# CLEAN DISRUPTION

## WHY CURRENT ENERGY AND TRANSPORTATION WILL BE OBSOLETE BY 2030

Presentation to:

## Petroleum Institute of Thailand

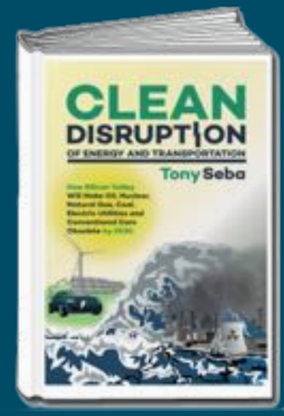
**PTIT 30th Anniversary Keynote**

Bangkok, Thailand

12 May 2016


**Tony Seba**

www.tonyseba.com



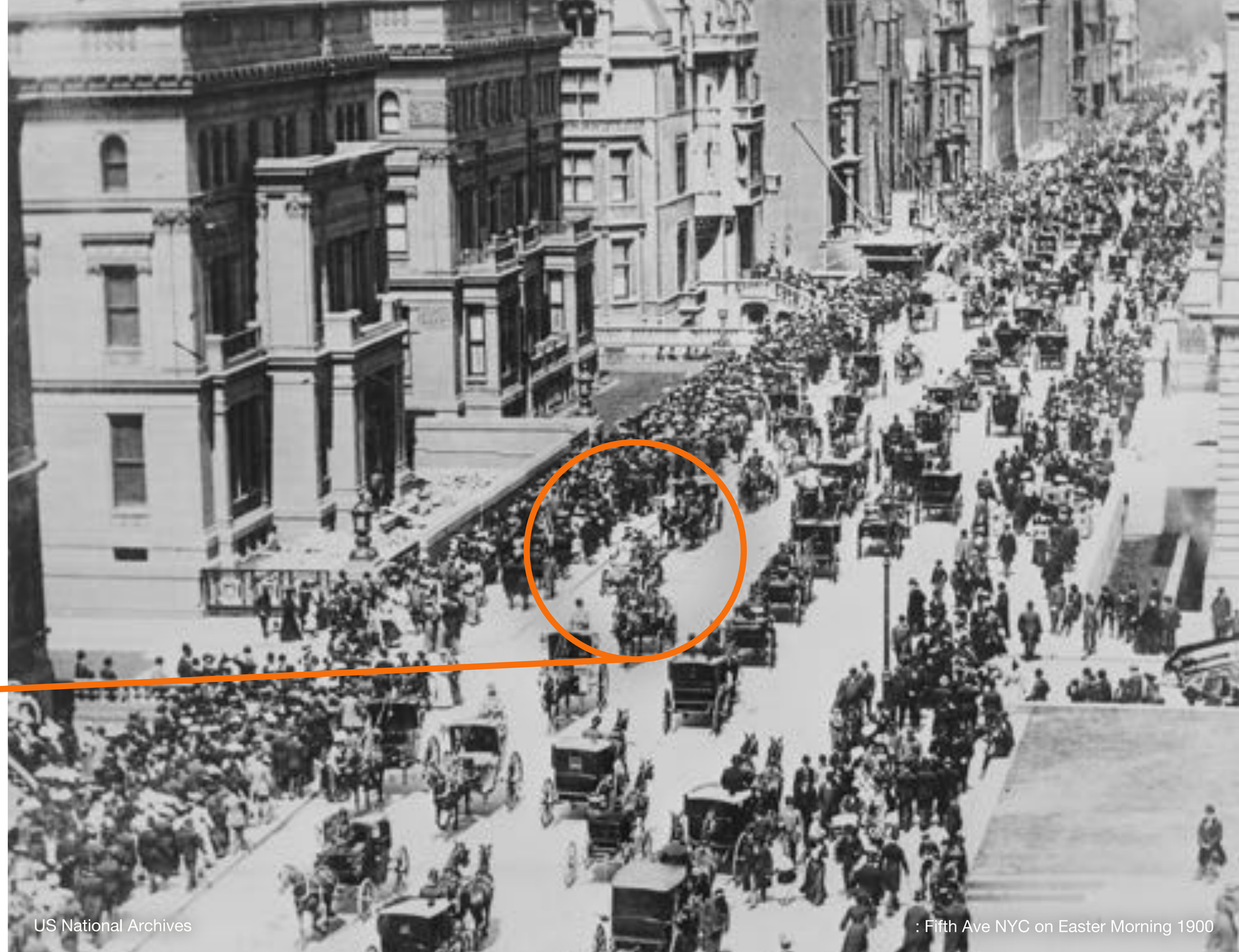
A STROLL DOWN

# Memory Lane

5th AVE NYC

# 1900

## Where is the car?



US National Archives

: Fifth Ave NYC on Easter Morning 1900

# 5th AVE NYC

# 1913

## Where is the horse?

George Grantham Bain Collection

Photo: Easter 1913, New York. Fifth Avenue looking north.

TECHNOLOGY BASED

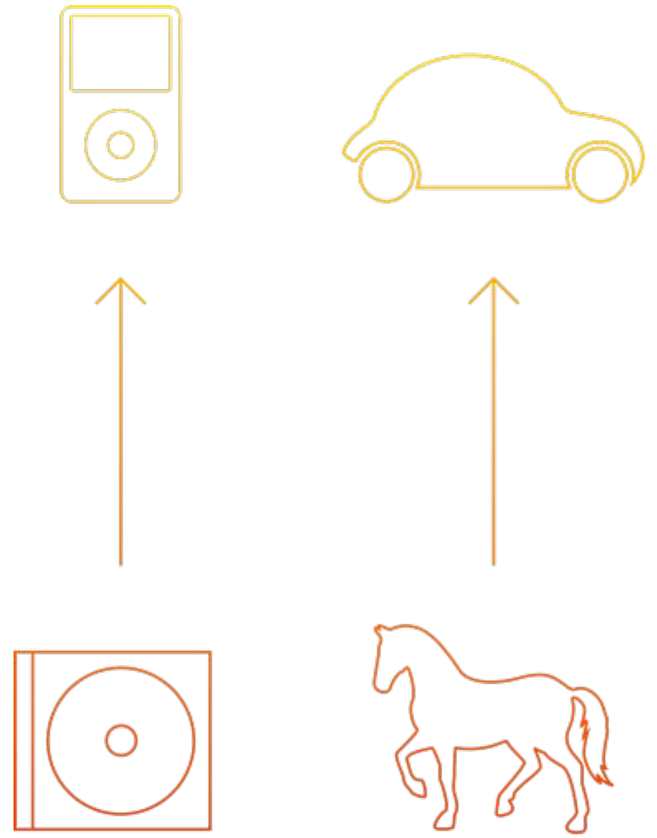
# Disruption

Rodin – Thinker
Photo: Tony Seba

# 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

# ‘Expert’ Disruption Forecasts

In the mid-1980s AT&T hired McKinsey & Co to forecast cell phone adoption by the year 2000

THEIR (15-YEAR) PREDICTION

900,000

SUBSCRIBERS

THE ACTUAL NUMBER WAS

109 million

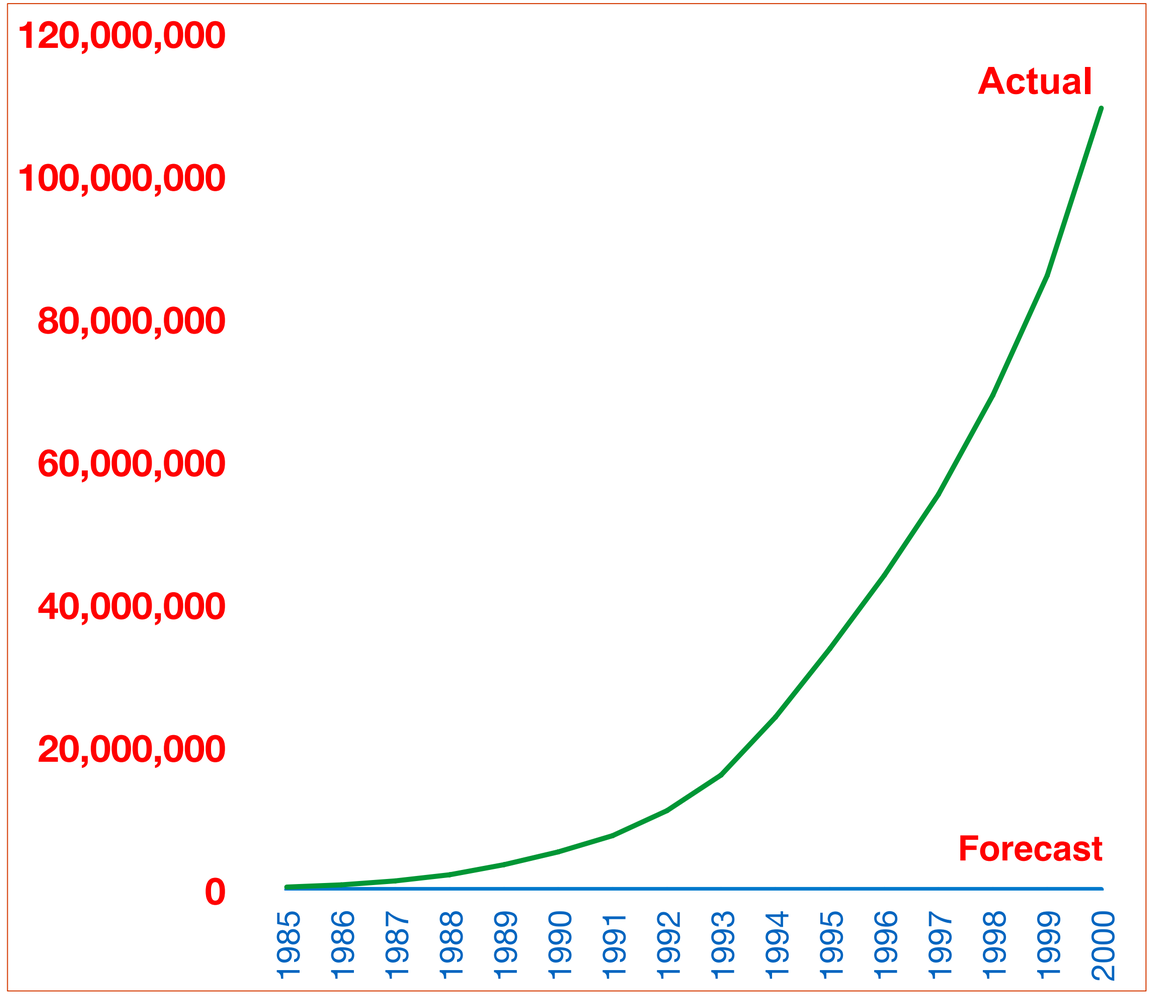
They were **off** by a factor of:

120x



Motorola DynaTAC 8000X from 1984. Source: Wikimedia, Source: Economist

# 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!

Subscriber Data Source: CTIA - The Wireless Association Internet Companies: Internet Report 2015 - Mary Meeker

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

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

*Bill Gates,CEO Microsoft, 1994*

"There is no reason anyone would want a computer in their home."

*Ken Olson, CEO DEC, 1977*

"The Internet will catastrophically collapse in 1996."

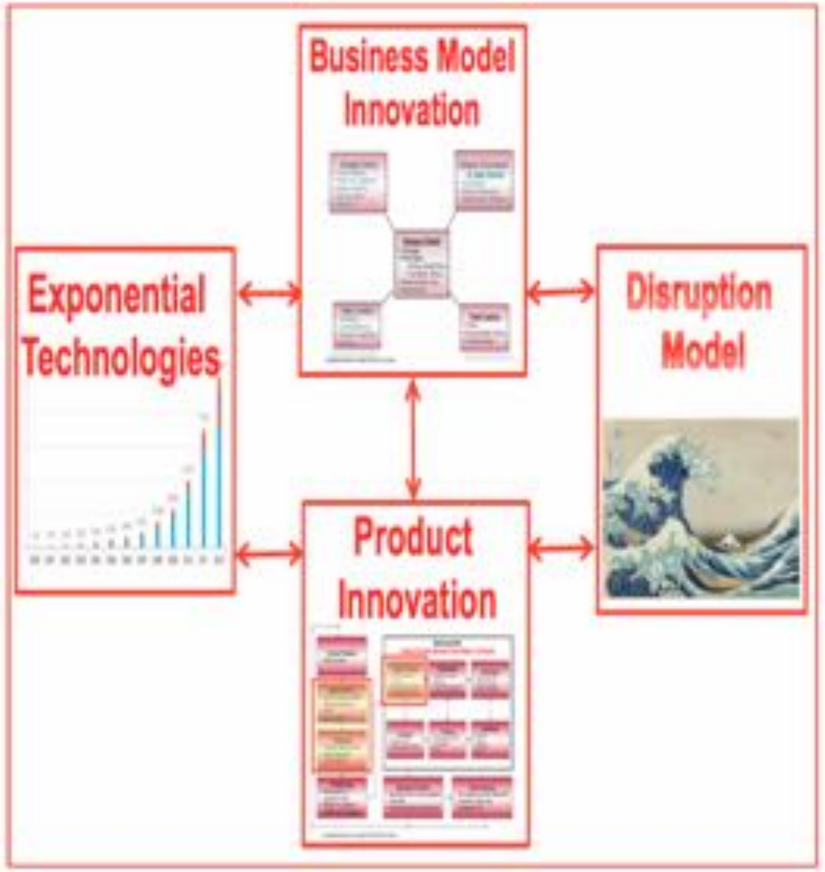
*Robert Metcalfe, founder 3Com, 1995*

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

Rodin – Thinker
Photo: Tony Seba

# Created New Tech Disruption Framework to Anticipate / Lead Market Disruptions

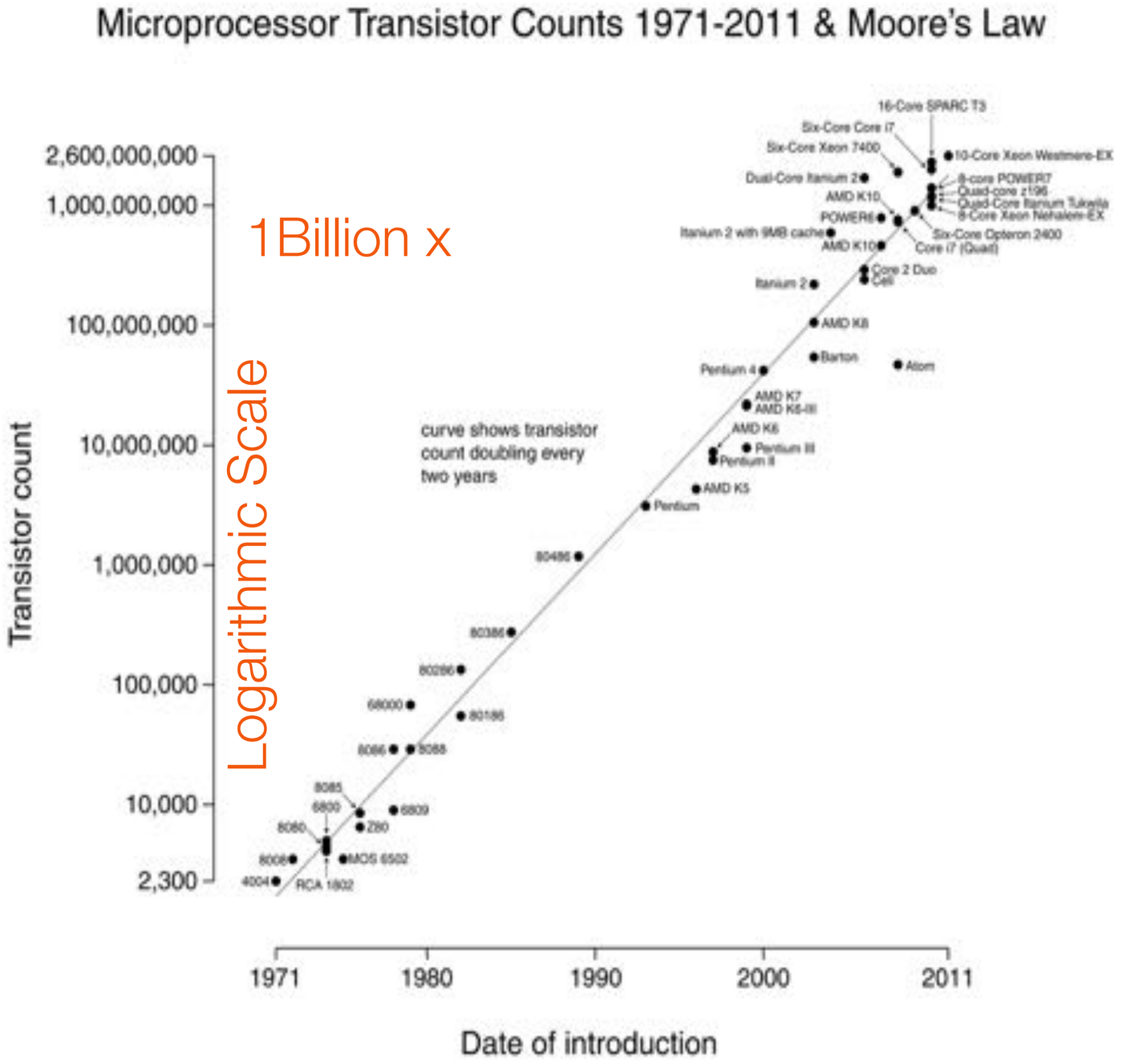
1. Disruption Models
2. Exponential Technologies
3. Business Model Innovation
4. Product Architecture & Innovation



# Exponential Technologies

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

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






Source: Wikipedia

# PC / Internet / Mobile Phone industries: Convergence of Exponential Technologies

- **Several Technologies improving at exponential rates**

- **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**



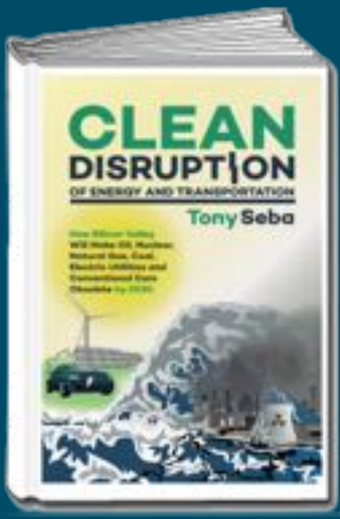

Source: Wikipedia Image: apple.com

# 2016: Key Exponential Technologies

1. Sensors / Internet of Things
2. Artificial Intelligence / Machine Learning
3. Robotics
4. Solar PV
5. Energy Storage
6. 3D Printing
7. 3D Visualization
8. Mobile Internet & Cloud
9. Big Data / Open Data
10. Unnamed Aerial Vehicles / Nano Satellites
11. eMoney / eFinance

# CLEAN DISRUPTION OF ENERGY & TRANSPORTATION

1. Energy Storage
2. Electric Vehicles
3. Self-driving Cars
4. Solar



# 1 Energy Storage

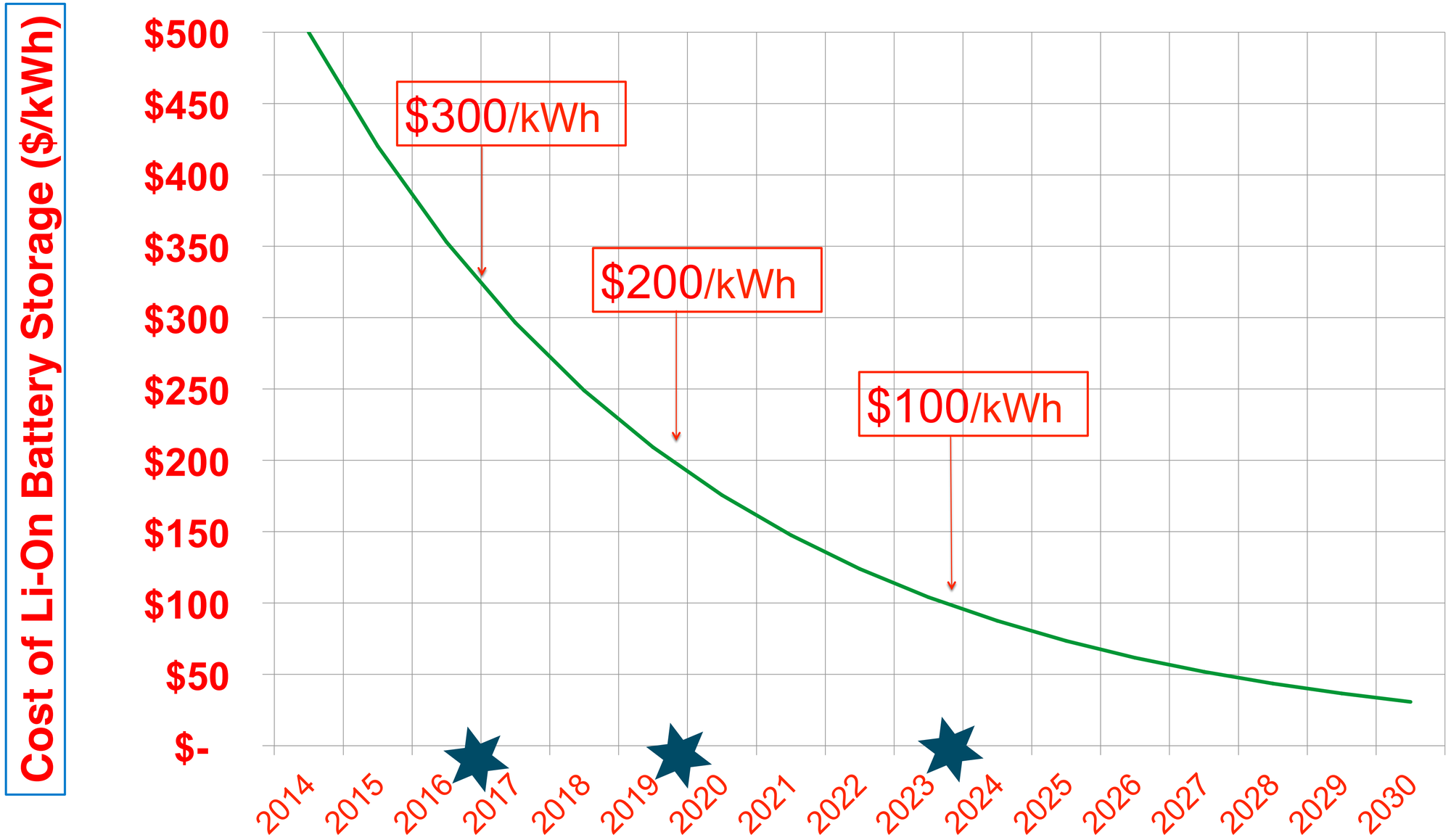

# Li-on Battery costs dropping exponentially

- **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**
- Since 2010, battery costs have dropped at ~**16%/year** ⟶ **ACCELERATING**




(1) Clean Disruption

# Projected cost of Li-On Battery $/kWh






**Assumption**: 16% /year Technology Cost Curve

Source: Clean Disruption

# Tesla's Battery GigaFactory

- **$5 Billion investment** (6,500 jobs)
- Battery pack output: **50 GWh year**

  → **500,000 cars/year**
- Double world battery production

**Reduce battery pack costs by** 30-50+ %

Tech improvement. "Tesla expects to increase pack capacity by roughly 5% per year." (1)



Sources: Tesla, (1) ChargeDevs Mag

Image: Tesla

# Tesla's Battery—Ahead of the curve

Tesla PowerWall residential battery

$350/kWh (7kWh or 10kWh)

Tesla Microgrid/Commercial battery

$250/kWh For Commercial/Microgrid (100kWh)

Image: Tesla

**Market reaction: Tesla received**

$800+million in orders/ reservations first week!



Sources: Tesla, Bloomberg

# Battery Megafactories are coming!

- **BYD** plans to add **6 GWh** every year.
  - 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, Bosch, TDK, Apple, Nissan, VW, etc.
- 12+ Megafactories expected to come online by 2020 (3)

**Tech Cost Curve could accelerate!**

Image Source: Samsung SDI



Sources: (1) Reuters, (2) (3) Benchmark Minerals

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%** (1)
- Similar business model that made solar skyrocket



Sources: (1) Bloomberg

# 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 | $55.2 | **$ 36.8** | $18.4 | $9.2 |



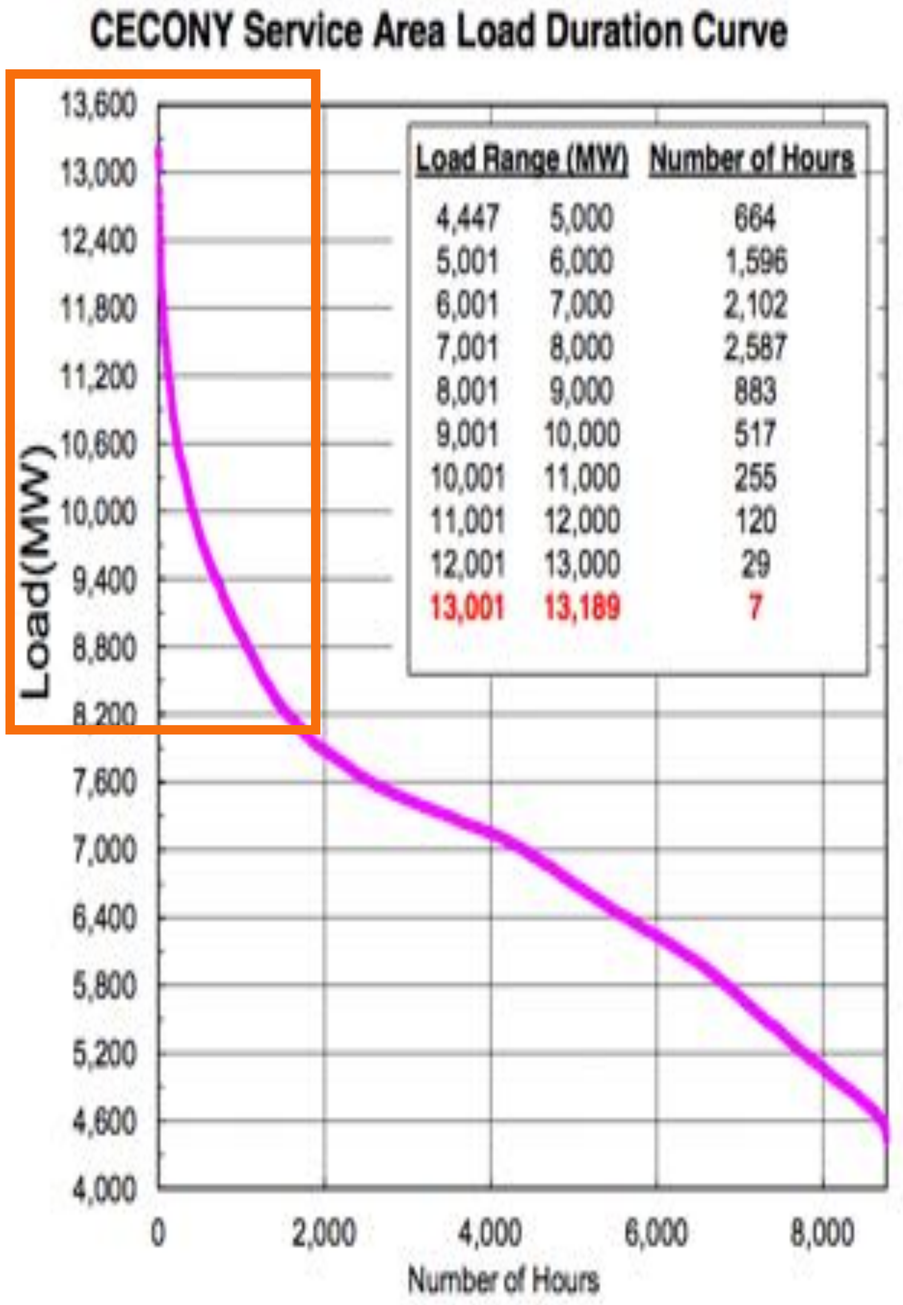
Assumptions: 4% cost of capital (mortgage) over 20 years

Source: Clean Disruption

# 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 / 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**
  - Peaking power = obsolete

> "Post 2020 there may never be another peaker built in the US."
>
> *NextEra Energy CEO Jim Robo (2)*

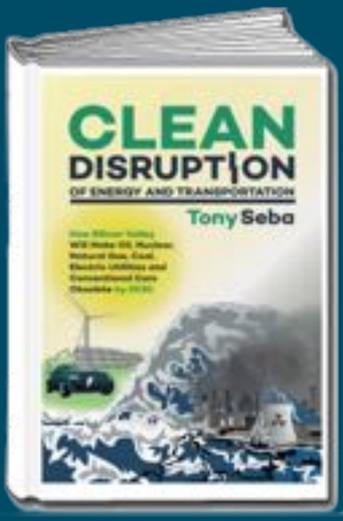





Sources: (1) Consolidated Edison of New York, (2) GreentechMedia

# 2 The Electric Vehicle Disruption

Photo: © Tesla Motors



MOTOR TREND

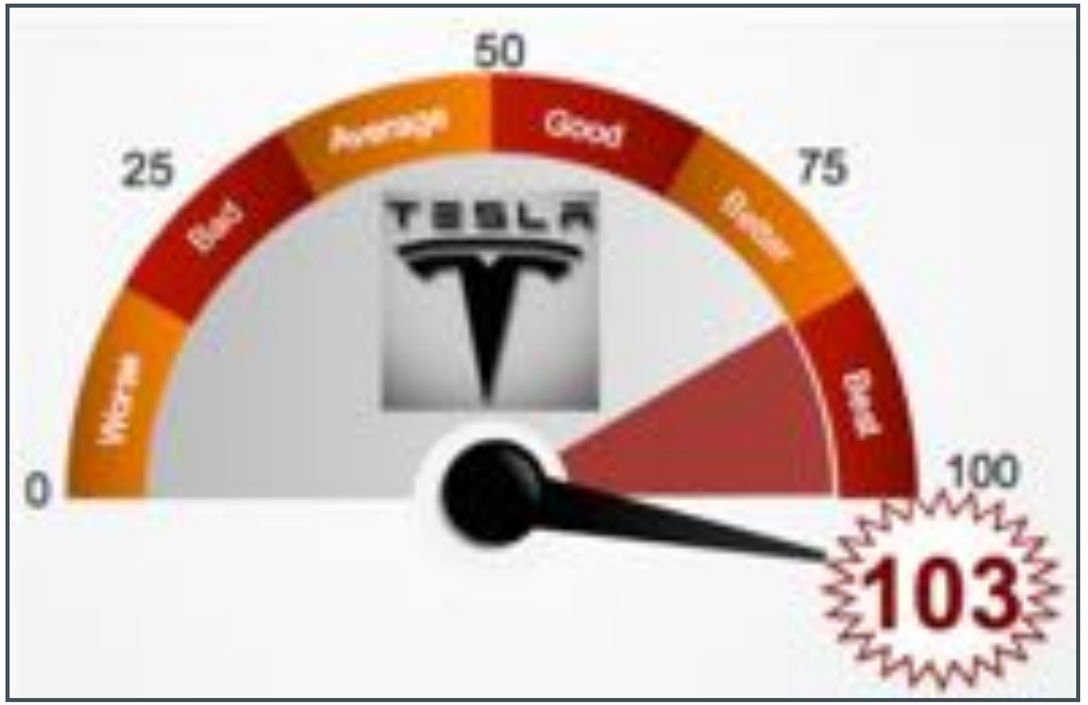
# 2013 CAR OF THE YEAR: TESLA MODEL S

*Best-selling high-end large luxury car in America!* (2)

*Consumer Reports:*
Best Car EVER! (1)

**U.S. Sales of Large Luxury Vehicles**

| MODEL | 2015 Sales | 2014 Sales | % Change |
|---|---|---|---|
| Tesla Model S | 25,202 | 16,689 | 51.01% |
| Audi A7 | 7,721 | 8,133 | -5.07% |
| Audi A8 | 4,990 | 5,904 | -15.48% |
| BMW 6-Series | 8,146 | 8,647 | -5.79% |
| BMW 7-Series | 9,292 | 9,744 | -4.64% |
| Jaguar XJ | 3,611 | 4,329 | -16.59% |
| Lexus LS | 7,165 | 8,559 | -16.29% |
| Mercedes-Benz CLS-Class | 6,152 | 6,981 | -11.88% |
| Mercedes-Benz S-Class | 21,934 | 25,276 | -13.22% |
| Porsche Panamera | 4,985 | 5,740 | -13.15% |
| **Total** | **99,198** | **100,002** | **-0.80%** |






Source: Motor Trends, (1) Consumer Reports, (2) Tesla


But who can afford an
Electric Vehicle?
Photo: © Tony Seba

# IS THE ELECTRIC VEHICLE Disruptive?

(You always need to ask)

Rodin – Thinker
Photo: Tony Seba

# 1. Electric Motor - 5X more Energy Efficient


Internal Combustion Engine

Electric Motor



Sources:ICE - DOE, EM Wikipedia, Image Sources: ICE - Tony Seba, Electric - BradMerritt.com

# 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 power electronics will increase this 10X

Image Source: jeep.com

**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 (1)

# 3. EVs: 100X fewer Moving Parts

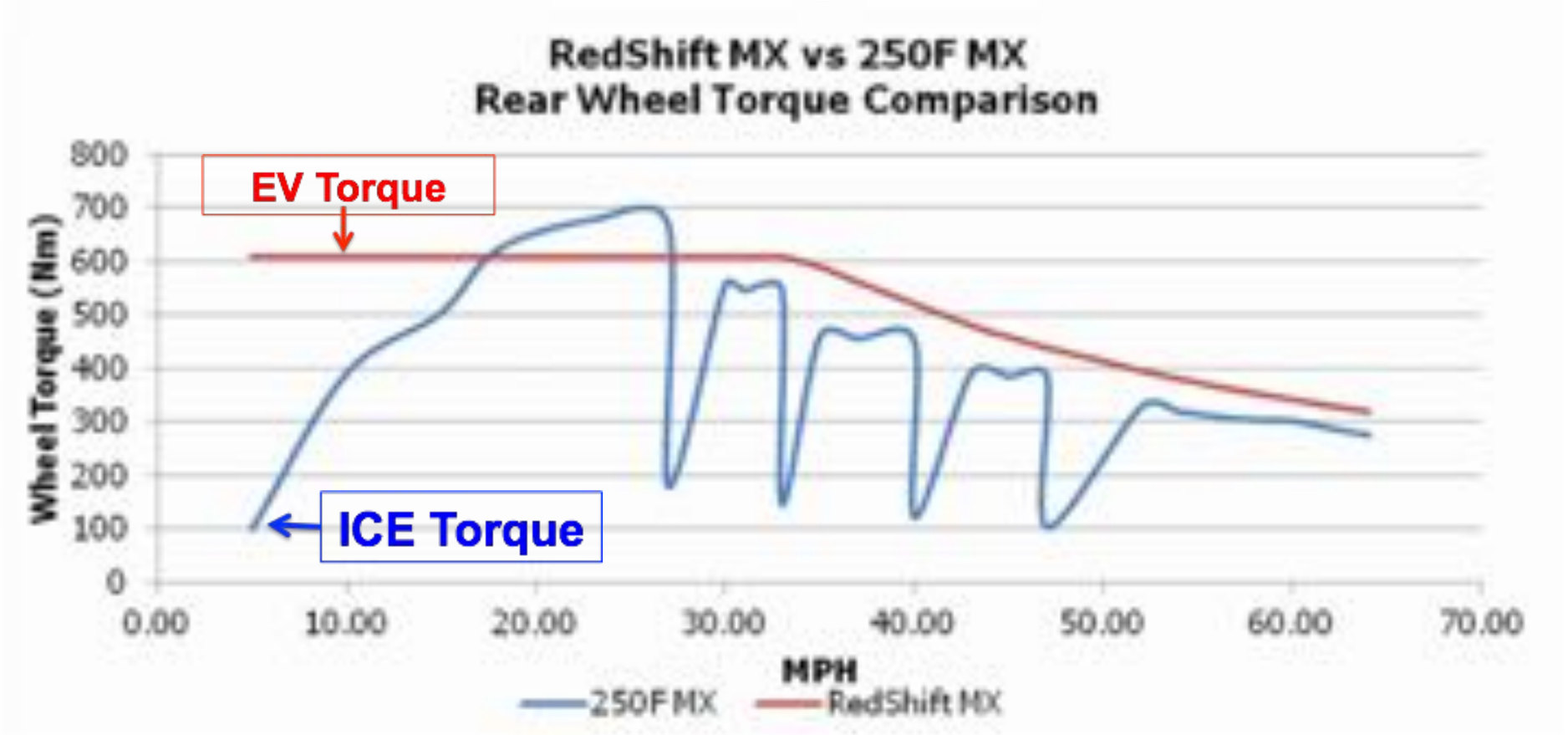
| ICE (Gas) Vehicle | Electric Vehicle (EV) |
| --- | --- |
| 2,000+ moving parts (1) | 18 moving parts (1) |
| Transmission, driveshaft, clutch, valves, differentials, pistons, gears, carburetors, crankshafts... | |

- EVs **10X-100X** cheaper to maintain!
- Tesla: **Infinite Mile** Warranty! (2)



Source: (1) Baron Funds, (2) Tesla Blog

# 4 – EVs FAR MORE powerful than ICE

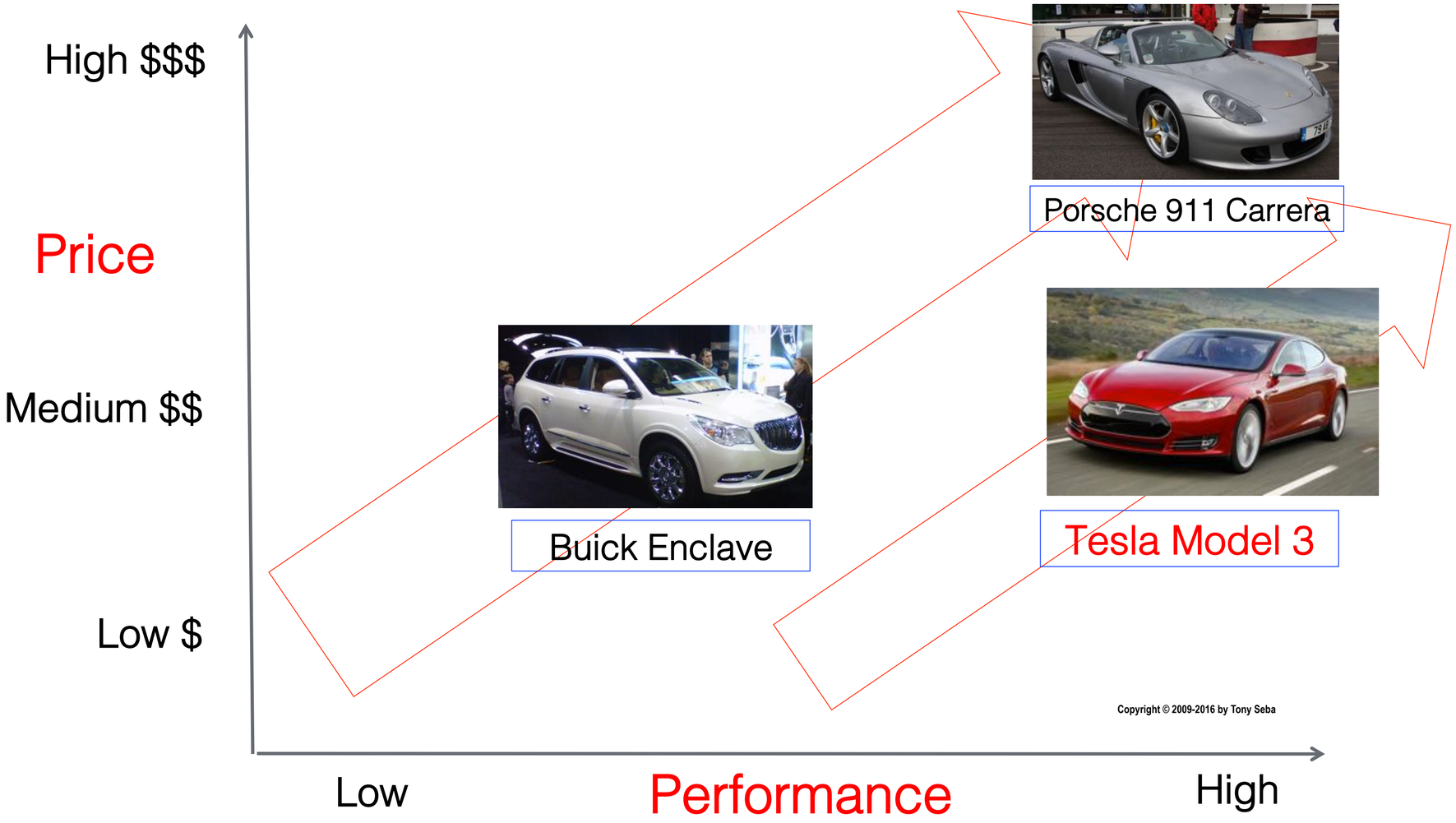



"The **Tesla** P90D **accelerates faster than $1 million gas 'supercars'** from Ferrari, McLaren, Lamborghini, Pagani and Porsche." (1)



(1) ChargeDevs Magazine, Image: BRD Motorcycles

# EVs Shift the Price/Performance equation: Disrupt the BASIS of COMPETITION




## EVs: Porsche performance for Buick prices!



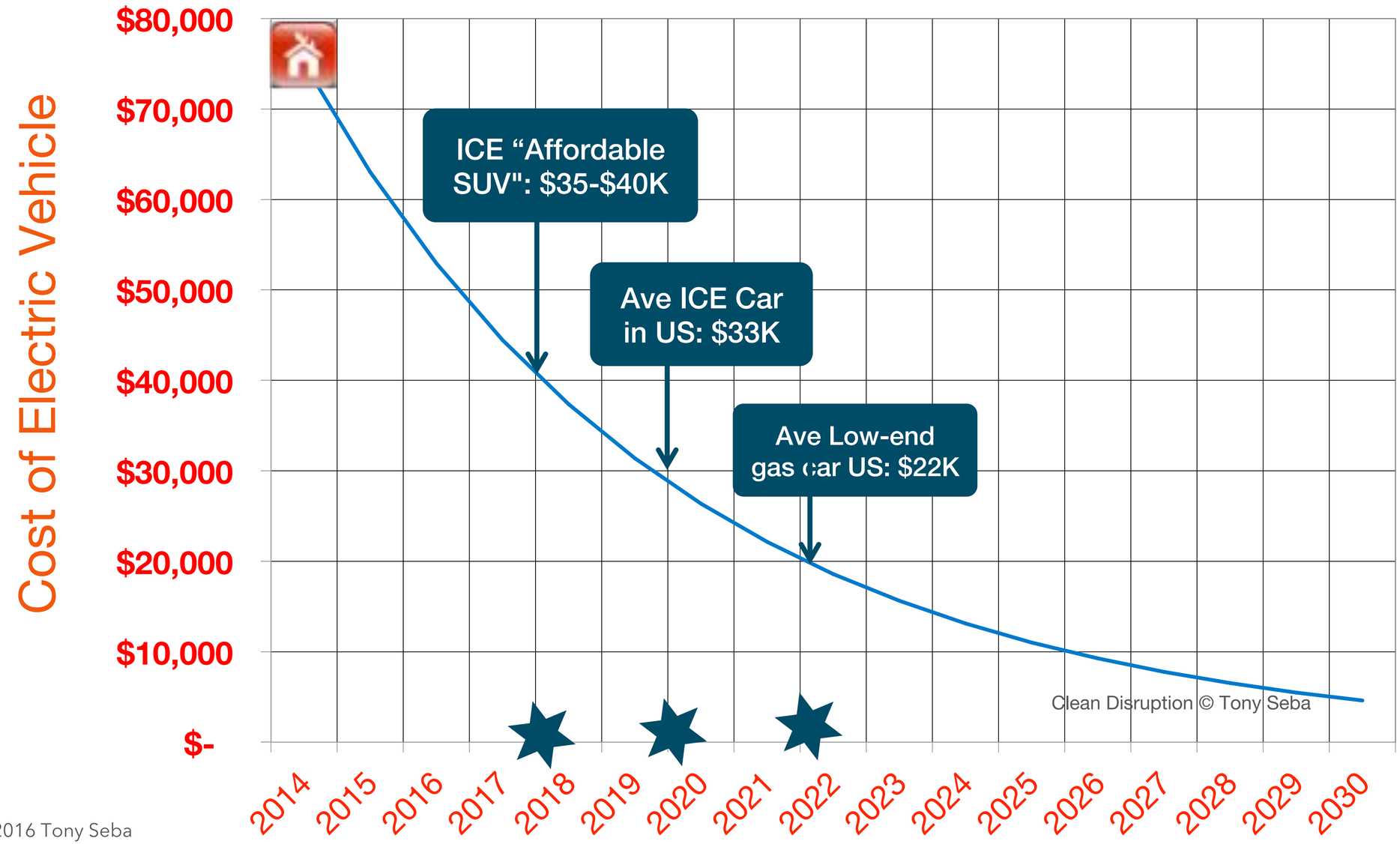
Car Image Sources: WikiMedia

# OK, SO THE EV IS **DISRUPTIVE**

# How long will the transition take?

# Disruption from Above

## 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

FORTUNE

January 9th, 2016

# 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

Source: (1) 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

Image: Tesla

**Market reaction:**

180,000 cars ordered / reserved first 24h!

>$6.3b pipeline first 24h!

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



Sources: Tesla,

BBC NEWS

December 11th, 2015

# FORD TO INVEST $4.5B IN ELECTRIC CARS

***"CEO Fields said Ford will invest $4.5 billion to develop 13 EVs by 2020."***

The company will enter the **carsharing** market and become a **'mobility service provider'**, a market worth **$5+ trillion**.

"We [now] get zero of that market." (1)

Source: (1) BBC News

COMPUTERWORLD

September 4th, 2014

# FOXCONN TO MAKE EV FOR $15,000

*"**Foxconn,** the maker of the Apple iPhone **to invest $811m** to **develop Electric Cars.**"*

*"Foxconn CEO Terry Gou said they are targeting EVs priced at less than **$15,000.**"* *(1)*



Source: (1) Computer World

ELECTRIC VEHICLE

# Business Model Innovations

(That can accelerate the Disruption)

# EV Free Charging

- EV Companies such as Nissan and Tesla offering limited Free EV Charging networks.
- SV Startup Volta offering FREE EV charging in exchange for media rights at prime high-value properties.
- If this business model succeeds, the EV **MARGINAL COST** of energy will be **ZERO**.




Sources: Volta, Nissan, Tesla

Image Sources: Tesla, Volta Charging

# EVs Generating $Revenue$ Providing Services to Grid

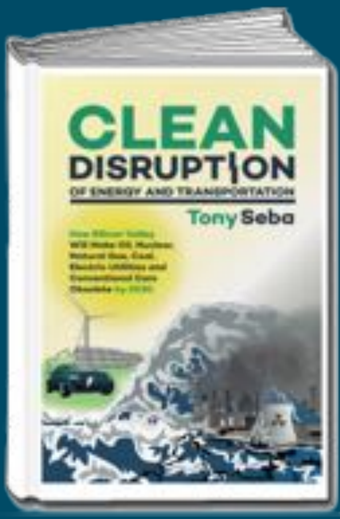
- With Vehicle-to-Grid (V2G) technology, an **Electric Vehicle** (Nissan Leaf) **can power a house** or small apt building for a day or two.
- EVs can also provide the grid with ancillary services that can **generate revenue for the EV owner.**
- At COP21 Paris, Nissan announced 2016 V2G rollout with ENEL plus stationary storage from end-of-life LEAF EV batteries with EATON
- **EVs = Power Plants on Wheels**




Image Sources: Tony Seba

# 3 The Autonomous Vehicle Disruption


Image: Wikipedia



FINANCIAL TIMES

May 5th, 2015

# NEVADA APPROVES AUTONOMOUS TRUCKS

THE VERGE

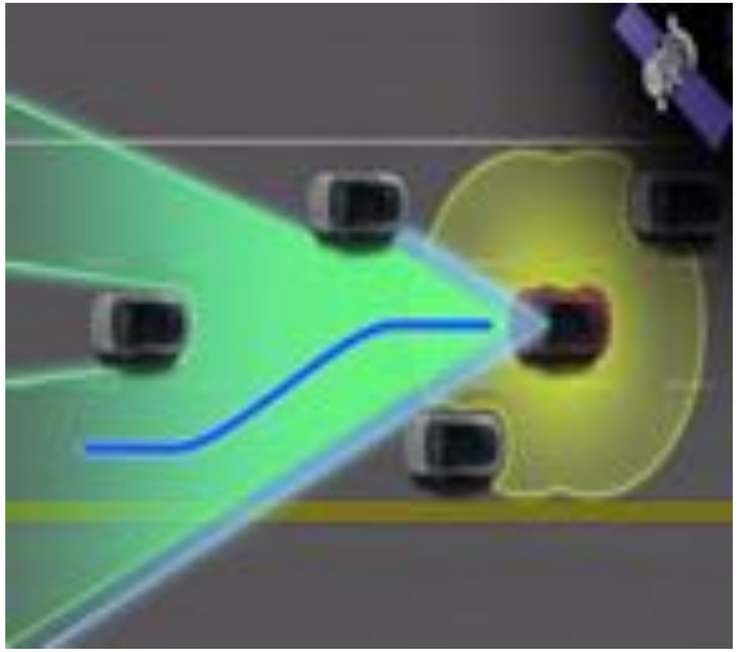
October 2nd, 2015

# TESLA CAPABLE OF SELF-DRIVING 90% OF THE TIME

*"90% Autonomous. For sure on highways."* (1)

***"Fully self-driving within 2 years."*** (2)

*Elon Musk, Dec 2015*






Sources: (1) UK Daily Mail, (2) Fortune

REUTERS

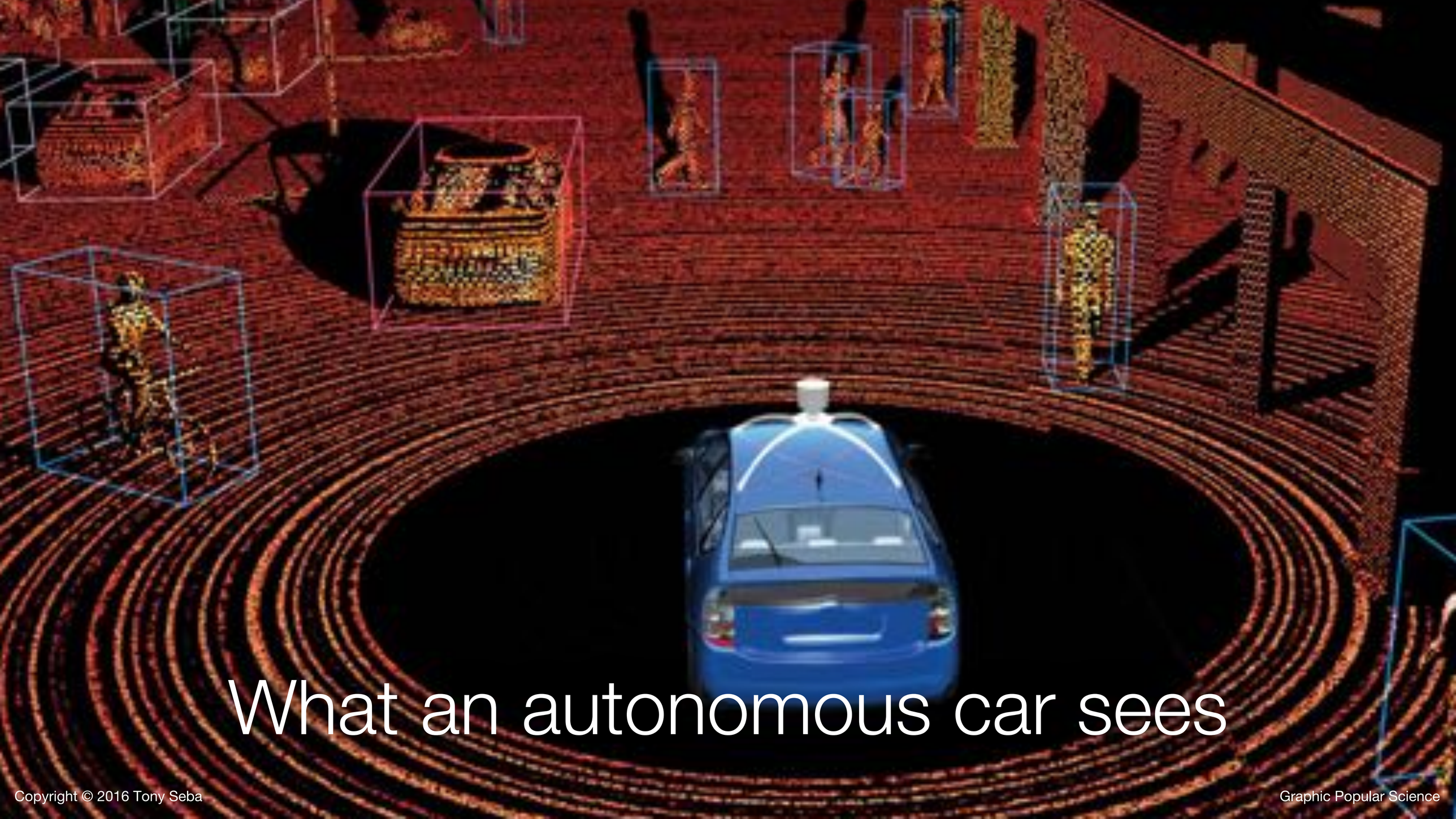
June 3rd, 2014

# SELF-DRIVING CARS MAY HIT THE ROAD IN 2018: RENAULT-NISSAN CEO

PARIS Tue Jun 3, 2014 1:03pm EDT

0 COMMENTS | Share this | Email | Print

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



# 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**

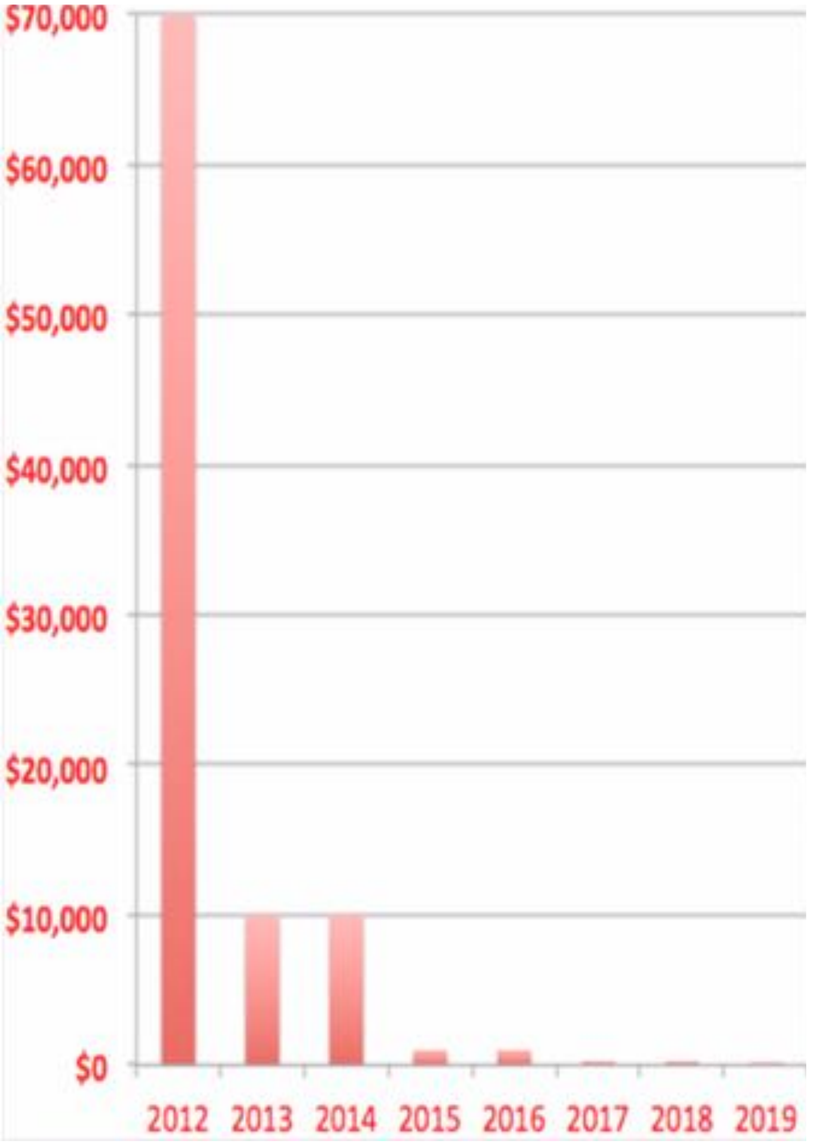
Image: Wikipedia

# 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 $1_{st}$ 1-TeraFlops Computer

## ASCI RED - Sandia National Labs

- Space = 1,600 sq ft **(150 m2)**
- Power Consumption = 850 kW
- **Cost = $46 million**

Image: Extreme Tech



Source: Wikipedia

# Exponential Technologies: 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

## Built for Self-Driving Cars

- Deep Learning Software
- Computer Vision w Advanced Rendering
- Over-the-air updates

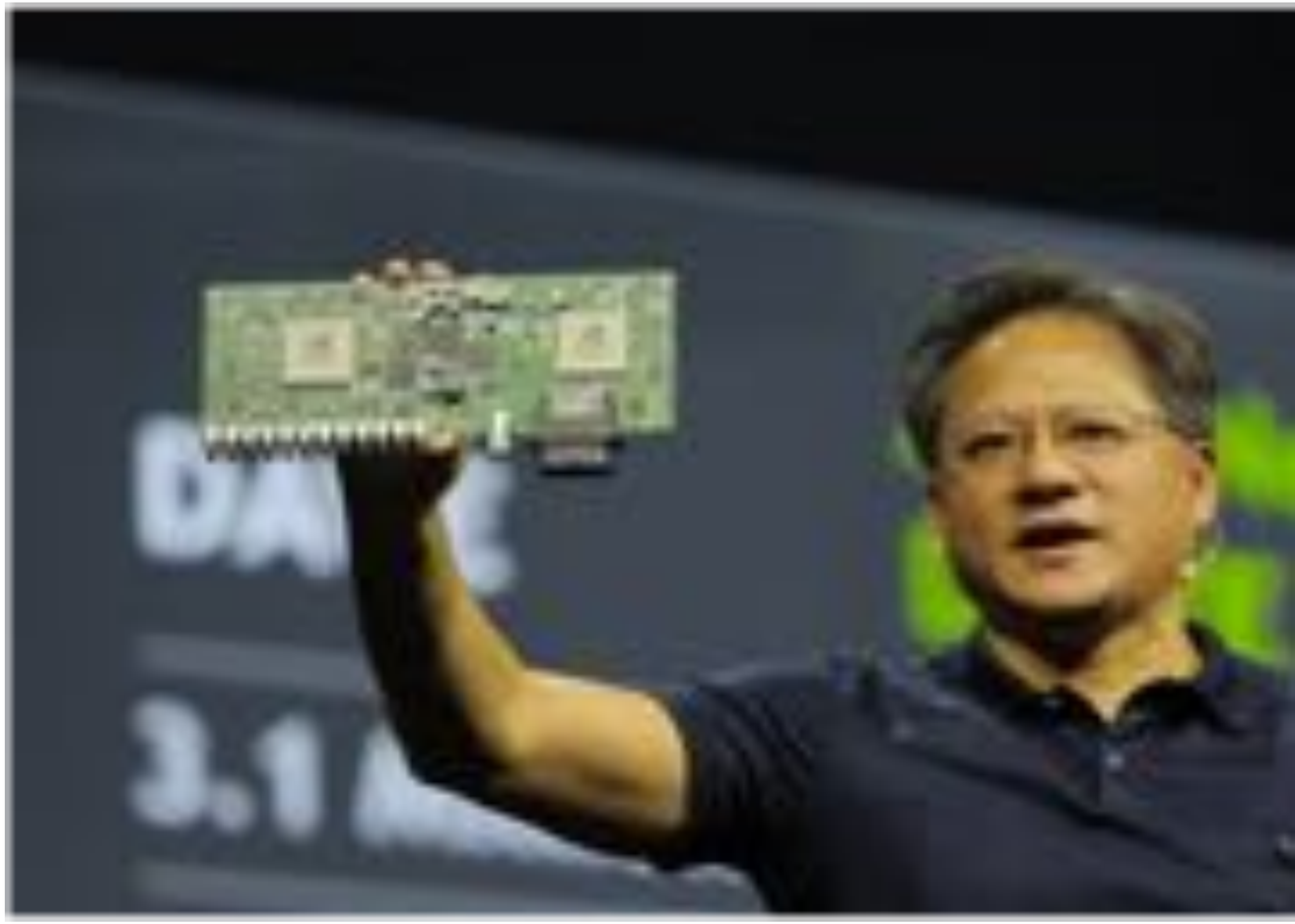




Image and Data Sources: NVIDIA

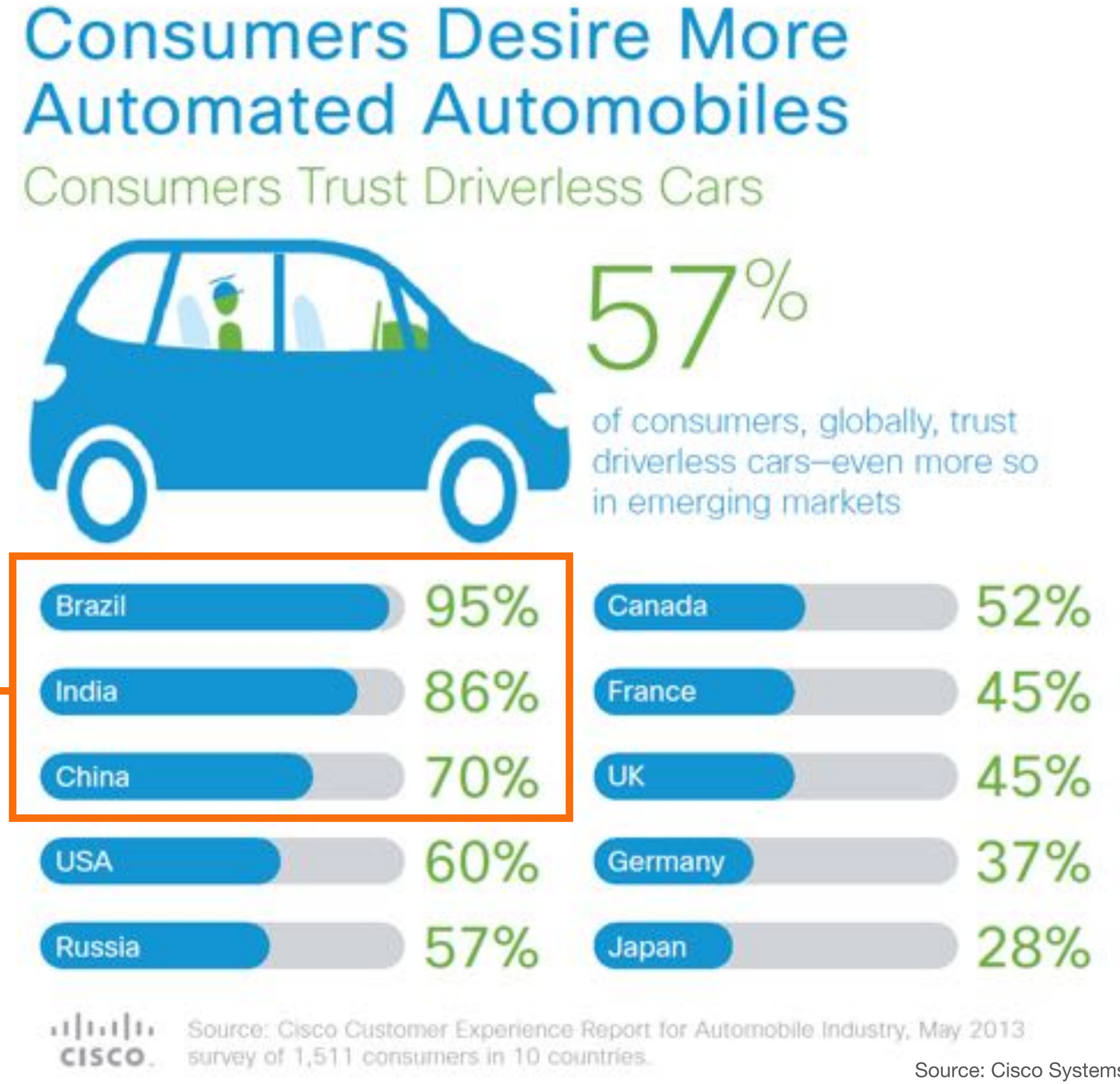
OK, COST IS NOT AN ISSUE… BUT,

# Is the market ready for the Self-Driving car?

Rodin – Thinker
Photo: Tony Seba

# Are consumers ready for autonomous cars?

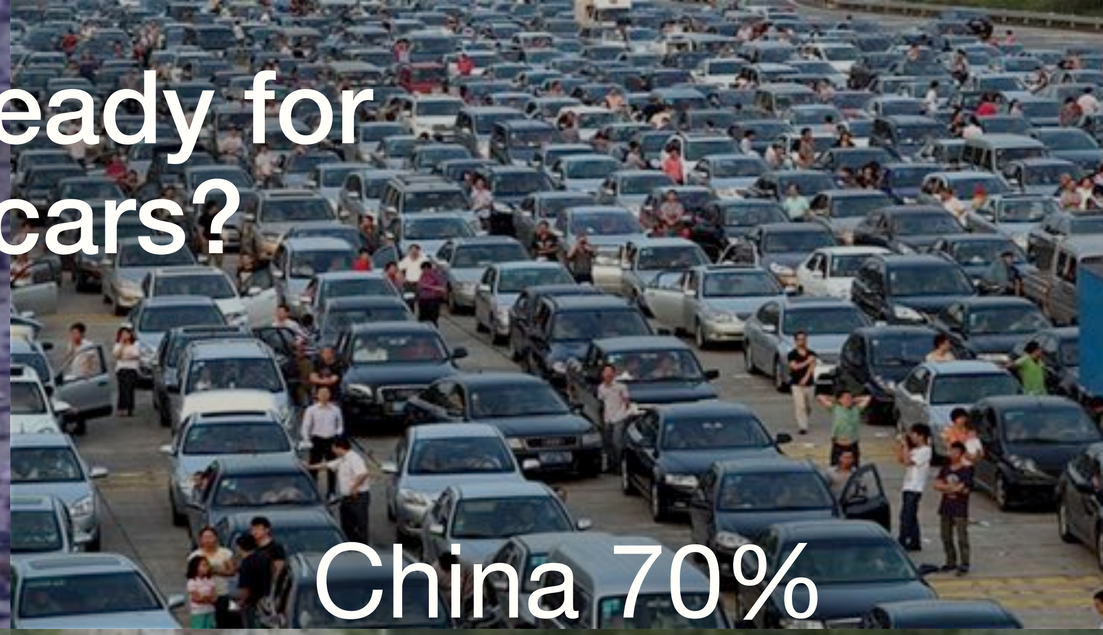
2.8 b people






Source: Cisco Systems

# Are consumers ready for autonomous cars?



China 70%

Brazil 95%

India 86%



Images Source: chinawshisper.com, inrix.com, ryot.org

Cool! I can

and also

while NOT driving!

BUT WHAT'S THE

# Disruptive Impact?

Rodin – Thinker
Photo: Tony Seba

BUSINESS MODEL INNOVATION:

# Car-as-a-Service

Rodin – Thinker
Photo: Tony Seba

# My Smartphone: On-demand Car-as-a-Service

## Plan & schedule All transportation needs with Apps

1. Buses: Muni, NextBus
2. Trains: CaltrainMe, iBART
3. **Car-Sharing: Zipcar**
4. **Ride-Sharing: Uber, Lyft**
5. On-Demand Bus: VTAFlex
6. Taxis: FlyWheel

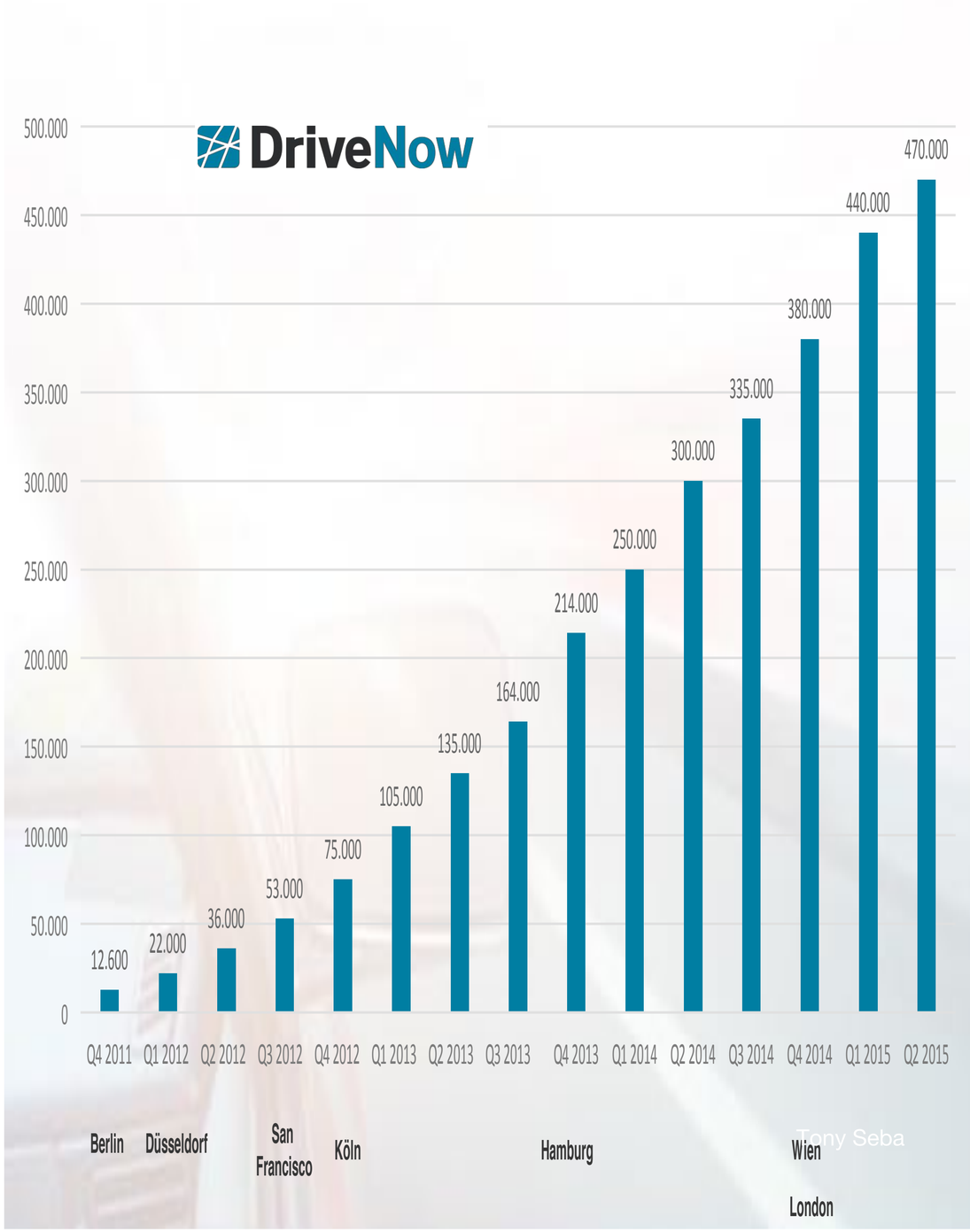

# CAR - Sharing

## Zipcar:

- On-demand individual transportation
  - By the hour, by the day
- 760k members and $270m in revenues (2012)
- **Share-to-own ration: 15**
  - **Each shared zipcar replaces 15 cars on the road**

## On-Demand Mobility:

- **Dramatically reduces the need for cars**
- DOT: 14% of Seattle Carsharing Members have given up on car ownership




Sources: Clean Disruption, Zipcar, BMW Rideshare, SDOT

# RIDE - Sharing

## Companies disrupting private and public transportation.

- Connecting users with drivers
- Ex: Uber, Lyft
- **Uber** (started 2009):
  - Est. **2015 Bookings = $10 billion** (2)
  - **1 million drivers** (global) (3)
  - **Valuation ($64b) > BMW ($54b)** (global) (4)

## San Francisco Figures

- # Uber Drivers (2015): 22,000
- # of Taxicabs (2012): 1,825 (5)
- **Carpooling** ~= **half** of Uber Rides


Image: Tony Seba



Sources: (1) (2) (3) Busines Insiders (4) Yahoo! Finance (5) Business Insider

# Cars: Hugely Inefficient Use of Assets

- Cars = 2nd largest Capital Expense
- Ave. car costs = $31k
- **Cars are parked 96% of the time!** (1)
- **4% Asset Utilization** is a disruption waiting to happen!


Photo: Tony Seba




Source: (1) Donald Shoup

SELF-DRIVING + CAR SHARING:

# Convergence of **Technology** & **Business Model** Innovation

Rodin – Thinker
Photo: Tony Seba

THE VERGE

February 2nd, 2015

# UBER ANNOUNCED SELF-DRIVING CAR PROJECT

*"Uber announced plans with Carnegie Mellon University to create the Uber Advanced Technologies Center: R&D of autonomous vehicles."*

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

Photo: Tony Seba

Mashable

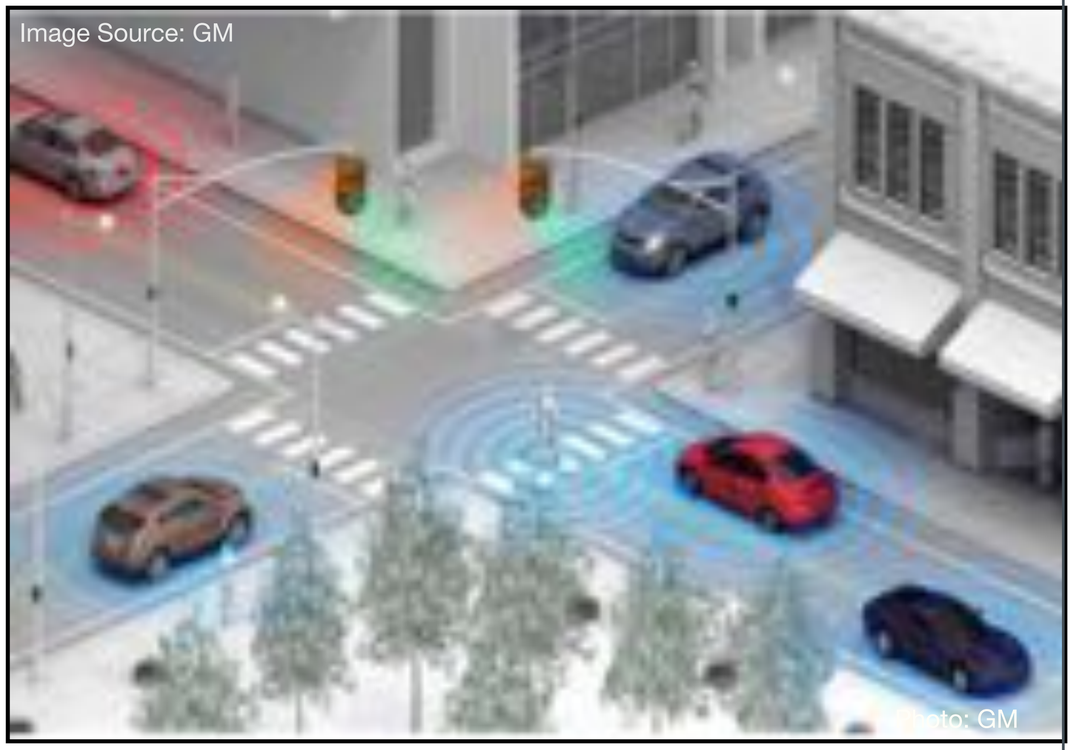
January 13th, 2016

# GM TO LAUNCH SELF-DRIVING LYFT FLEET IN AUSTIN, TX

*"The first mainstream deployment of **autonomous** vehicles won't be to customers but to a **ride-share** platform." GM President Dan Ammann*

"This makes sense for GM:

1. An **autonomous Bolt EV** will be in use **60-70%** of the **time**.
2. Easier to create a car that works in a known city within certain limits below 30mph.
3. **Open up new markets**."



# Car-as-a-Service: The End of Car Ownership

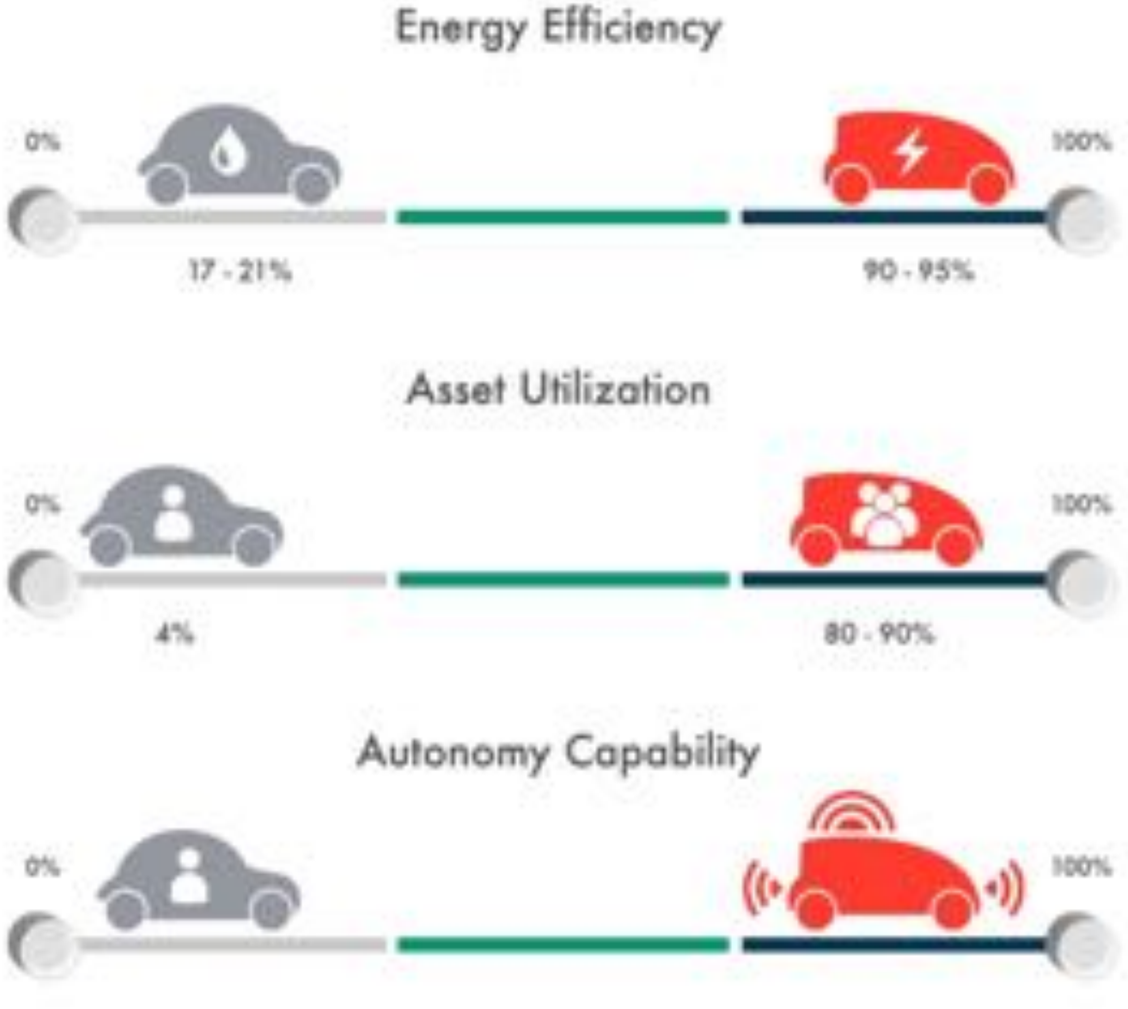
- Mobility on Demand / Car-as-a-service:
  - **Self-Driving** tech plus
  - **Car/Ride Sharing** biz model
- Vehicle Asset Utilization goes UP 10X-20X
  - From **4%** to **~80+%**
  - **Cost** / mile **~10X cheaper**
- Car Fleet **~80% smaller**
  - 80+% fewer parking spots (1)





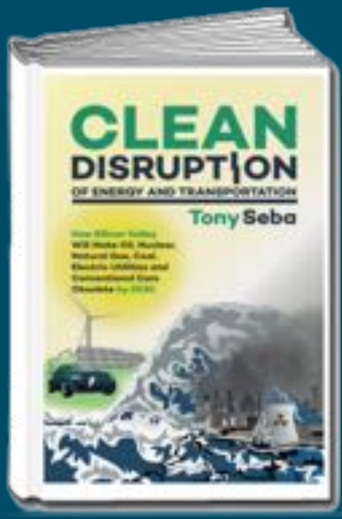
Source: (1) Clean Disruption

# 3D - CLEAN DISRUPTION OF TRANSPORTATION

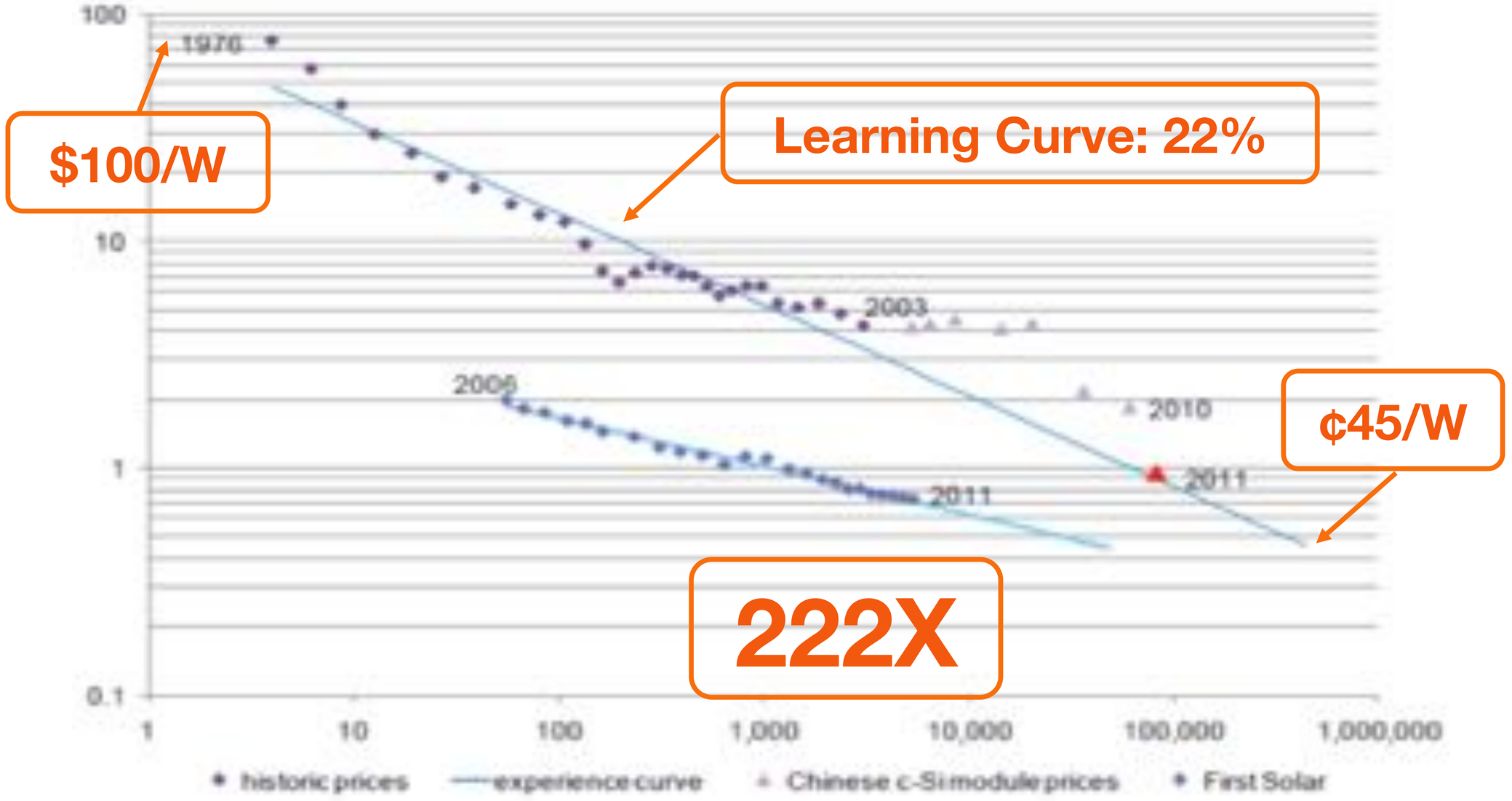


# 4 The Solar Disruption

Image: Tony Seba



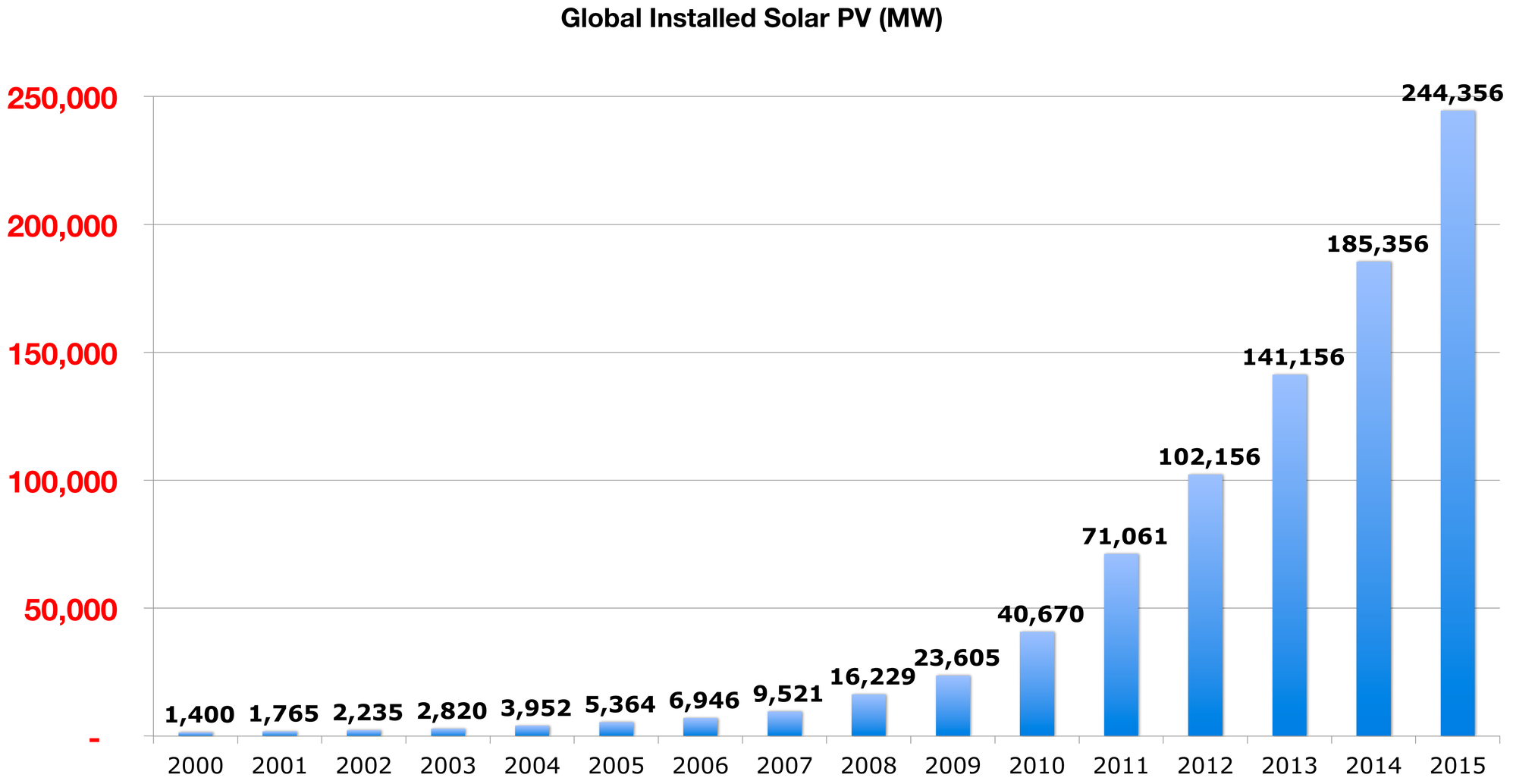
# Solar PV Costs: DOWN 222X






Source: BNEF - Economics of PV Power

# Market: Solar PV Installed Capacity: UP 174X

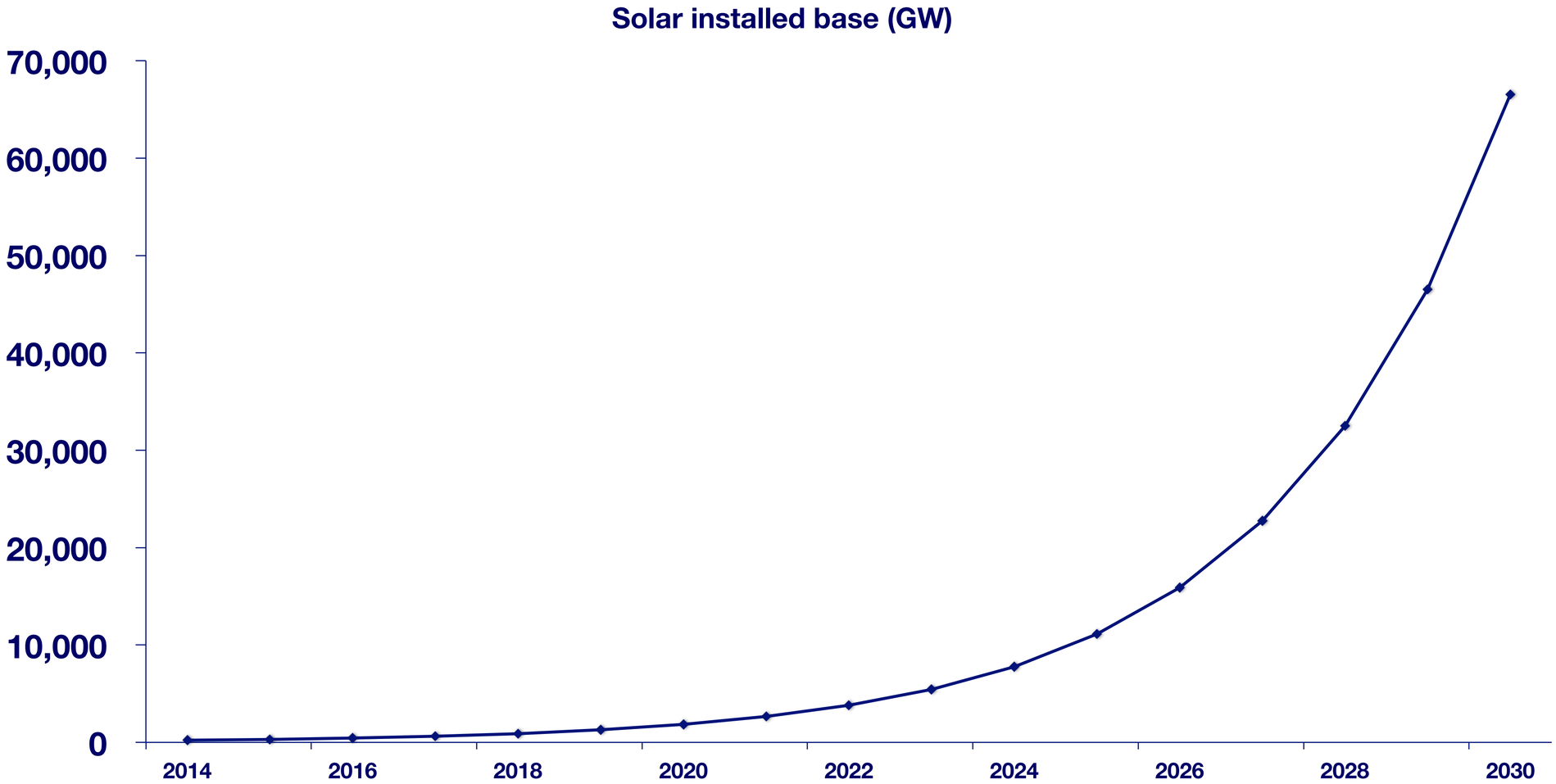



- **Solar PV Market CAGR 2000-2015 ~41%**
- Solar PV installed Capacity 2000-2015 Growth **~ 174X**



Source: EPIA, PV Magazine

# Energy = 100% Solar by 2030?




- **If Solar PV continues growing at ~41% CAGR**
- **100%** of all **energy** (not just electricity) in the world would be solar by 2030



Source: Clean Disruption

# Can Solar Continue Growing at this Rate?

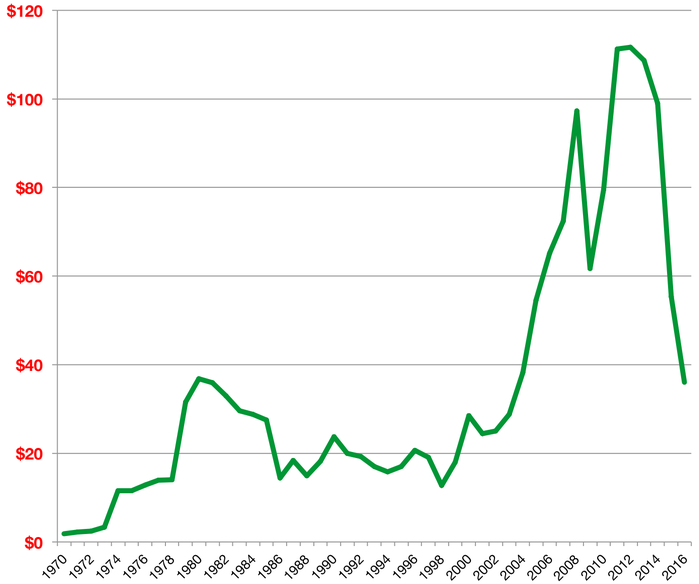
Rodin – Thinker
Photo: Tony Seba

# Solar Cost Trends

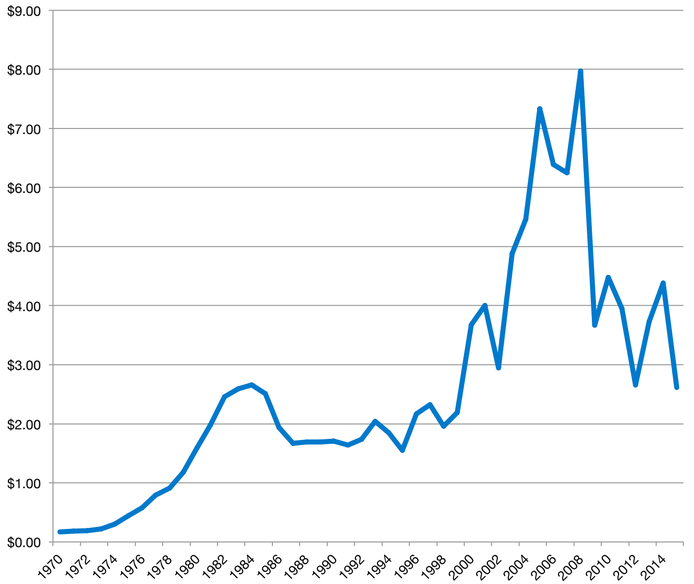
**vs**

# Conventional Energy

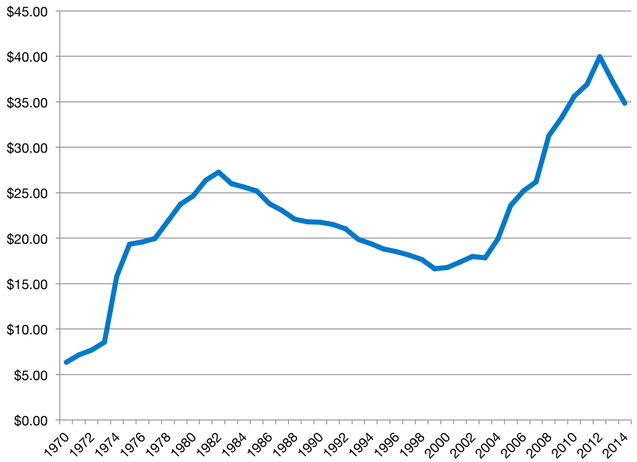
# Since 1970 Prices for conventional resource-based energy sources are up 6X - 16X



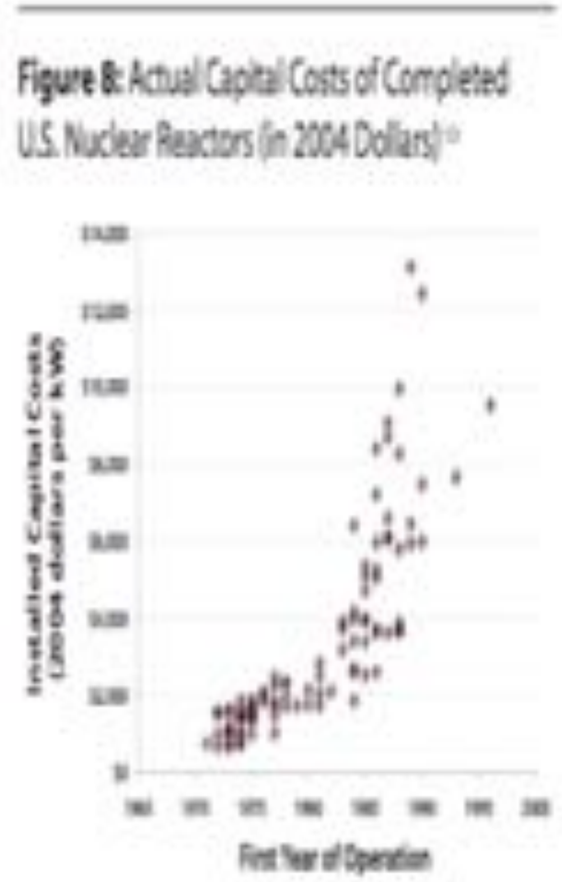

Oil




Nat Gas




Coal




Nuclear



Source: DOE, Clean Disruption

# Solar Cost Improvement vs. Conventional Energy

| Solar PV Cost Improvement relative to: | Times improvement (1970-2016) |
|---|---|
| Petroleum | 2,110x |
| Nuclear | 2,929x |
| Natural Gas | 3,284x |
| Coal | 1,294x |

Oil at $30/bbl

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

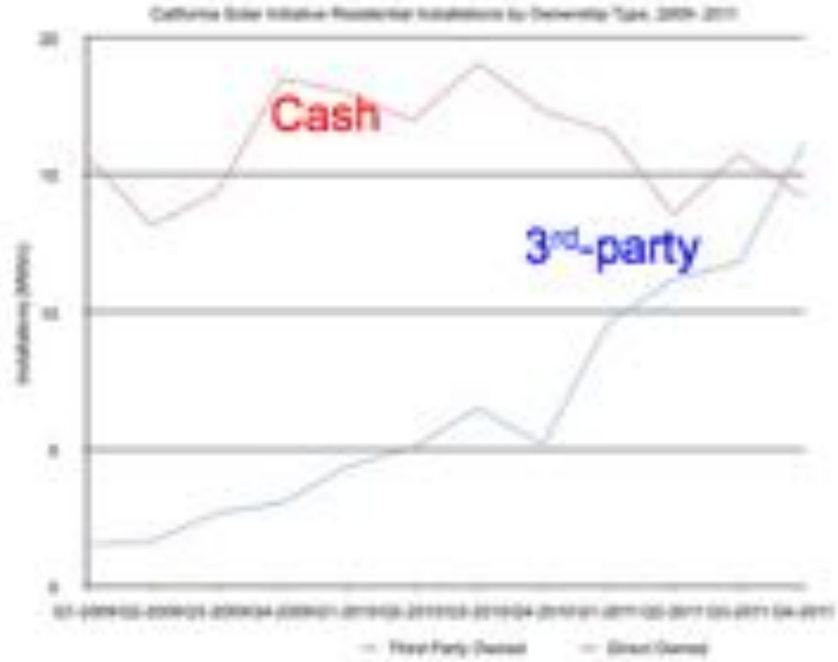


Source: Clean Disruption

# Business / Financial Model Innovation

# Zero Money Down Solar – 3rd Party Finance

- **~80%** of California Residential Solar PV was **third-party** owned & financed (March 2012) (1)
  - Including Solar PPA and Leasing
  - CA 3rd party finance = **enabled substantially all growth in residential solar**… since 2009




**California** Solar Initiative


**Colorado** Excel Energy



Image Source: GTM Research, Source: (1) PV Solar Report

# Financial / Business Innovations

Financial / business model innovations are **lowering the cost of capital** and **accelerating solar adoption**

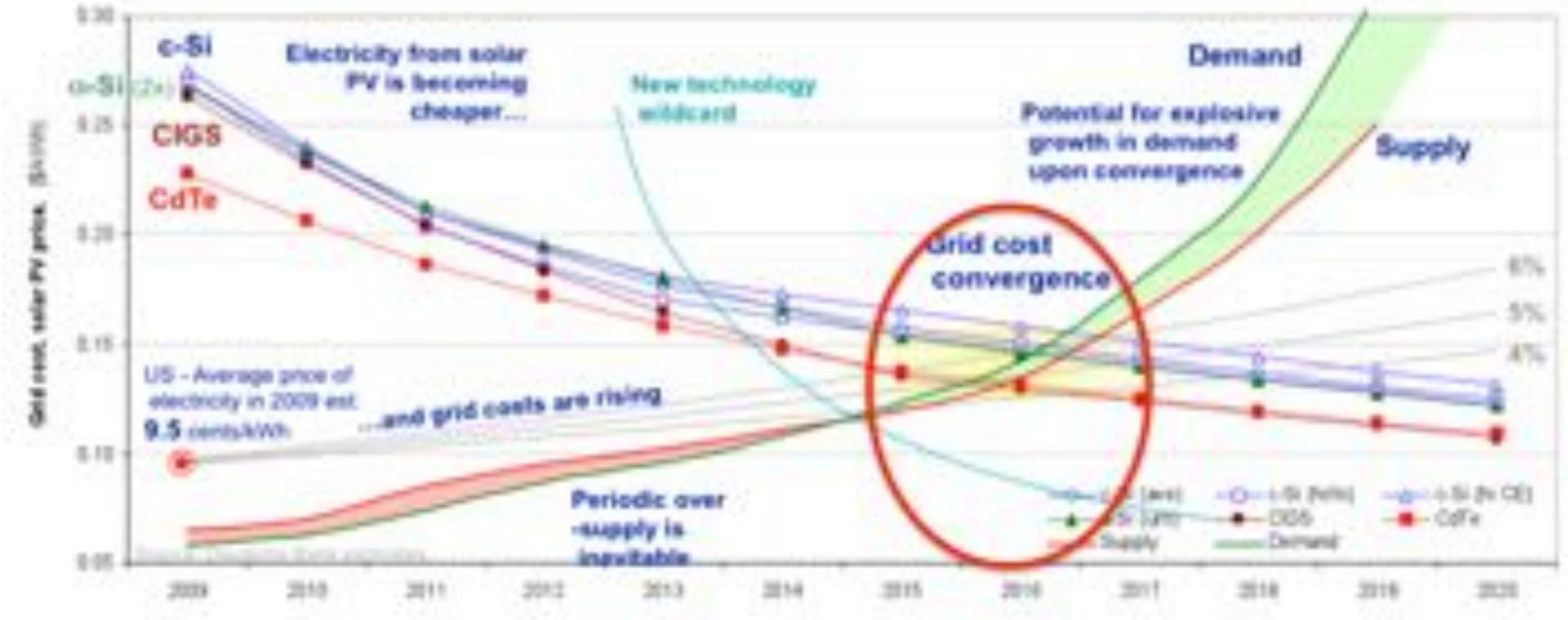
1. **Third-Party Finance -** PPA & Lease
2. Solar Loans
3. YieldCo
4. PACE - Property Assessed Clean Energy
5. Bond - PPA Hybrid
6. CrowdFunding
7. MLP - Master Limited Partnership?
8. REIT - Real Estate Investment Trust?

BACK TO SOLAR COST TRENDS:

# Grid Parity or God Parity?

Rodin – Thinker
Photo: Tony Seba

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

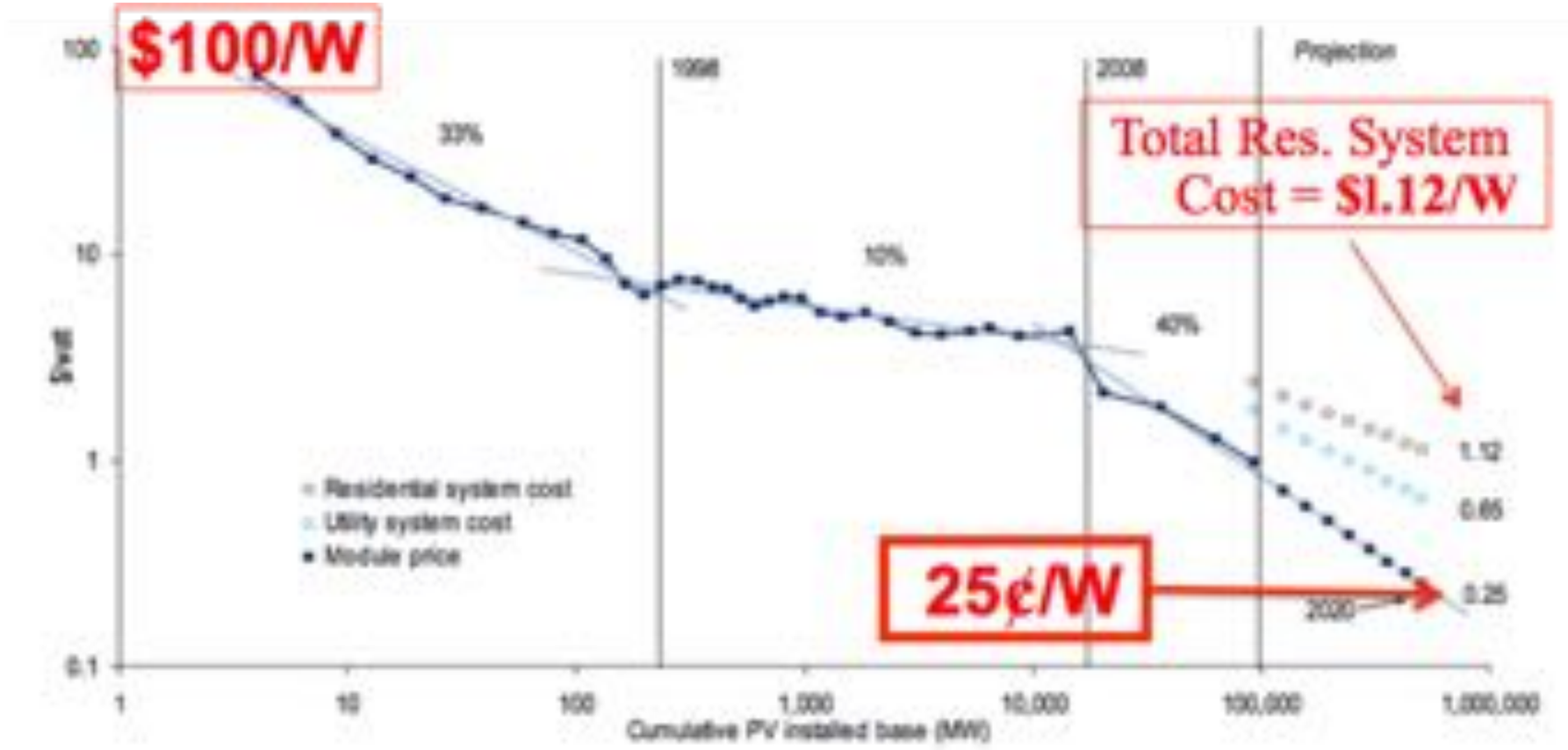



- **Solar at/below grid parity in 100's of markets globally** TODAY
- Deutsche Bank: **Solar Below Grid Parity** in
  - 47 states in the US by 2016
  - Up to **80% of Global market by 2017**



Source: Deutsche Bank

# Solar PV costs to drop another 50%+ by 2020




- **Solar PV costs down 400X from 1970-2020**
- Citi: installed cost of Residential solar ~$1.12/W by 2020
  - Installed cost already <$1.4/W in Australia (2)



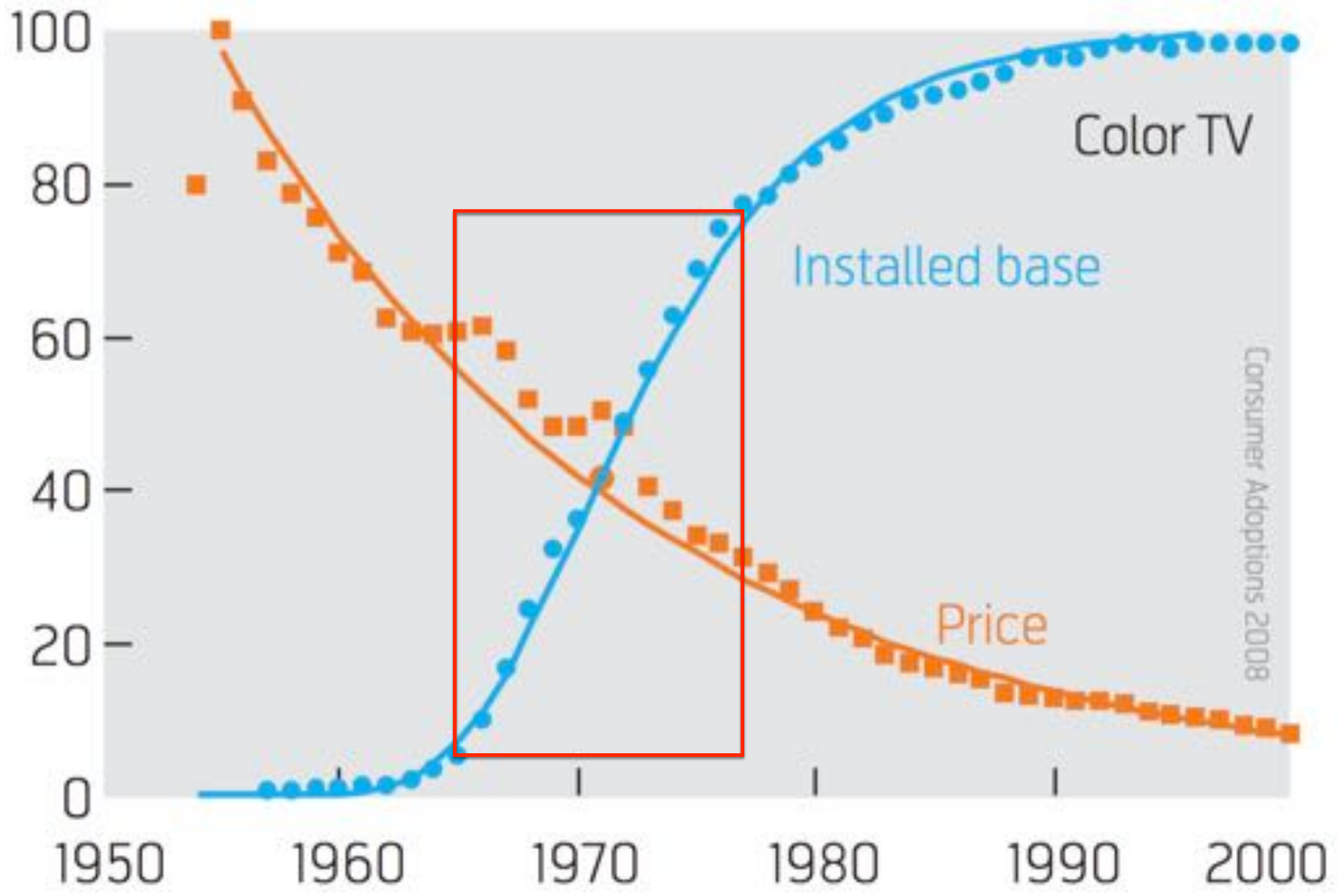
Source: 1) Renew Economy, (2) SolarChoice.net.au Graph Source: Citi Bank and GTM

# Solar Growth Rate may Accelerate!

## (TECH S-CURVE)

Rodin – Thinker
Photo: Tony Seba

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



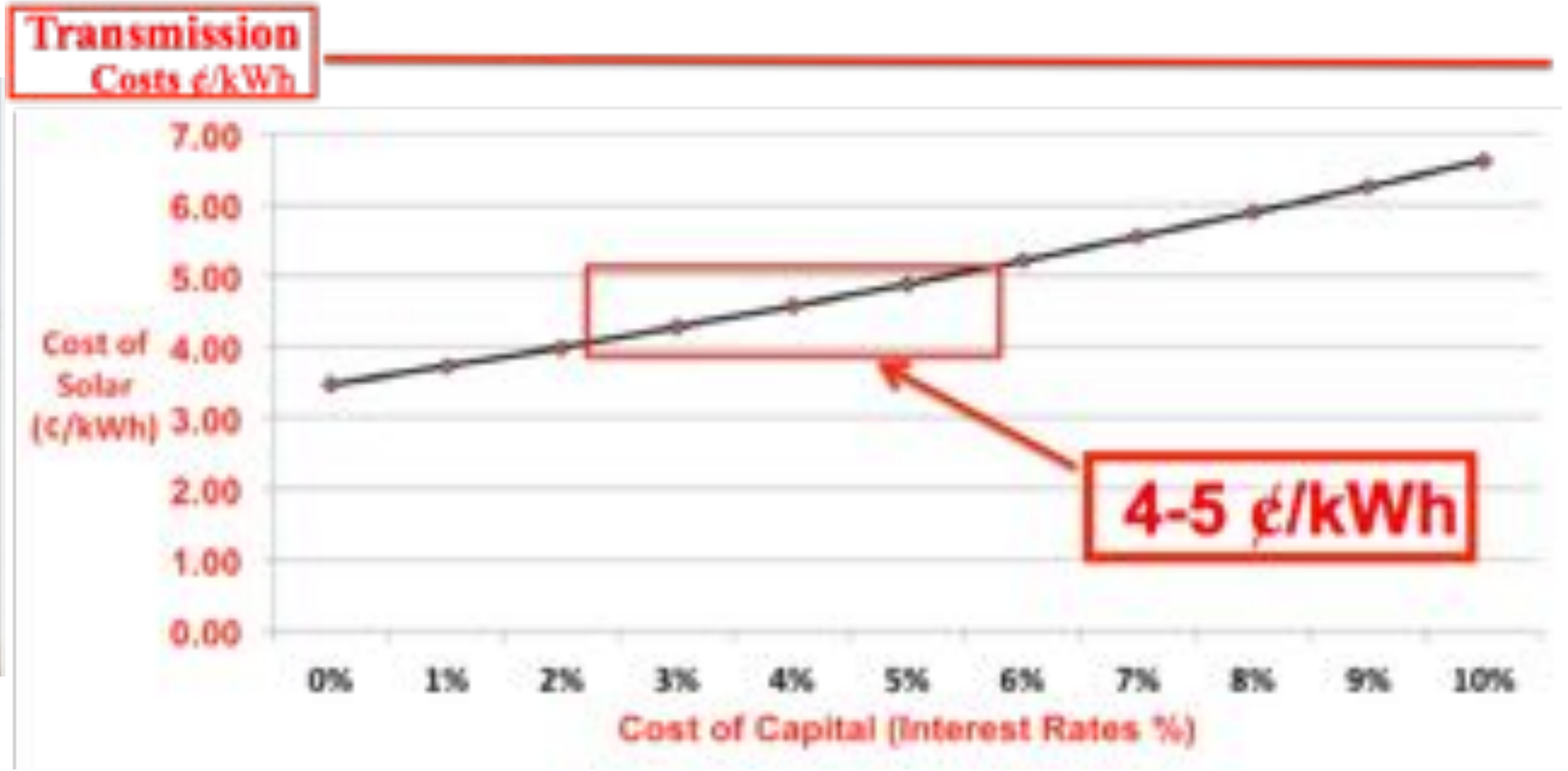

- **Solar PV** is a **technology**
- Tech adoption is not linear but follows an **S-Curve**



Graph Source: Technology Futures, Inc.


Solar GOD Parity
Point of No Return

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

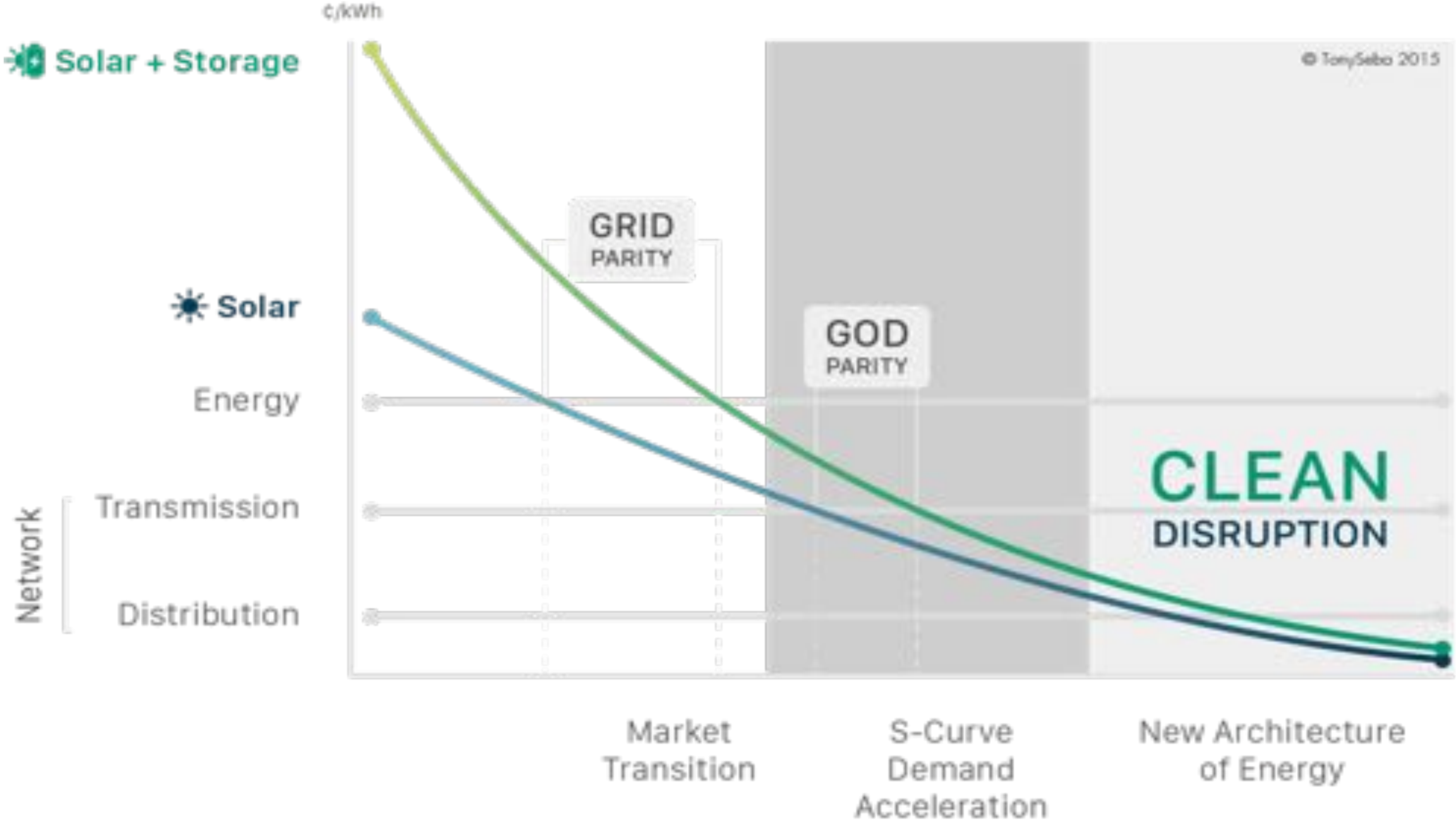



- **God Parity: cost of** (unsub) **rooftop solar lower than cost of transmission!**
- Centralized Generation can't compete
  - Obsolete: Nuclear, Natural Gas, and Coal



Source: Clean Disruption

# Solar + Storage GOD Parity




- **Solar and Storage costs decreasing exponentially**



Graph Source: Tony Seba

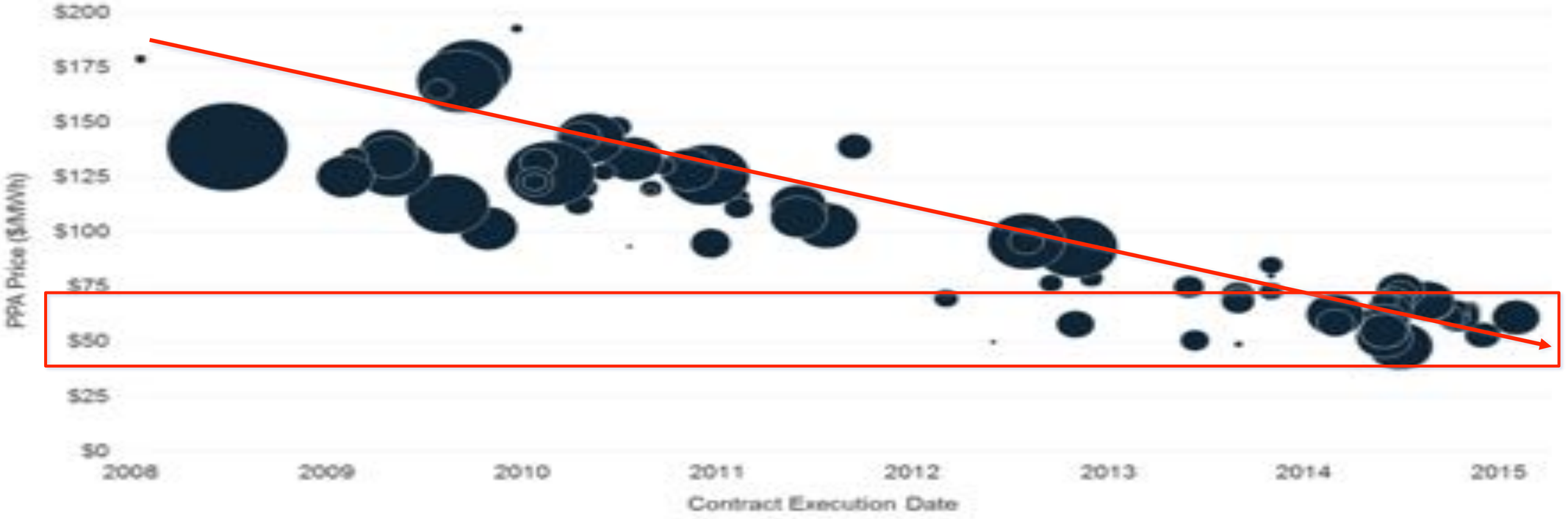
# BUT NOT ALL POWER GENERATION WILL BE ROOFTOP, RIGHT?

## What about **Utility Scale**?

Photo: Tony Seba

Rodin – Thinker
Photo: Tony Seba

# Utility Scale Solar –> Dropping below ~5¢/kWh




- USA 2015 PPAs **~5 ¢/kWh** (+/- **1¢/kWh**) (1)
- Saudi Arabia PPA **4.9 ¢/kWh (unsub)** (Aug '15) (2)
- Dubai PPA bid at **2.99 ¢/kWh (unsub)** (May '16) (3)
- "Solar at **5.8** ¢/kWh is competitive with **oil** at **US$10/bbl** and gas at US$5/MMBtu" (4)



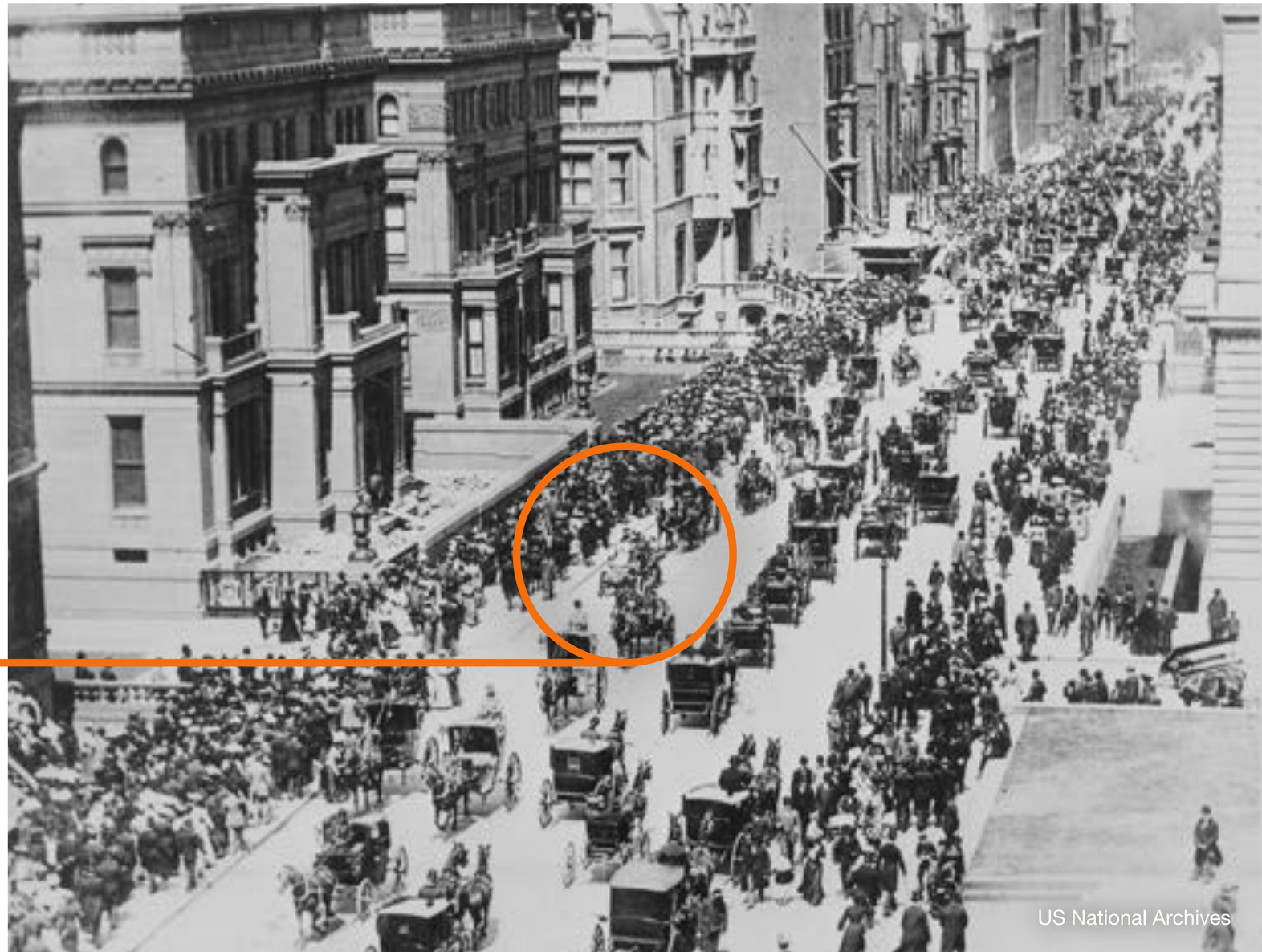
Sources: (1) GTM Research ((2) CleanTechnica (3) Bloomberg (4) University of Cambridge & PwC

# Back to the Future

# Summary: On the Cusp of major Disruptions in Energy and Transportation

2016

**We are here**



US National Archives

# 2016 - Clean Disruption of Energy & Transportation

- The technologies, skills, and organizations of the industrial revolution have run out of steam
- They are being replaced by the technologies, skills, and organizations of the **information technology revolution**

1. **Energy Storage**
2. **Electric Vehicles**
3. **Self-Driving Cars**
4. **Solar PV**

- We will see **more changes** in energy & transportation over the **next 5-10 years** than we have seen in a century - since the invention of **the gasoline/diesel ICE vehicle** and the **central generation electric utility**

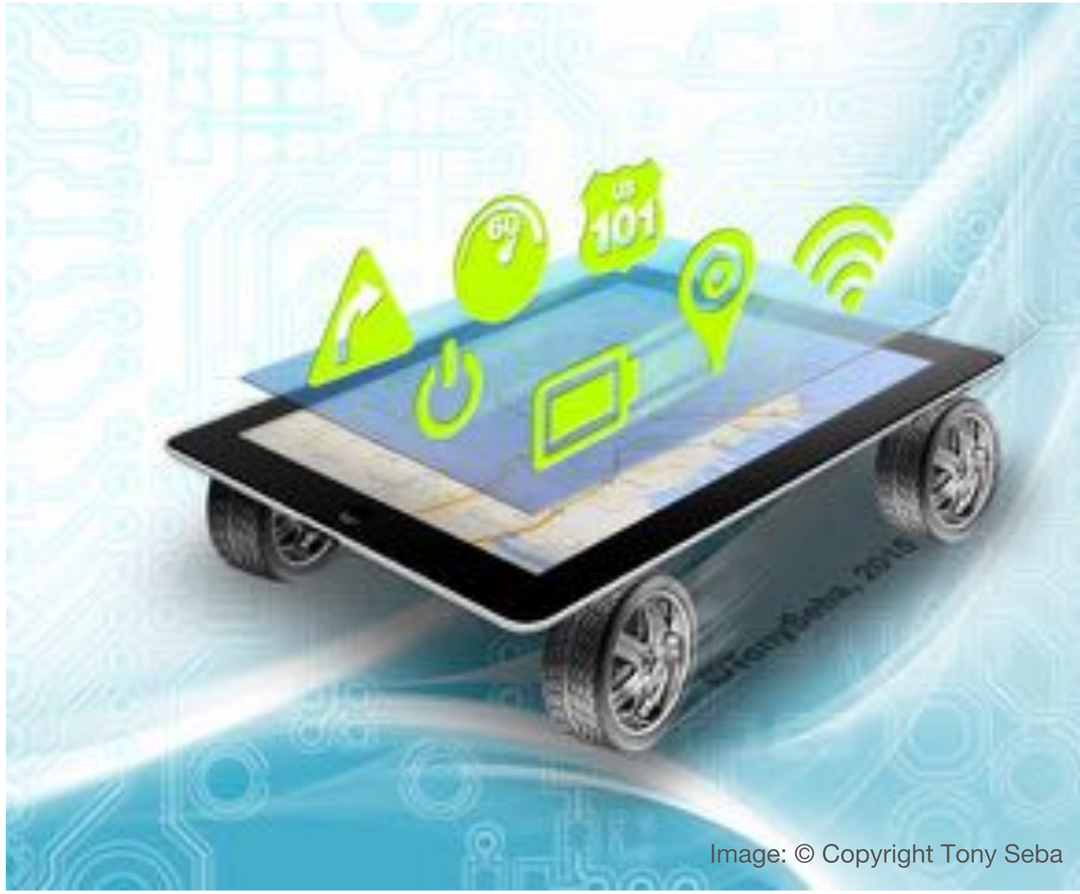


Image: © Copyright Tony Seba

# This Disruption is not in the future.
# It is NOW!




Photo: Tony Seba

# Thank You!

**www.tonyseba.com**

# CLEAN DISRUPTION

## WHY CURRENT ENERGY AND TRANSPORTATION WILL BE OBSOLETE BY 2030

Presentation to:

## Petroleum Institute of Thailand

**PTIT 30th Anniversary Keynote**

Bangkok, Thailand

12 May 2016


**Tony Seba**

www.tonyseba.com