Electricity Business: Generation and Transmission

Adly Khair and Cameron Connolly
Generation
What is generation?

- “The creation of flowing electrons”
  - Coal, nuclear, natural gas, fuel oil, hydro, renewables (including inexhaustible)

- How?
  - Turbines (boiler, combustion, flowing system), reactors, photovoltaics

(Shively, B., & Ferrare, J., 2012, p. 35)
Classical Energy Generation via Coal Plant

Duke Energy, 2018
U.S. Generation Capacity

1.04 TW

(EIA, 2018)
**Generation vs. Capacity**

**Capacity (Max)**
- Coal: 30%
- Natural Gas: 42%
- Nuclear: 9%
- Non-hydro: 6%
- Hydro: 9%
- Fuel Oil (other): 4%

*Source: Short-Term Energy Outlook, August 2018*
Generation Usage

- Concept of baseload relies on sources with low variable cost
- Varies during day

(Shively, B., & Ferrare, J., 2012, p. 50)
Future Energy Distribution

Electricity generation from selected fuels
billion kilowatthours

<table>
<thead>
<tr>
<th>Year</th>
<th>History</th>
<th>Projections</th>
</tr>
</thead>
</table>

- **Natural Gas**
- **Renewables**
- **Coal**
- **Nuclear**

Reference case

- **Low Oil and Gas Resource and Technology**
- **High Oil and Gas Resource and Technology**

(EIA, 2017)
Future Energy Distribution

Net electricity generation from select fuels
billion kilowatthours

- natural gas
- renewables
- coal
- nuclear
- petroleum

2017
history projection

1990 2000 2010 2020 2030 2040 2050

Reference case
Reference with Clean Power Plan

(EIA, 2017)
Arizona Generation Distribution

Arizona Net Electricity Generation by Source, May. 2018

- Petroleum-Fired
- Natural Gas-Fired
- Coal-Fired
- Nuclear
- Hydroelectric
- Nonhydroelectric Renewables

Source: Energy Information Administration, Electric Power Monthly

https://www.eia.gov/state/?sid=AZ
- (APS) Generation Distribution
  - Palo Verde Generating Station
    - Nuclear
    - 70% of Arizona’s “clean-air energy”
  - Four Corners, Cholla, Navajo
    - Coal
  - Redhawk, West Phoenix
    - 7 combined-cycle natural gas plants

(APS, 2018)
Utility Profile

STATE OF ARIZONA - ELECTRIC

Revised January 1, 2018

(ACC, 2018)
Trying to Make Sense of this Portfolio: “Profile Analysis”

- Opportunities for more generation within Arizona?
  - Very small industrial sector
    - 14th most populated, but 44th in per capita energy consumption
  - Geographical Drivers
    - Major mine is Kayenta, which is closing in 2019 along with Navajo Generating Station
      - ⅖ of Arizona’s coal capacity
    - No significant oil or gas reserves
    - Largest nuclear power plant in the nation
      - Not near large body of water
      - Low chance of natural disasters
    - A lot of energy used for pumping water from Colorado River
    - Hydroelectric in Northern Arizona
      - Glen Canyon Dam and Hoover Dam on Colorado River
    - 2nd largest solar potential behind Nevada
      - 3 largest capacity behind California and North Carolina

(EIA, 2017)
Future of Arizona Energy Generation, as decided by the ACC

- Arizona’s Energy Modernization Plan
  - Proposed by Commissioner Andy Tobin
  - January 30, 2018
  - 80% clean energy by 2050
  - 3 GW of energy storage by 2030
  - Clean Peak Target (CPT)
    - “To set this target, regulated utilities shall quantify existing levels of clean resources deployed during peak hours to establish a baseline, and incrementally increase that baseline figure 1.5% per year on average until 2030”
  - 60 MW of nameplate capacity biomass from “high-risk” fuel
Future of Solar Generation - Part 1: EIA 2018 Outlook

- From 2020 → 2050 utility scale
  - Wind to grow 20 GW
  - Solar to grow 127 GW
  - Battery storage cost expected to decline
- PV electricity generation
  - Expected to be 14% of total electricity generation by 2050
    - 53% utility 47% small-scale
Concept of Levelized Cost of Electricity (LCOE)

DOE Office of Indian Energy, 2015
Future of Solar Generation - Part 2: LCOE

- Levelized Cost of Electricity (LCOE)
  - A good measurement of “overall competitiveness”
  - Does it make economic sense going forward?
- https://openei.org/apps/TCDB/#blank

Table A1a. Estimated levelized cost of electricity (capacity-weighted average\(^1\)) for new generation resources entering service in 2020 (2017 $/MWh)

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Capacity factor (%)</th>
<th>Levelized capital cost</th>
<th>Levelized fixed O&amp;M</th>
<th>Levelized variable O&amp;M</th>
<th>Levelized transmission cost</th>
<th>Total system LCOE</th>
<th>Levelized tax credit(^2)</th>
<th>Total LCOE including tax credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispatchable technologies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional CC</td>
<td>87</td>
<td>11.1</td>
<td>1.5</td>
<td>33.6</td>
<td>1.0</td>
<td>47.1</td>
<td>NA</td>
<td>47.1</td>
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<tr>
<td>Advanced CC</td>
<td>87</td>
<td>13.2</td>
<td>1.3</td>
<td>29.5</td>
<td>1.0</td>
<td>45.1</td>
<td>NA</td>
<td>45.1</td>
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<tr>
<td>Conventional CT</td>
<td>30</td>
<td>30.7</td>
<td>6.7</td>
<td>48.0</td>
<td>2.7</td>
<td>88.1</td>
<td>NA</td>
<td>88.1</td>
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<tr>
<td>Advanced CT</td>
<td>30</td>
<td>19.5</td>
<td>2.6</td>
<td>52.7</td>
<td>2.7</td>
<td>77.5</td>
<td>NA</td>
<td>77.5</td>
</tr>
<tr>
<td>Non-dispatchable technologies</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Wind, onshore</td>
<td>42</td>
<td>32.7</td>
<td>13.1</td>
<td>0.0</td>
<td>2.4</td>
<td>48.1</td>
<td>-17.5</td>
<td>30.6</td>
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<tr>
<td>Solar PV(^3)</td>
<td>31</td>
<td>46.5</td>
<td>8.1</td>
<td>0.0</td>
<td>3.1</td>
<td>57.7</td>
<td>-13.9</td>
<td>43.8</td>
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</tbody>
</table>

\(^1\) The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions in 2018-2020.

\(^2\) The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2020 and the substantial phase out of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as NA or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

\(^3\) Costs are expressed in terms of net AC power available to the grid for the installed capacity. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Transmission
Transmission is the movement of electrical energy from generating site to electrical substation.

(FERC, 2004)
A Little History

1882
First practical long-distance transmission of electric power using direct current (DC) in Munich.

1886
First practical demonstration of a transformer and alternating current (AC) lighting system developed by William Stanley, Jr. in Massachusetts.

1891
First three-phase alternating current (AC) using high voltage in Frankfurt.

(Wikipedia, 2018)
NYC in 1890

Different classes of loads (i.e. lighting, fixed motors, and railway systems) required different voltages. So, different generators and circuits were used.

(Wikipedia, 2018)
In 1968, North American Reliability Corporation (NERC) was formed to oversee the regional reliability entities and encompass the interconnections of US, Canada and portion of Baja California in Mexico.

This ensures reliability of North America bulk power system by sharing peak load coverage and backup power.

Interconnections are electrically independent from each other except for a few small DC-linking ties.

(Wikipedia, 2009)
Total Utility Electricity Expense in the U.S. in 2016

- Production: $100.9 B
- Transmission: $10.4 B
- Distribution: $4.7 B

(EIA, 2018)
Transmission System Costs

$130,000 per mile for lower voltages (115kV)

$500,000 per mile for higher voltages (230kV)

$1 million per mile for ultra high voltages (345kV and above)

(Electricity Business, 2012)
Issues with Transmission Construction

- **Public opposition**
  - Land use issues
  - Impacts on property values
  - Environmental issues
  - Electromagnetic field (EMF) threats

- **Regulatory issues**
  - Mechanism to recover cost in rates
  - How costs are assigned to market participants
  - How projects that cross state lines can be effectively planned
  - Procedures for obtaining construction permits (especially difficult for projects crossing multiple states)

(Electricity Business, 2012)
Policies in the U.S.

- Primary regulatory agency: **Federal Energy Regulatory Commission (FERC)**
- Two notable policies: **Order No. 888** and **Energy Policy of Act (EPA) of 2005**

(Wikipedia, 2018)
Order No. 888 and EPA 2005

Order No. 888

Implemented in 1996 to encourage competition in the wholesale bulk power marketplace and bring more efficient and lower cost power to electricity consumers

- Required utilities to unbundle their generation functions and provide open access to their transmission facilities

EPA 2005

Implemented to enforce electric transmission reliability standards (in response to 2003 blackout) and establish rate incentives to encourage investment in electric transmission

- FERC granted authority to oversee mandatory reliability standards of the grid
- Authorized loan guarantees and tax credits for clean sources

(FERC, 2010)
(EPA, 2005)
- Steady increase in investment in transmission due to upgrades and replacement, improvements in reliability and security, and expansion to integrate alternative sources
- Relatively small investment in underground transmission
- “Other” mostly made up of operational and maintenance (O&M) cost
Electrical transmission map across the US with voltages of 345kV or more (EIA, 2015)
In 2001, T&D losses almost 20% of generation.
- Mainly due to technical inefficiency and theft.
- In 2013, India’s five regional grids were interconnected.
- India also more than doubled the mileage and capacity of lines since 2002.
- India government also funded the installation of IT-based and tamper-proof energy monitoring, metering and accounting systems and equipment.

(EIA, 2015)
Smart Grid Technologies

- **Power characteristics monitoring device** like Phasor Measurement Units (PMUs)
- **Power quality and flow control devices** to maintain or control system parameters like Flexible AC Transmission Systems (FACTS) and Phase Angle Regulators (PAR)
- **Remote substation monitoring and control devices** like Intelligent Electronic Devices (IED), Remote Terminal Units (RTU), Programmable Logic Controllers (PLC) and Programmable Automation Controllers (PAC)
- **Advanced IT systems** that allow operators to make practical use of information and control capabilities like Energy Management System (EMS)

(Electricity Business, 2012)
Current & Future Status in the US

- Require ongoing investment to meet the ever-growing demands
- Estimated to nearly triple the number of miles transmission lines are constructed during the next five years
- Expected increase in commercialization of new technologies that will allow existing lines to carry more power
- Estimated increase in electricity transmission from renewable sources

(Electricity Business, 2012)
Resources for Generation

Resources for Transmission


Thanks!

Any questions?