My perspective

• 30 years in electric industry (plus gas, oil and water)
• 8 years at Electric Power Research Institute
• Certified technology nerd
• Published author
• Utility, venture capital, private equity and consulting background
• A DOUG:
  ✓ Dumb
  ✓ Old
  ✓ Utility
  ✓ Guy
Who we are

- Serve 40 million Americans
- 15-state footprint
- 1.4 million square miles
- 49 offices
- ~700 customers
- Top-10 largest transmission utility in country
Mission breakout

**RELIABILITY**
- 651 people
- and
- 28 percent
  - of dollars invested in maintenance and related areas

**MARKETING**
- Including purchase power and wheeling
- 158 people
- and
- 42 percent
  - of dollars committed to power marketing areas

**DELIVERY**
- 334 people
- and
- 22 percent
  - of dollars dedicated to power operations and engineering areas

**COST-BASED**
- and related services
- 298 people
- and
- 8 percent
  - of dollars applied to support the mission
Untangling giant hairball of electricity
The vast networks of electrification are the greatest engineering achievement of the 20th century.

– U.S. National Academy of Engineering
Dot-com era circa 1880: electricity

1882, First electric station built by Edison on Pearl Street
Do you recognize this man?

Samuel Insull, *aka* the Monopoly Man
Basic rules of electricity

• Electrons are governed by the laws of physics
  – Flows to the point of least resistance
  – Always must be in supply and demand balance
  – No storage outside of fossil fuel, water and some chemical reactions
• Electricity is governed by the laws of politics
Build it bigger

- The U.S. power supply network is the largest most complex machine ever created
- Engages enterprise involving:
  - 5,000 corporate entities
  - Several forms of ownership and levels of regulatory oversight
  - Some 100 million customers
- Attempts to satisfy conflicting economic, social political and environmental objectives
- Complexity is increasing driving need for more system intelligence
Challenges in the energy frontier

- Aging Infrastructure
- Increased regulation
- Intermittent resources
- Decreased hydropower production
- More customer-side resources
- Changing markets
- Security
Challenge of system operations

“Typical” 500 MW peaking utility

<table>
<thead>
<tr>
<th>Power Level</th>
<th>Generation Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 MW</td>
<td>Base load generation</td>
</tr>
<tr>
<td></td>
<td>Coal/nuclear/hydro/natural gas</td>
</tr>
<tr>
<td>100 MW</td>
<td>Mid-term contracts or market positions</td>
</tr>
<tr>
<td></td>
<td>Natural gas</td>
</tr>
<tr>
<td>100 MW</td>
<td>Spot Market, peakers, renewables</td>
</tr>
</tbody>
</table>

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Key concepts

• Utilities *make* money on assets
• Utilities *collect* money based on kWhs used
• Utilities may also act as tax collectors for states, municipalities and counties
• In many states (California) there is no benefit to utilities selling more electricity
Megatrend: Carbon/Capacity Conflict

We are on track for the “t***n w***k” of regulations vs. carbon et al.
Carbon constraints/capacity conflict

- Demand for new power sources will outstrip capacity
- Demand for clean energy will outstrip the capacity
- Public perception contrasts with the reality of the system
- Renewables are being promoted as the only answer
- Cost of renewables creates financial challenges

Developed world demand dead?
Developing world demand galloping!
The Solar/Peak Conundrum (even in Arizona)

253 MW Peak Reduction

Demand After Sr
763 MW Solar

Hourly Electric System Demand (MW)

Hourly Solar DE Production (MW)

Hour Ending

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California duck curve

California Independent System Operator Duck Curve

Net Load - March 31

Ramp need ~13,000 MW in three hours

Overgeneration risk

Western Area Power Administration
Fundamental change

The challenge for the utility of today is not only what is real but what is perceived as real.
Generation mix

Electric sector generation mix over time by technology and scenario

Source: Electric Power Research Institute
Change is upon us

Wind-penetration record
62.13% at 1:54 a.m.
on March 31, 2018
USVI Solar Farm post hurricane
Advanced Small Modular Reactors (SMRs)

- DOE generation priority
- Black-start capability
- Baseload resource
- Self-contained “island-mode” power
Contrasting world views

- Reality of system ops generally ignored
- Sky is falling?
- Sky is not falling?
- Reliability hangs in balance
- Surge in demand may lead to significant shortages
- Timing of regulations affect regions differently
- Belief, not engineering, leads the way
Choice vs. risk

Utilities Risk
- Fixed rates
- Fixed rates annual adjustment

Customer Risk
- Energy charge adjustment
- Time of use
- Critical peak pricing
- Real-time pricing

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Dinosaurs to Avatars
Connected world
Distributed generation

• Generation at point of consumption
• Increase dispatch and accessibility
• Retail driven
• Risks:
  • Diseconomies of scale
  • Strand existing assets
Home tech drives smart grid benefits

4.92 billion wireless devices globally / 66% penetration

Source: Hootsuite, January 2017
Storage scale

- WAPA has 10,000 MW of nameplate capacity
- 1 tractor trailer = 1 MW of storage
- Battery life = 4 hours
- Need 60,000 trailers to replace WAPA’s hydro capacity
EV trip: New York to Florida

- 40 gallons of gasoline
- 286 pounds of coal
- 2,500 cubic feet of natural gas
- 7 days of 10-kW rooftop array
- 33 minutes of giant offshore wind turbine
# Renewable vs carbon free

<table>
<thead>
<tr>
<th>Renewable</th>
<th>Carbon free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Wind</td>
</tr>
<tr>
<td>Solar</td>
<td>Solar</td>
</tr>
<tr>
<td>Biomass/gas</td>
<td>Biomass/gas</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Geothermal</td>
</tr>
<tr>
<td></td>
<td>Hydropower</td>
</tr>
<tr>
<td></td>
<td>Nuclear</td>
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</table>
Societal changes
The future nexus
## U.S. and World Populations

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median household income</td>
<td>$61,372</td>
<td>$9,733</td>
</tr>
<tr>
<td>No internet access</td>
<td>24%</td>
<td>45%</td>
</tr>
<tr>
<td>Renters</td>
<td>36.6%</td>
<td>33.1%</td>
</tr>
</tbody>
</table>
Water-energy nexus

<table>
<thead>
<tr>
<th>Project</th>
<th>Annual H₂O need (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genesis Solar</td>
<td>536 million</td>
</tr>
<tr>
<td>Mojave Solar</td>
<td>705 million</td>
</tr>
</tbody>
</table>
Economic challenge

How can we manage in a Twitter–centric world?
Radical thoughts

The kilowatt-hour is dead

Time-of-purchase vs. time-of-use

All-you-can-eat energy
Key takeaways

The industry is changing at a rapid pace. There is no microgrid without a macrogrid. 100% carbon free versus 100% renewable. We need the best and the brightest to stay ahead and remain competitive.
Contact/follow me

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