CLEAN DISRUPTION
WHY CONVENTIONAL ENERGY AND TRANSPORTATION WILL BE OBSOLETE BY 2030

Presentation to:
DGIF
Green Business Summit
Copenhagen, Denmark

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A STROLL DOWN
Memory Lane
5th AVE NYC

1900

Where is the car?
Where is the horse?
How can we anticipate Disruptions in Energy and Transportation?
SEBA Tech Disruption Framework to Anticipate / Lead Market Disruptions

1. Disruption Models
2. Technology Cost Curves
3. Business Model Innovation
4. Product Innovation & Architecture
CLEAN DISRUPTION OF ENERGY & TRANSPORTATION

1. Energy Storage
2. Electric Vehicles
3. Self-Driving
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
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
**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)

**Market reaction:** Tesla received $800+ million in orders/reservations first week!

Sources: Tesla, Bloomberg
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** could **Triple** expected output to 105 GWh (cells) / 150 GWh (packs) (4)

**Tech Cost Curve could accelerate!**

Sources: (1) Reuters, (2) (3) Benchmark Minerals (4) Electrek
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.
ENERGY STORAGE

Business Model

Innovation
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)
- Other potential benefits: storage also increases resiliency and may allow C&I businesses to participate in wholesale markets demand response programs.

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

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

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
Every house, retail business, warehouse, building, factory, parking lot, device will have smart, connected BATTERIES...
2 The Electric Vehicle Disruption

Photo: © Tesla Motors

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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

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

Source: Motor Trends, (1) Consumer Reports, (2) Tesla
But who can afford an Electric Vehicle?
IS THE ELECTRIC VEHICLE Disruptive?

(You always need to ask)
1. Electric Motor - 5X more Energy Efficient

Energy Efficiency

Internal Combustion Engine: 17 - 21%

Electric Motor: 90 - 95%

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

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.
3. Maintenance - Gasoline Car: 2,000+ moving parts (1)
3. EVs: 100X fewer Moving Parts

ICE (Gas) Vehicle
2,000+ moving parts (1)

Electric Vehicle (EV)
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
"The Tesla P90D accelerates faster than $1 million gas 'supercars' from Ferrari, McLaren, Lamborghini, Pagani and Porsche." (1)
“University Student team builds EV that breaks world acceleration record (0-100 Km/h in 1.51 sec) beats the $1m Porsche 918 Spyder (2.2 sec)” (1)
5 - Wireless Charging

- Inductive Power Transfer (IPT) technology allows EVs (buses, cars, bikes, trains) to charge the battery wirelessly.
- While EVs wait at the bus stop, traffic light, shopping, parking garage, etc.
- EV vs ICE is like Mobile vs landline phone!
EVs Shift the Price/Performance equation:
Disrupt the BASIS of COMPETITION

EVs: Porsche performance for Buick prices!
OK, SO THE EV IS DISRUPTIVE

How long will the transition take?
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."  

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

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

Market reaction:
180,000 cars ordered / reserved first 24h!
>$6.3b pipeline first 24h!

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

Sources: Tesla, Image: Tesla
FOXCONN TO MAKE EV FOR $15,000

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

“CEO Terry Gou said they are targeting EVs priced at $15,000.”

"200+ Chinese startup EV companies developing 4,000+ models."
ELECTRIC VEHICLE / CHARGING

Business Model Innovations

(That can accelerate the Disruption)
Renault launched Elbnb, a P2P EV Charging Platform

*ElBnb enables anyone's power outlets to become public Electric Vehicle Plug-In Stations.*

“The home stations will be featured on a map accessible by EV drivers. Charging times and prices are determined by homeowners and drivers.”  

Source: (1) RoadShow by CNET
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.
With Vehicle-to-Grid (V2G) technology, an Electric Vehicle can power a house or small apt building for 1-2 days. EVs can also provide the grid with ancillary services that can generate revenue for the EV owner. Nissan announced V2G rollout with ENEL plus. Stationary storage from end-of-life LEAF EV batteries with EATON. EVs = Power Plants on Wheels.