## Electric Transportation

<table>
<thead>
<tr>
<th>Road</th>
<th>Non-Road</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger Vehicles:</strong></td>
<td><strong>Material Handling - Forklifts:</strong></td>
</tr>
<tr>
<td>Trucks, Fleets, Delivery</td>
<td><strong>Airport Ground Support Equipment:</strong></td>
</tr>
<tr>
<td>Vehicles</td>
<td><strong>Port Electrification:</strong></td>
</tr>
<tr>
<td><strong>Heavy-Duty</strong></td>
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</tr>
</tbody>
</table>
Declining battery prices spur increasing sales worldwide

Lithium-ion battery pack prices have fallen 79% since 2010

Source: Bloomberg New Energy Finance
Nationally, EV sales grew 30% YOY in 2017 despite continued low gas prices due to wider model availability.

Source: Union of Concerned Scientists
Duke Energy – NC Transportation Emissions Reductions Projects

- 200 public, Level 2 charging stations throughout North Carolina.
  Increases public L2 charging by 30% in NC.

- Electric transit bus charging infrastructure
  Greensboro will deploy the first battery electric transit bus in North Carolina.

- Truck Stop Electrification (TSE)
  Funding $1.5M of TSE projects throughout North Carolina.
  - Kenly, NC - Big Boys Truck Stop
  - Hickory, NC – MDI electric Transport Refrigeration Unit (eTRU)
Charging Infrastructure Support Program

North Carolina Electric Vehicles & Charging Stations

Electric Vehicle Registrations (2015)

Map Created by Advanced Energy in the NC-PEV Source Code

Public Charging Stations Installed

Public Charging Stations Proposed

Source: Advanced Energy
Duke Energy Florida – EV Infrastructure Pilot

- Installing a foundational level of charging infrastructure 500+ stations across Florida:
  - Level 2: Multifamily 325
    - Workplace 100
    - Public 75
  - DCFC: Corridor Charging 30

- Education and outreach – 5% of program budget

- Disadvantaged communities – 10% of stations

- Transit bus opportunities:
  - PSTA electric bus deployment
Grid Benefits

- Electric Transportation increases electric system utilization and can provide downward rate pressure.

Source: MJ Bradley, E3
Gasoline vs. Electricity Price (real price, July 2016)

SOURCE: EIA, Short-Term Energy Outlook, July 2016
Environmental Benefits

**Relative Emissions for Passenger Cars**

50-90% reduction in lifetime CO2 emissions

**NC - Transportation NOx Emissions**

- **Aircraft**: 30%
- **Locomotive**: 43%
- **Non-Road**: 17%
- **On-Road Heavy Duty**: 6%
- **On-Road Light Duty**: 6%

SOURCE: EEI, EPRI-NRDC, *Environmental Assessment of a Full Electric Transportation Portfolio*
Electric Transportation = Economic Development

- Fuel and maintenance cost savings remain in-state.
- Improved air quality facilitates continued industrial recruitment.
- Automakers are expanding electric drive manufacturing and supply chain.
- Downward rate pressure preserves attractive electricity costs.
APS & New Technologies

Kelly Patton
March 5, 2018
UEDA Winter Forum
Agenda

• Landscape
• Customer
  – Modern Rates
  – Customer Resources
  – Joint Use Resources
• Grid
  – Power Quality
  – Non-Wires Alternatives
  – Solar Plus Storage
Landscape - Current and Future Utility Challenges

How do utilities address the following challenges?

- Managing the “Duck Curve”
- Integration of new technologies
- Updating rates to reflect operational challenges
- Alignment of customer goals with need of utilities
Customer Solutions
Modern Rates to Align with Operational Needs & Lower Cost

- Modern rates provide customer value for use that aligns to low cost time-periods of service
- Modern rates support the integration of existing otherwise curtailed renewable energy
  - 27% of the time, renewable energy is the marginal system resource during the Super Off-Peak period
- Modern rates Encourage customer shifting demand to lower energy price hours
  - Smarter use of energy to integrate more renewable resources
Customer Resources

Water Heaters – Thermal Energy Storage
- Shift customer water heater usage during super-off peak to allow more clean energy integration on the grid and out of On-Peak periods
- **Reduce system peak** and provide **load management benefits** by shifting water heater demand
- Installed on targeted feeders

Thermostat Demand Response
- Connected residential smart thermostats can be controlled to provide **demand response load reductions** during system peak events
- APS has the ability to slightly adjust their thermostat settings (typically no more than 2 degrees) during up to 20 peak events in summer months
- Participating customers will still retain control of their thermostats and can override events without penalties, which will encourage customer participation and retention
- Proposed 25,000 new smart thermostats in 2018 DSM plan for management on modern rates including precooling to use otherwise curtailed renewables
Reverse Demand Response

• **What is Reverse Demand Response?**
  – IS: Dispatch-able load resource for negative market prices that otherwise would not exist
  – IS Not: Load shifting

• **Why isn’t it load shifting?**
  – Advanced rates capture load shifting through time differentiated rates
  – Market prices have not converged

• **Customer Value**
  – Participating customer receives free energy for a benefiting technology
  – Market activity benefits go to customers through adjustor mechanism
Electrification

Residential New Construction Program
• proposed incentive for $100/new home to pre-wire new homes to be EV level 2 charger ready (dedicated 240VAC/40amp circuit with NEMA 14-50 outlet in garage).

School Bus EV Program
• Provide limited income school districts with electric buses and charging infrastructure.
• This program promotes sustainability by reduced use of diesel fuel, reduced air emissions, reduced noise pollution, reduced maintenance costs and improved student health. The buses are a symbol of sustainability within the community to impact and or spur adoption of electric vehicles and buses.
• Another goal of the plan is to charge the busses during the solar PV peak and will be managed charging outside the system peak periods.

Managed EV Charging Program
• APS would own, operate an manage EV charging infrastructure for three different non-residential programs: Charging of commercial fleet vehicles; Workplace charging stations and Multi-family property charging stations.
• Goal is to promote EV charging during excess PV generation periods and avoid charging during the peak demand hours.
• The program will include customer submitted Peak Management plan which allow customers to control their site experience related to grid integration.

APS Interstate Fast Charging:
• APS is exploring interstate DC fast charging opportunities along the main highway corridors (I10, I17 & 40).
Joint Use Resources

• **Residential Energy Storage System (RESS)**
  - Small battery systems (typically <10kW) located at residences
  - Used to either manage customer load consumption or export power when needed for feeder support
  - Program supports 5kW batteries on targeted feeders

<table>
<thead>
<tr>
<th>Use Cases</th>
<th>RESS</th>
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<tbody>
<tr>
<td>Reduce system peak via demand response events</td>
<td></td>
</tr>
<tr>
<td>Reduce system peak via daily scheduled load shift / Provide feeder congestion relief</td>
<td>✔️</td>
</tr>
<tr>
<td>Solar sponging / duck curve management</td>
<td>✔️</td>
</tr>
<tr>
<td>Customer peak demand charge management</td>
<td>✔️</td>
</tr>
<tr>
<td>Voltage support</td>
<td></td>
</tr>
</tbody>
</table>
Joint Use Resources (Cont.)

**APS Microgrids** – in commercial operation since 2017 for mission critical customers

**Marine Corps Air Station – Yuma:**
- 22MW generation interconnected at 12.47kV

**Aligned Data Center – Phoenix:**
- 11MW generation interconnected at 12.47kV
- Integrated with battery ride through

**Microgrid features:**
- Five operating modes including Autonomous Frequency Response (AFR)
  - <20 seconds to full power synched with grid
  - <10 seconds to full power in island mode
- Responded to over 30 AFR events since coming on line
- Utility owned, operated and maintained; 24/7 monitoring and control
Grid Solutions
Addressing Power Quality

• **SPP Battery Energy Storage System (BESS)**
  – Designed to improve power quality on high penetration solar PV feeders (high voltage; low PF)
  – Two identical systems:
    • One located near substation
    • One located at end of feeder
  – 18 month evaluation to determine impact of location on feeder to power quality improvement (continuation of SPP study)
  – Each BESS is 2MW/2MWh in size

• **IFESS - Intermediate Feeder Energy Storage System**
  – Medium sized battery (100kW to 1MW) located on a feeder to help support power consumption needs and power quality of the feeder
  – Solve voltage support issues on targeted feeders
Non-Wires Alternatives

Punkin Center

- Defer the rebuild of 16.5 miles of 21kV distribution line by dispatching energy storage to keep loading below the line rating

- Initial installation of 2MW/8MWh in first half of 2018 with plans to add capacity as additional load growth appears

- This unique non-wired solution used new technology to serve our customers reliable power
Solar Plus Storage

First Solar / APS Solar + Storage

- First-of-its-kind Solar plus storage (50-megawatt (MW), 135 MWh solar-fueled battery with 65-megawatt solar field)
- One of the largest battery storage systems in the country
- APS has signed a 15-year power-purchase agreement with First Solar that will enable APS to use the stored battery power when energy use is at its peak later in the day
  - APS only receives power during hours of need
At Last! ComEd Welcomes Amazon to Chicago
Our Journey’s Beginning

✓ In October 2011, the Illinois General Assembly enacted the Energy Infrastructure Modernization Act (EIMA)
✓ $2.6 billion ten year investment by ComEd to strengthen and modernize the state’s electric grid that had not changed much in over a century
✓ The Investment Plan had two primary components:
  • Reliability-Related Investments – 5 year program, $1.3B
  • Smart Grid-Related Investments – 10 year program, $1.3B
### EIMA Status Since Inception

<table>
<thead>
<tr>
<th>Program Name</th>
<th>% Complete</th>
<th>2012</th>
<th>2017 (AMI-2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>URD (1) Cable Remediation (Miles)</td>
<td>100%</td>
<td>3,890</td>
<td></td>
</tr>
<tr>
<td>Manhole (2) Assessments (Manholes)</td>
<td>100%</td>
<td>34,712</td>
<td></td>
</tr>
<tr>
<td>Underground (1) Mainline Cable Replacement (Miles)</td>
<td>100%</td>
<td>683</td>
<td></td>
</tr>
<tr>
<td>Ridgeland 69kV Cable Replacement (Miles)</td>
<td>100%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Wood Pole Inspection and Treatment (Poles)</td>
<td>100%</td>
<td>737,344</td>
<td></td>
</tr>
<tr>
<td>Wood Pole Remediation (Poles)</td>
<td>100%</td>
<td>20,548</td>
<td></td>
</tr>
<tr>
<td>Storm Hardening - Engineering Solutions (3) (Jobs)</td>
<td>100%</td>
<td>769</td>
<td></td>
</tr>
<tr>
<td>Storm Hardening - Enhanced Veg Mgmt (3) (Miles)</td>
<td>100%</td>
<td>806</td>
<td></td>
</tr>
<tr>
<td>Training Facility Upgrades (Locations)</td>
<td>100%</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Distribution Automation (Devices)</td>
<td>100%</td>
<td>2,609</td>
<td></td>
</tr>
<tr>
<td>Smart Substation Upgrades through 2017 (Stations)</td>
<td>100%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Additional Smart Substation Upgrades through 2021 (4) (Stations)</td>
<td>0%</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>AMI - Smart Meter Installation (5)</td>
<td>88%</td>
<td>3,646,994</td>
<td></td>
</tr>
</tbody>
</table>

(1) URD = Underground Residential Distribution. Full scope is consistent with 2017 ICC filing (3,468 miles replacement, 412 miles injection). Mainline Cable Replacement scope is consistent with 2017 ICC filing (680 miles replacement).

(2) Completion number represents assessment of manholes on ComEd system.

(3) Remaining scope are estimates – developed annually based on criteria.

(4) Full scope is consistent with 2017 ICC filing (16 Smart Substation upgrades).

(5) Advanced Metering Infrastructure (AMI) numbers include 127,857 meters installed during the pilot program.
Distribution Automation – 2,600 New Installations

S&C Electric 34kV IntelliRupter

S&C 12kV Padmount IntelliRupter

G&W Electric Viper 12kV Recloser

All equipment manufactured in the Chicago area!
**Significant Reliability Improvements**

**40% reduction in URD faults, 55% in customer impacted**

- **Primary URD Faults**
  - 12 Month Rolling
  - **EIMA**
  - **CI**

- **Mainline UG Faults Impacting SAIFI**
  - 12 Month Rolling
  - **EIMA**

**~85% reduction in customers experiencing repeat outages**

**Over 80% reduction in customers experiencing long outages during storms**

*2017 data is preliminary and subject to change.*
The Future Energy Jobs Act—or “FEJA”—passed the Illinois General Assembly with broad bipartisan support in November 2016. This law provides major benefits to the state of Illinois.

FEJA pivots Illinois to the new clean energy economy, saving and creating thousands of clean energy jobs and providing job training for the future workforce, while also creating significant consumer and environmental benefits.

The law strengthens the Illinois economy by taking important steps toward our state’s clean energy future and preserving competitive rates. FEJA will:

- **Stimulate** job creation with new investments in energy efficiency, renewables, and energy innovation
- **Enhance** Illinois’ position as a leader in the clean energy economy, attracting investment and new companies to Illinois
- **Preserve** Illinois’ low energy rates for residents and businesses
The Act’s Importance to ComEd

**Energy Efficiency**
Allows ComEd to **earn on energy efficiency investments.**

**Solar**
Places ComEd firmly in a **stronger reputational position** on solar, with support for community solar & ability to compete for $50M in low-income solar funding.

**Formula Rate Extension**
Extends formula ratemaking through 2022.

**Voltage Optimization**
To be deployed on ~3,000 feeders system wide from over 500 Substations.

**Decoupling**
Protects utilities financially from declining load.
Voltage Optimization - Benefits

- On average, customers voltage will decrease 2-3%
- Customer energy use will decrease 1.4 - 2.1%
- Customers realize benefit without changing energy use habits
  
  - System wide energy use could be decreased 1,900 GWH per year after full deployment
  - Peak load estimated to decrease 360MW when fully deployed
    - Size of the largest wind farm in Illinois
As a result from FEJA, Increased Penetration of DER

Potential challenges to the grid:
- Intermittency and limited controllability
- Protection & Distribution Automation schemes to be revised
- Limited hosting capacity
- Impact to other applications like Voltage Optimization

Potential benefits to the grid:
- Reduction of network loading
- Voltage regulation
- Reduced losses
- Increased diversity in energy sources

Some tools and technologies that will contribute to DER seamless implementation:

- **Hosting Capacity Maps**
  Show the amount of DER a distribution feeder can host without negatively impacting performance under existing control and infrastructure configurations.

- **Smart Inverter**
  Advanced Inverter technology is important to support managing the electric grid with the growth of distributed energy resources.

- **Energy Storage**
  Energy storage to smooth PV output and mitigate voltage fluctuations, as well as contributing to shave the load at the substation avoiding reaching the system peak.
Leveraging the Smart Grid To Provide New Services

ComEd is leveraging the full value of smart grid investments and our core networks to provide new value to our customers and our communities.

<table>
<thead>
<tr>
<th>Water Meter</th>
<th>Battery-Powered Device (BPD)</th>
<th>Continuously-Powered Devices (CPD)</th>
<th>ComEd AMI Network</th>
<th>Head-end Software</th>
<th>Water Utility Data Transfers</th>
</tr>
</thead>
</table>

**Outage Detection:** Faster awareness of trouble & verification; avoided 20,000 truck rolls in 2017

**Water Metering:** Leveraging the AMI network to transmit water meter data for municipalities across the ComEd service territory

**Community Energy Storage:** Demonstrate the use of battery energy storage technology as a grid asset to improve reliability

**Smart LED Streetlights:** Combine high efficiency LED luminaires with wireless two-way communications for remote monitoring and advanced control
## City of Chicago’s Bronzeville Neighborhood Microgrid

**Microgrid Development Efforts:** Filed with the IL Commerce Commission for installing a Microgrid in the Bronzeville Community located on the south side of Chicago and the home of IIT

### Advanced Performance Metrics

Development of a comprehensive set of microgrid performance metrics and covering energy and non-energy benefits

- Quantifiable and directly aligned with business objectives and regulatory requirements
- Based on the three pillars of resilience
  - Energy system resilience
  - Critical Infrastructure resilience
  - Community resilience

### DOE Grant: Microgrid Master Controller

The DOE awarded $1.2 million to ComEd and its partners to develop and test a commercial-grade microgrid controller capable of managing two or more interconnected microgrids – September of 2014

### DOE Grant: SHINES

The DOE has awarded $4 million to ComEd and its partners to implement a combined solar PV and energy storage, to research the sustainable deployment of solar PV in a microgrid setting

---

**Microgrid controller enabling clustering**
Enhancing Visual Appeal – DC in a Box (DCIB)

Innovative 34-12kV Distribution Center substation design in use 2005-2018

Typical DC 34kV to Single 12kV Feeder from 1960’s to 2005
Reforming the Energy Vision – New Energy Solutions

Joe Russo – Lead Economic Development Representative
Engaging in the Energy Landscape

Social & Economic Pressure on Central Power Plants

Reforming the Energy Vision (REV)
- Demonstrations
  - Fruit Belt Neighborhood Solar
  - Distributed System Platform
  - Potsdam Resiliency
  - Clifton Park Convenience

Electric Transmission Congestion

Natural Gas Transmission Access

50% Renewable Energy Target by the 2030
Reforming the Energy Vision (REV)

- Reforming the Energy Vision
  - Industry in Transition
    - Technology Innovation
    - Age of the Infrastructure
    - Increased Demand for Renewable Energy
    - System Resiliency – Challenges of Weather
  - Essence of REV
    - Alternative Business Model to Traditional Solutions
Current Utility Structure

Color Key:
Black: Generation
Blue: Transmission
Green: Distribution

Generating Station

Generating Step Up Transformer

Transmission lines 765, 500, 345, 230, and 138 kV

Transmission Customer 138kV or 230kV

Substation Step Down Transformer

Subtransmission Customer 26kV and 69kV

Primary Customer 13kV and 4kV

Secondary Customer 120V and 240V

Privately Held

Utility Ownership

Market
National Grid REV Demonstration

Buffalo Niagara Medical Campus

Fruit Belt “Neighborhood” Solar
- LMI
- Utility Ownership
- Multiplier
- System Impact

BNMC DSP
- Value of “D”
- Unlocking DER Potential
- Test Platform & a “NOC”
- Vendor Partner Alignment

Resiliency
- Area System Exposure
- Aligned DG Assets
- Community Partnership
- Infrastructure

Customer Convenience
- Energy Insights
- Comfort & Convenience
- Peak Reward
- Choice & Control

Potsdam

Clifton Park
Implementation Challenge

- Technology
  - Adaptive to New Application
  - Innovation
- Policy
  - Regulation
  - Legislation
  - Who Pays?
- Market Place
  - Market Perception
  - Market Acceptance
  - Market Demand
# Integrated Resource Plan

"Balance! A KW by Any Other Name is a KW"

<table>
<thead>
<tr>
<th>Supply</th>
<th>Delivery</th>
<th>Demand</th>
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</thead>
<tbody>
<tr>
<td>Central or Local</td>
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<td>Demand Response</td>
</tr>
<tr>
<td>Renewable Energy</td>
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<td>Energy Efficiency</td>
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<tr>
<td>Source</td>
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<td>Energy Management</td>
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<tr>
<td>- Wind</td>
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<td>Peak Shaving</td>
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<tr>
<td>Storage!</td>
<td></td>
<td>- Ice Storage</td>
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<tr>
<td>- Solar</td>
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<td>Human Behavior</td>
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<td>- Bio</td>
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<td>- Usage Pattern</td>
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<td>- Hydro</td>
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<td>- Vehicle of the Future</td>
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<td>Co-Generation</td>
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<td>- District Htg/Clg</td>
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<td>Age of Infrastructure</td>
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<td>Size to Supply</td>
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<td>Size to Consumption</td>
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<td>Speculative Build?</td>
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<td>Overhead – Underground</td>
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<td></td>
<td>Voltage Diversity</td>
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<td>Reliability &amp; Power Quality</td>
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*Image of a chart with categories for Supply, Delivery, and Demand, each with subcategories related to energy resources and management strategies.*
Prioritization! – Regional Councils

- **Renaissance**
  - Energize our Micropolitan Cities
  - Create Greenest Energy Economy

- **Target Industry Sectors**
  - Manufacturing
  - Agriculture and Food
  - Energy
  - Higher Education
  - Tourism and Recreation
  - National Defense

- **Strategies**
  - Workforce Development
  - Incentives for Research and Entrepreneurial Activity
  - Elevate Global Recognition
  - Build Energy Networks for Clean Energy Sources

- **The Energy Economy**
  - $12.2 Trillion in Global Generating Capacity
  - $3.7 Trillion in Global Solar
  - $30 Billion in NY Ageing Electric Infrastructure
Next Steps

- Solve the Three Legged Energy Stool
  - Technology, Market Demand and Policy
  - What are the Growth Opportunities?
- Continue to Engage Stakeholders!
  - Align Business and Regulatory Agenda
  - What are key Business Advocacy Positions?
- Exercise the Academic Community
  - Engineering, Business, Law and Environmental Schools
  - Develop Objective Proof Points
- Leverage Available Investments!
Our world is changing…

By 2040 the % of energy market that will be electric will DOUBLE and will reach 50% by 2050

A global push for cleaner and more renewable sources

TRANSPORTATION ELECTRIFICATION

DECENTRALIZED GENERATION

BEYOND-THE-METER TECHNOLOGIES

$275B
23% of U.S. GDP

2017

$480B
40% of U.S. GDP

2040
OUR VISION

To be our customers’ most-trusted energy partner.

Today, customers expect more ...
We will focus on four strategies

1. Deliver exceptional customer experiences
2. Invest in a reliable and clean energy future
3. Build a smarter, more resilient grid
4. Pursue excellence in our work
Potential Solutions

- **Battery Storage**
  - homes, microgrids, substations
- **Transportation Electrification**
  - cars, buses, autonomous vehicles
- **Distributed Generation**
- **Smart Streetlights**