



Vehicle production costs & Total cost of ownership

ECI 189G: Lecture 7

Dan Sperling

Alan Jenn

Spring 2022



Production costs

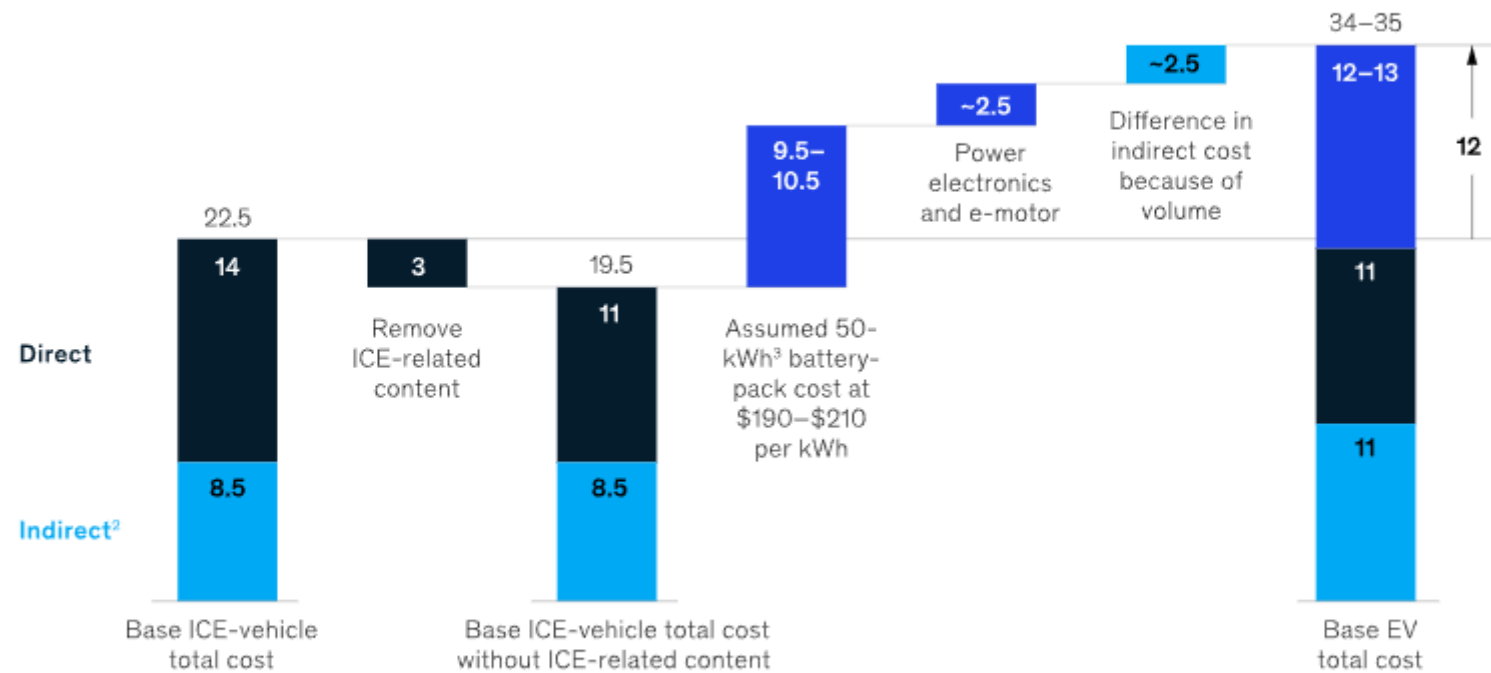
Vehicle production costs

- Vehicles have been mass produced for over 100 years, starting with the Ford Model T
- In a heavily competitive market across dozens of automakers, the production has been extremely refined and costs are well understood



How much do electric vehicles cost?

Cost walk of ICE¹ to electric-vehicle (EV) C-Car in 2019, estimated average per vehicle, \$ thousand



¹Internal combustion engine.

²Includes average incentive cost of \$2,000.

³Kilowatt-hour; includes battery-management system.

Source: Industry experts; UBS; McKinsey analysis

EV Supply Chain

Raw material
mining



Battery cell
manufacturing



Battery pack
assembling



EV
manufacturing



EV component
recycling



EV services

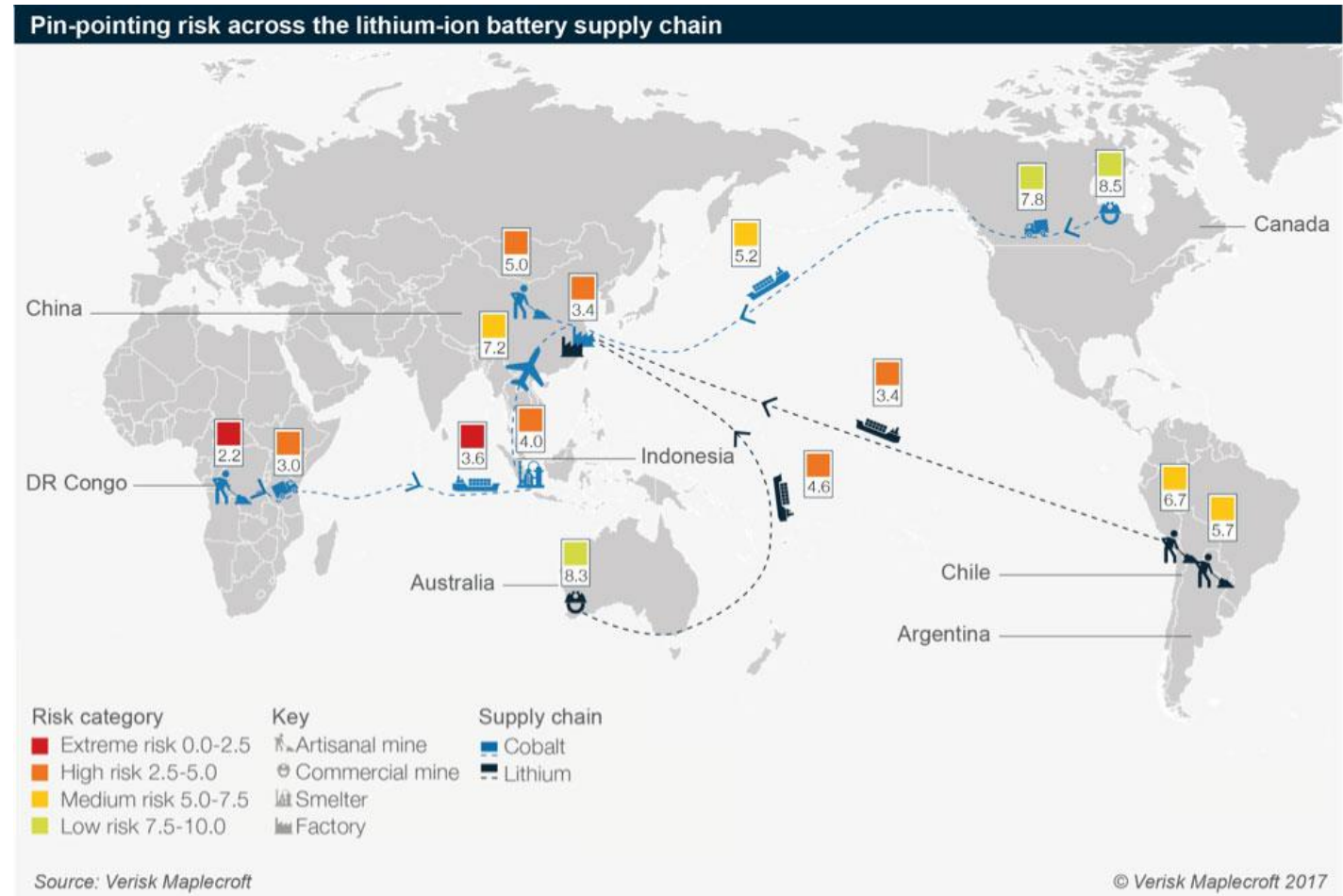


EV sales and
dealership

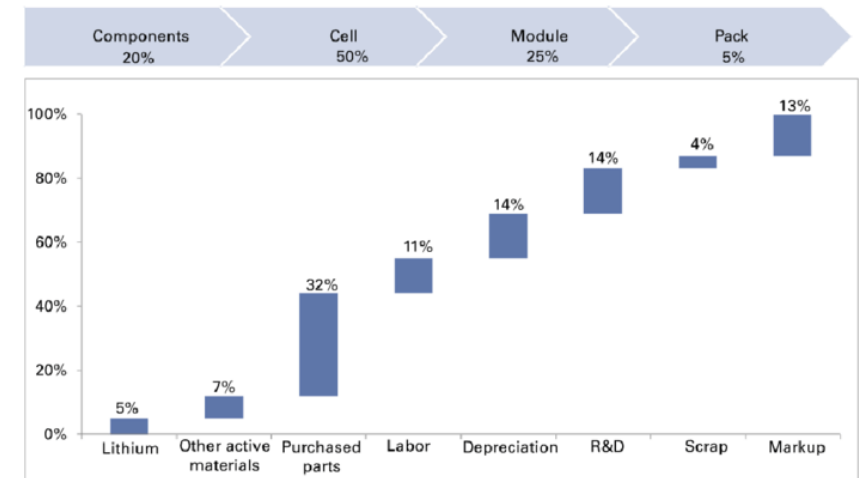
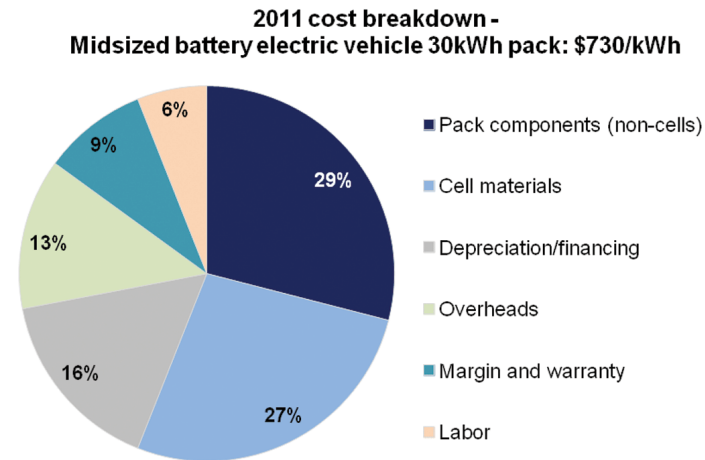
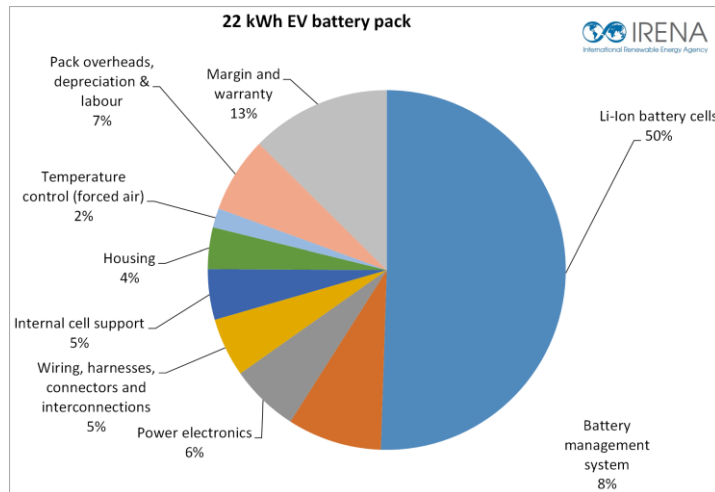


Battery material supply chain

- Much higher reliance on international markets
- Higher risks for some materials:
 - “conflict” minerals linked to child labor
 - Environmental damages and questions of mining sustainability



Battery cost breakdown



- Details of battery costs are difficult to measure accurately! Often confidential information due to competitive secrecy
- Many components of costs that studies have attempted to estimate—though there is substantial variation in the numbers...

Economies of Scale (the more you build)

- Cost advantages that increase based on the scale of operation
- Common sources of scaling:
 - Purchasing in bulk (discounting in contracts)
 - Managerial specialization
 - Financial scaling (better interest rates when borrowing money)
 - Marketing (spreading costs of advertising)
 - Technological (returns to scale in production)

Learning Curves (the more you build it)

- The idea that technologies become cheaper with increased production: the more a task is performed, the less time is required on each subsequent iteration
 - Labor efficiency – workers become more dexterous, mentally more confident, less hesitancy, learning shortcuts
 - Standardization specialization, methods improvements – standardization tends to increase efficiency
 - Technology-driven learning – automated production technology
 - Better use of equipment – higher production leads to better exploitation of equipment
 - Changes in the resource mix
 - Product redesign
 - Use-cost reductions
 - Shared experience effects

Example learning curve calculation

- There are several different ways to calculate a learning curve, but a basic function might look like:

$$Y = aX^{\ln(b)}$$

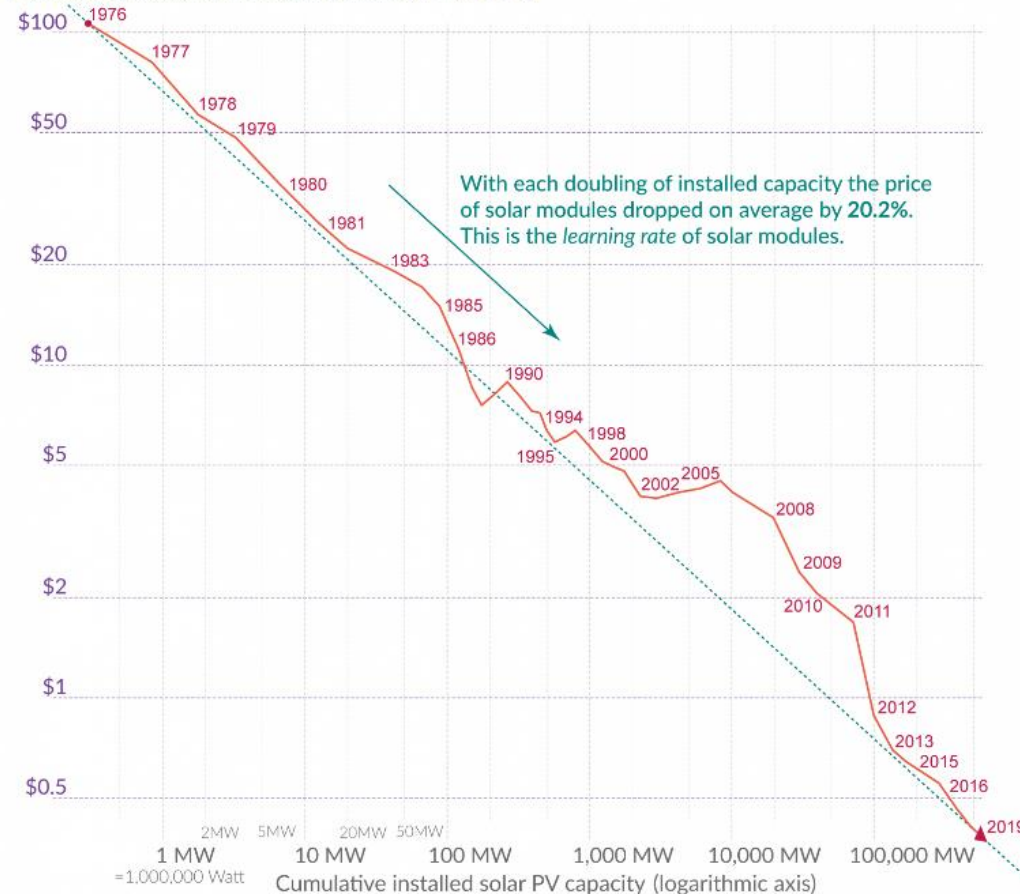
- Where:
 - Y = cumulative cost per unit
 - a = cost of the first unit produced
 - X = cumulative number of units produced
 - b = learning parameter
- This is a simple exponential decay function!

Example of learning rates for solar PV

The price of solar modules declined by 99.6% since 1976



Price per Watt of solar photovoltaics (PV) modules (logarithmic axis)
The prices are adjusted for inflation and presented in 2019 US-\$.



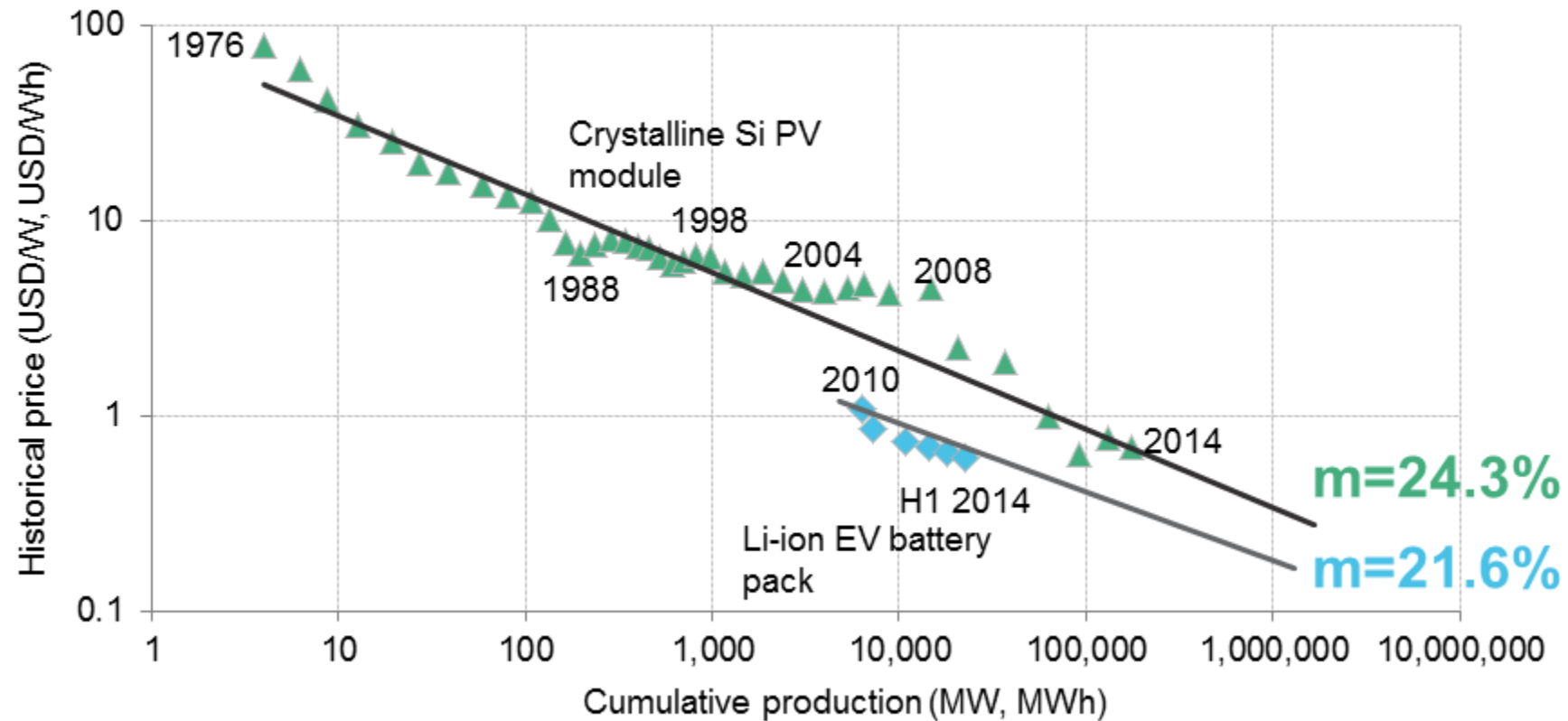
Data: Lafond et al. (2017) and IRENA Database; the reported learning rate is an average over several studies reported by de La Tour et al (2013) in Energy. The rate has remained very similar since then. OurWorldinData.org - Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the author Max Roser

Li-Ion Learning Curve

LITHIUM-ION EV BATTERY EXPERIENCE CURVE
COMPARED WITH SOLAR PV EXPERIENCE CURVE

Bloomberg
NEW ENERGY FINANCE



Note: Prices are in real (2014) USD.

Source: Bloomberg New Energy Finance, Maycock, Battery University, MIT

Michael Liebreich, New York, 14 April 2015

@MLiebreich

#BNEFSummit

1



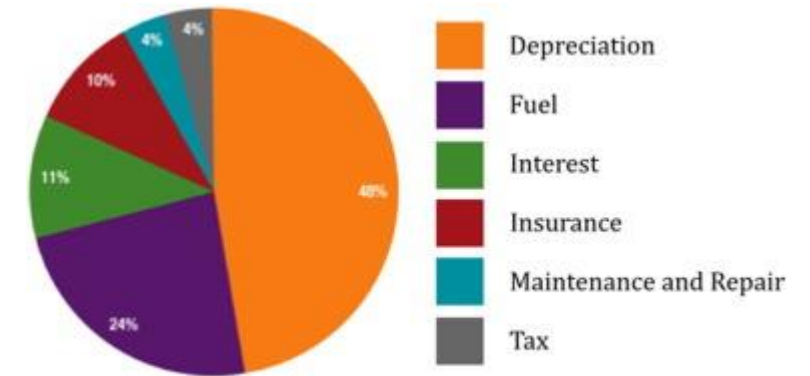
Total Cost of Ownership

Total Cost of Ownership (TCO)

- Consider the question: is an EV cheaper or is a gasoline car cheaper? What does this mean?
- Purchasing a new car represents only a portion of the total costs, there are many other cost components of owning a car
- Why do we care about the TCO?
 - Now with different vehicle technologies, comparing just the purchase price doesn't provide an apples-to-apples comparison of the cost of owning a vehicle

Components of Total Cost of Ownership

- Common cost components to consider in a TCO analysis:
 - Purchase price and associated interest
 - Fuel
 - Insurance
 - Maintenance and repair
- How do *you* think each of these components compare in gas vs electric cars?



5-year owner costs

Total cost of ownership for the typical newly bought vehicle in the US (Consumer Report, 2015).

Vehicle Purchase Price

- There are actually three (!) different prices to keep in mind:
 - Manufacturer's suggested retail price (MSRP)
 - Dealership listing price
 - Transaction price
- Ideally the transaction price would be used for analysis, but this data can be hard to come by
- Tesla doesn't have dealerships! What you see online is what you get, no more negotiation hassles...but they change their MSRP constantly!



Model 3
Standard Range Plus

Price
\$36,990

Range
263 miles (Est.)

Model 3
Long Range

\$45,990

353 miles (EPA est.)

Model Y
Long Range

\$48,990

326 miles (EPA est.)

How do we compare costs of different fuels?!

PG&E ENERGY STATEMENT Account No: 1023456789-0
www.pge.com/MyEnergy Statement Date: mm/dd/yyyy
 Due Date: mm/dd/yyyy

2 Service For:
 RESIDENTIAL CUSTOMER
 1234 MAIN STREET
 ANYTOWN, CA 00000

3 Your Account Summary

Amount Due on Previous Statement	\$57.87
Payment(s) Received Since Last Statement	-57.87
Previous Unpaid Balance	\$0.00
Current Electric Charges	\$58.09
Current Gas Charges	5.81
Total Amount Due by XX/XX/20XX	\$63.90

4 Questions about your bill?
 Monday-Friday 7 a.m.-9 p.m.
 Saturday 8 a.m.-6 p.m.
 Phone: 1-800-743-5000
www.pge.com/MyEnergy

5 **6** **7** **8** **9**

Ways To Pay
www.pge.com/waystopay

Your Enrolled Programs
 CARE Discount

Monthly Billing History

Daily Usage Comparison

1 Year Ago	Last Period	Current Period
10.21	9.08	5.30
Electric kWh / Day		
0.16	0.16	0.16
Gas Therms / Day		

Visit www.pge.com/MyEnergy for a detailed bill comparison

Important Messages
Neighborhood payment centers Did you know it's FREE to pay your PG&E bill at any of our 600 authorized neighborhood payment centers? Payments made by 5 p.m. will post to your PG&E account the same day. Locations and times of operation may be more convenient for your schedule. Call 1-888-743-0011 to find a location near you.

VS.



Calculating fueling costs: gasoline

- Let's consider an "average" gas car in the US (about 25 MPG) with gas prices of \$5 per gallon
- How much does it cost to drive per mile?

$$\frac{\$5}{\text{gallon of gas}} \times \frac{1 \text{ gallon of gas}}{25 \text{ miles}} = \frac{\$0.20}{\text{mile}}$$

- How much would it cost to drive a more efficient Toyota Prius (about 55 MPG)?

$$\frac{\$5}{\text{gallon of gas}} \times \frac{1 \text{ gallon of gas}}{55 \text{ miles}} \approx \frac{\$0.09}{\text{mile}}$$

Cost of fueling EV

EVgo Fast Charging Pricing

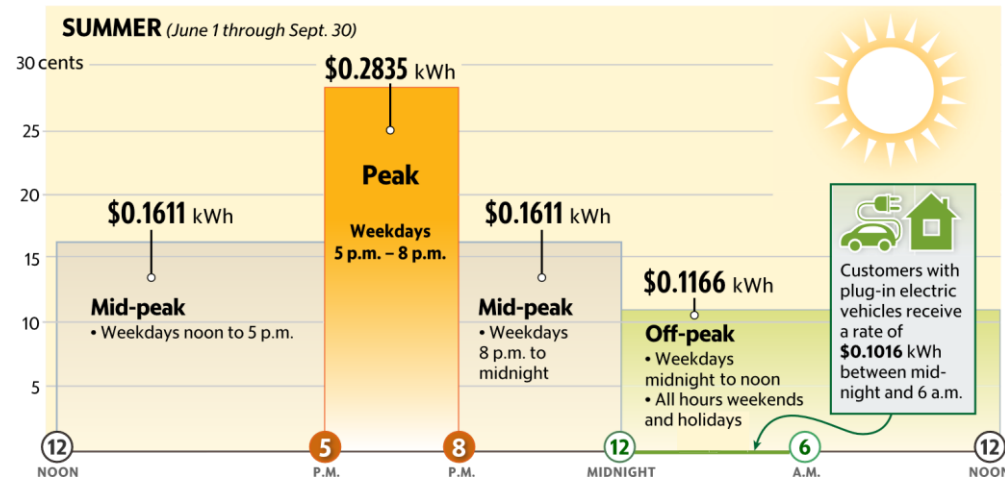
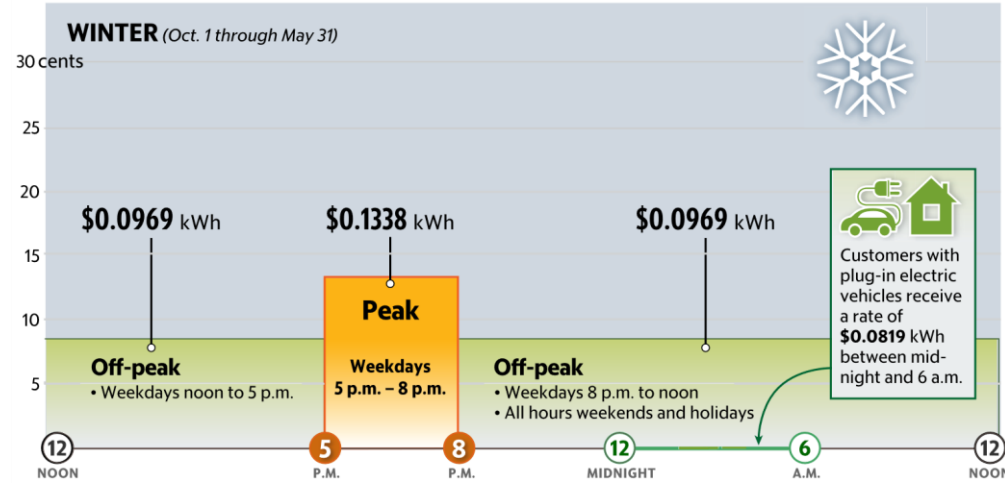
Choose Your Region
CA - Bay Area

Plan	Starting at (per kWh)	Recommended for
Pay As You Go	\$0.29 ⁺	occasional charging
EVgo Member	\$0.29 ⁺	1x month charging
EVgo Plus™	\$0.25 ⁺	lowest rates

Rates in CA vary based on Time of Use (TOU)

Plan	session fees	prepaid charging credit	monthly subscription	reservations
Pay As You Go	\$1.99	\$0.00	\$0.00	\$3.00
EVgo Member	\$0.00	\$4.99	\$0.00	\$3.00
EVgo Plus™	\$0.00	\$0.00	\$6.99	\$0.00

Sign Up



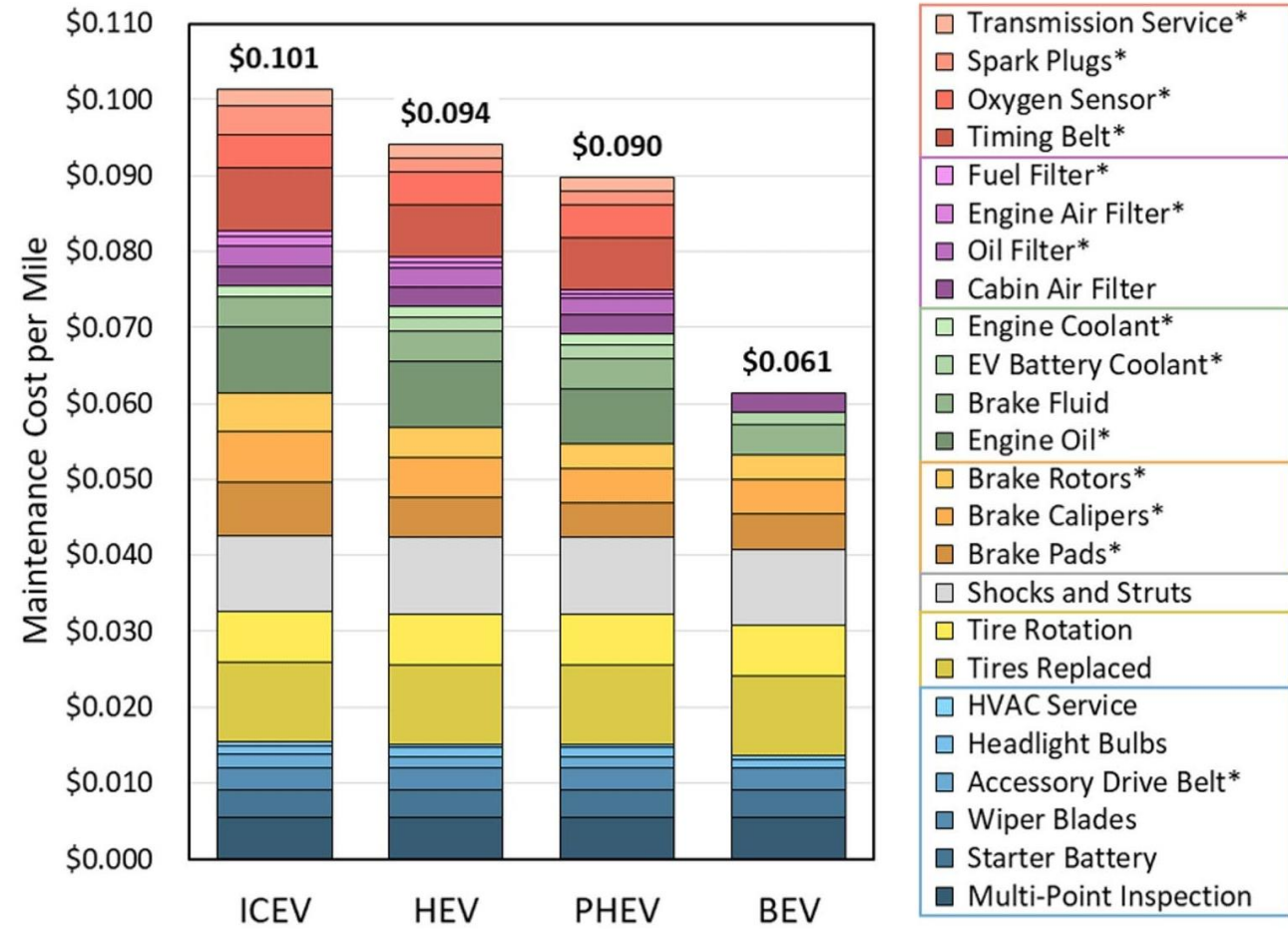
Calculating fueling costs: electricity

- Let's consider an “average” electric car in the US (about .3 kWh/mile) with electricity prices of \$0.30/kWh
- How much does it cost to drive per mile?

$$\frac{\$0.30}{\text{kWh}} \times \frac{0.3 \text{ kWh}}{\text{mile}} = \frac{\$0.09}{\text{mile}}$$

Maintenance costs

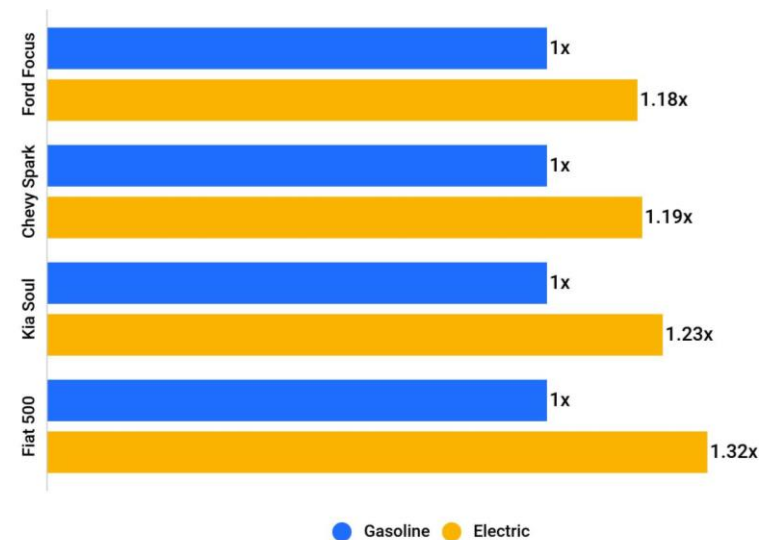
- Maintenance costs for EVs are generally agreed to be cheaper than gas cars across the board
- EVs do not require any maintenance for parts related to the gasoline engine drivetrain, brakes last longer too due to regenerative braking
- Consider a \$0.04 savings per mile over a lifetime 150,000 miles: a savings of \$6,000!



Insurance costs

- Lots of online insurance calculators to compare prices between gas and electric
- ...but one technology is not clearly cheaper than the other

	Average price for electric vehicles	National average price, including internal combustion engine cars
Including Tesla	\$2,515	\$952
Excluding Tesla	\$1,415	\$952



APPROX. \$70,000



2018 Tesla Model 3
Price: \$1,618/year



2018 Lexus GS - F Sport
Price: \$2,271/year

APPROX. \$40,000



2018 Nissan Leaf
Price: \$1,367/year



2018 Nissan Maxima
Price: \$1,536/year

APPROX. \$35,000



2018 Kia Soul EV
Price: \$1,464/year



2018 Kia Soul SX
Price: \$1,569/year

- All prices based on the following assumptions:
- 35 years old living in Oakville, ON
 - Home insurance bundled together
 - Clean driving record
 - Coverages = \$1mil liability, \$1000 deductible for comprehensive and collision, accident forgiveness, and depreciation waiver

Time Discounting

- Preference between the value of consumption today and consumption in the future
- Is money worth more to you now or in the future?

Calculating with discount rates

- The present value PV of a quantity of money “C” spent in some future year “n” is given by:

$$PV(C) = \frac{C}{(1+i)^n}$$

What discount rate should be used?

- There is no one right answer
- Businesses often use 10-15% real discount rates
- Regulated utilities 6%
- Investments in developing countries 15-25%
- The higher the risk the higher the discount rate

Let's compare:



Volkswagen Tiguan
Compact SUV
Gasoline Engine



Volkswagen ID.4
Compact SUV
Battery Electric

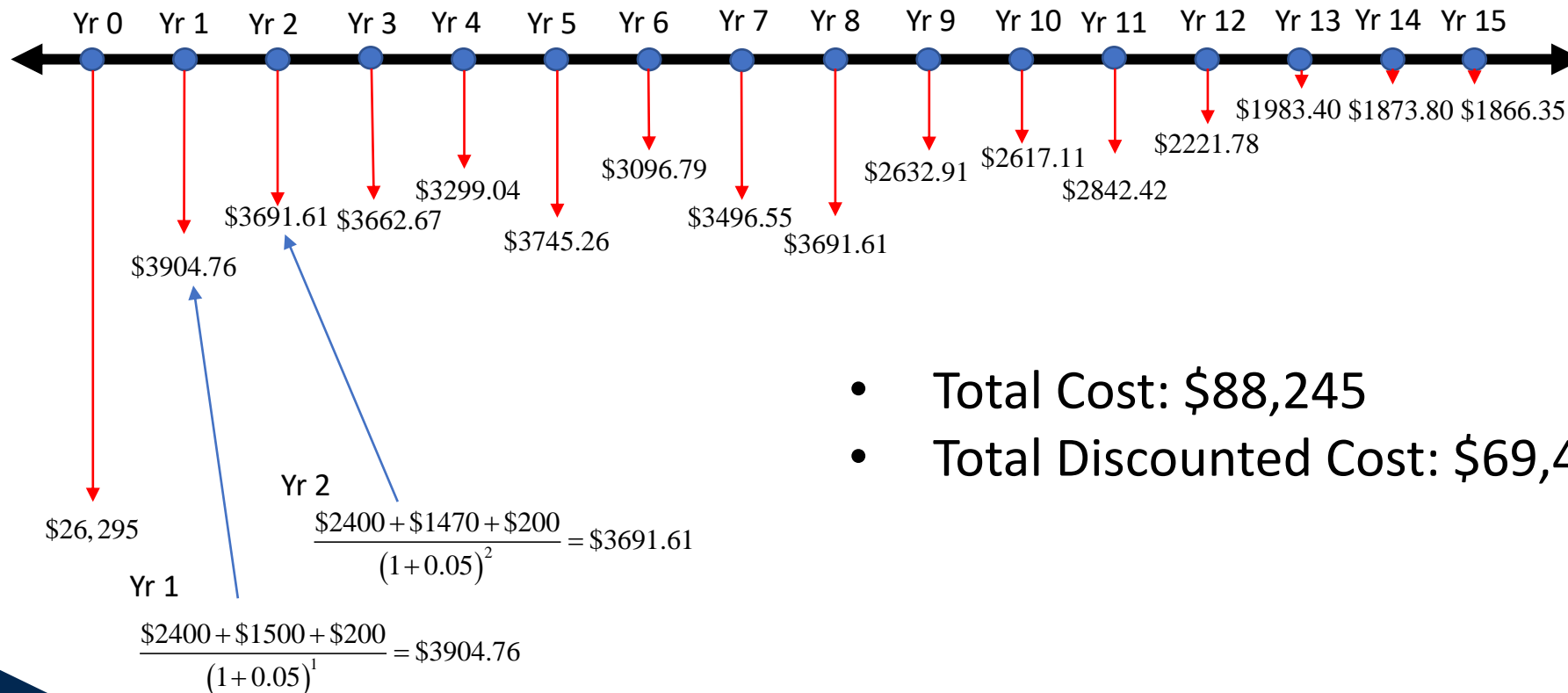
Example TCO calculation: gas car

- Relevant Volkswagen Tiguan attributes:
 - \$26,295 MSRP
 - 25 miles per gallon
- Assumptions:
 - Drives 12,000 miles per year
 - Gasoline costs \$5/gallon
 - Insurance rates starting at \$1,500/year dropping \$30/year
 - Discount rate of 5%
- Let's assume the following maintenance schedule
 - Oil change, oil filter, tire rotation: twice a year (\$100 each time)
 - Air and fuel filter: every 3 years (\$200)
 - Brakes, coolant, transmission fluid, power steering fluid: every 5 years (\$800)
 - Spark plugs and timing belt: once over lifetime of vehicle (\$1000)

Example TCO calculation: gas car continued

Annual Fuel Cost:

$$\frac{12,000 \text{ mi}}{\text{yr}} \times \frac{1 \text{ gal}}{25 \text{ mi}} \times \frac{\$5}{\text{gal}} = \frac{\$2400}{\text{yr}}$$



- Total Cost: \$88,245
- Total Discounted Cost: \$69,440

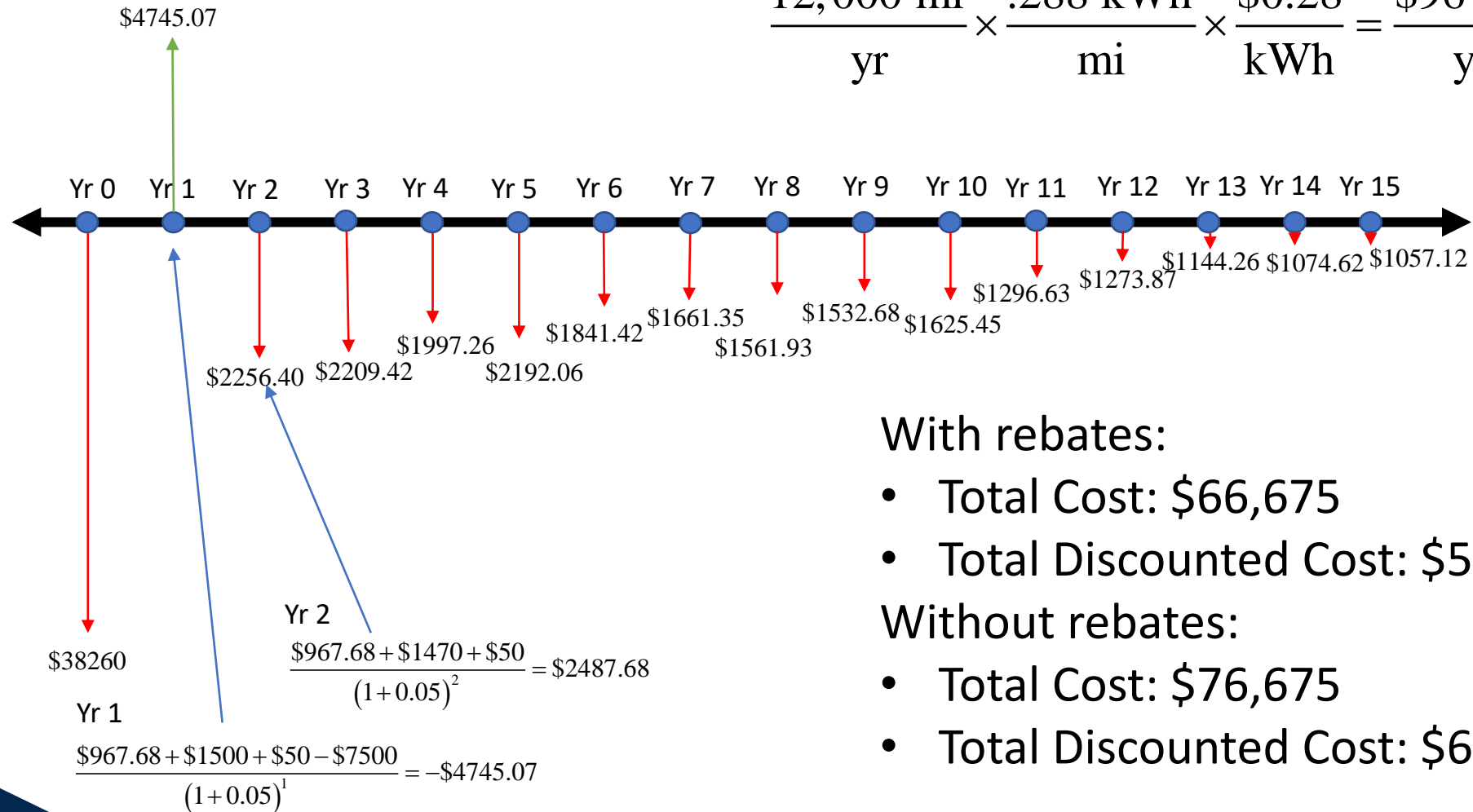
Example TCO calculation: EV

- Relevant Volkswagen ID.4 attributes:
 - \$40,760 MSRP, \$2500 California rebate (immediate) and \$7500 tax credit (when you file taxes)
 - 28.8 kWh/100 miles
- Assumptions:
 - Drives 12,000 miles per year
 - Electricity price at \$0.28 per kWh
 - Insurance rates starting at \$1,500/year dropping \$30/year
 - Discount rate of 5%
- Let's assume the following maintenance schedule
 - Tire rotation: twice a year (\$150 each time)
 - Air filter: every 3 years (\$100)
 - Brakes: every 5 years (\$400)

Example TCO calculations: EV continued

Annual Fuel Cost:

$$\frac{12,000 \text{ mi}}{\text{yr}} \times \frac{.288 \text{ kWh}}{\text{mi}} \times \frac{\$0.28}{\text{kWh}} = \frac{\$967.68}{\text{yr}}$$



With rebates:

- Total Cost: \$66,675
- Total Discounted Cost: \$56,239

Without rebates:

- Total Cost: \$76,675
- Total Discounted Cost: \$65,882

...so which one is cheaper...?

- The TCO of the VW ID.4 is cheaper than the VW Tiguan both discounted and undiscounted, regardless of the incentive
- But!:
 - What if the driver drove less than 12,000 miles per year?
 - What if gasoline prices were lower?
 - What if electricity prices were higher?
 - What if you had to replace the battery in the EV?
- ...also is the Tiguan the correct counterfactual? Recall that in the early 2000s, many Priuses were actually replacing BMWs, Mercedes, and Porsches!

Buying cars and TCO

- Do buyers calculate TCO when deciding between cars to purchase?
- What other factors might influence a consumer's purchasing decision?