On the Road to Mass Market Electric Vehicles

September 4, 2018
1:15 to 2:15 PM EDT
Registration: 640

Julian Bentley
Managing Director of Bentley Energy
Visiting Scholar at George Washington University’s Environmental and Energy Management Institute

Edward Saltzberg
Managing Director
Security & Sustainability Forum
Moderator

Environmental And Energy Institute

EEMI Graduate Programs and Studies

- Climate Change
- Energy Management
  - Data Center Energy Efficiency
  - Green Buildings
  - Environmentally Preferable Products
  - Green, Smart & Sustainable Cities
- Water
- Next Generation Self-Governance
Professional Certificates are offered at GWU in collaboration with the European Energy Center (EEC). The two-day classroom courses include:

- Solar Photovoltaic Fundamentals
- Renewable Energy Management & Finance
- Environmental Management Beyond Compliance (Implementing an ISO 14001 System)
- Distributed Generation and Storage
- Electric Vehicle Technologies, Policies and Markets
- Practical Application of Circular Economy Methods

Students travel from all over the world to get the course certificate.

### EV Professional Development Course Format

- **Current Classroom Courses** – *Delivered at GWU over two intense days*
- **Proposed Online Courses** – *The EV online course will be four modules*
  - Self-paced videos – about 3 hours in each module
  - **Four webinars** – Q&A with the Julian
  - GWU School of Engineering Certificate for passing the optional course exam
- **Please take the webinar exit survey:** Questions about
  - Format
  - Scheduling
  - Cost
  - Suggestions
  - Pre-registration (25% discount for registering with no obligation).
Course Instructor

Julian Bentley Managing Director and founder of Bentley Energy Consulting. He has more than 20 years of experience providing energy and environmental management consulting services to the federal government, including DoD fuel management, DoD operational energy initiatives, federal fleet management, energy policy, strategic planning, utility procurement policy, and cost-benefit analyses.

Add your questions to the Go to Webinar question box.
Agenda

- Overview of Electric Vehicles
- Overview of Electric Vehicle Charging Infrastructure
- Drivers of EV Market Growth and Market Challenges
- EV Course Overview
- Questions

Types of Electric Vehicles

<table>
<thead>
<tr>
<th>Drive Source(s)</th>
<th>Hybrid</th>
<th>Plug-in Hybrid</th>
<th>Battery</th>
<th>Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal combustion engine</td>
<td>Internal combustion engine</td>
<td>Electric motor</td>
<td>Electric motor</td>
</tr>
<tr>
<td></td>
<td>Electric motor</td>
<td>Electric motor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Battery Size</th>
<th>Hybrid</th>
<th>Plug-in Hybrid</th>
<th>Battery</th>
<th>Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 kWh</td>
<td></td>
<td></td>
<td>20-100 kWh</td>
<td>None</td>
</tr>
<tr>
<td>4-20 kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-100 kWh</td>
<td></td>
<td></td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electric Power Source</th>
<th>Hybrid</th>
<th>Plug-in Hybrid</th>
<th>Battery</th>
<th>Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regenerative braking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regenerative braking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside electric power (plug-in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen gas combines with oxygen to produce electricity, which runs a motor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Electric Vehicle Charging Infrastructure

![Diagram showing electric vehicle charging infrastructure](source: Evatran, pluglesspower.com)

## Electric Vehicle Charging Levels/Types

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>DC Fast Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Circuit</strong></td>
<td>Standard outlet 120 V, 15-20 A</td>
<td>Dedicated circuit 240 V, 30-40 A</td>
<td>Dedicated circuit 480 V, 125 A</td>
</tr>
<tr>
<td><strong>EVSE</strong></td>
<td>Regular GFI outlet, available everywhere</td>
<td>Charging station (electrician)</td>
<td>Charging station (electrician)</td>
</tr>
<tr>
<td><strong>Cord Set</strong></td>
<td>Included with car, 3 prong w/ J1772</td>
<td>After-market, cord w/ J1772</td>
<td>After-market, multiple standards</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>1.44 kW</td>
<td>3.3-6.6 kW</td>
<td>50 kW</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>12-24 hours</td>
<td>4-8 hours</td>
<td>30 minutes</td>
</tr>
<tr>
<td><strong>Charge Time</strong></td>
<td>3 to 5 miles per hour charge</td>
<td>10 to 25 miles per hour charge</td>
<td>200 miles per hour charge</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>None</td>
<td>$1.5k-$5k + install</td>
<td>$10k-$30k + install</td>
</tr>
<tr>
<td><strong>Best for...</strong></td>
<td>LSEVs PHEVs &lt;20 mile</td>
<td>BEVs PHEVs &gt;20 mile</td>
<td>Fast Charge BEVs PHEVs &gt;20 mile</td>
</tr>
</tbody>
</table>
### Expected charging times by charging level

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>DC Fast Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Charge power</strong></td>
<td>1.5 kW</td>
<td>6.6 kW</td>
<td>20-120 kW</td>
</tr>
<tr>
<td><strong>Range/charge hr.</strong></td>
<td>4 mi/hr</td>
<td>22 mi/hr</td>
<td>140-330 mi/hr</td>
</tr>
<tr>
<td><strong>Toyota Prius Prime</strong></td>
<td>4 hours</td>
<td>1 hour</td>
<td>Not available</td>
</tr>
<tr>
<td>(4.4 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chevy Volt</strong></td>
<td>12 hours</td>
<td>3 hours</td>
<td>Not available</td>
</tr>
<tr>
<td>(16 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BMW i3</strong></td>
<td>15 hours</td>
<td>4 hours</td>
<td>24 kW (80% in 30 min)</td>
</tr>
<tr>
<td>(22 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nissan Leaf</strong></td>
<td>16 hours</td>
<td>5 hours</td>
<td>50 kW (80% in 20 min)</td>
</tr>
<tr>
<td>(32 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chevy Bolt</strong></td>
<td>40 hours</td>
<td>10 hours</td>
<td>50 kW (80% in 60 min)</td>
</tr>
<tr>
<td>(60 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tesla Model S85</strong></td>
<td>60 hours</td>
<td>15 hours</td>
<td>120 kW (80% in 40 min)</td>
</tr>
<tr>
<td>(90 kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Primary Drivers (and Challenges) of EV Market Growth

- **Oil Dependence**
- **Climate Change Policy**
- **Battery Technology Advances**
- **Cost Parity**
- **Oil Prices**
- **Congestion and Air Quality**
- **Technology Advances**
- **Availability of charging stations**
- **Economies of Scale**
- **Convenience**

Source: PRTM
Forecasts for large growth in EV market through 2040

- Predicts an “inflection point” in late 2020s, where EVs reach cost parity with internal combustion engine vehicles (ICEVs)
- BEVs will begin to comprise majority of EV sales after 2025

Oil and gasoline prices expected to grow steadily

- Crude oil prices in 2016 were at their lowest level since 2004
- Oil prices forecast to increase 50% from $75 today to $114 in 2050
- Geopolitics can have huge effect on oil prices
How will Trump Administration climate change policy impact EV adoption

**Corporate Average Fuel Economy Standards**

- Corporate Average Fuel Economy (CAFE) standards effective at increasing light-duty vehicle fuel economy to over 25 mpg in 2017
- Since EVs are more cost-effective than ICEVs in large increases in fuel economy, CAFE standards are major factor in increasing EV adoption
- Environmental Protection Agency recently proposed to roll back Obama administration CAFE standards

**Average U.S. Fuel Economy (1975-2017)**

- Battery costs will decrease.... but how quickly
- As orders increase, per kWh costs for batteries are falling faster than expected (19% per doubling of manufacturing capacity)
- Average battery energy density expected to almost double by 2030 to over 200 Wh/kg
- At roughly $100/kWh, battery electric vehicles achieve cost parity with ICEVs; expected to occur near 2026
### Acquisition cost for PHEVs vs. comparable ICEVs

<table>
<thead>
<tr>
<th>PHEV</th>
<th>EV Range</th>
<th>Sticker Price</th>
<th>Comparable ICEV</th>
<th>Comparable ICEV Price Premium</th>
<th>Segment Price Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford C-Max Energi</td>
<td>20 miles</td>
<td>$27,120</td>
<td>$18,175</td>
<td>(Ford Focus)</td>
<td>$8,945</td>
</tr>
<tr>
<td>Honda Clarity PHEV</td>
<td>47 miles</td>
<td>$33,400</td>
<td>$27,470</td>
<td>(Honda Accord)</td>
<td>$5,930</td>
</tr>
<tr>
<td>Ford Fusion Energi</td>
<td>21 miles</td>
<td>$36,595</td>
<td>$34,340</td>
<td>(Ford Fusion)</td>
<td>$2,255</td>
</tr>
<tr>
<td>Chrysler Pacifica PHEV</td>
<td>33 miles</td>
<td>$41,995</td>
<td>$35,695</td>
<td>(Chrysler Pacifica)</td>
<td>$6,300</td>
</tr>
</tbody>
</table>

### Acquisition cost for BEVs vs. comparable ICEVs

<table>
<thead>
<tr>
<th>BEV</th>
<th>EV Range</th>
<th>Sticker Price</th>
<th>Comparable ICEV</th>
<th>Comparable ICEV Price Premium</th>
<th>Segment Price Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevy Bolt</td>
<td>238 miles</td>
<td>$36,620</td>
<td>$21,920</td>
<td>(Chevy Cruze)</td>
<td>$14,700</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>151 miles</td>
<td>$32,490</td>
<td>$16,500</td>
<td>(Nissan Versa)</td>
<td>$15,590</td>
</tr>
<tr>
<td>Tesla Model 3</td>
<td>220 miles</td>
<td>$42,000</td>
<td>$40,250</td>
<td>(BMW 330)</td>
<td>$1,750</td>
</tr>
<tr>
<td>Tesla Model X</td>
<td>263 miles</td>
<td>$125,000</td>
<td>$124,600</td>
<td>(Porsche Cayenne Turbo)</td>
<td>$400</td>
</tr>
</tbody>
</table>
Falling battery prices will help BEVs achieve cost parity

- Batteries currently account for 48% of BEV cost, and most of the cost premium over ICEVs
- With falling battery prices, BEVs will cost parity with ICEVs near 2026
- Shortly afterwards inflection point where BEVs sales increase rapidly

Federal EV Incentives

- **Purchasers of plug-in electric vehicles can receive a tax credit of to $7,500 (PHEVs vary based on size of battery)**
- **Tax credits phase out after each manufacturer sells the 200,000th plug-in vehicle**

<table>
<thead>
<tr>
<th>Quarter that 200,000 EV sales is reached</th>
<th>Quarter following 200,000 EV sales</th>
<th>Second quarter following 200,000 EV sales</th>
<th>Third quarter following 200,000 EV sales</th>
<th>Fourth quarter following 200,000 EV sales</th>
<th>Fifth quarter following 200,000 EV sales</th>
<th>Sixth quarter following 200,000 EV sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Level</td>
<td>100%</td>
<td>100%</td>
<td>50%</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Full Credit Amount</td>
<td>$7,500</td>
<td>$7,500</td>
<td>$3,750</td>
<td>$3,750</td>
<td>$1,875</td>
<td>$1,875</td>
</tr>
</tbody>
</table>

- **Tesla and GM models expected to phase out in Q2 2018 and Q3 2018, respectively**
### Availability of cost- and feature-competitive EVs across vehicle segments

#### Cars
- **Small**: Annualized Sales - 2.42M, Market Share - 14.1%
- **Midsize**: Annualized Sales - 2.42M, Market Share - 14.1%
- **Luxury**: Annualized Sales - 900k, Market Share - 5.2%

#### Trucks
- **Crossover**: Annualized Sales - 5.91M, Market Share - 34.4%
- **Pickup**: Annualized Sales - 2.73M, Market Share - 15.9%
- **Midsize SUV**: Annualized Sales - 920k, Market Share - 5.4%
- **Minivan**: Annualized Sales - 527k, Market Share - 3.1%
- **Van**: Annualized Sales - 432k, Market Share - 2.5%
- **Large SUV**: Annualized Sales - 329k, Market Share - 1.9%
- **Small SUV**: Annualized Sales - 315k, Market Share - 1.8%
- **Luxury SUV**: Annualized Sales - 260k, Market Share - 1.5%

#### BEVs
- **Model S**: 114 mi
- **Model X**: 237-289 mi
- **Model 3**: 220 mi
- **Chevy Bolt**: 238 mi
- **Nissan Leaf**: 151 mi
- **Fiat 500e**: 84 mi
- **Pacifica Hybrid**: 5,925

#### PHEVs
- **Ford C-Max**: 5,252
- **Prius Prime**: 24,881
- **Chevy Volt**: 17,640
- **Ford Fusion**: 8,980
- **Honda Clarity**: 6,127
- **BMW 530e**: 6,185
- **BMW 330e**: 3,529
- **BMW X5**: 6,237
- **Pacifica Hybrid**: 5,925

### Widespread adoption requires solving BEV range anxiety issues

- **Acceptable Minimum Driving Range**
  - **Model S**: 249-315 mi
  - **Model X**: 21,545
  - **Model 3**: 20,077
  - **Bolt EV**: 24,172
  - **Fiat 500e**: 3,434
  - **Nissan Leaf**: 10,780

- **Current EV Consumer**
  - **Model S**: 250 mi
  - **Model X**: 300 mi
  - **Model 3**: 237-289 mi
  - **Chevy Bolt**: 238 mi
  - **Nissan Leaf**: 249-315 mi
  - **Fiat 500e**: 238 mi
  - **Bolt EV**: 250 mi

- **Current Non-EV Consumer**
  - **Model S**: 249-315 mi
  - **Model X**: 21,545
  - **Model 3**: 20,077
  - **Bolt EV**: 24,172
  - **Fiat 500e**: 3,434
  - **Nissan Leaf**: 10,780

**Maximum Driving Range**

---

11
**Improving the EV charging experience**

**Gasoline**
- 3 minutes

**300kW DC Fast Charger**
- 15 minutes

**50kW DC Fast Charger**
- 1 hour

**240V Station**
- 8 hours

**240V Home**
- 20 hours

**120V Outlet**
- 40 hours

Refueling Time (200 Miles of Range)

**Building out a charging network to support BEVs**

**EV Charging Happens Where Life Happens**

- **At Home**
  - Used for daily “fill-ups”
  - Available at 50% of households
  - 80% of kWh

- **At Work**
  - Used for “top-ups”
  - Helps drivers with limited access to home charging

- **Around Town**
  - Provides same transportation freedom as an ICEV
  - Relieves “range anxiety” concerns
  - 20% of kWh

- **Out of Town**
  - DC Fast Chargers support “road trips”

Optimal ratios for publicly-accessible chargers are 15 EVs per level 2 charger and 130 EVs per fast charger

Source: Chargepoint

Consumer
EV Course: How you can use what you'll learn

- Create an EV knowledge foundation
- Develop a framework for understanding the EV market and industry players
- Understand primary factors affecting the growth of the EV market and how the market may overcome potential barriers

<table>
<thead>
<tr>
<th>Academics and Educators</th>
<th>Government Decision Makers</th>
<th>Corporate Sustainability Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Prepare for teaching your own EV course</td>
<td>• Identify regulatory areas that may need to be updated to support EVs</td>
<td>• Determine if and how EVs make sense for your (or your client's) fleet</td>
</tr>
<tr>
<td>• Understand EV issues and topics that require academic research and support</td>
<td>• Determine how and where to deploy government resources to support EV deployment</td>
<td>• Identify EV technologies that are worth investing in today versus for the future</td>
</tr>
<tr>
<td>• Develop the core EV knowledge to support industry research</td>
<td>• Estimate impacts of EVs on other industries</td>
<td>• Plan for, deploy, and understand business models for EV charging infrastructure</td>
</tr>
<tr>
<td>• Determine if and how EVs make sense for your campus fleet</td>
<td></td>
<td>• Identify business opportunities in the EV market</td>
</tr>
</tbody>
</table>

EV Course: Modules

<table>
<thead>
<tr>
<th>Understanding Electric Vehicles</th>
<th>The Electric Vehicle Market</th>
<th>Charging Infrastructure</th>
<th>Charging Station Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 5: Electric Vehicle Challenges</td>
<td>Lesson 13: Forecasts for Electric Vehicle Adoption</td>
<td></td>
<td>Lesson 24: Putting it All Together</td>
</tr>
<tr>
<td>Lesson 6: Costs for Electric Vehicles</td>
<td>Lesson 14: Policies and Incentives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson 7: Operating Electric Vehicles</td>
<td>Lesson 15: Consumer Attitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson 8: Electric Vehicle Batteries</td>
<td>Lesson 16: Autonomous Vehicles and EVs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Panel Discussion and Q&A

Julian Bentley  
julian@bentleyenergy.com

Edward Saltzberg  
esaltzberg@securityandsustainabilityforum.org

EV Professional Development Course Format

- **Current Classroom Courses** – *Delivered at GWU over two intense days*
- **Proposed Online Courses** – *The EV online course will be four modules*
  - Self paced videos – about 3 hours in each module
  - **Four webinars – Q&A with the Julian**
  - GWU School of Engineering Certificate for passing the optional course exam
- **Please take the webinar exit survey:** Questions about
  - Format
  - Scheduling
  - Cost
  - Suggestions
  - Pre-registration (25% discount for registering with no obligation).

Going online with the EEMI Professional Development Certificate Courses.  
*Please take the exit survey to help us do that.*
On the Road to Mass Market Electric Vehicles

September 4, 2018
1:15 to 2:15 PM EDT

Julian Bentley
Managing Director of Bentley Energy
Visiting Scholar at George Washington University’s Environmental and Energy Management Institute

Edward Saltzberg
Managing Director
Security & Sustainability Forum
Moderator

Access the Free SSF Webinar Archives
Subscribe for Webinar Alerts
www.ssfonline.org

WILLDAN
www.Willdan.com
Smart Cities Applications