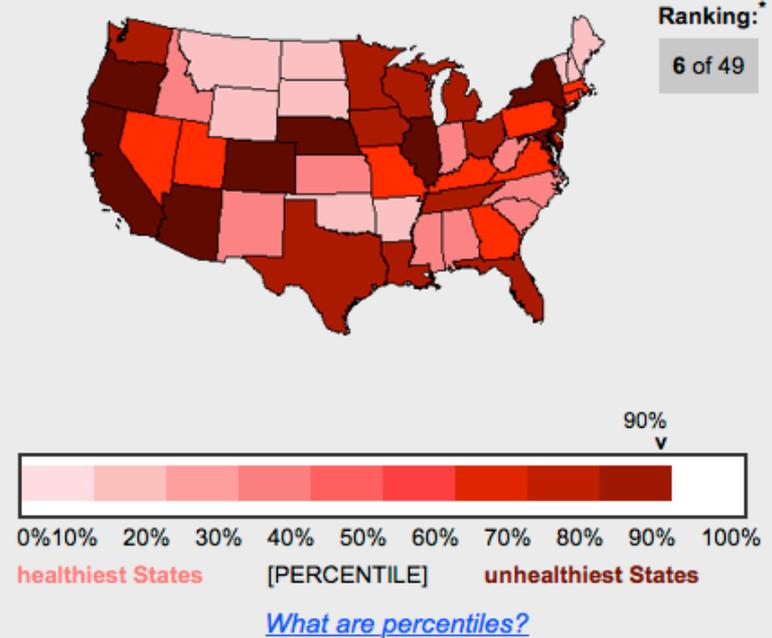


- What actions can I take immediately?
- When should I get an EV?
- Do I like red meat enough to shorten my life?
- When should I get a heat pump?
- How much air travel do I really need?
- When should I get a HPWH?
- Should I get solar or community solar?

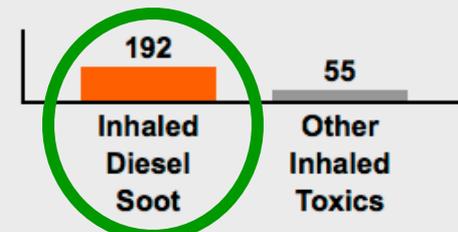
Implications for your business

- 10-year plan to save money and time on buildings and vehicles
- Eliminating diesel emissions also cuts healthcare costs
- Business opportunities in the energy revolution

How the Risk from Diesel Soot in Oregon Compares to the Other Lower 48 States and District of Columbia:



Cancers per Million in Oregon:



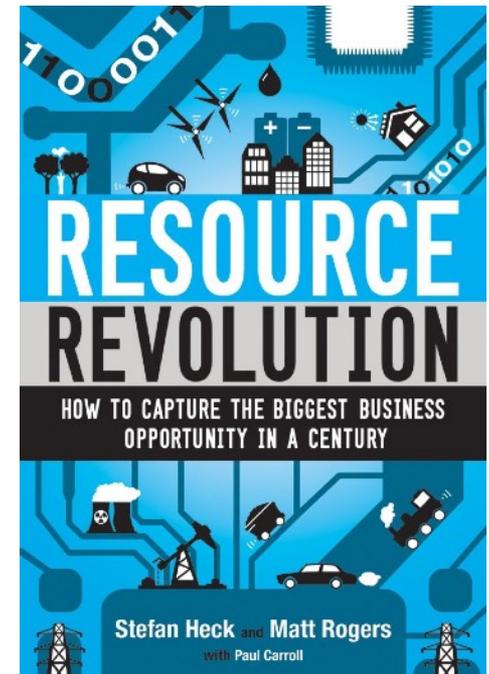
[How did CAIF compare the risk of diesel particulate to other air toxics?](#)

[Source](#)

Implications for Business

New opportunities everywhere

- Wind, solar, smart grid
- Storage, batteries
- Energy and water efficiencies
- Biofuels, biochar, transport
- Recycling, waste recovery
- Integrating across silos
- New business models
- New financing models
- All the associated infrastructure
- Etc., etc.



For entrepreneurs

- What should be electrified next?
- Autonomous EVs on-demand
- What will the new economics enable? (e.g., today, semiconductor memory and radios are free)
- Robots for forest and ag work
- What new infrastructure is implied?
- Infrastructure that monitors itself & needs less maintenance
- Metrology infrastructure
- Products that save both energy and water
- What combinations of technologies will enable new benefits?
- Half-life of market research: ~12 months
- If you're in a global market, how can you achieve and maintain world-class cost-performance?

Managing exponential cost reductions



Clean energy is all about financing

- Wind and solar fuels are free, and operating and maintenance costs are much lower
- Electric vehicles are much cheaper to fuel and maintain
- So it's about getting over the financing hurdle
- Resources:
 - Energy Trust of Oregon
 - GO! Solarize programs (residential and business in the Gorge)
 - Federal tax credits (for a few more years)



Implications for Oregon policies

- Unprecedented opportunity to keep energy spending in the state--\$11 billion is a huge “job-killing tax”!
- We kill as many Oregonians by vehicle pollution as we do in vehicle accidents
- Retooling creates thousands of jobs that can’t be outsourced
- How to efficiently accelerate clean energy adoptions?
- How to [comprehensively plan](#) for energy and emissions?

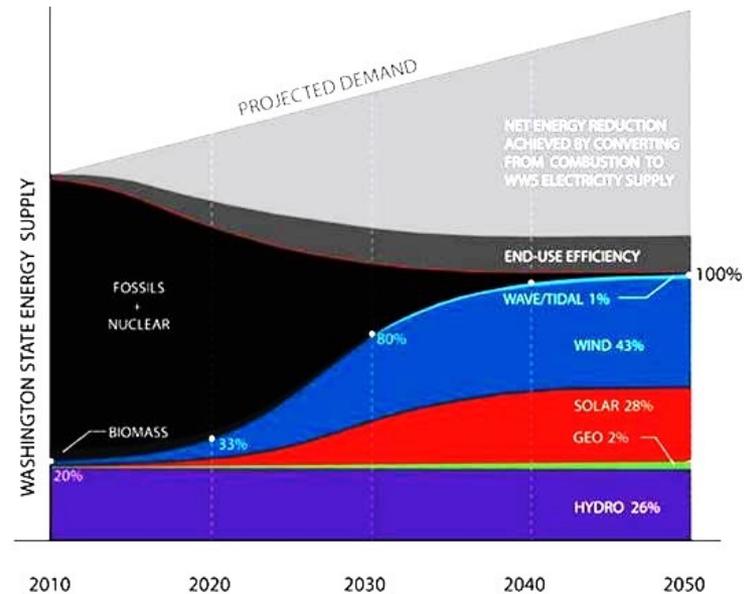
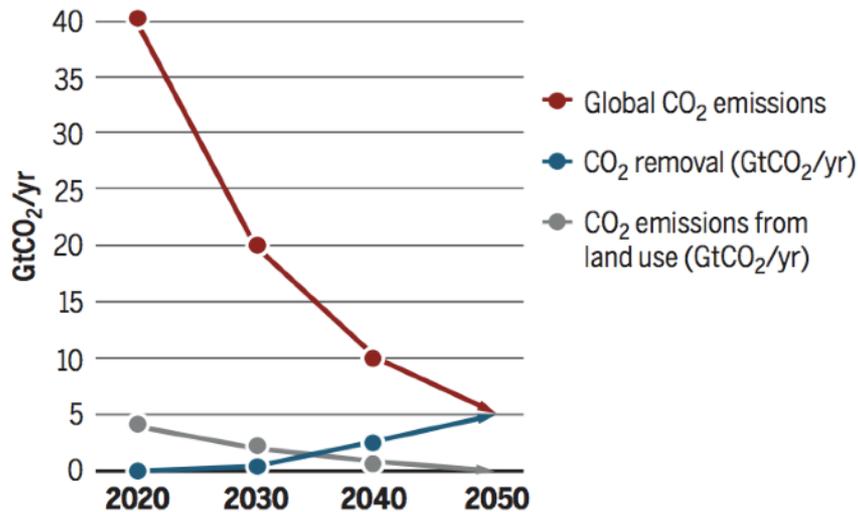


Top-down planning enables long-range view instead of incrementing existing programs

Global Roadmap (2017)

Washington Study (Jacobson 2014)

Global carbon law guiding decadal pathways



- 100% renewables by 2050; hydrogen storage

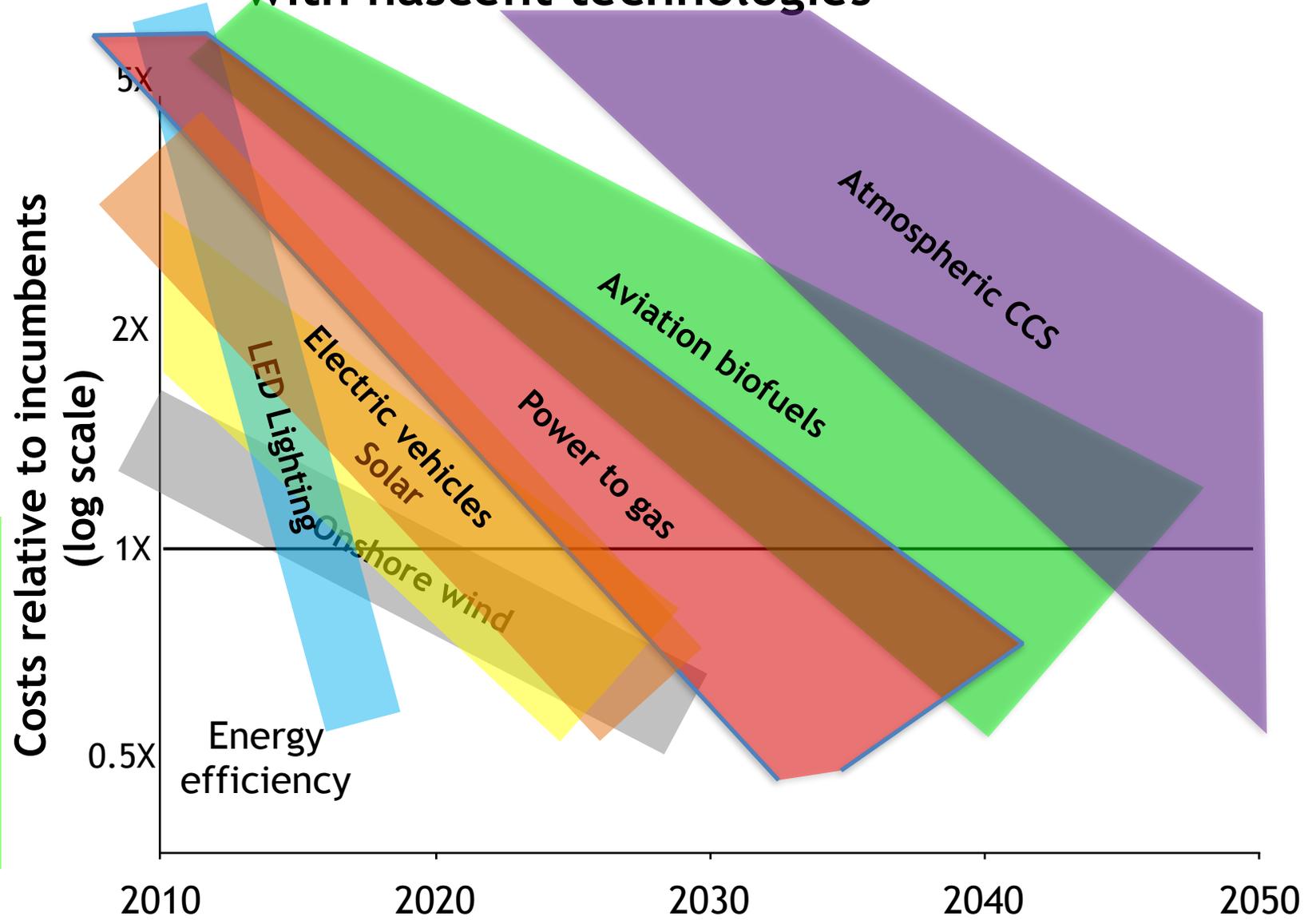
Choosing a goal like zero net emissions by 2050 implies multiple clear objectives

- Clean electricity
 - 100% RPS, from wind, solar, existing hydro, misc.
 - More transmission, demand response, various storage
 - Energy efficiencies necessary but not sufficient
- Clean natural gas
 - 100% RPS, from waste streams, power-to-gas (H₂, CH₄)
 - Main usages may be shipping, heavy trucking, and grid stabilization
- All transport is electric or carbon-neutral biofuels
 - EVs likely for all except heavy freight
 - Trains go electric
 - Aviation biofuels
- Agriculture, forestry, cement,... need new processes
- Atmospheric carbon capture and sequestration processes

Clean-Energy Cost Trajectories

with nascent technologies

Research
Development
Pilot deployment
Mass markets

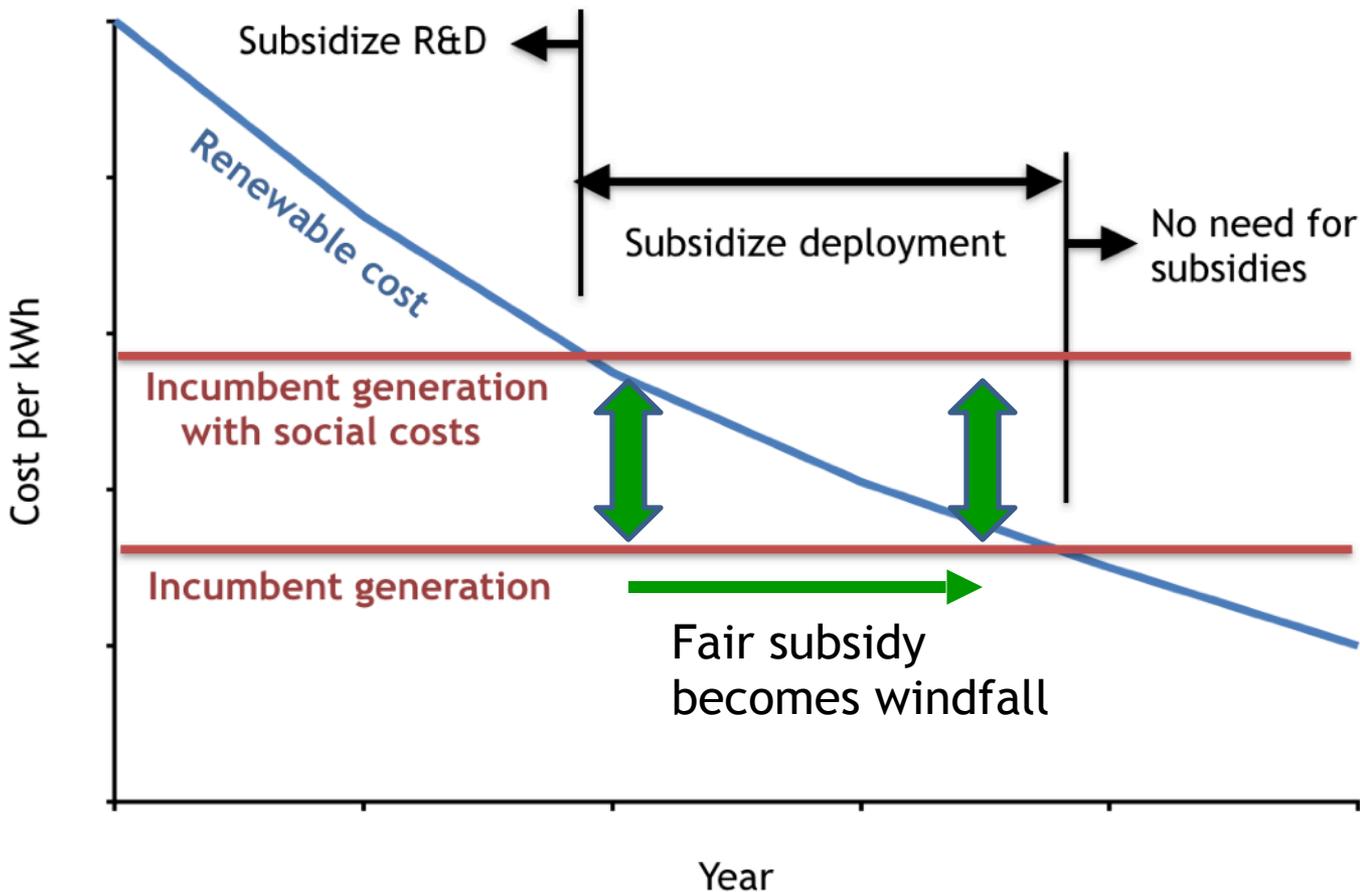


What will decarbonizing Oregon cost?

1. Most of our dirty infrastructure will be replaced within 30 years anyway
2. As clean energy gets cheaper, the transition cost arguably goes negative
3. Depends on the cost of capital to finance it
 - Green banks are leveraging public capital by 3X to 12X
4. The transition creates many jobs and ongoing savings
5. Social costs of fossil fuels are very high

Subsidies must consider cost trajectories

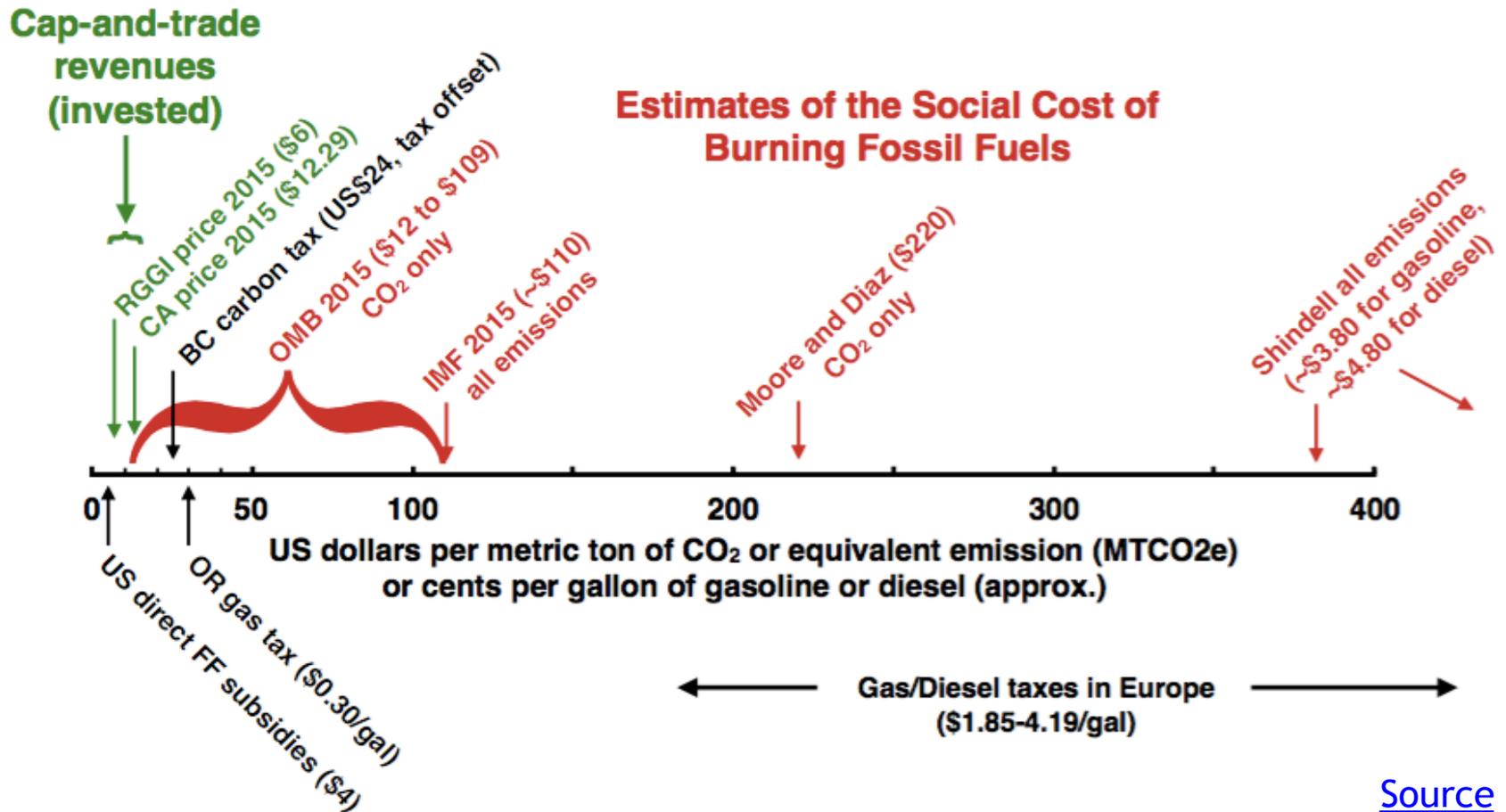
How to Accelerate Clean-Energy Deployment?



If prices were fair, we'd have dumped fossil fuels long ago

Various Costs and Prices of Fossil-Fuel Damages

(Dollars per ton of CO₂)



Political Implications

“The energy industry is probably the most macho and socially backwards and corruption-ridden industry in the world. That’s not even controversial.”-- Michael Liebreich, BNEF

“The Senate is now controlled by the Koch brothers.” - Jeff Merkley, 2016

Clean Energy is NOT Partisan

Why do so many Republicans support taking action to accelerate the development and use of clean energy?



Support so American innovation can create economic growth and jobs at home



Support so America is less dependent on energy from the Middle East

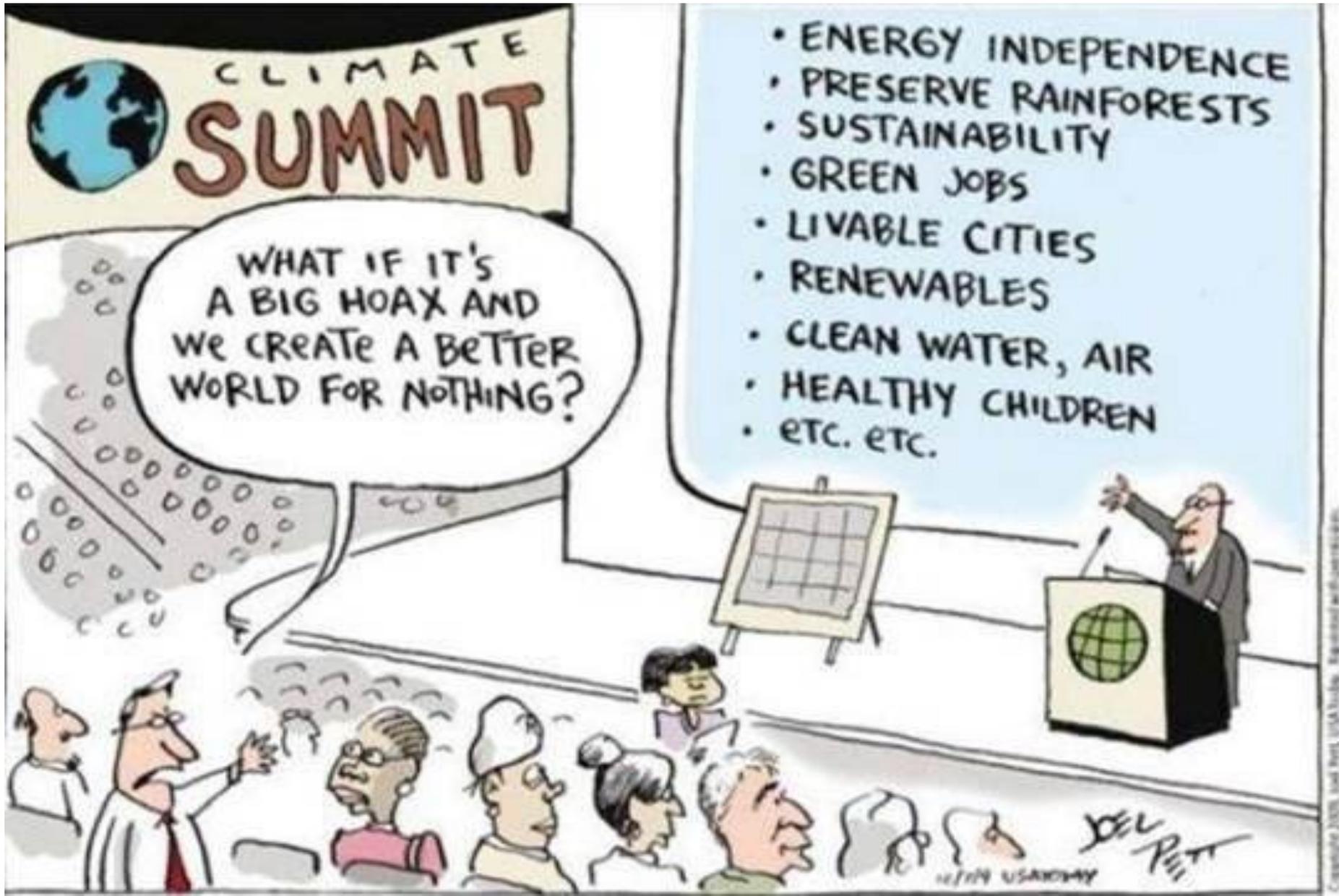


Support so America will have cleaner, healthier air and less pollution

"The best messaging on clean energy **de-politicizes** climate and emphasizes the wide array of benefits that clean energy provides."

Kristen Soltis Anderson, partner at Echelon Insights

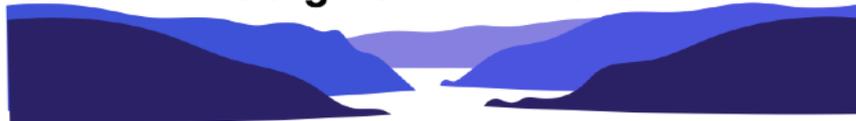
Clean Energy is an existential problem for Big Oil



Summary

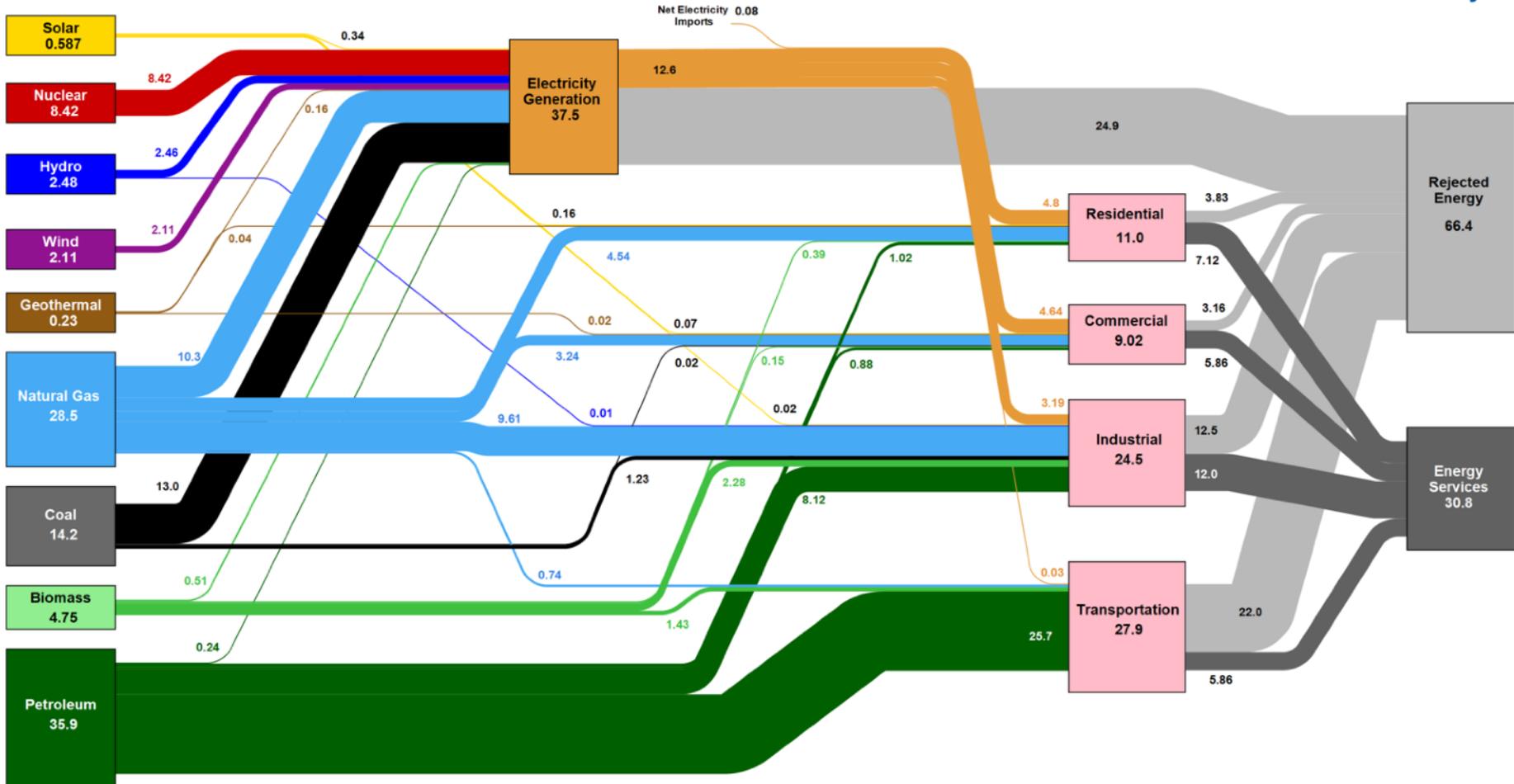
- A massive clean energy transition is accelerating
 - Wind and solar ramping now
 - Storage and EVs next
- Clean energy is **cheaper** and **healthier**
- \$11B “tax” savings available to Oregon, plus many billions in healthcare costs
- Retooling creates thousands of jobs
- Divest from fossil fuels now and plan for the next-gen infrastructure

Columbia Gorge Climate Action Network



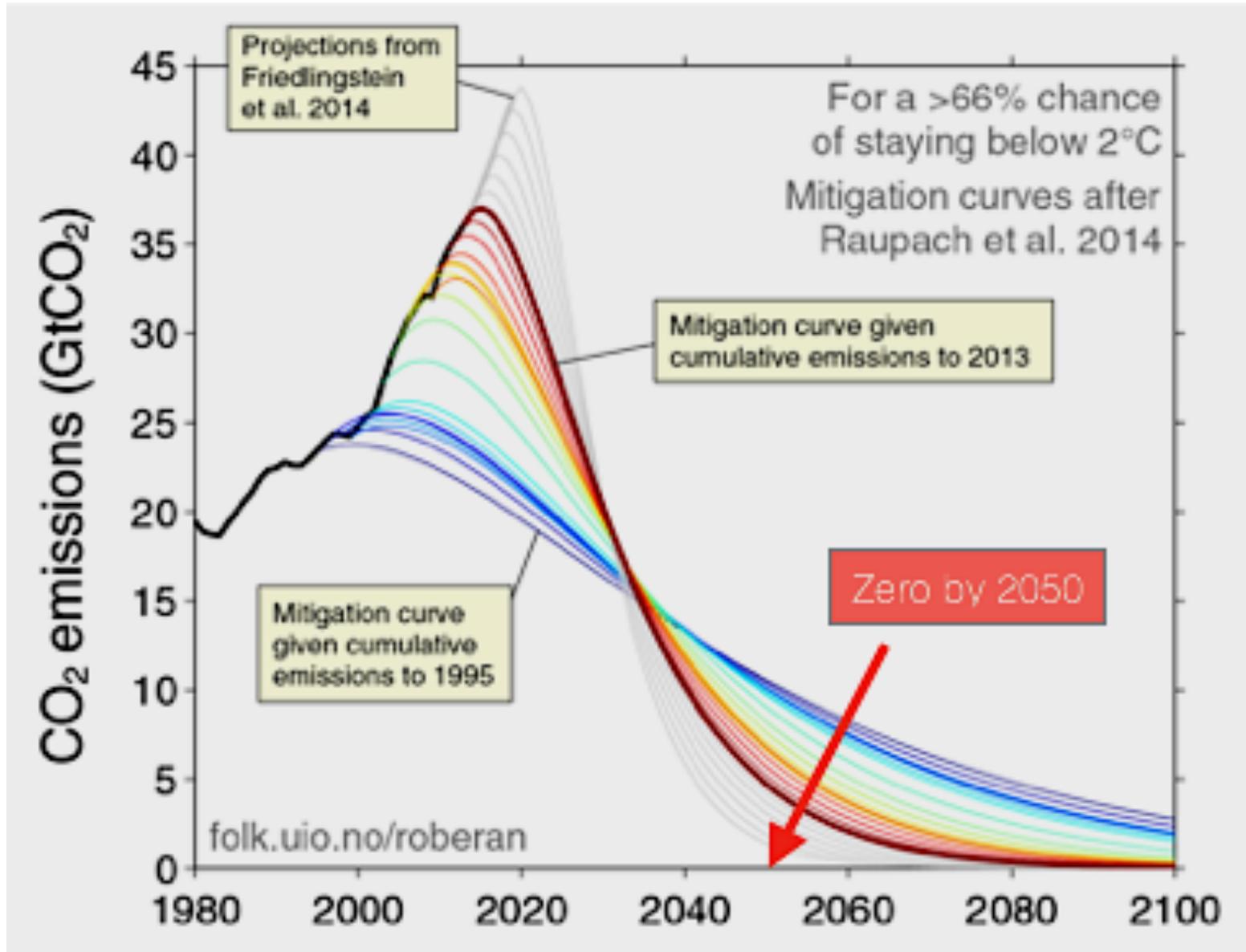
More data

Estimated U.S. Energy Consumption in 2016: 97.3 Quads

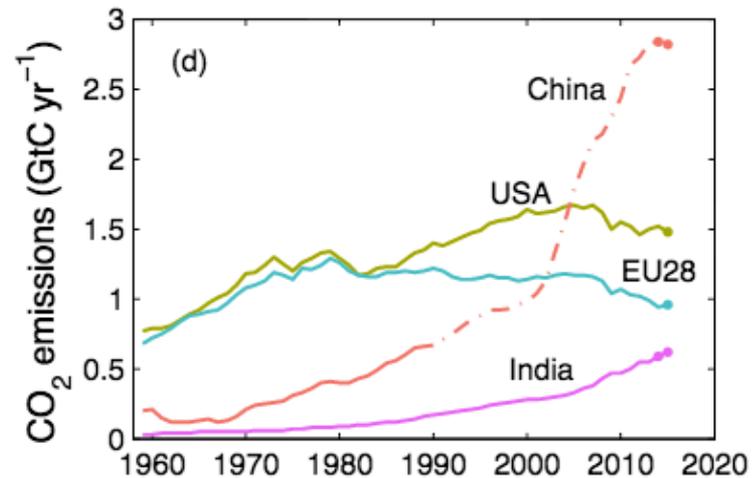
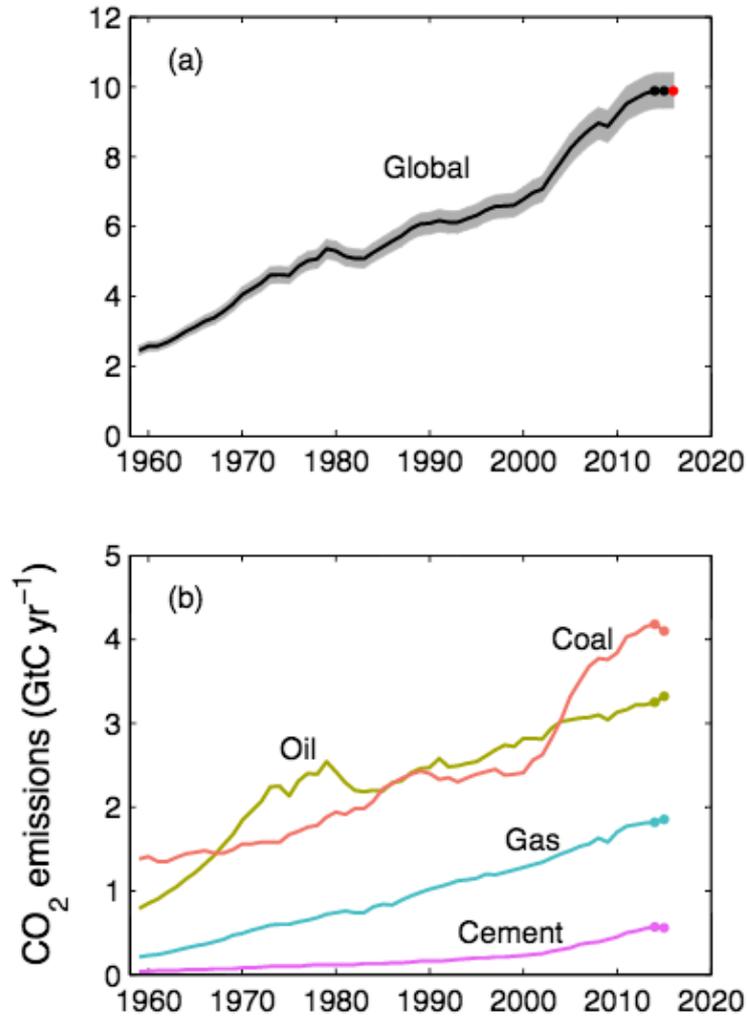


Source: LLNL March, 2017. Data is based on DOE/EIA MER (2016). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Need Zero Emissions by 2050



Global GHG Emissions

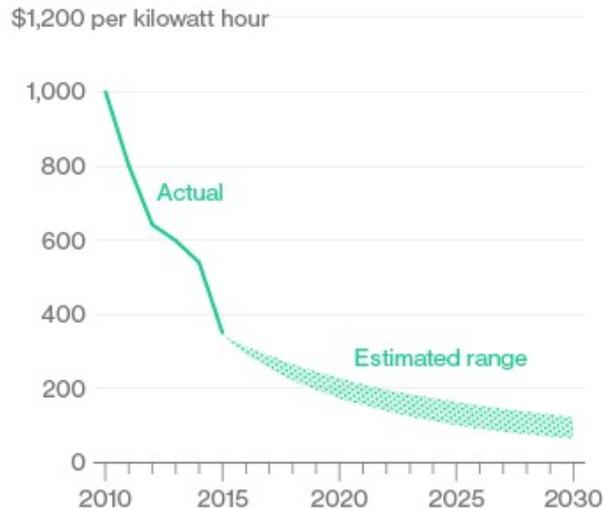


Li-ion battery cost trajectories

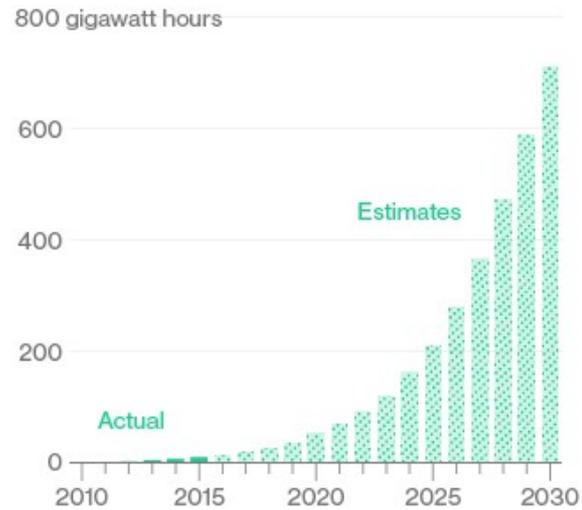
It's All About the Batteries

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

P2G Plant near The Dalles?

- Power-to-gas (P2G): use excess wind or solar power to make hydrogen or methane for seasonal storage
- P2G being developed and deployed in Europe

