SYSTEM RESOURCES
Commercially Available Technologies
### System Resources – Commercially Available Technologies

<table>
<thead>
<tr>
<th>Renewable</th>
<th>Storage</th>
<th>Firm/Dispatchable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>BESS¹</td>
<td>CTG²</td>
</tr>
<tr>
<td>Solar</td>
<td></td>
<td>CC³</td>
</tr>
</tbody>
</table>

1) Battery Energy Storage System (“BESS”)  
2) Combustion Turbine Generator (“CTG”)  
3) Combined Cycle (“CC”)

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System Resources – Commercially Available Technology Modeling Benefits

• Current market established cost and production profiles
  – Actionable near-term modeling results (this decade) - Predictable
  – Cost established
  – Time to market established
  – Current infrastructure certainty – Reuse of existing interconnections beneficial

• Solves near term needs with today’s technology
  – Leaves opportunity for “horizon” planning and integration of emerging technologies
# System Resources – Commercially Available Technology Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Wind</th>
<th>Solar</th>
<th>BESS(^3)</th>
<th>Long Duration BESS(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm and Dispatchable</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Limited Duration</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
<td>Multi-day</td>
</tr>
<tr>
<td>Proposed Accreditation Method</td>
<td>ELCC(^2)</td>
<td>ELCC(^2)</td>
<td>ELCC(^2)</td>
<td>TBD</td>
</tr>
<tr>
<td>Summer Capacity Accreditation</td>
<td>~20%</td>
<td>~75%</td>
<td>&gt;95%</td>
<td>TBD</td>
</tr>
<tr>
<td>Winter Capacity Accreditation</td>
<td>~20%</td>
<td>&lt;5%</td>
<td>~80%</td>
<td>TBD</td>
</tr>
<tr>
<td>Construction Cost ($/kW)</td>
<td>1,200-2,400</td>
<td>1,200-2,400</td>
<td>1,500-2,100</td>
<td>TBD</td>
</tr>
<tr>
<td>Heat Rate (MMBtu/kWh)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Expected Capacity Factor (%)</td>
<td>45-55</td>
<td>28-35</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>CO(_2) Free</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1) PBA – Performance Based Accreditation  
2) ELCC – Effective Load Carrying Capability  
3) BESS – Battery Energy Storage System – Round Trip Efficiencies: ~ 80% - 85%  
4) BESS – Longer Term Durations – Round Trip Efficiencies: ~ 40% - 50%
System Resources – Renewable – Wind

- Convert’s the wind energy into electricity
- Large, three-bladed Wind Turbine Generators (“WTGs”) aggregated to produce hundreds of MWs
- Intermittent resource
- Capacity factors range from 45%-55% in eastern New Mexico.
- Moderate capacity accreditation due to noncoincidental peak generation profiles.
- Land use:125 acre/MW
- PTC/ITC Eligible
System Resources – Renewable – Solar (PV)

- Converts the sun’s energy (photons of light) into electricity
- Several forms: Photovoltaic (“PV”), concentrating PV, or concentrating solar power
- Intermittent resource
- Capacity factors range from 30%-35% in eastern New Mexico
- Max output occurs prior to load peak, therefore, less capacity accreditation than nameplate
- Available during the daytime. Generation rises and falls with the sun barring any sky cover such as clouds or fog
- Land use: 8 acre/MW
- PTC/ITC Eligible

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System Resources – Storage – BESS

- Power from Electrochemical Process, or other Potential Energy Sources (springs, gravity, etc.)
- Various battery chemistries available, Lithium-ion most currently most prevalent
- Storage typically ranges in size from 10 MW to over 250 MW for durations from 2 to 8 hours
- Balances the intermittent nature of wind and solar
- Dispatchable
- Longer term storage durations in development
System Resources – Storage – Long Duration BESS

• Battery Energy Storage ("BESS") Long Duration:
• Long duration, multi-day
  – Form Energy’s Iron-air BESS – 10MW/100-hour storage duration
  – Xcel Energy has two pilot projects underway planned for our Northern and Colorado sister utilities
  – Uses electricity to form elemental iron; when the iron rusts again, it releases energy in the form of electricity that can be put back on the grid
## System Resources – Commercially Available Technology Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>CTG</th>
<th>CC</th>
<th>Future CTG²,³</th>
<th>Future CC²,³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm and Dispatchable</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Limited Duration</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Proposed Accreditation Method</td>
<td>PBA¹</td>
<td>PBA¹</td>
<td>PBA¹</td>
<td>PBA¹</td>
</tr>
<tr>
<td>Summer Capacity Accreditation</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
</tr>
<tr>
<td>Winter Capacity Accreditation</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
</tr>
<tr>
<td>Construction Cost ($/kW)</td>
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<td>TBD</td>
<td>TBD</td>
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<tr>
<td>Heat Rate (MMBtu/kWh)</td>
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<td>TBD</td>
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<tr>
<td>Expected Capacity Factor (%)</td>
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<td>25-80</td>
<td>0-25</td>
<td>25-80</td>
</tr>
<tr>
<td>CO₂ Free</td>
<td>No</td>
<td>No</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

1) PBA – Performance Based Accreditation  
2) Hydrogen Capable  
3) Carbon Capture and Storage
System Resources – Thermal – CTG

- Typically referred to a simple-cycles because they operate on a single thermal cycle known as the Brayton Cycle
- Operate utilizing several established fuel sources but are traditionally fired with natural gas with a backup fuel such as fuel oil
- Available in a wide capacity range from 4 MW to over 400 MW
- Provide extremely fast start capabilities and ramp rates, excellent load following
- Firm and dispatchable
- Technological advancements have allowed utilization of carbon-free H2, currently blended (38% blend achieved currently)
- Carbon capture an option in the future
System Resources – Thermal – CC

• Utilize CTGs in conjunction with Heat Recovery Steam Generators (“HRSGs”) and a Steam Turbine Generator (“STG”)
• Referred to as CCs because they combine the thermodynamic Brayton and Rankine Cycles
• Exhaust heat from the CTG(s) are ducted through the HRSG(s) to generator steam used by the STG
• Operate in multiple configurations, i.e., 1-on-1, 2-on-1, 3-on-1, etc.
• Operate on various established fuel sources
• Come in a variety of sizes that can range from 100 MW to 1,600 MW
• Efficient due to the “waste” heat is used to generate electricity
• Excellent at load following, Firm and dispatchable
• Hydrogen capable
• Carbon capture an option in the future
System Resources – Emerging Technologies

Hydrogen (H2):

• **Green**
  - Hydrogen produced using surplus renewable energy resources, such as solar or wind power, to power an electrolyzer which splits water into hydrogen and oxygen (process known as electrolysis)

• **Blue**
  - Hydrogen produced from natural gas and supported by carbon capture and storage. The CO2 generated during the manufacturing process is captured and stored

• **Pink**
  - Hydrogen produced using surplus nuclear energy to power an electrolyzer.
Carbon Capture and Storage/Sequestration ("CCS"):  
• Carbon Dioxide (CO2) chemically separated from combustion exhaust  
• Capable of exceed 95% efficiency  
• Often stored in geological formations or other forms for reuse in other processes
System Resources – Emerging Technologies

Emerging Technologies:

• The following discussion is not an exhaustive list nor are major technical details discussed

• Material is meant to inform at a high level of some of the emerging technologies that might be of interest to stakeholders.

• If more information is required, Xcel Energy would be happy to provide
System Resources – Emerging Technologies

Nuclear – Small Modular Reactors (SMRs):

- As the name implies, modular scale of proven nuclear reactor designs
- Fully factory fabricated power modules (~77 MW)
  - E.g. - NuScale plants from ~ 230 MW – 900 MW
  - Reduces the financial risks associated w/ conventional builds
- Carbon free energy production

Source Image: Popular Mechanics Jan/Feb 2021
System Resources – Emerging Technologies

Linear Generators

• Reaction vs combustion
• Modular
  – ~1.5MW/module
• Natural gas or biogas fuels
• 100% H2 Capable

Source Image: Mainspring Energy
System Resources – Modeling Emerging Technology

• “Place holders” representative of technology types available for the model to select
• What would stakeholders prefer to model, need suggestions by July 6 preferably
QUESTIONS ?