

# Clean Disruption of Energy & Transportation

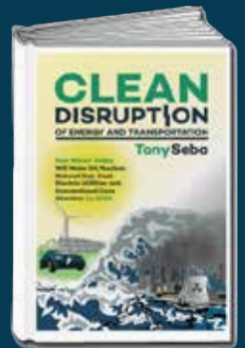
## Clean Energy Action Sunshine Award Boulder, CO

8 June 2017

Presentation to:

**RethinkX**

Tony Seba  
[www.tonyseba.com](http://www.tonyseba.com)

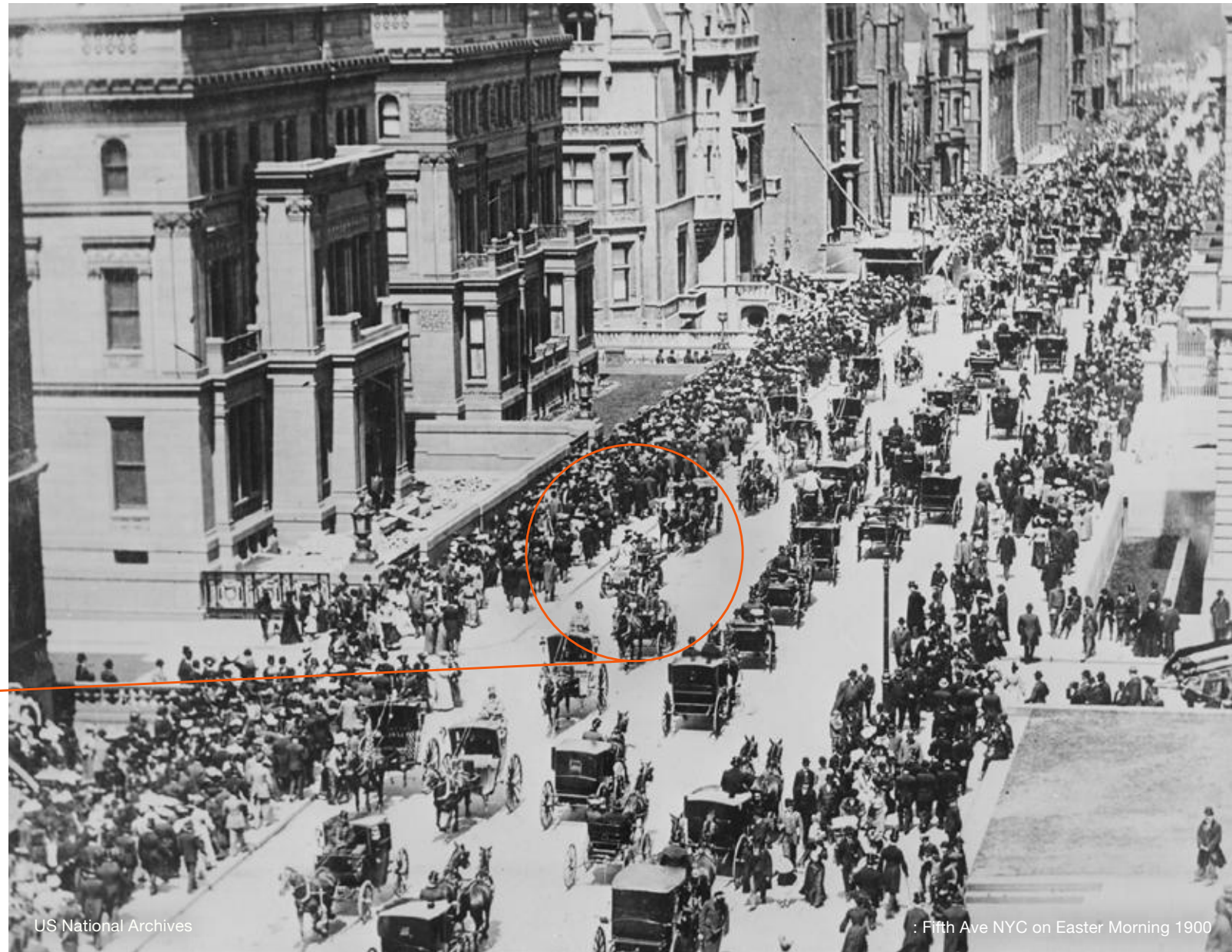


A STROLL DOWN  
Memory Lane

5<sup>th</sup> AVE NYC

1900

Where is  
**the  
car?**



5<sup>th</sup> AVE NYC

1913

Where is  
**the**  
**horse?**



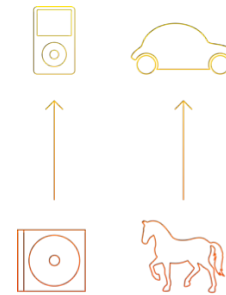
# TECHNOLOGY Disruption



# What is a Disruption?

WHEN A NEW PRODUCT OR SERVICE HELPS  
**create a new market**

AND  
significantly **weaken,**  
**transform,** or  
**destroy** an existing product,  
market category / industry





FAST FORWARD TO 1985

▶▶ 1985



Image: GMAuthority.com

# ‘Expert’ Disruption Forecasts

AT&T hired McKinsey & Co to forecast cell phone adoption by the year 2000

THEIR (15-YEAR) PREDICTION

900,000

SUBSCRIBERS

THE ACTUAL Year 2000 NUMBER WAS

109 million

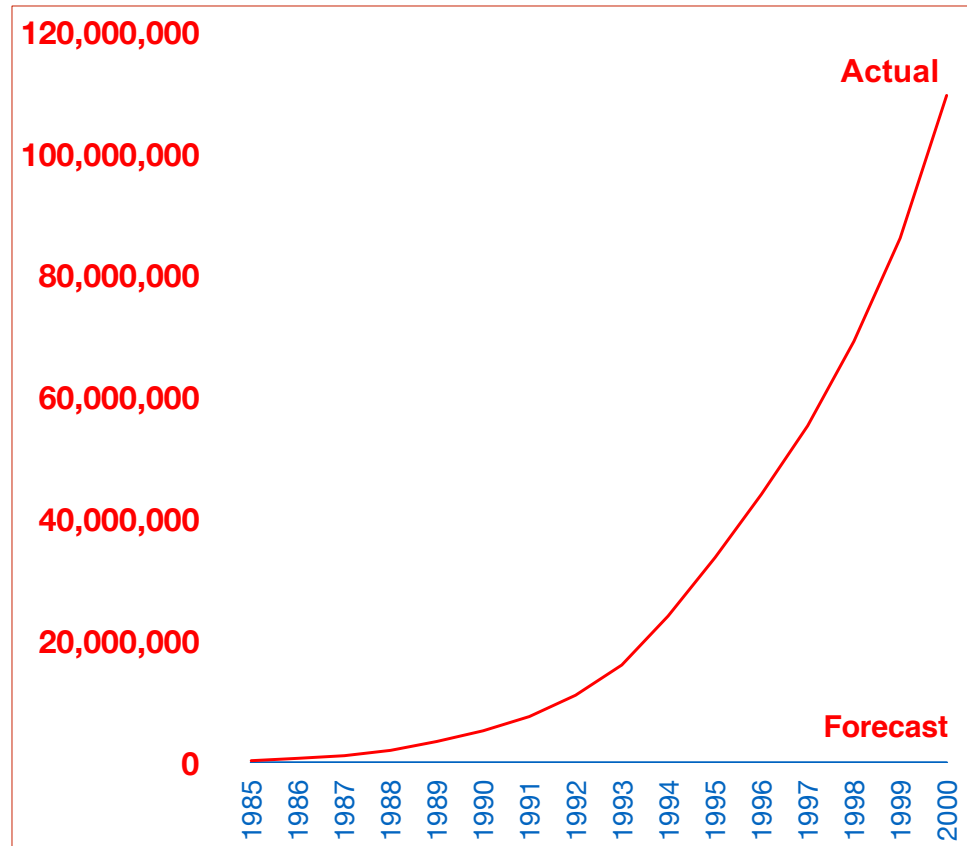
They were off  
by a factor of:

120x





# AT&T Disrupted - while \$\$ Trillions Created



	Company	Home Country	Market Cap. (\$MM)
1	Apple	USA	\$763,567
2	Google	USA	373,437
3	Alibaba	China	232,755
4	Facebook	USA	226,009
5	Amazon.com	USA	199,139
6	Tencent	China	190,110
7	eBay	USA	72,549
8	Baidu	China	71,581
9	Priceline Group	USA	62,645
10	Salesforce.com	USA	49,173
11	JD.com	China	47,711
12	Yahoo!	USA	40,808
13	Netflix	USA	37,700
14	LinkedIn	USA	24,718
15	Twitter	USA	23,965
Total Market Cap of Top 15			\$2,415,867

- ▶ AT&T's landline telephony market was disrupted
- ▶ It missed out on multi-trillion dollar opportunities!

It's usually the **'experts'** and **'insiders'**  
who **dismiss** Disruptive Opportunities

**“There's no chance that the iPhone is going to get any significant market share. No chance....”**

**Steve Ballmer**, CEO Microsoft, 2007

**“The iPhone's impact will be minimal. It will only appeal to a few gadget freaks. Nokia and Motorola have nothing to worry about.”**

**Bloomberg Analyst**, 2007

**“It's important that [Internet] expectations aren't cranked too high.  
The total number of users is still very small...”**

FAST FORWARD TO 2000

▶▶ 2000



# Kodak FY 2000: Record Results

- ▶ FY **2000** Financial Results:

- ▶ Revenues: \$14 B
- ▶ Operating Earnings: \$2.2 B
- ▶ Net Profits: \$1.4 B

"A great brand, a great balance sheet, cash flow. This is a very smart time to be in the picture business"

*Daniel Carp, CEO, Kodak  
Letter to Investors, FY 2000*

- ▶ "Picture-taking at an **all-time high worldwide:**"<sup>(1)</sup>

- ▶ **Record** # of **Pictures** taken: 80 billion.
- ▶ **Record** # of **Prints** ordered: 100 billion.

- ▶ **2012** - Kodak Filed for **Bankruptcy Protection**



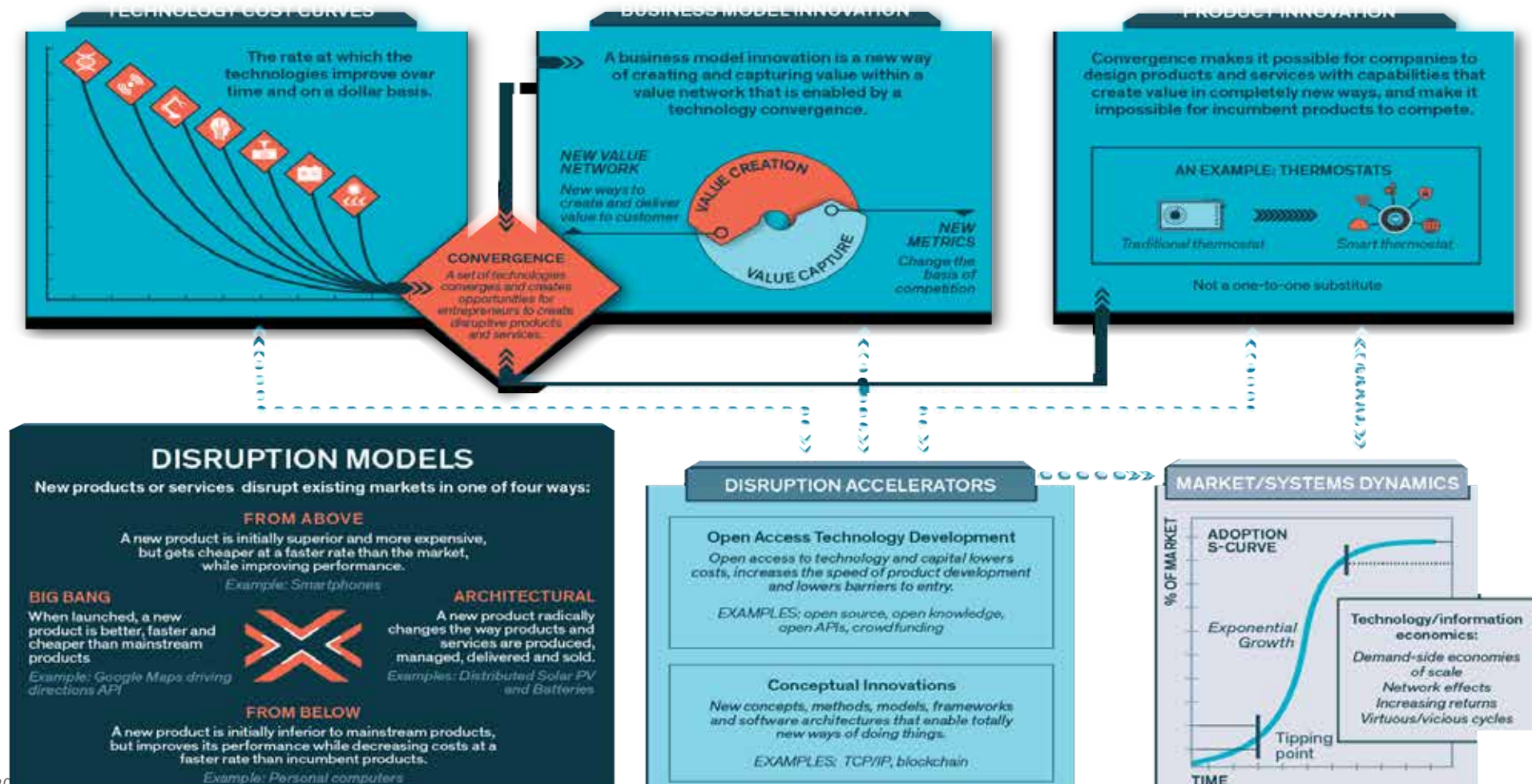
Why do smart people  
at smart organizations  
consistently fail  
to anticipate or lead  
Market Disruptions?



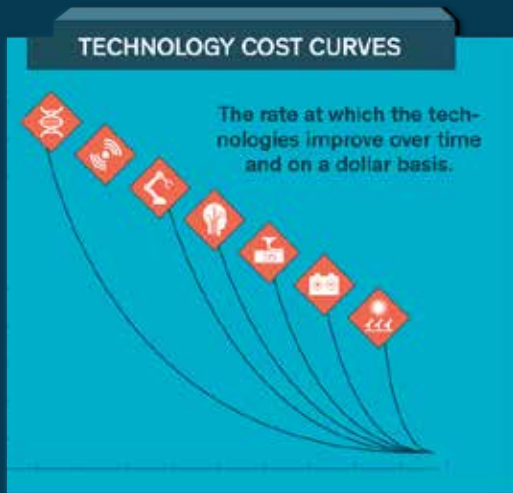
## HOW DISRUPTIONS HAPPEN

Disruptions are when new products and services enter a market and significantly outperform existing products in the markets or industries.

## Second-Order Technology Disruption Framework





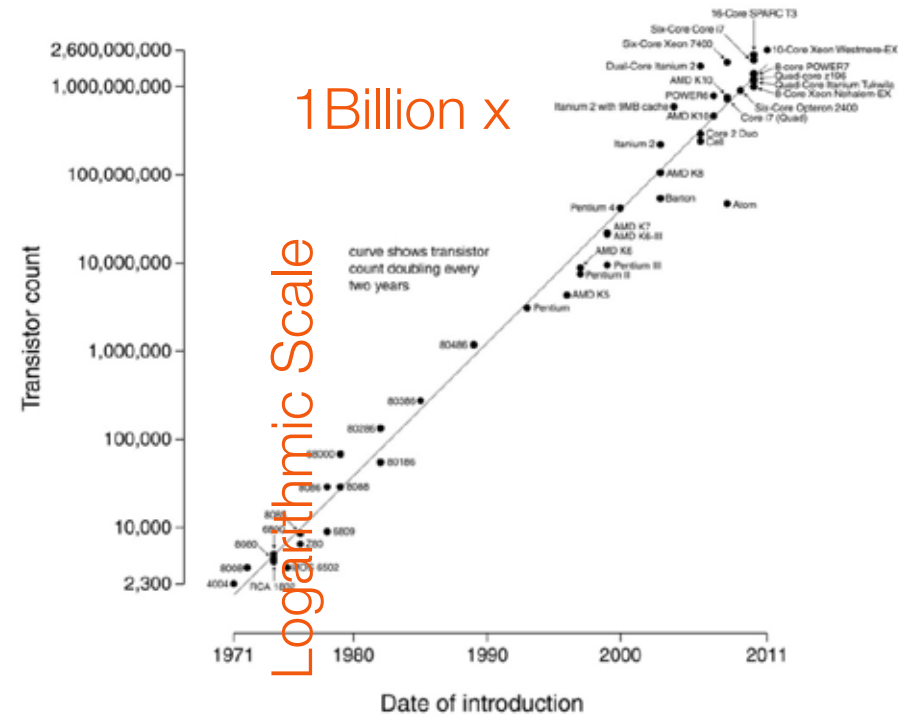


# Technology Cost Curves

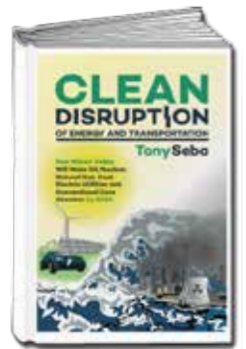
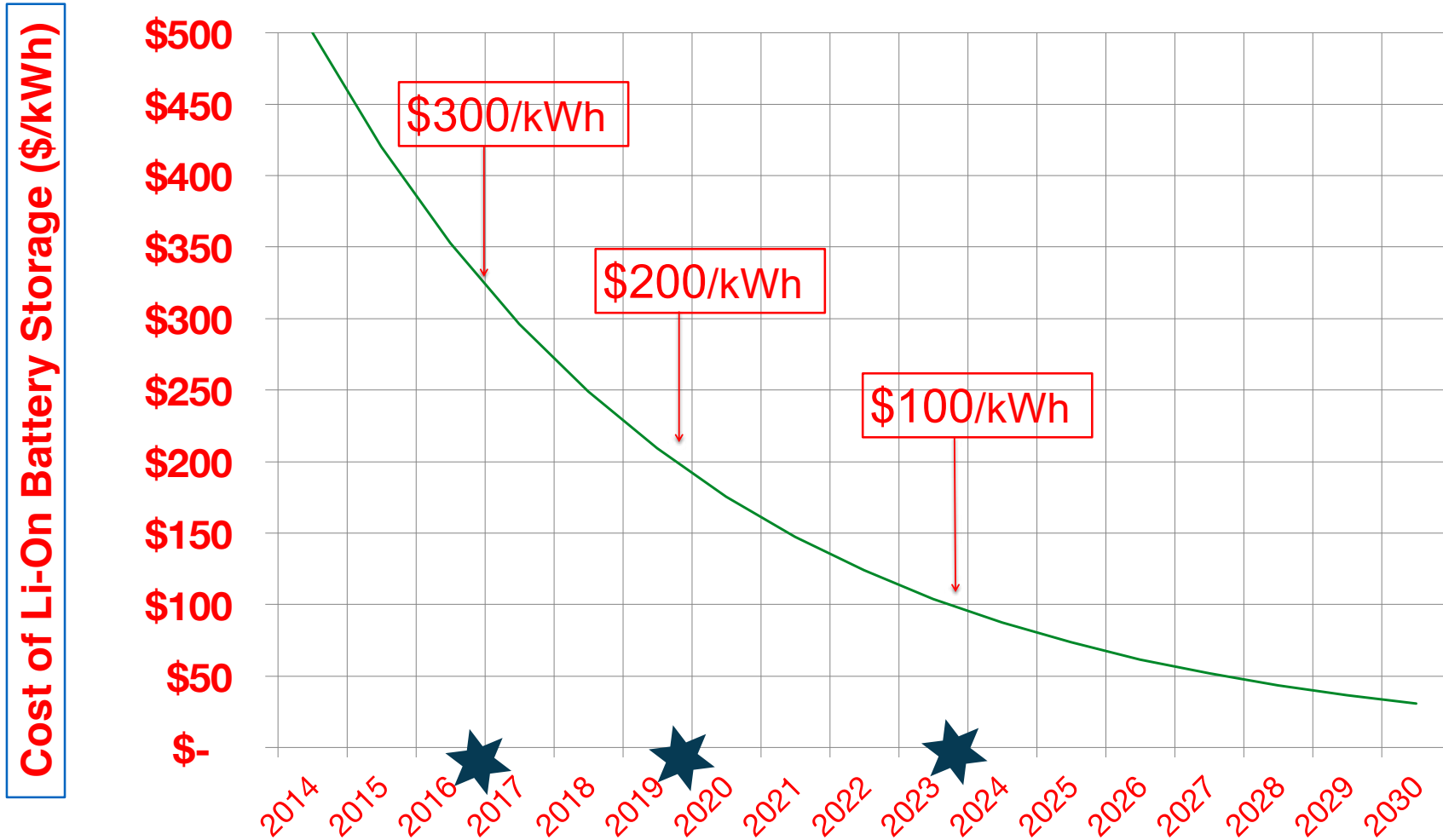
# Computing: Moore's Law (1971 - 2011)

- ▶ # of transistors doubles (roughly) **every two years.**
- ▶ Annual improvement rate **~41.4%**
- ▶ **Exponential growth** in # of transistors

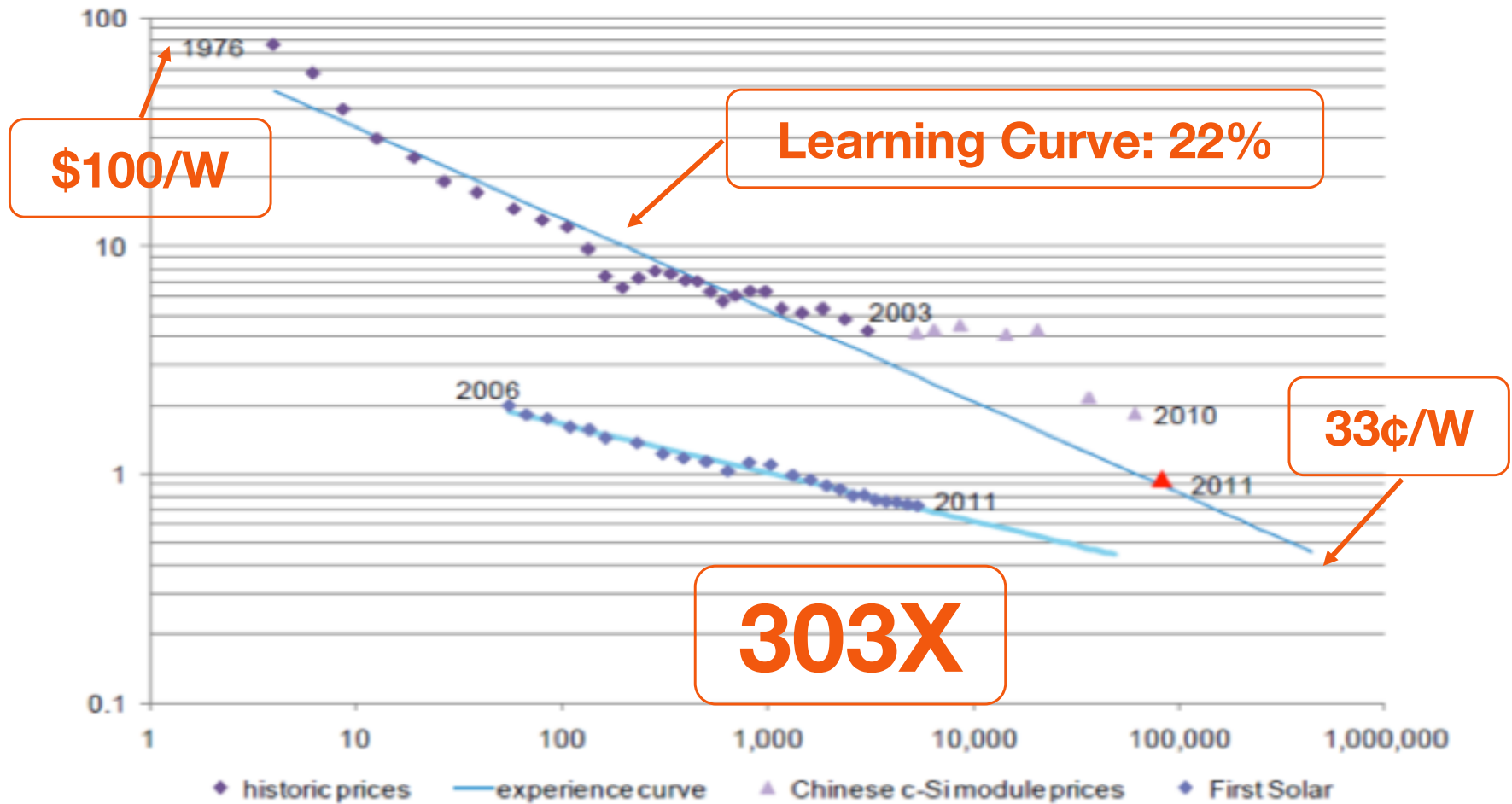
## Microprocessor Transistor Counts 1971-2011 & Moore's Law

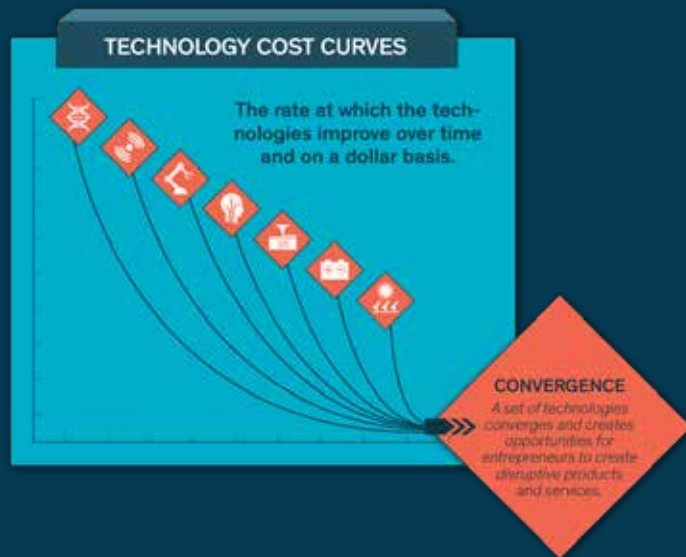


# Projected cost of Li-ion Battery \$/kWh



# Solar PV Costs: DOWN 303X





# Technology Convergence

# Convergence 2007 - Smartphone

- ▶ **Technology convergence in 2007 to make the smartphone possible**
- ▶ **Data Storage** – Kryder's Law
  - ▶ Hard Disk \$ cost per bit down **50% every 18 months**
- ▶ **Digital Imaging** – Hendy's Law
  - ▶ Pixels per \$ - **59% / year**
- ▶ **Network Capacity** – Butter's Law of Photonics
  - ▶ The \$ cost of transmitting a bit decreases by **50% every 9 months**
- ▶ **Touchscreen, Li-ion batteries, computing, sensors...**

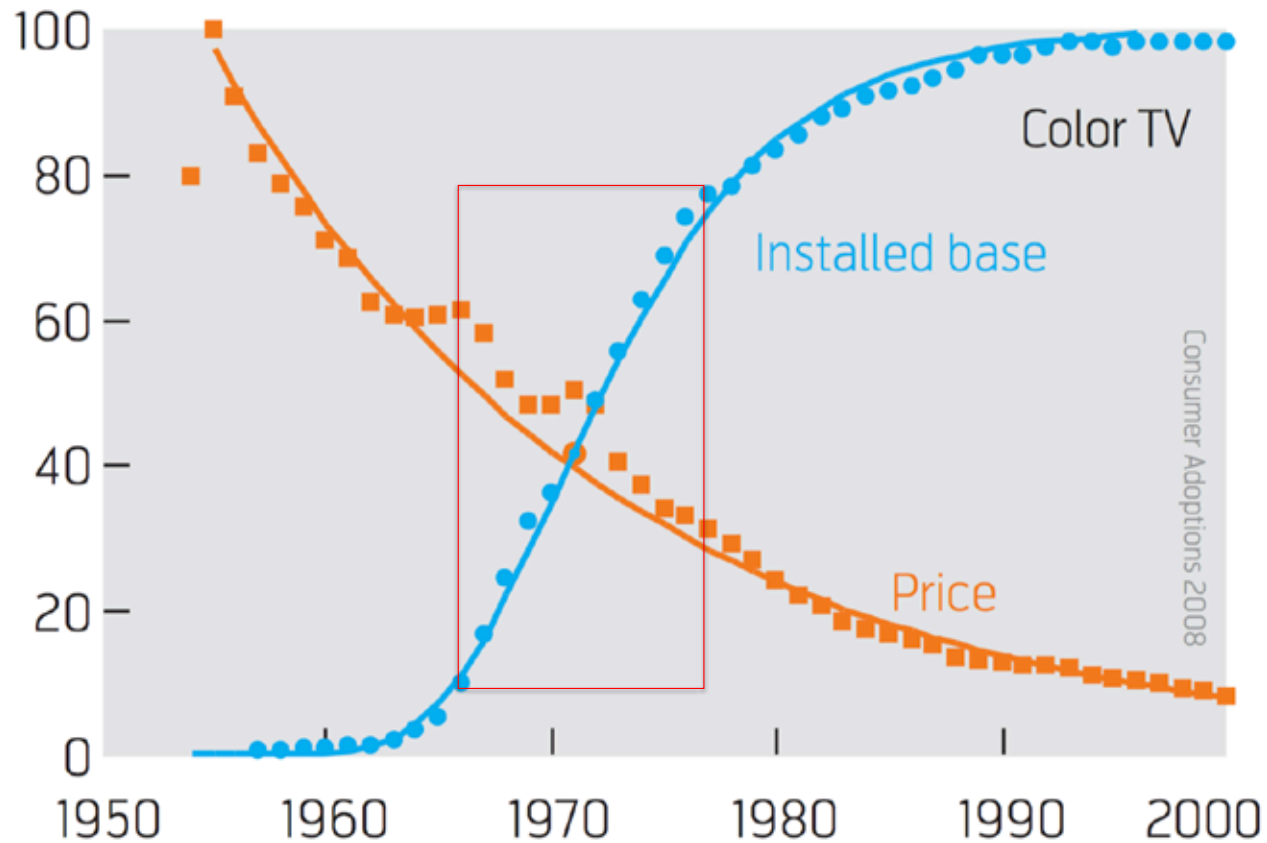






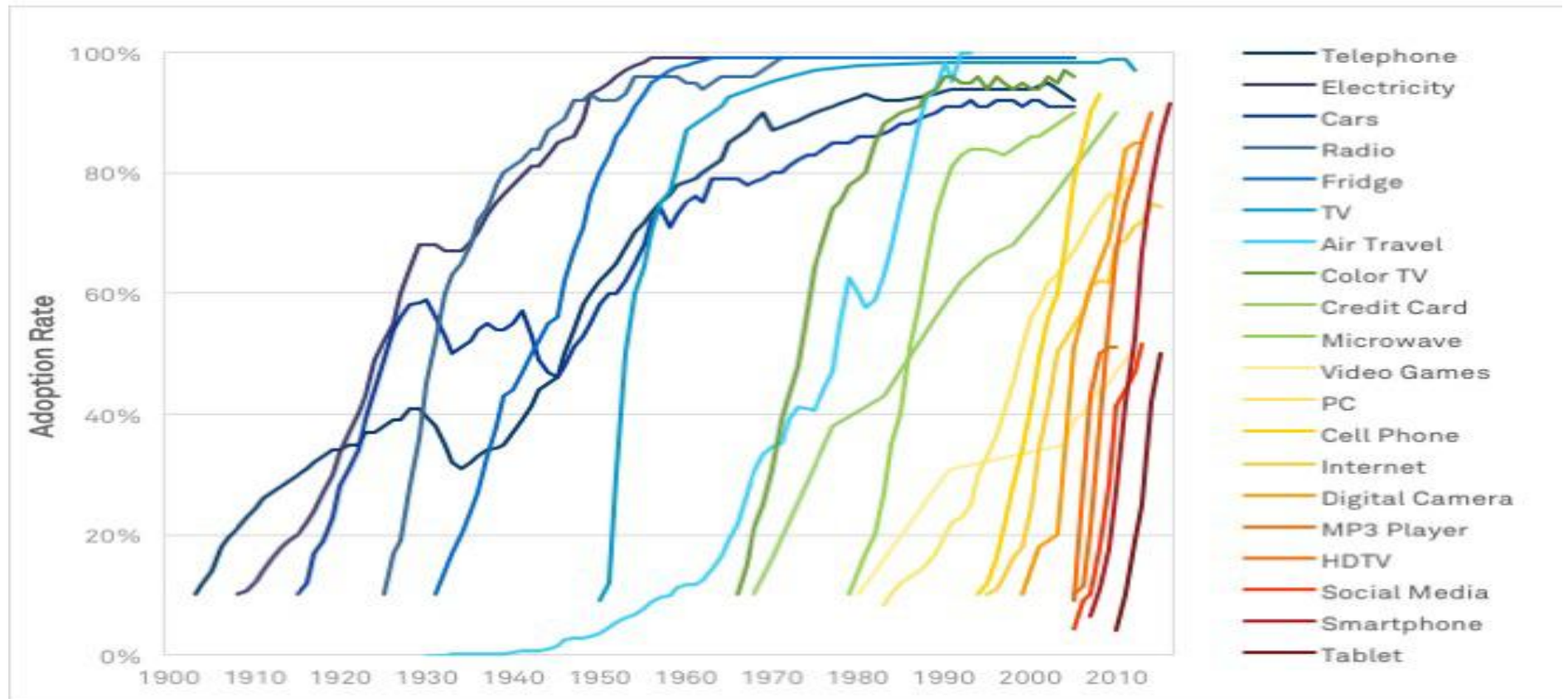
# Exponential Market Adoption S-Curve

# Technology Adoption S-Curve (Color TV % US)



✓ Tech adoption is not linear but follows an exponential **S-Curve**

# Technology Adoption S-Curves Accelerating



Source: Asymco

BLACKROCK®

► Tech adoption S-Curves is are happening faster!

## BUSINESS MODEL INNOVATION

A business model innovation is a new way of creating and capturing value within a value network that is enabled by a technology convergence.

NEW VALUE NETWORK

New ways to create and deliver value to customer

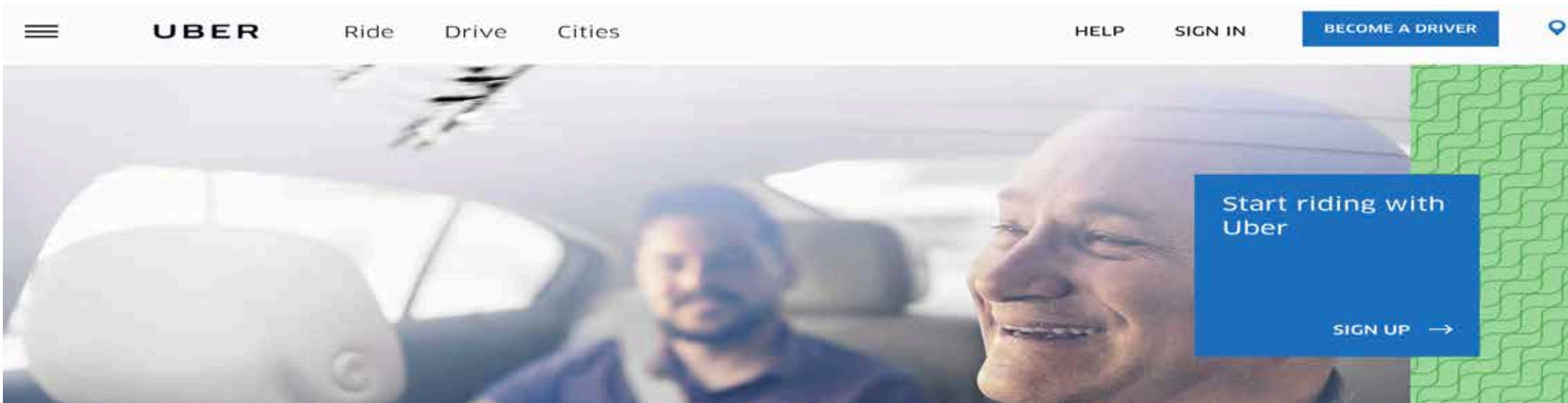


NEW METRICS

Change the basis of competition

# Business Model Innovation

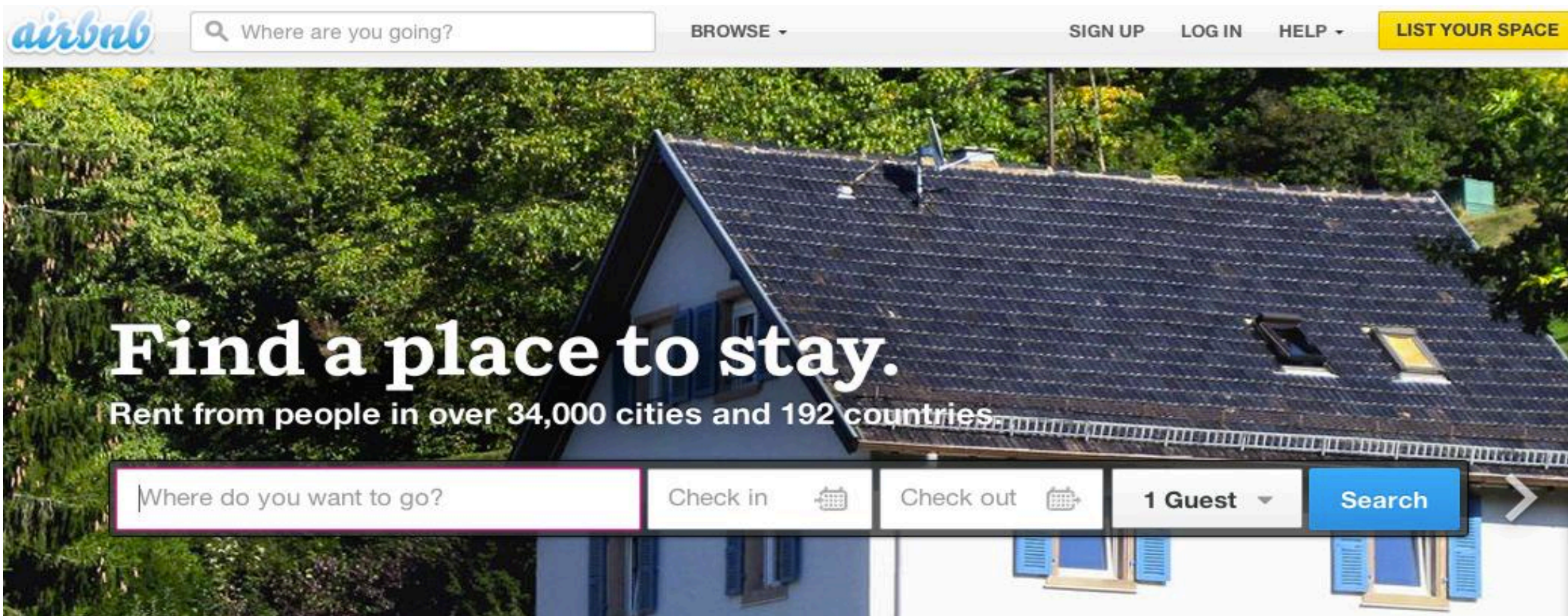
# Business Model Innovation: Ride-Sharing (Uber, Didi, Lyft, Ola...)



- **Uber Bookings > US Taxi Industry Revenues (2016)**
- **New York City = 500,000 Ride-Hailing Rides per day <sup>(1)</sup>**



# Business Model Innovation: AirBnb Marketplace Broker





**Business Model Disruption**

**Business Model**

**Innovation**

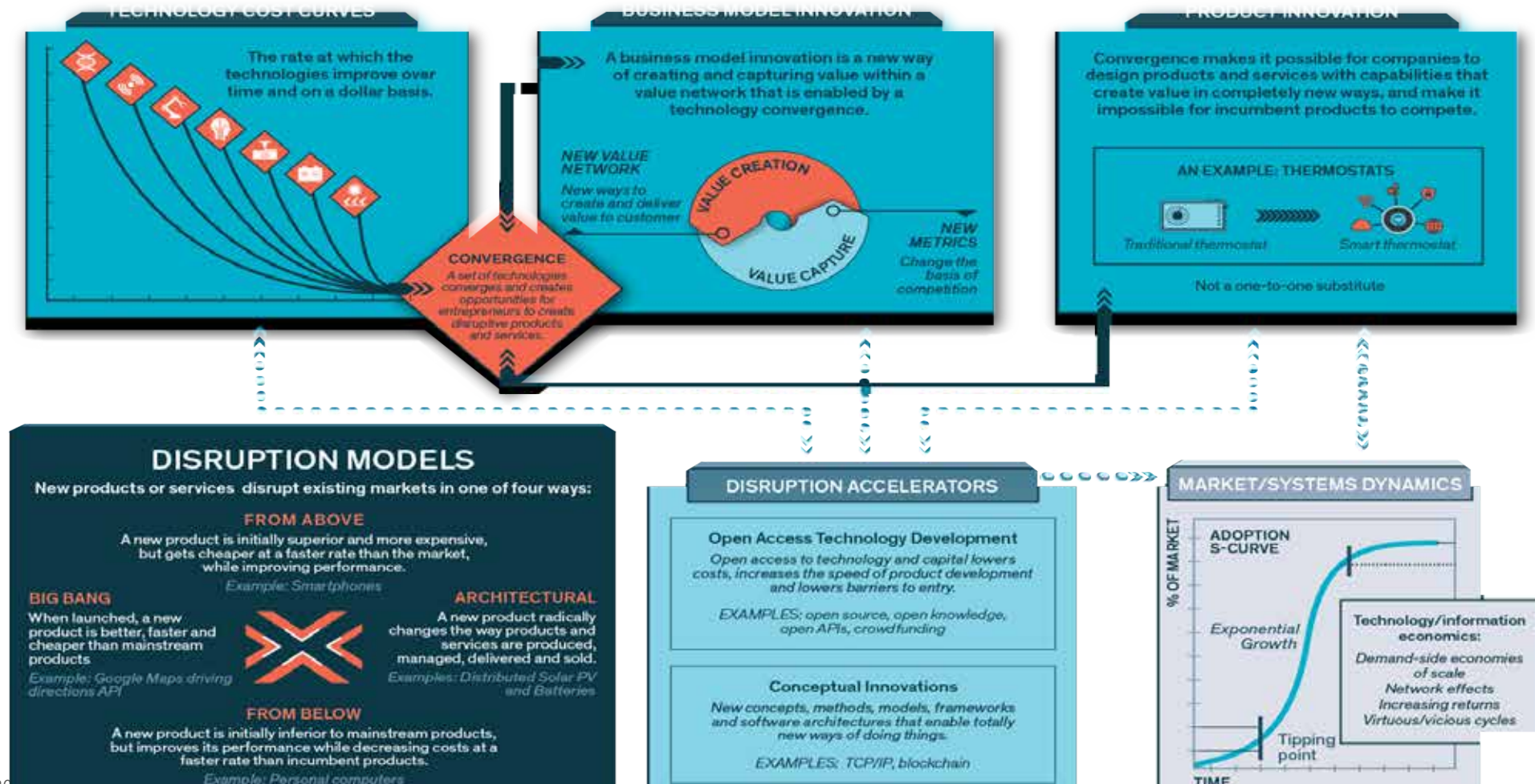
is as important & disruptive as

**Technology Innovation**

## HOW DISRUPTIONS HAPPEN

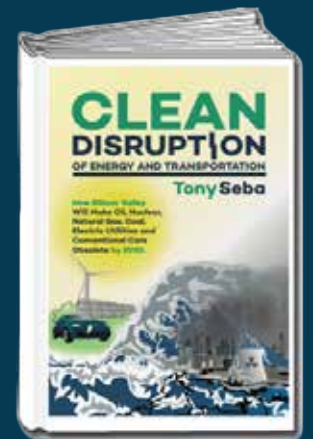
Disruptions are when new products and services enter a market and significantly outperform existing products in the same markets or industries.

## Second-Order Technology Disruption Framework



# CLEAN DISRUPTION OF ENERGY & TRANSPORTATION

- 1 Batteries
- 2 Electric Vehicles
- 3 Autonomous Vehicles
- 4 Ride-Hailing
- 5 Solar



# Batteries / Energy Storage



# Li-on Battery costs dropping exponentially

- ▶ **Laptop Li-on battery costs dropped ~14% per year over 15 years.** (1)
- ▶ Investments in battery tech increasing dramatically:
  - ▶ **3 multi-trillion \$ industries investing:**
    1. IT/ Electronics
    2. Automotive
    3. Energy
- ▶ **2010-2014, battery costs dropped at ~16%/year → ACCELERATION**





# Investments in Battery Megafactories increasing

- ▶ **BYD** could ramp up to **34 GWh** by 2020 - matching Tesla's **35 GWh** (1)
- ▶ **Foxconn** and **LG Chem** could add combined **22 GWh** (2)
- ▶ **Samsung SDI**, **Dyson**, Total, Bosch, Boston Power, TDK, Apple, Nissan, Daimler, VW, etc.
- ▶ **12+ Megafactories** expected to come online by 2020 (3)
- ▶ **Tesla** may **Triple** expected output to 105 GWh (cells) / 150 GWh (packs) (4)

**Tech Cost Curve has accelerated to ~20% (2010-2016)**



Image Source: Samsung SDI



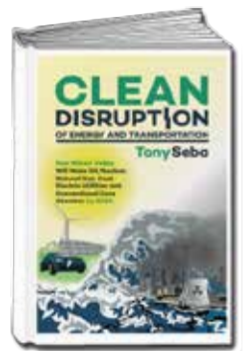
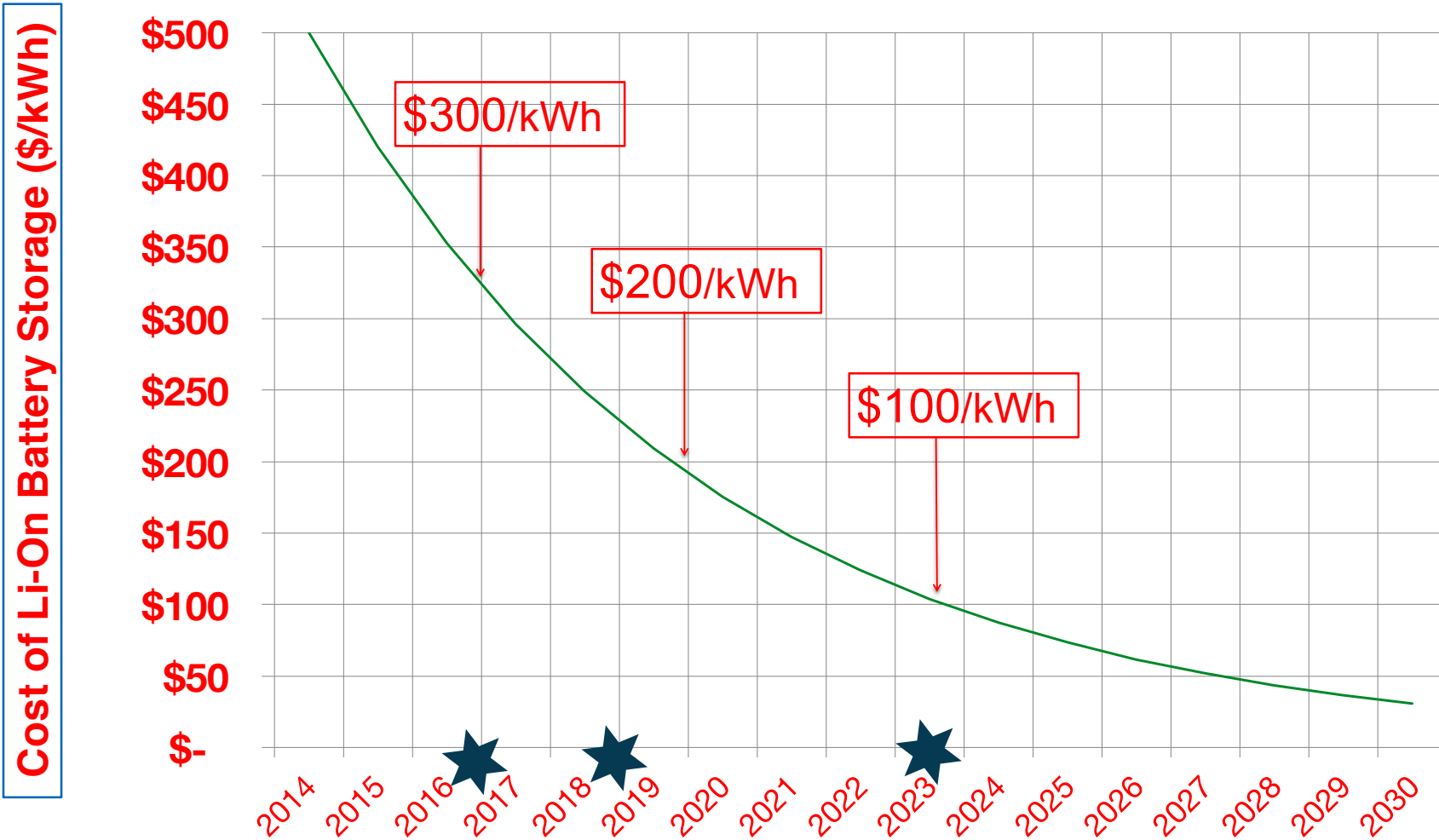
## DYSON Developing Electric Car

Vaccum maker *Dyson* to **invest £1 billion in batteries** over the next five years.

Last October, the company acquired solid-state battery maker Sakti3 for \$90m, which "developed a battery breakthrough", according to company founder James Dyson <sup>(1)</sup>

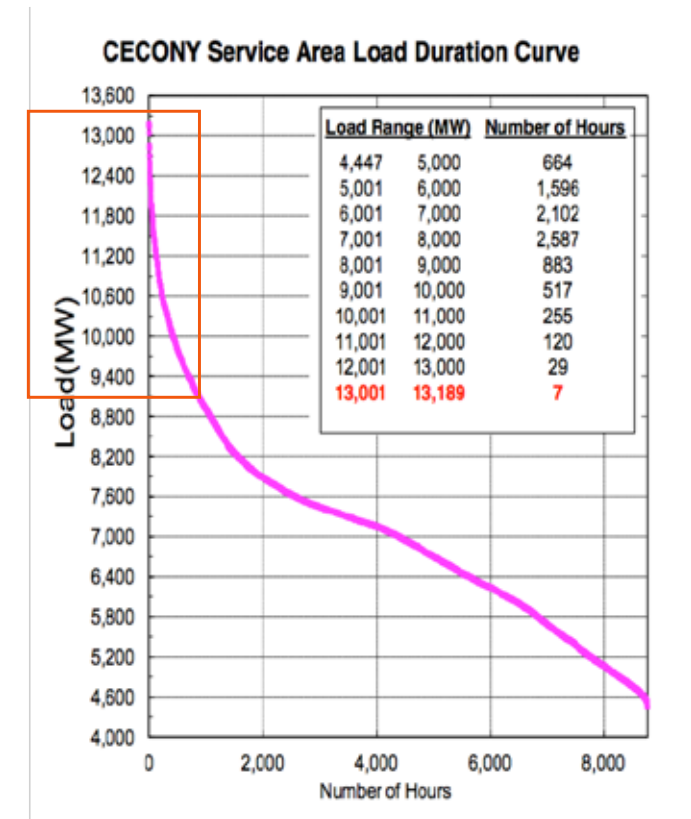


# Projected cost of Li-On Battery \$/kWh



# Storage Disruption - Grid Scale

- ▶ The grid works like a **just-in-time supply chain without inventory**
- ▶ Grid: inefficient use of Assets
  - ▶ \$\$ Billions in generating assets used just a few hours per year
- ▶ Ex: ConEd - **32%** of Generation **assets** used < 517 hrs/yr (5.9%)
  - ▶ 189 MW used 7 hrs (0.08%)
  - ▶ 1 GW used 29 hrs (0.33%)
  - ▶ 1 GW used 120 hrs (1.37%)
- ▶ **Energy Storage can replace generation assets on the grid**
  - ▶ Peakers = obsolete



“Post 2020 there may never be another peaker built in the US.”

*NextEra Energy CEO Jim Robo (2)*

# Tesla Inaugurates 20 MW/80MWh Battery System

*Southern California Edison contracted the system to **meet PEAK Demand** needs following its Alyson Canyon **natural gas leaks**. Under concerns of electric reliability risk CA's regulators ordered SCE to rapidly procure utility scale energy storage <sup>(1)</sup>*

*Tesla's 80MWh system was completed in 88 days.*

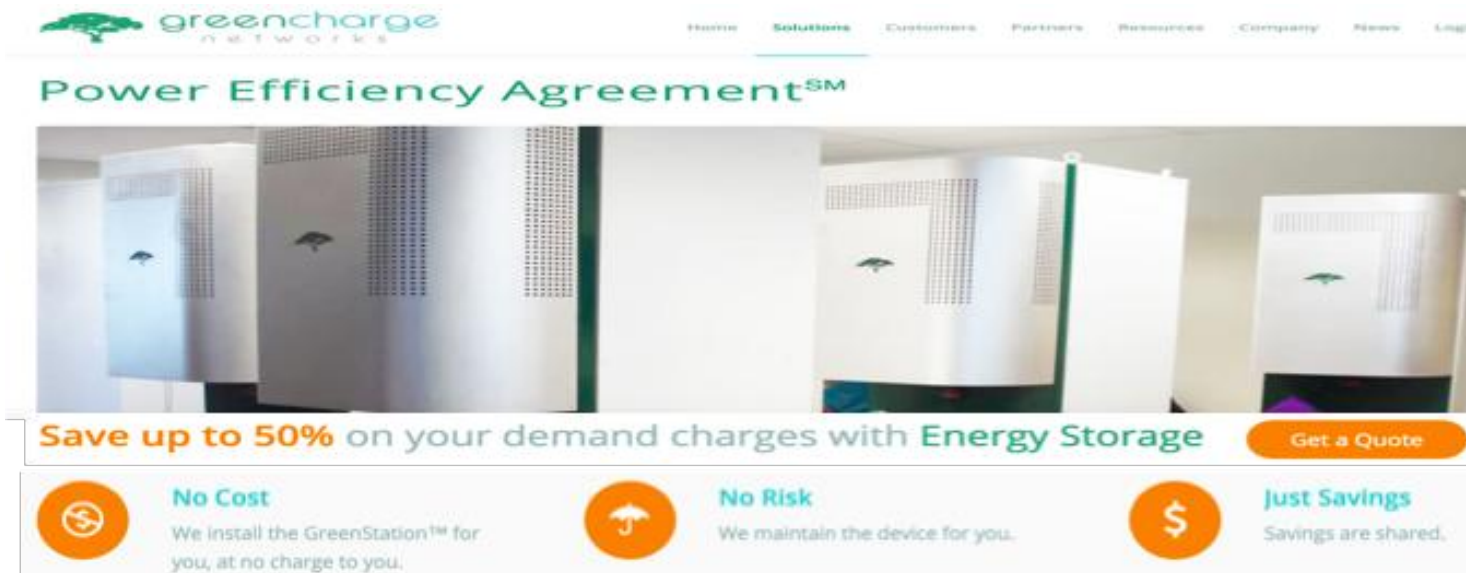


Photo Source: Business Insider

ENERGY STORAGE

# Business Model Innovation

# Business Model Innovation: **Storage as a Service**



- ▶ Stem and GreenCharge Networks offering **storage-as-service** to reduce DEMAND CHARGES for businesses
  - ▶ **Zero-money down**, 10 years
- ▶ **Lower utility bills by 10-50%** <sup>(1)</sup>
- ▶ Similar business model that made solar skyrocket



# Storage Disruption: Residential and Commercial

- ▶ Average American consumes 903 kWh/month → ~ 30kWh/day
- ▶ By 2020 it will cost **\$36.8/month (\$1.2/day)** for a full day of electricity storage

Monthly cost of residential storage			Target year ->			2014	2020	2024	2028
Purchase cost of battery storage system (US\$/kWh) ->			\$600	\$500	\$300		\$200	\$100	\$50
SaaS services	Hours	kWh	Storage: Monthly Cost						
Demand response	1	1.25	\$4.6	\$3.8	\$2.3		\$1.5	\$0.8	\$0.4
Avoid peak, buy low & shift usage	4	5	\$18.4	\$15.3	\$9.2		\$6.1	\$3.1	\$1.5
Store all solar self-generation	8	10	\$36.8	\$30.7	\$18.4		\$12.3	\$6.1	\$3.1
Self-sufficiency	16	20	\$73.6	\$61.3	\$36.8		\$24.5	\$12.3	\$6.1
Full day	24	30	\$110.4	\$92.0	\$55.2		<b>\$ 36.8</b>	\$18.4	\$9.2

## Island of Ta'u runs on 100% solar + storage

*The Pacific Island of Ta'u now runs on **100% solar + storage microgrid**. SolarCity installed 1.4 MW of solar and 6 MWh of energy storage (60 Tesla Powerpacks).*

*The **microgrid** provides **24/7 power**, is **cheaper than diesel** and **ends power rationing and shortages**.*

***Key Roadblock was Funding.**  
**Implementation took less than 1 year.***



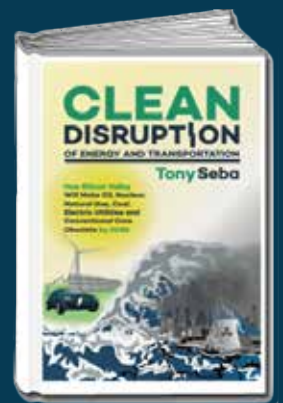
Source: SolarCity

Every house, business,  
warehouse, building, factory,  
parking, device will have smart,  
connected  
BATTERIES...

# The Electric Vehicle Disruption



Photo: © Tesla Motors



# IS THE ELECTRIC VEHICLE Disruptive?

(You always need to ask)

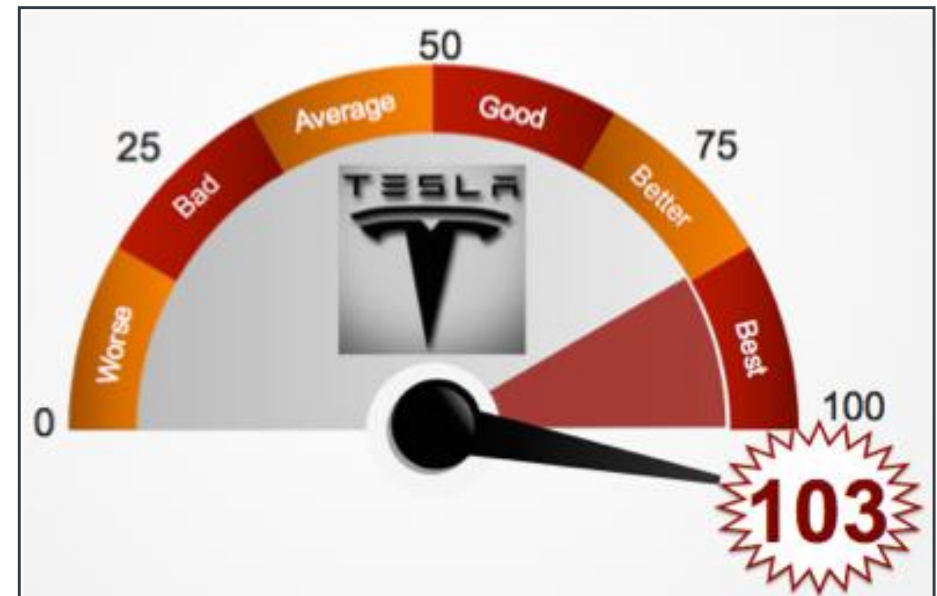


# 2013 CAR OF THE YEAR: TESLA MODEL S

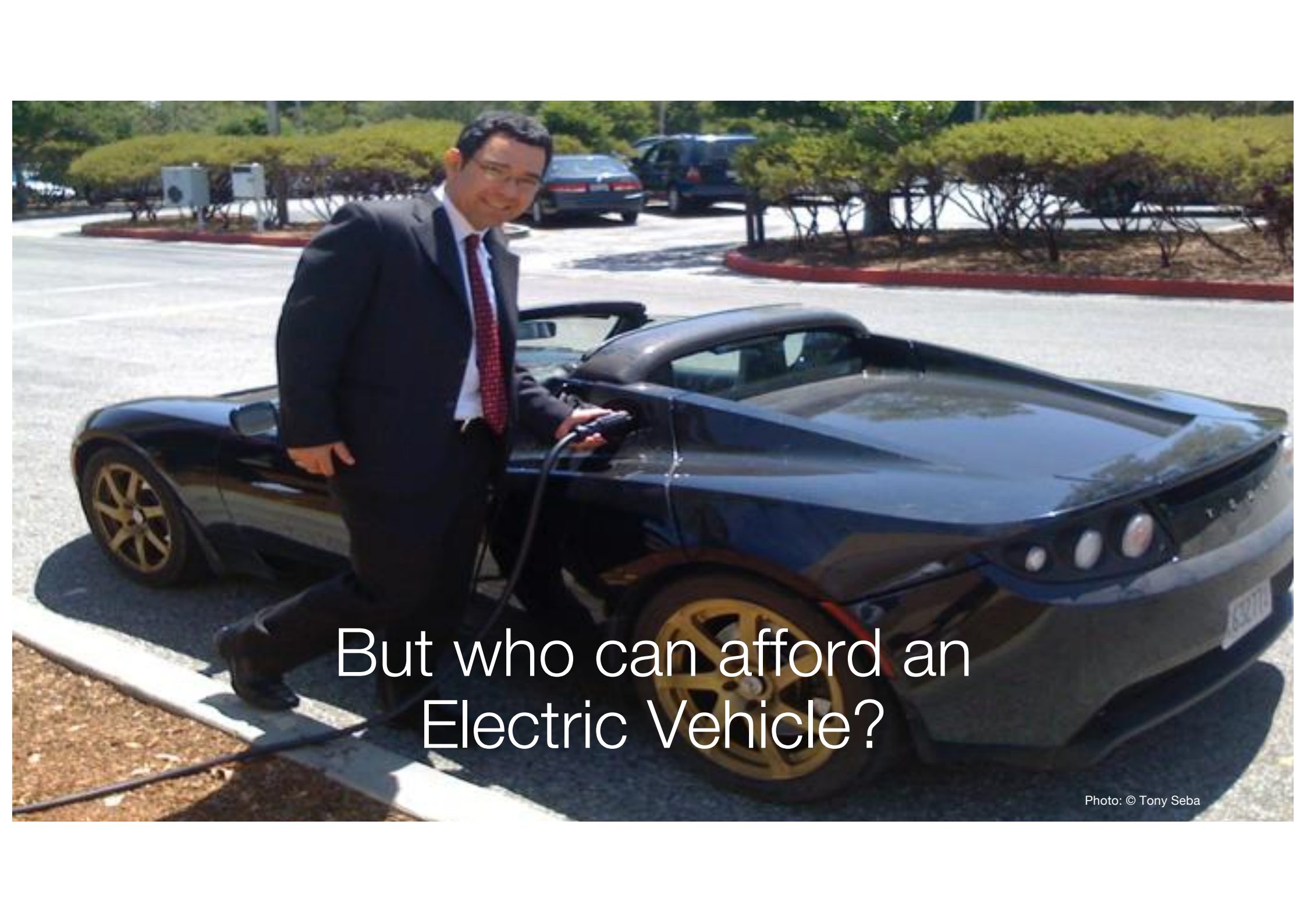
**Best-selling high-end large luxury car in America!** <sup>(2)</sup>

U.S. Large Luxury Sedans				
MODEL	Q3 2016	Q3 2015	% Change	% of Total
Tesla Model S	9,156	5,756	59%	32%
Mercedes-Benz S-Class	4,921	5,414	-9%	17%
BMW 7-Series	3,634	1,140	219%	13%
Mercedes-Benz CLS-Class	1,983	1,815	9%	7%
Maserati Ghibli	1,541	NA	NA	5%
Audi A7	1,532	2,132	-28%	5%
Lexus LS	1,235	1,569	-21%	4%
Porsche Panamera	1,143	1,393	-18%	4%
BMW 6-Series	1,096	834	31%	4%
Audi A8	1,010	1,300	-22%	4%
Jaguar XJ	903	1,064	-15%	3%
Maserati Quattroporte	702	NA	NA	2%
<b>Total</b>	<b>28,856</b>	<b>22,417</b>	<b>29%</b>	<b>100%</b>

Consumer Reports:  
**Best Car EVER!** <sup>(1)</sup>





A man in a dark suit, white shirt, and red patterned tie is smiling while plugging a charging cable into a dark blue sports car. The car is parked on a paved lot with some greenery and other vehicles in the background. The text "But who can afford an Electric Vehicle?" is overlaid in white on the lower right portion of the image.

But who can afford an  
Electric Vehicle?

Photo: © Tony Seba

# 1. Electric Motor - 5X more Energy Efficient

## Energy Efficiency



Internal  
Combustion  
Engine



Electric  
Motor

## 2. EVs are **10X** cheaper to charge/fuel

- ▶ It costs **\$15,000** to fill up a (gas) Jeep Liberty over **five years** (Consumer Reports)
- ▶ An **Electric** Jeep Liberty would cost **\$1,565** in electricity
- ▶ Improvements in software and power electronics to **increase this >10X**

### Assumptions:

12,000 miles/year

Tesla Roadster: 4.6 miles per kWh.

Ave retail electricity in the U.S.: 12 ¢/kWh

5 year-cost = (60,000 miles \* 0.12 \$/kWh) / 4.6 miles/kWh = \$1,565.



Sources: Consumer Reports, DOE, Clean Disruption



### 3. Maintenance - Gasoline Car: 2,000+ moving parts <sup>(1)</sup>



### 3. EVs: **10X** cheaper to Maintain

ICE (Gas) Vehicle

**2,000+** moving parts <sup>(1)</sup>

Transmission,  
driveshaft, clutch,  
valves, differentials,  
pistons, gears,  
carburetors,  
crankshafts...



Electric Vehicle (EV)

**18** moving parts <sup>(1)</sup>



- ▶ EVs **100X** fewer parts
- ▶ Tesla: **Infinite Mile Warranty!** <sup>(2)</sup>

## 4 – EVs Lifetime 2.5x > than ICE

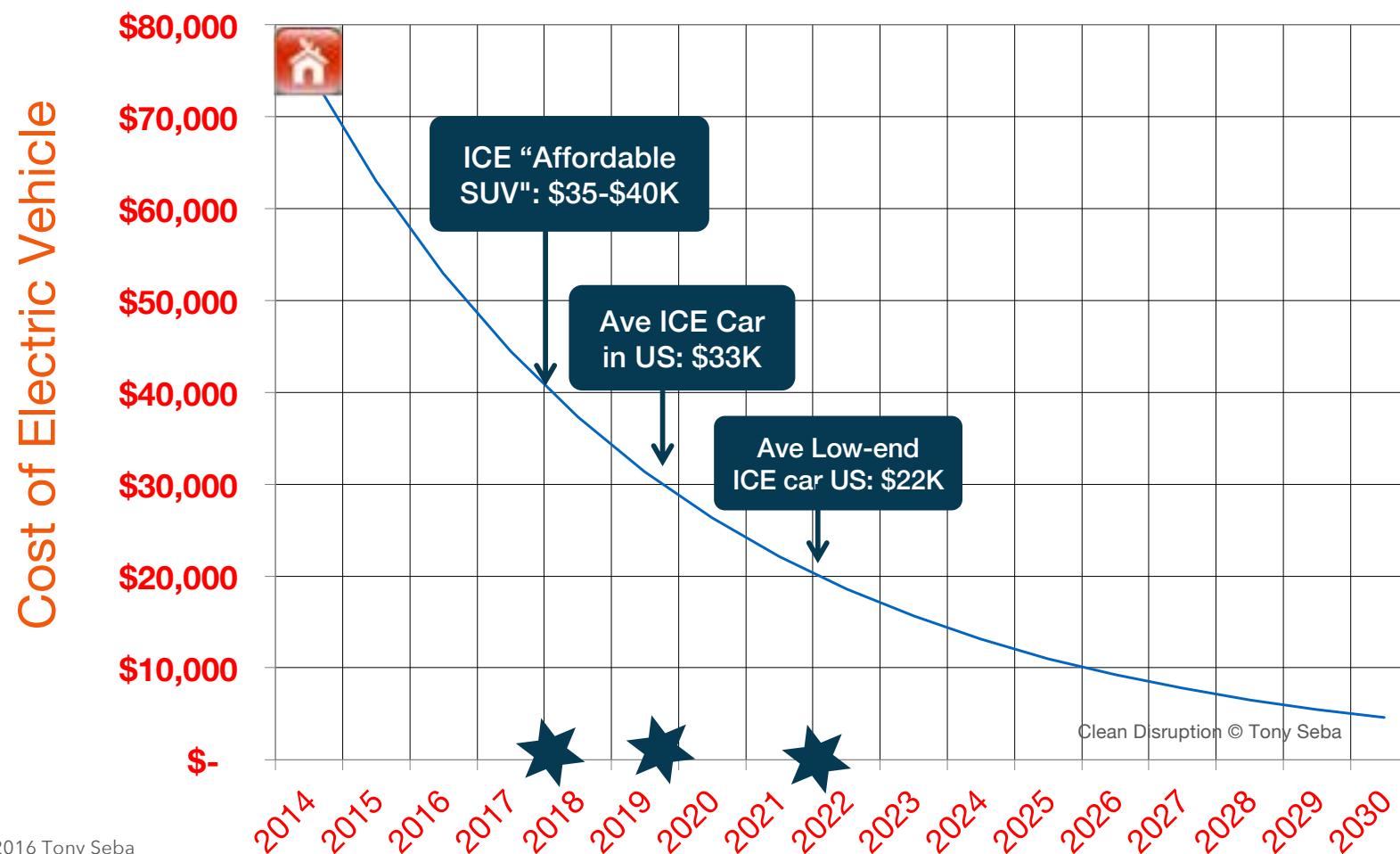


- **EV powertrains** can last **500,000 miles** (800,000 Km)
- Tesla (& others) building **1,000,000-mile** (1.6m Km) Powertrain
- **That's 5x ICE vehicles** <sup>(1)</sup>



# Anticipating Disruption from Above – Electric Vehicles

## Cost of EV with 200-mile (320 Km) range



### Assumptions:

- 4 miles/kWh,
- 50kWh batteries,
- 16% yearly battery cost improvement,
- EV Cost = 3X battery

Source: Clean Disruption

# CEO BARRA UNVEILS BOLT EV @CES

**2017 Chevy Bolt: 200-mile range**  
**Electric Vehicle for \$37,500**  
**[unsub]**

*"It's more than a car, it's an upgradeable platform for new technologies." (1)*

*"Car-sharing, new ownership models, automated driving... down the road."*



Image Source: Fortune

# Tesla Model 3 – Record Single-Day Sales for any Product of Any Kind Ever!

Tesla Model 3

**\$ 35,000**

Unsubsidized

Autopilot (semi-autonomous)

**215-mile** range

0-60mph in < 6 secs

## Market reaction:

180,000 cars ordered / reserved **first 24h!**

**>\$6.3b** pipeline **first 24h!**

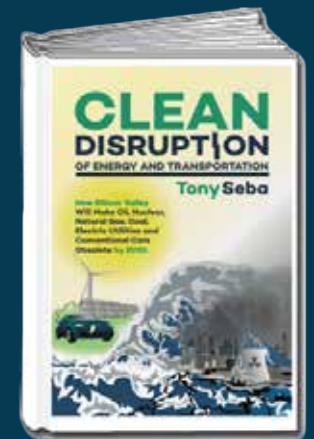
**Biggest Crowdfunding Event in History: \$400m & counting!**



# The Autonomous Vehicle Disruption



Image: Wikipedia



# World's First Self-Driving Taxi Debuts In Singapore

*The first ever self-driving taxis **have started picking up passengers in Singapore.***

*MIT spinoff NuTonomy will be offering rides in 2.5 sqmi business district 1-North. Delphi also announced autonomous trial in Singapore.*



Photo : The Verge



## UBER'S SELF-DRIVING FLEET ARRIVES IN PITTSBURGH

*"Uber's Pittsburgh fleet, will consist of **100 modified Volvo XC90 SUVs**.*

Uber riders logging **100 million miles per day**.  
Uber can use the data collected from its app to quickly improve its self-driving mapping and navigation systems." (1)

*"When there's no [driver], the cost of taking an Uber anywhere becomes cheaper than owning a vehicle and then **car ownership goes away**." Uber's CEO (2)*



Sources: (1) Bloomberg, (2) the Verge , Picture: Uber



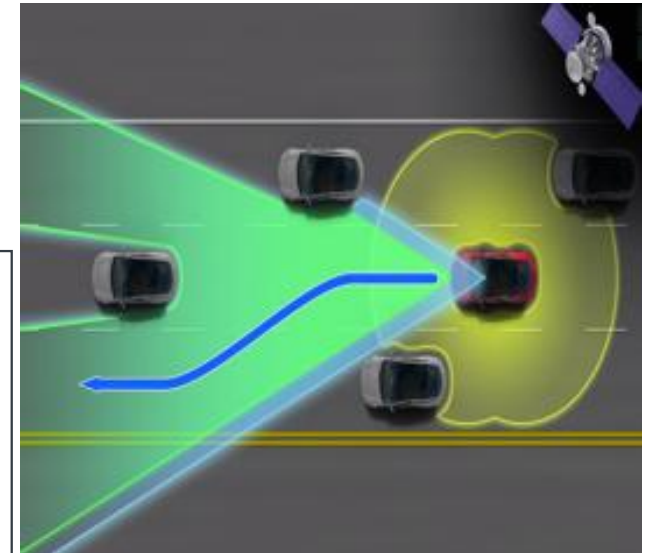
## 33 Corporations Working on Autonomous Vehicles



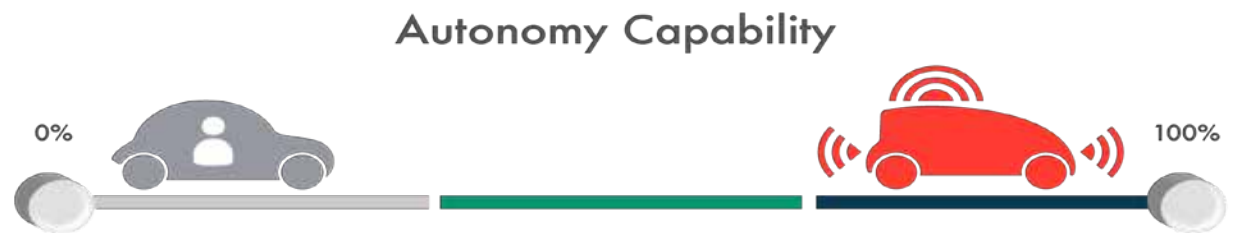
# TESLA TO TRANSITION TO LEVEL 5 - FULLY SELF-DRIVING - 2019

"U.S. National Highway Traffic Safety Administration (NHTSA): **Tesla with Autopilot 40% Safer.**" (1) Jan 2017

Elon Musk: "**From Parking Lot in California to Parking Lot in New York without touching controls by Dec 2017.**" (2) April 2017



"**Level 5 Autonomy in two years [2019].**" (2)



# WHAT ABOUT THE **COST** of Autonomous Vehicles?







# What an autonomous car sees



# Exponential Technologies: Machine Vision (LIDAR Sensors)

2012

Google announced that the cost of technology in its self-driving car was

~\$150k

LIDAR Sensor (for Machine Vision) was

\$70k

By the end of

2013

The next generation LIDAR was

\$10k

By Oct

2014

A SV Startup company announced LIDAR for

\$1k

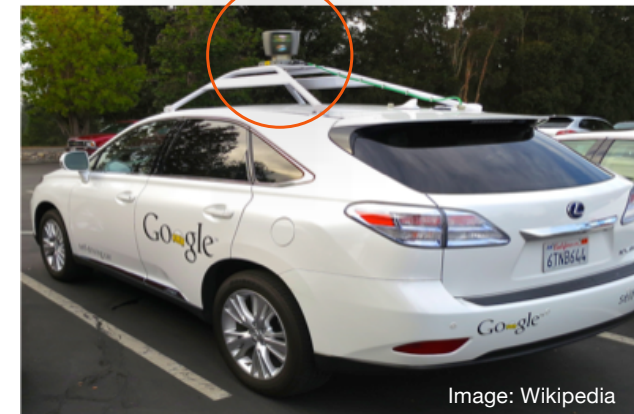


Image: Wikipedia

# LIDAR: From \$70,000 to \$250

2015 GEN 1 LIDAR

\$1,000

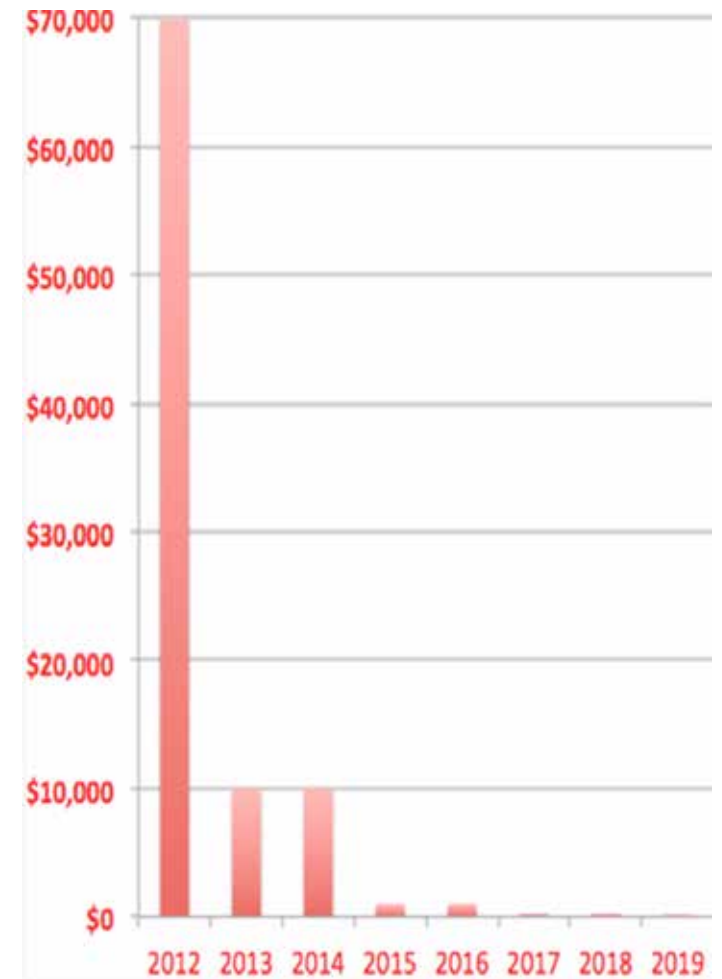
2016 GEN 2 SOLID STATE LIDAR

\$250



GEN 3 (POSTAGE STAMP)

\$90



Sources: Quanergy, Clean Disruption

# Autonomous Vehicles = Computer on Wheels

WHAT IS THE

Cost Curve  
of Computing  
Power

TO PROCESS SENSOR  
INPUT?





# Year 2000: World's 1<sup>st</sup> 1-TeraFlops Computer

## ASCI RED - Sandia National Labs

- ▶ Space = 1,600 sq ft **(150 m<sup>2</sup>)**
- ▶ Power Consumption = 850 kW
- ▶ **Cost = \$46 million**



Image: Extreme Tech

# Exponential Tech Improvement: GPU NVIDIA Drive™ PX

Dual Tegra® X1 GPU Processor  
**2.3 TeraFlops**

Power Consumption = **15 W**

56,666X improvement

Cost = **\$59**

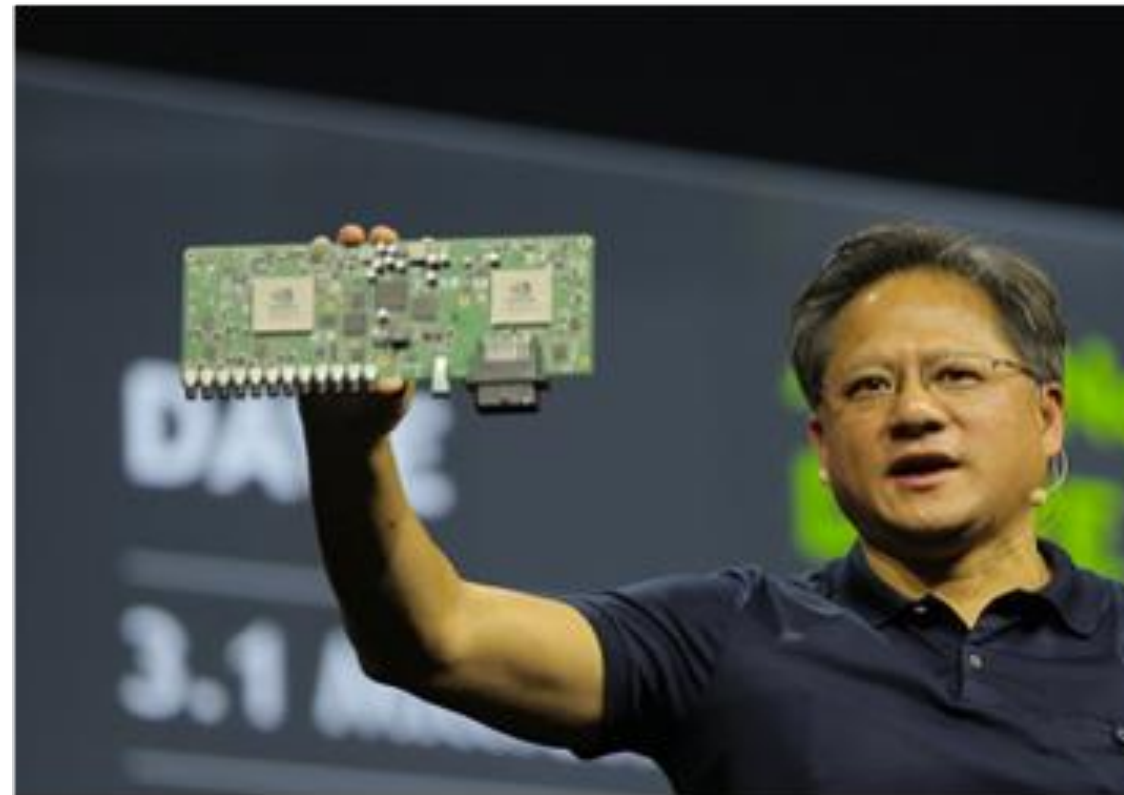
~1 million X improvement

✓ Xavier® (end 2017): **20 TFlops**

✓ Built for Self-Driving Cars

▶ Deep Learning Software

✓ **1,000x** improvement by **2025**



#### DISRUPTION ACCELERATORS

##### Open Access Technology Development

Open access to technology and capital lowers costs, increases the speed of product development and lowers barriers to entry.

EXAMPLES: open source, open knowledge, open APIs, crowdfunding

##### Conceptual Innovations

New concepts, methods, models, frameworks and software architectures that enable totally new ways of doing things.

EXAMPLES: TCP/IP, blockchain

# Disruption Accelerators Open Source

## First Person To Build a Self-Driving Car in his GARAGE!

*"George Hotz built a Self-Driving car with off-the-shelf parts with \$50,000 investment. The goal is to sell the self-driving package for \$1,000 per unit."* (1)

*"Hotz **Open Sources** the **Software** (Open Pilot) and hardware (Comma Neo) needed for self-driving." (2) Nov 2016*



Photo Sources: Bloomberg

Cool! I can



Instagram

and also



while NOT driving!



---

BUT WHAT'S THE  
Disruptive Impact?

# Transportation As A Service





# Cars: Huge Waste of Space and Money

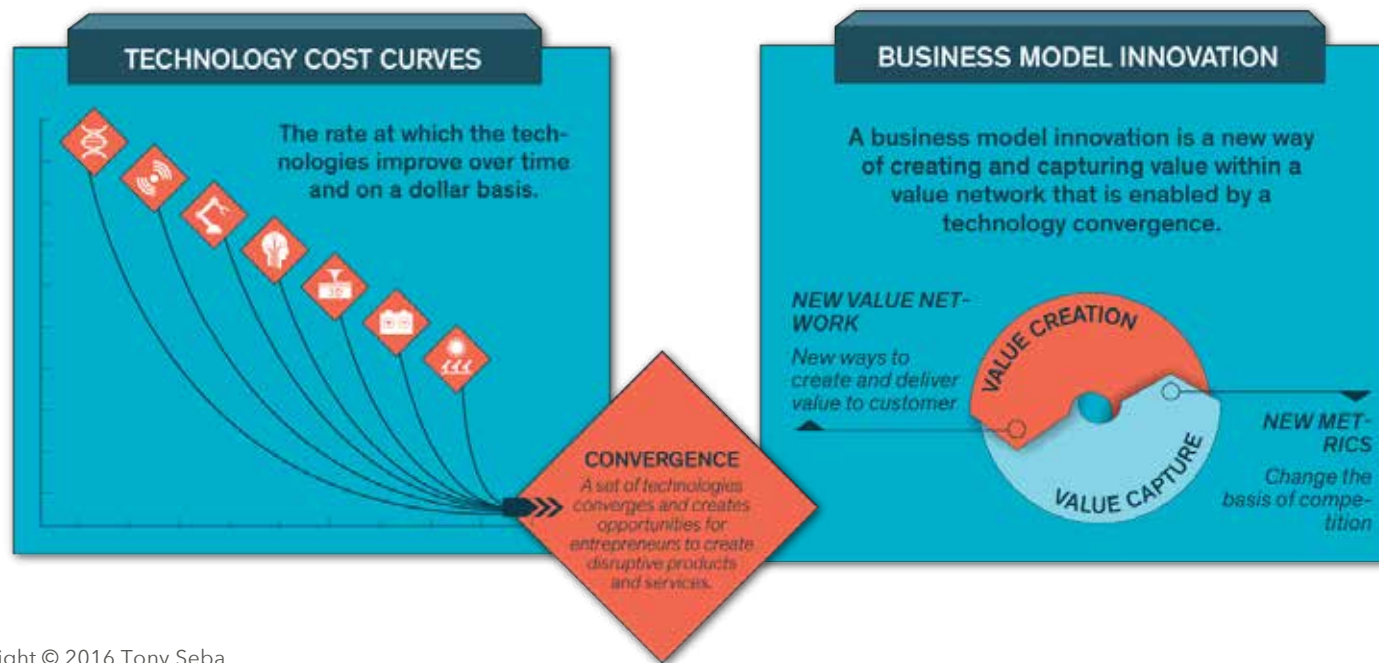
- ▶ Cars = 2<sup>nd</sup> largest Capital Expense
  - ▶ Ave. new car costs = \$33k
- ▶ Cars are parked **96% of the time!** <sup>(1)</sup>
- ▶ **4% Asset Utilization**  
is a disruption waiting to happen!





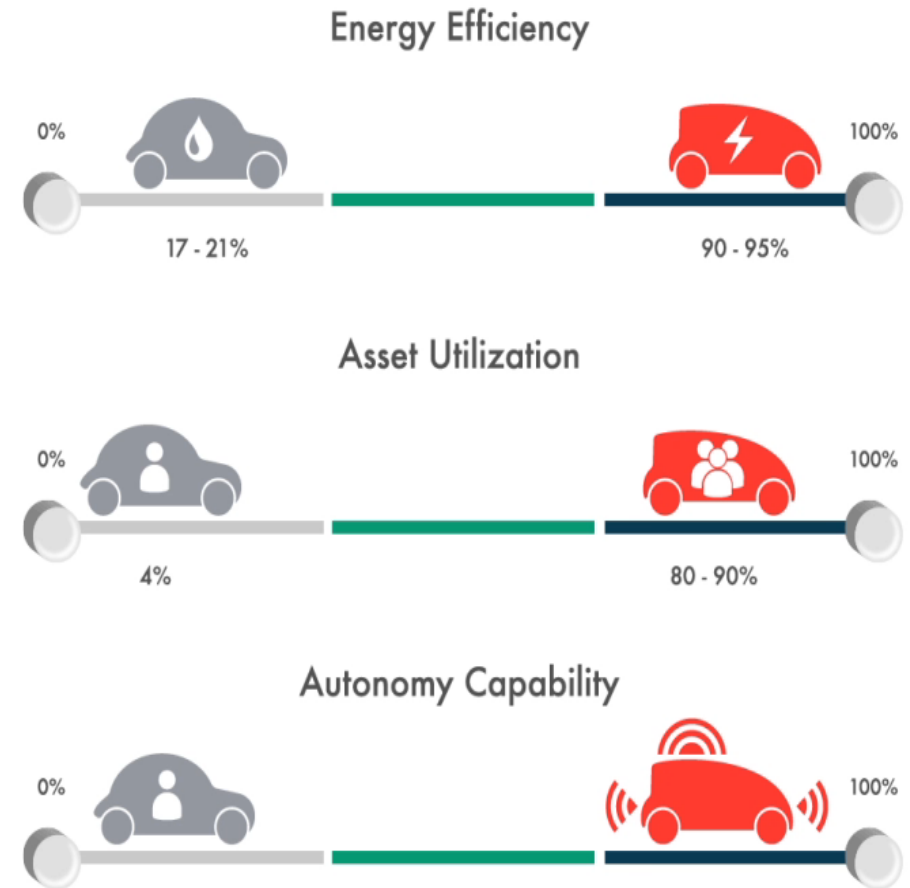
On Demand + SELF-DRIVING + ELECTRIC:

# Convergence of Technology & Business Model Innovation



# TaaS - Transport-as-a-Service: On Demand, Electric, Autonomous

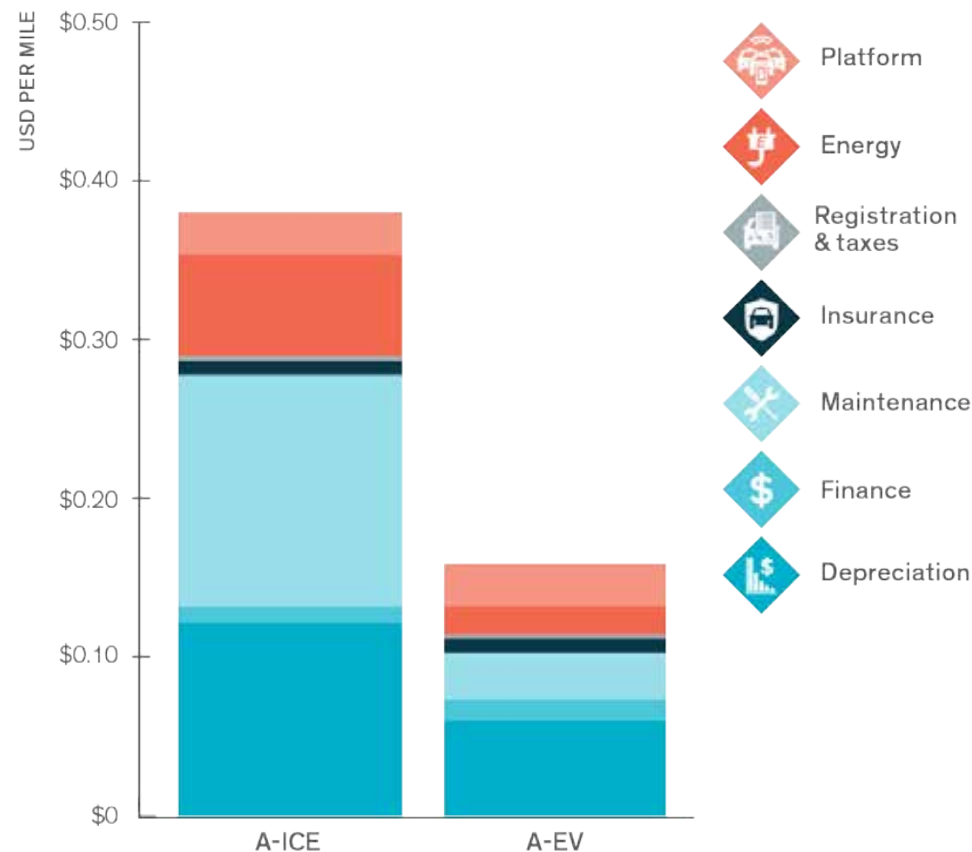
- ▶ Transport As A Service (TaaS)
  - ▶ **Ride-Hailing** biz model
  - ▶ **Electric Vehicle** tech
  - ▶ **Autonomous Vehicle** tech
- ▶ Driving time goes from **4%** to **40%**
- ▶ Vehicle Asset Utilization goes **UP 10X**
- ▶ Cars can **drive 100,000 miles/year** (up from 10k miles/yr)



# Do the Math: A-EV far cheaper than A-ICE

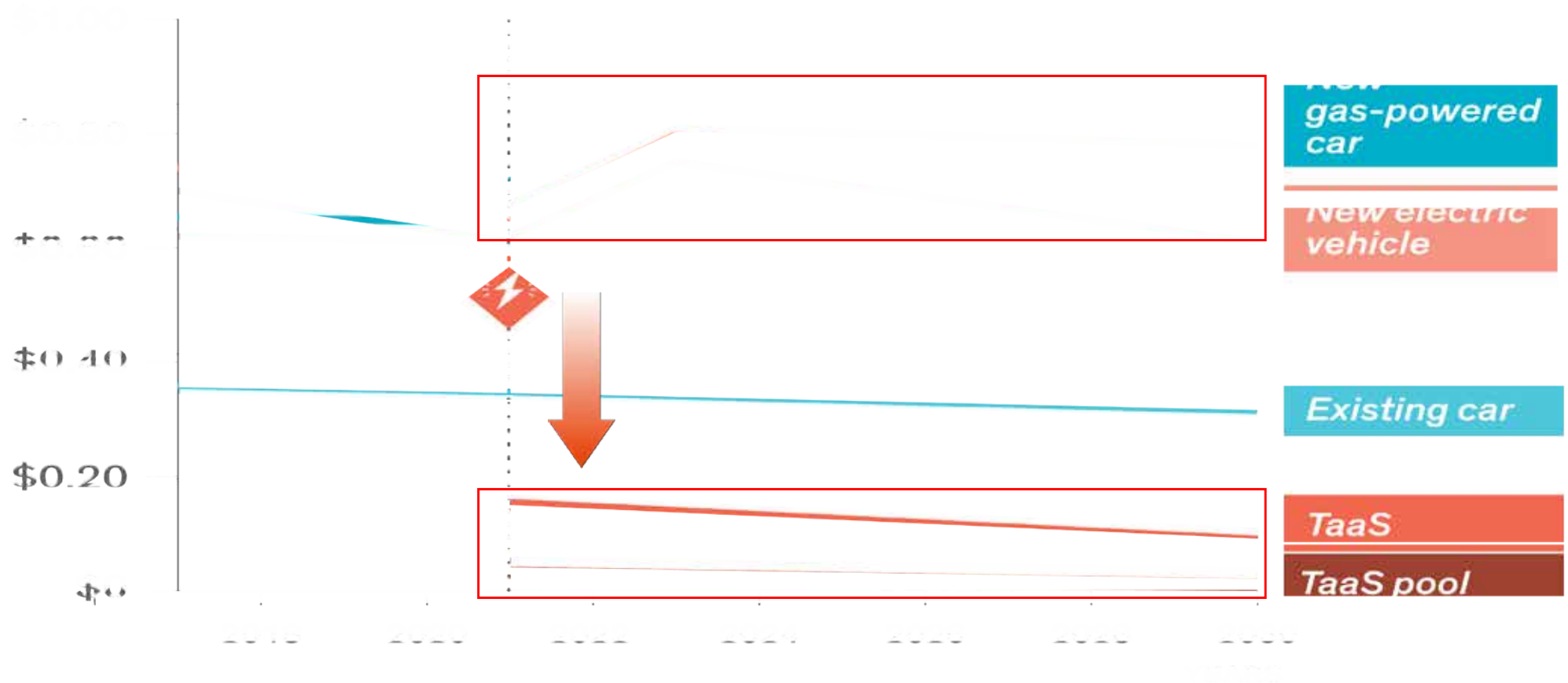
» A-ICE vs. A-EV as basis for fleet choice in 2021

- ▶ Autonomous **Internal Combustion Engine** Vehicles **can't compete** with Autonomous **Electric Vehicles**.
- ▶ TaaS companies that use A-ICE will either go bankrupt or switch to A-EVs



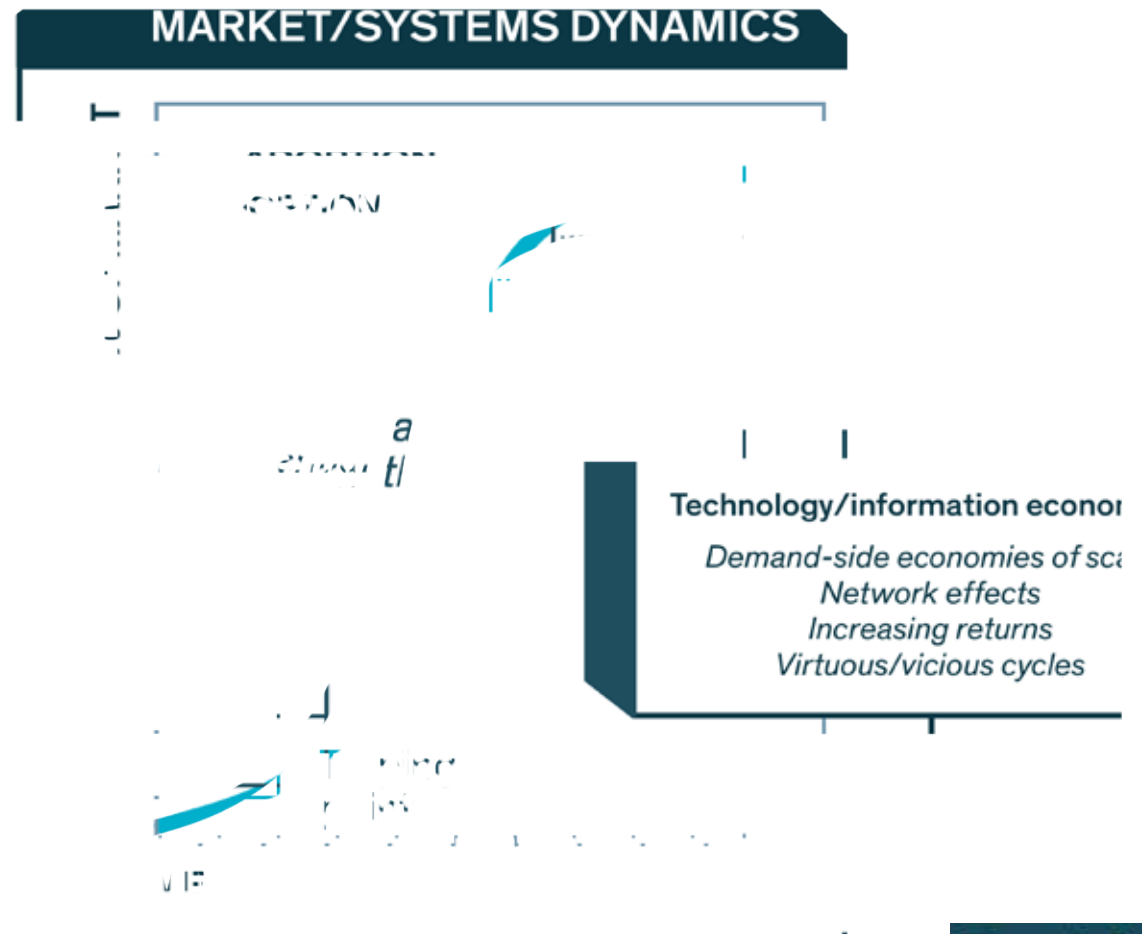
Copyright © 2017 RethinkX

# TaaS: 4x-10x Cheaper than IO Vehicles

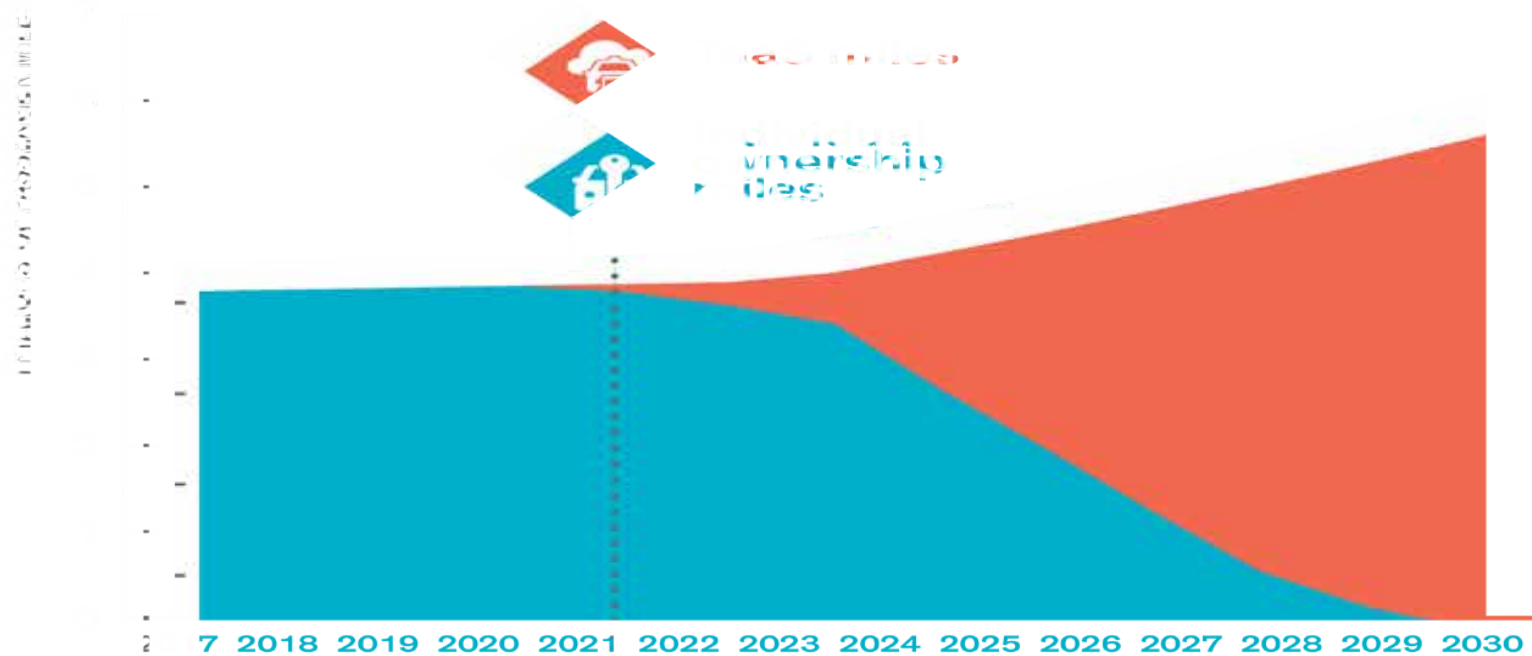


# Technology Adoption S-Curve

- ▶ Technology adoption:
  - ▶ S-curves
  - ▶ Exponential growth after tipping point



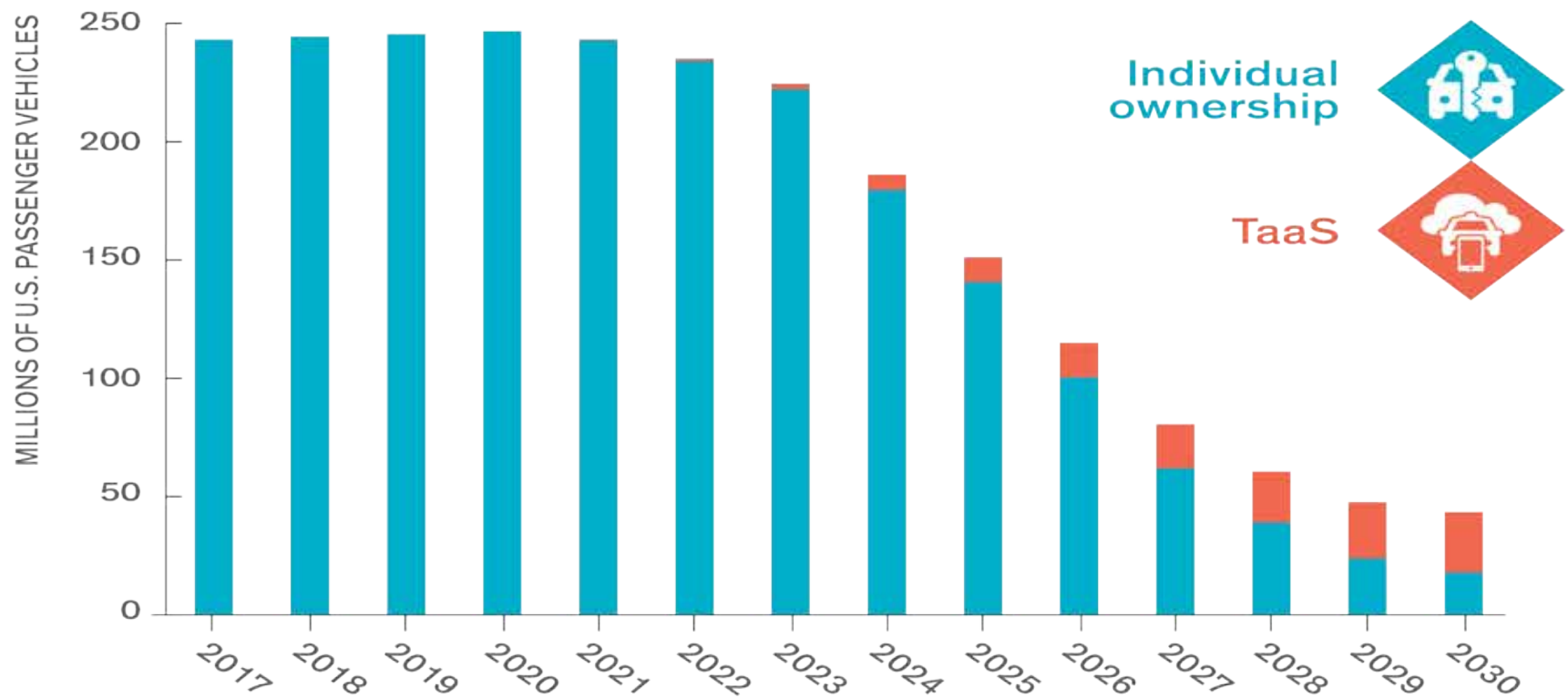
# 95% of Passenger Miles TaaS (AEV) by 2030



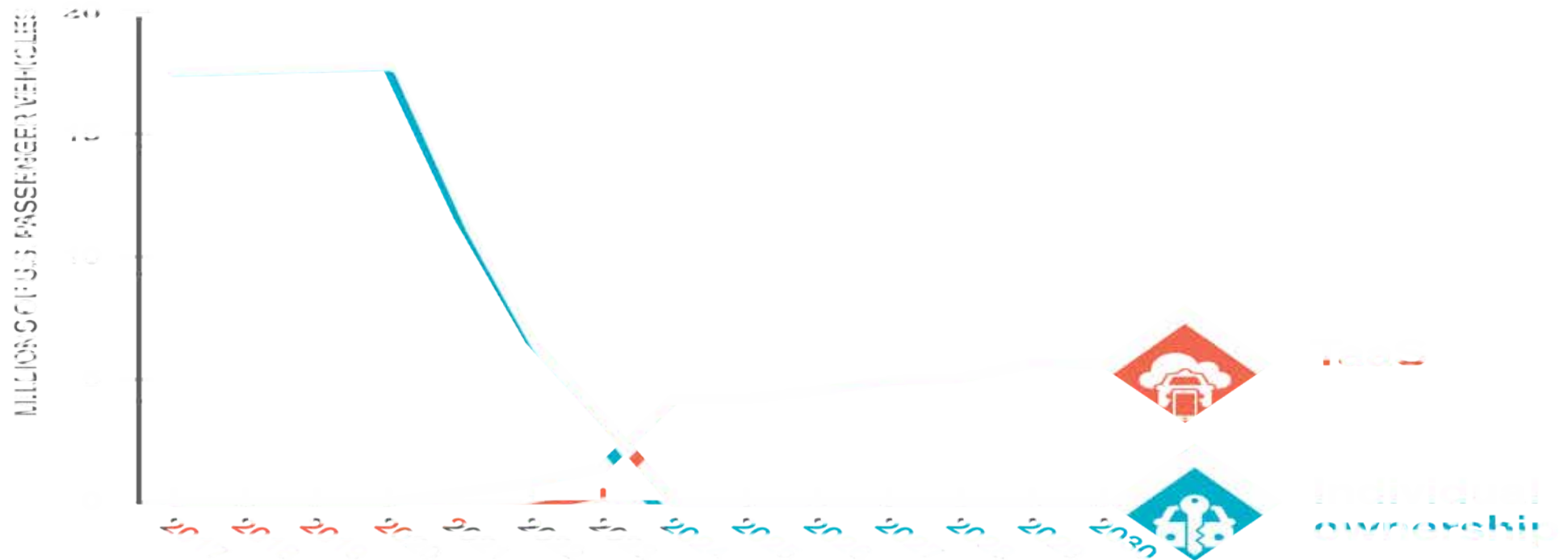


# End of ICE & IO

# U.S Vehicle Fleet Shrinks by 80%



# Annual Demand for New Vehicles Shrinks by 70%

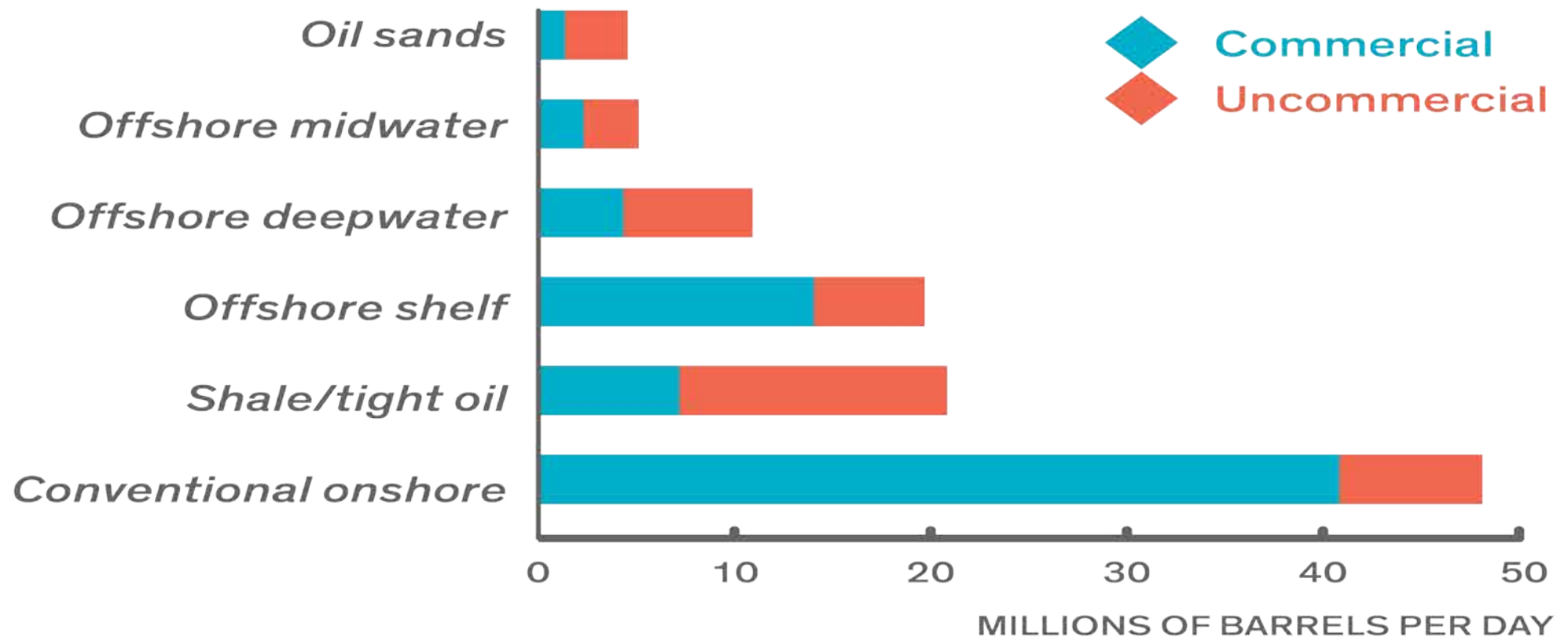


# Disruption of Oil

# Global Oil Demand Peaks at 100mpd 2020 Drops to 70mpd 2030



# Up to 70% of Deepwater Oil, Shale Oil, Oil Sands Uncommercial = Stranded Assets

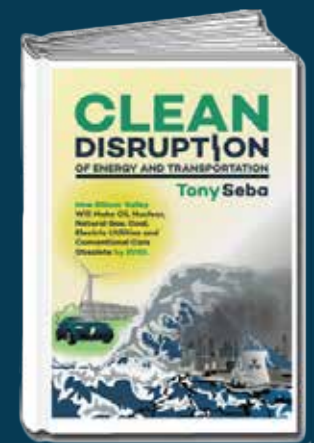




# The Solar Disruption



Image: Tony Seba



## Denmark School generates 50% of energy needs with Solar

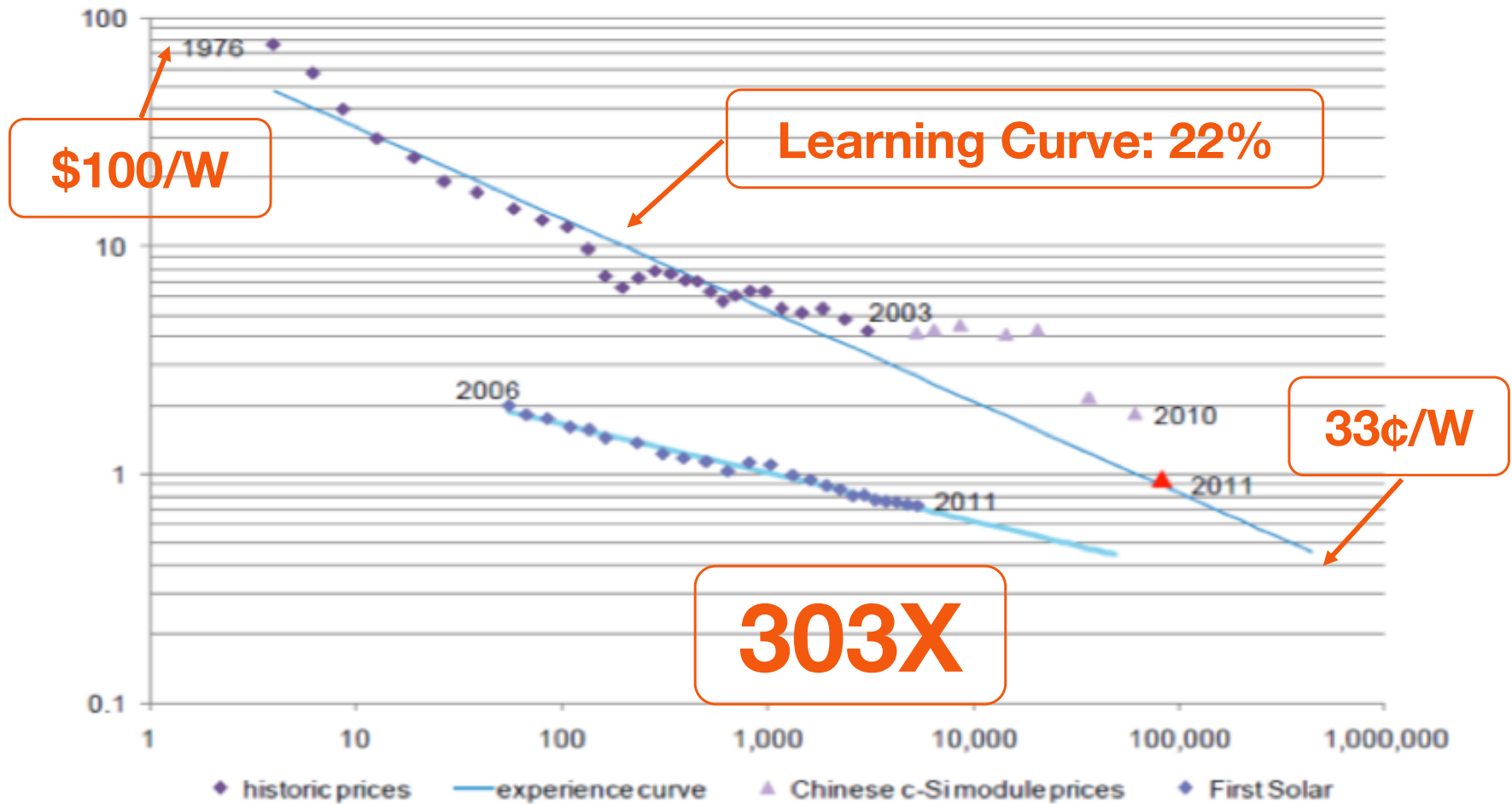
*Solar generates 300MWh of solar, 50% of Copenhagen International School annual energy consumption. "*

*Copenhagen is 3° South of Juneau, Alaska.<sup>(2)</sup>*



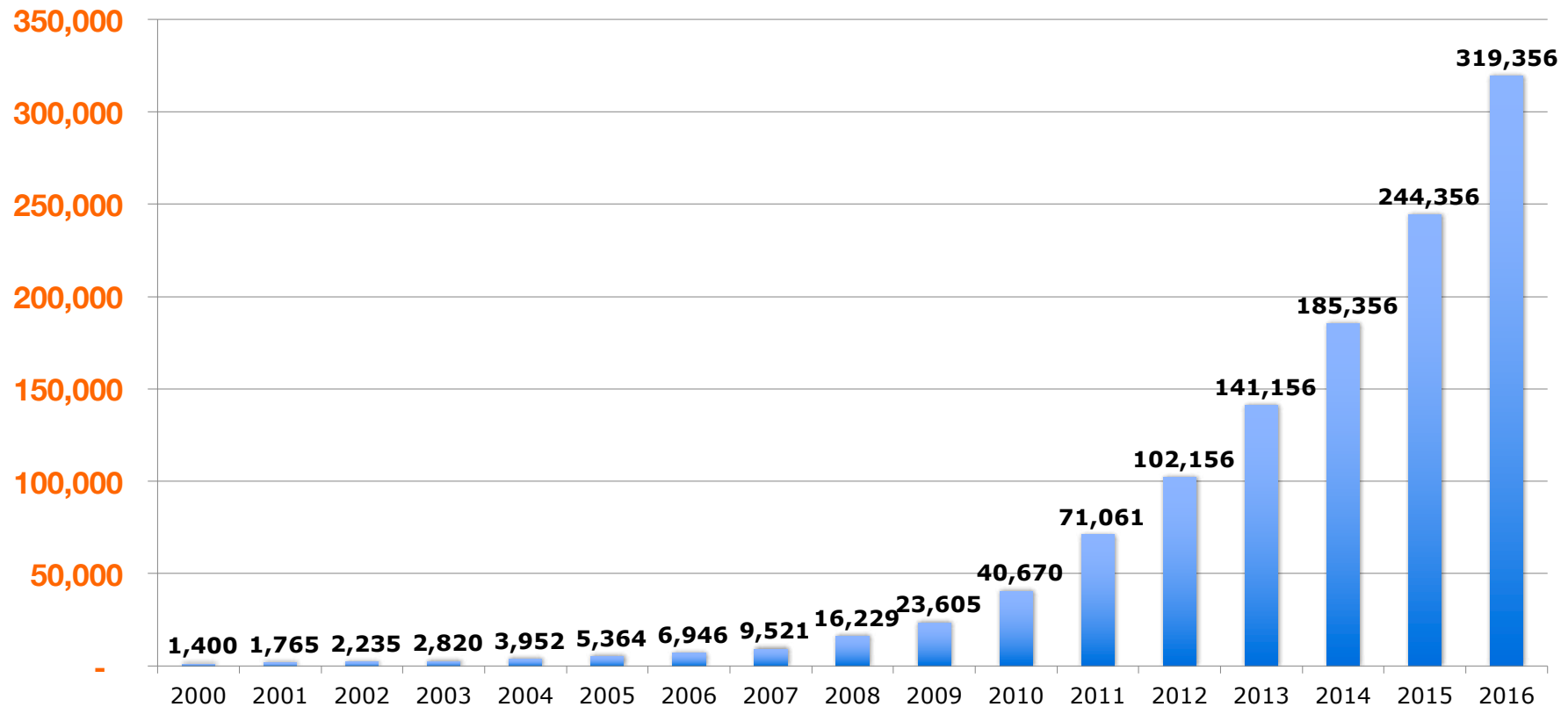
Photo Sources: FFPL

# Solar PV Costs: DOWN 303X



# Market: Solar PV Installed Capacity: **UP ~227x**

Global Installed Solar PV (MW)



- ▶ **Solar PV Exponential Market Growth 2000-2016 ~40% / year**
- ▶ **Solar PV installed Capacity 2000-2016 Growth ~ 227x**

Can Solar  
Continue Growing  
at this Rate?



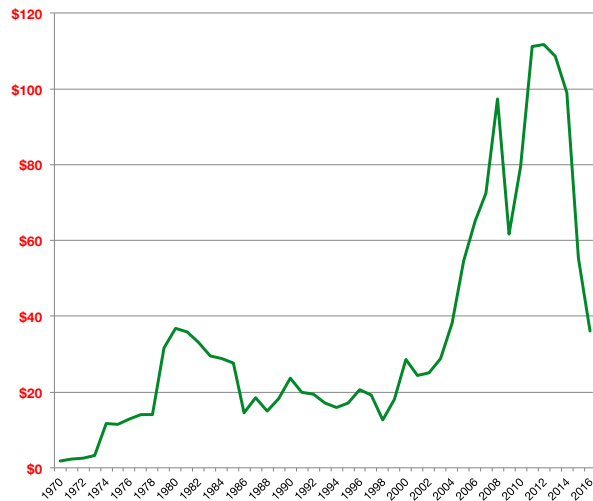
# Solar Cost Trends

vs

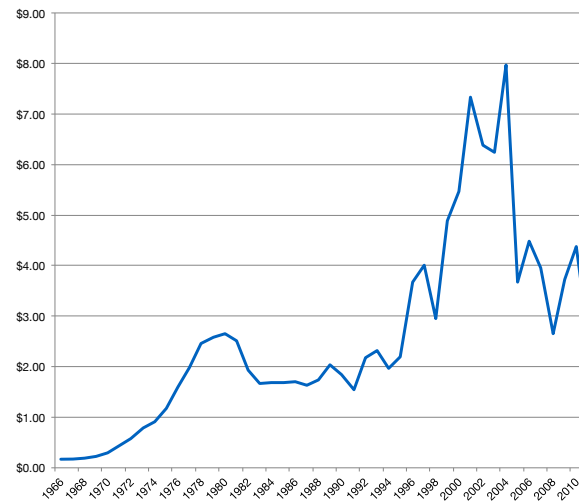
# Conventional Energy



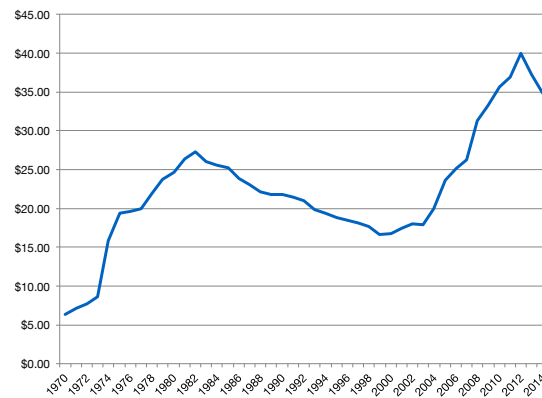
# Since 1970 Prices for conventional resource-based energy sources are up 6X - 16X



Oil

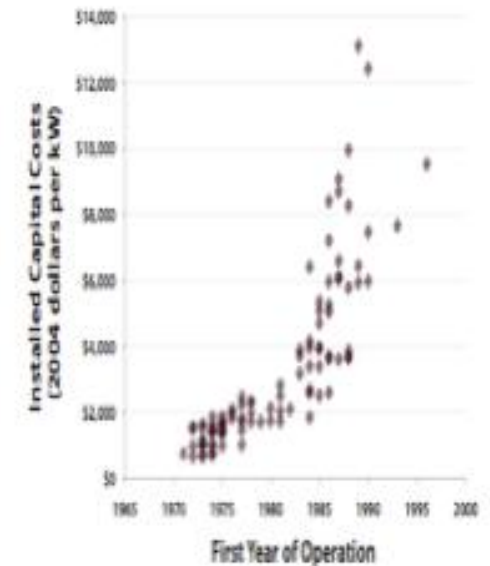


Nat Gas



Coal

Figure 8: Actual Capital Costs of Completed U.S. Nuclear Reactors (in 2004 Dollars)<sup>12</sup>



Nuclear

# Solar Cost Improvement vs. Conventional Energy

Oil at \$50/bbl →

Solar PV <u>Cost Improvement</u> relative to:	<u>Times</u> improvement (1970-2017)
Petroleum	4,795x
Nuclear	3,994x
Natural Gas	4,478x
Coal	1,764x

Source: Clean Disruption

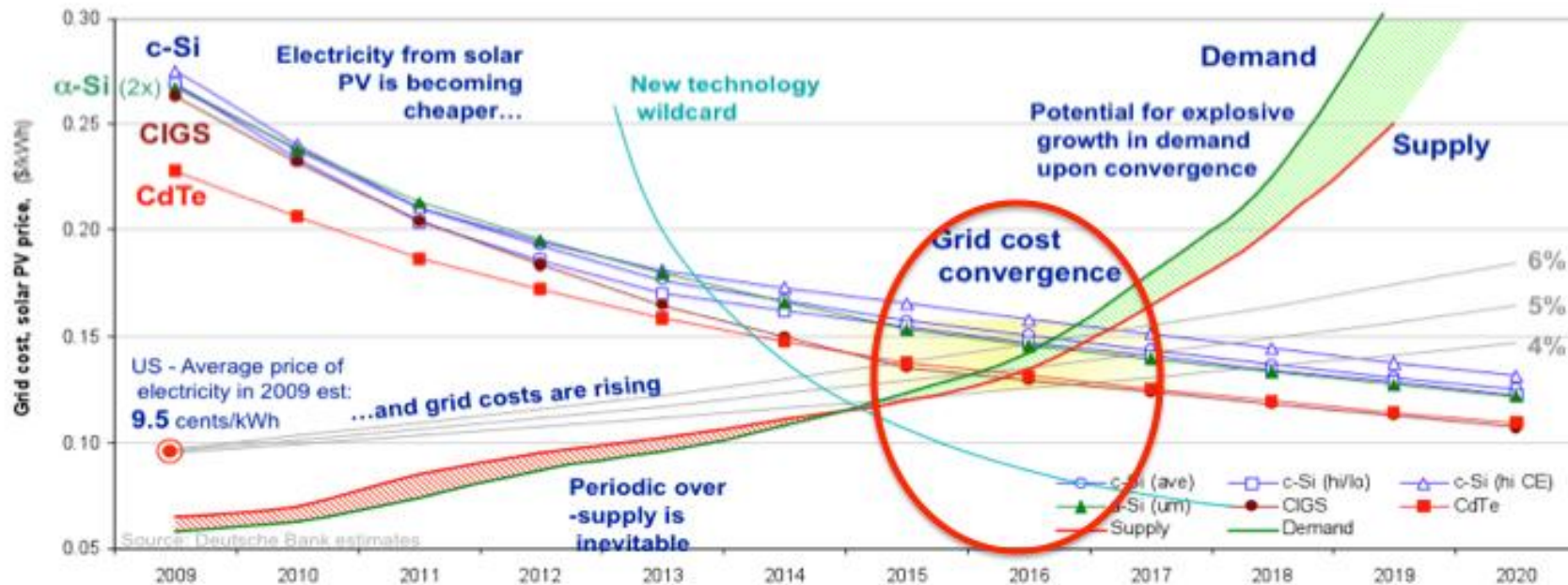
- ▶ Since 1970 Solar PV has improved cost by thousands of times relative to conventional forms of energy
- ▶ Note: unsubsidized cost of solar PV

BACK TO SOLAR COST TRENDS:

1 - Grid Parity, then  
2 - God Parity?



## DB: Grid Parity in 80% Global Markets by 2017



- ▶ Deutsche Bank: **Solar Below Grid Parity** in
  - ▶ **Up to 80% of Global market by 2017** <sup>(1)</sup>
- ▶ PWC: **69% of Corporations** actively pursuing solar purchases <sup>(2)</sup>

## Mandalay Bay installs Largest Rooftop Solar System in US

*"NRG Energy installs 8.3MW solar array on MGM Resort International's Mandalay Bay Convention Center."*

"The system can provide **25% of the entire electricity demand of the Mandalay Bay Resort and Casino complex**. NRG is the owner of the system and will sell the electricity through a 25-year Power Purchase Agreement to MGM Resorts International."



# Solar Growth Rate may Accelerate! (TECH S-CURVE)



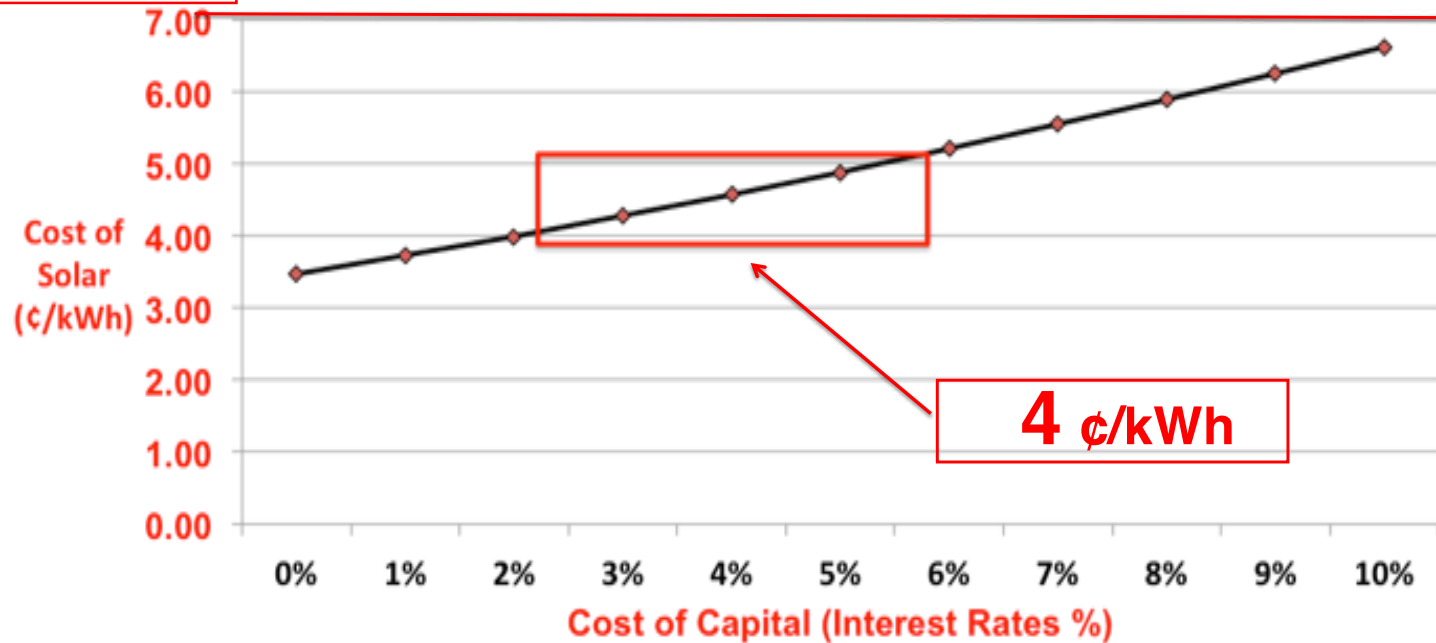


The background image is a high-contrast, artistic representation of a solar event, likely a coronal mass ejection or a large solar flare. It features a bright, turbulent mass of orange and yellow plasma erupting from a dark, circular base, resembling a crater or a point of origin. The surrounding space is dark, filled with numerous small, distant stars, creating a sense of vastness and cosmic scale. The overall color palette is dominated by the warm, fiery tones of the solar event, contrasting sharply with the deep blacks and greys of the cosmic background.

Solar GOD Parity  
Point of No Return

# God Parity by 2020 - \$ Rooftop Solar < \$ Transmission

Transmission  
Costs ¢/kWh



- ▶ **God Parity: cost of (unsub) rooftop solar lower than cost of transmission!**
- ▶ Centralized Generation can't compete
  - ▶ Obsolete: Nuclear, Natural Gas, and Coal



Every house, business,  
warehouse, building, factory,  
shopping center everywhere  
will have  
**SOLAR...**

BUT NOT ALL POWER GENERATION  
WILL BE ROOFTOP, RIGHT?

What about **Utility Scale?**



Photo: Tony Seba





## Utility Scale Solar → Dropping below 3 ¢/kWh



- ▶ 2016 USA PPAs ~4 ¢/kWh (+/- 1 ¢/kWh) (1)
- ▶ “Solar at 5.8 ¢/kWh is competitive with oil at US\$10/bbl and gas at US\$5/MMBtu” (2)
- ▶ 2016 Chile @ 2.91 ¢/kWh (unsub) & Dubai @ 2.99 ¢/kWh (3) (4)
- ▶ 2016 Abu Dhabi PPA @ 2.42 ¢/kWh (unsub) (Sept'16) (5)

## Tucson Electric **Solar + Storage** PPA at **4.5 ¢/kWh**

*Tucson Electric has signed a PPA for **100 MW solar** array plus with a **30 MW / 120 MWh battery storage** system to deliver **dispatchable solar** for "less than" **4.5 ¢/kWh**.*

*The solar portion is "less than" **3 ¢/kWh***

**Conventional Peakers** in Arizona  
produce power at ~**20 ¢/kWh**



Photo: By Zerech – CC BY 3.0 Wikimedia



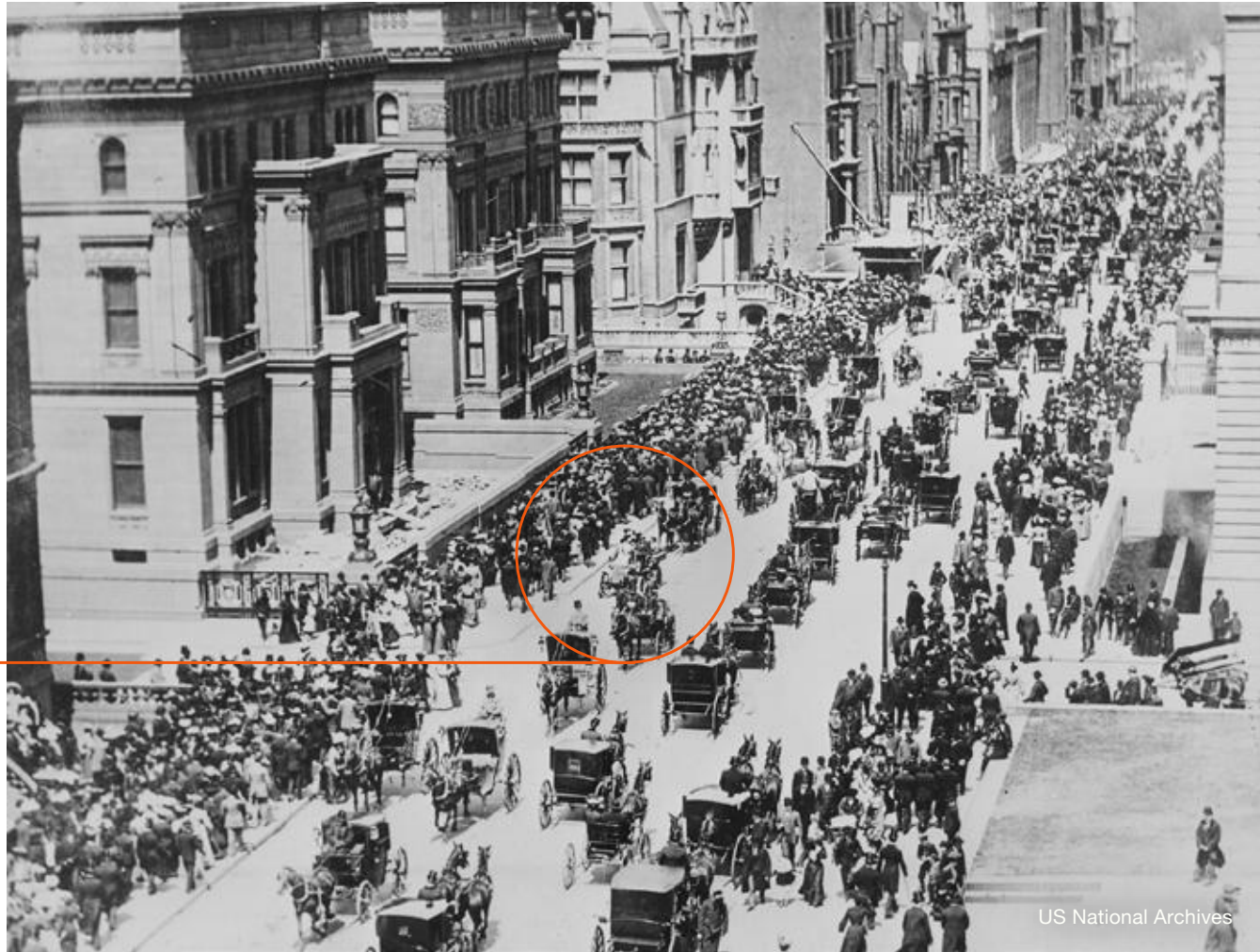
# Back to the Future

# On the Cusp of Clean Disruption of Energy & Transportation

2017

We are here

---



# This is **NOT** an Energy Transition This is a **Technology Disruption**

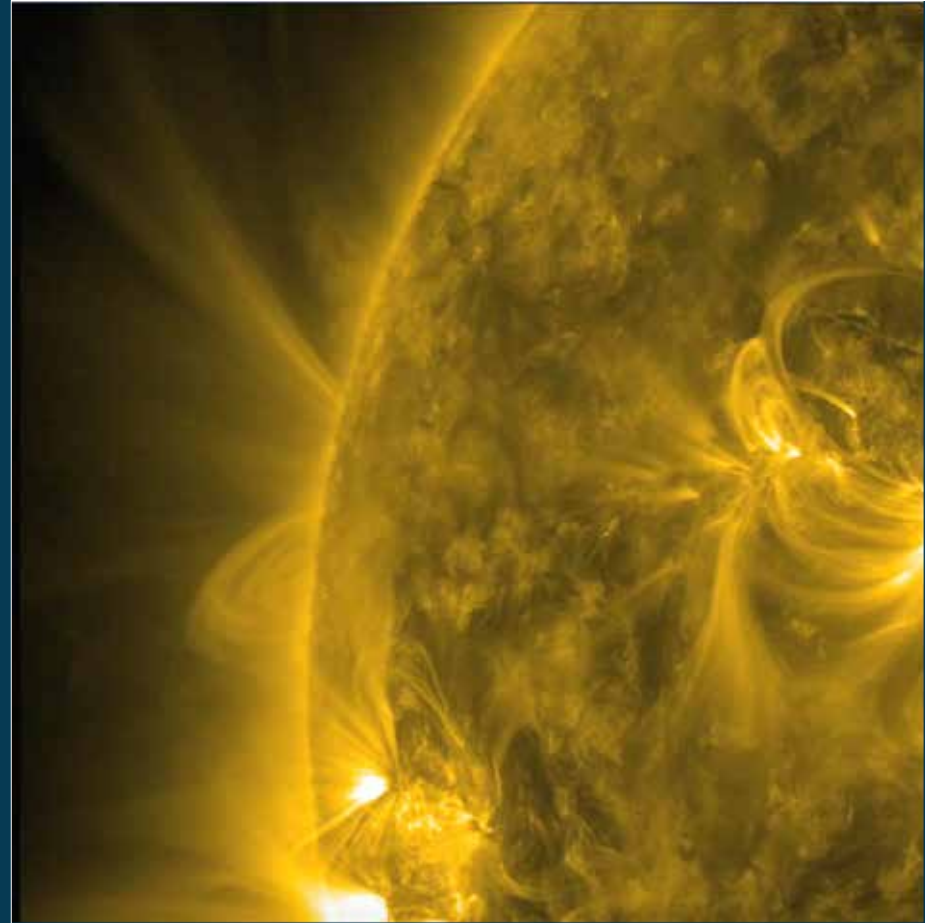


Photo: Tony Seba

Copyright 2016 Tony Seba



# Thank You!



# Clean Disruption of Energy & Transportation

## Clean Energy Action Sunshine Award Boulder, CO

8 June 2017

Presentation to:

**RethinkX**

Tony Seba  
[www.tonyseba.com](http://www.tonyseba.com)

