Analysis of Electrical Grid Capacity by Interconnection for Urban Air Mobility

2022 AIAA Aviation Forum
David Thipphavong

ATS-03: Aviation Emissions and Efficiency
6/27/2022, 14:00-15:40 CDT (UTC-5)
This is an exploratory study with a top-level, first-order analysis with the following caveats

- This study does not capture the dynamic behavior of electrical grids and users
- This study does not capture potential future developments in electrical grids and electrical devices
- Therefore, the results of this study are not to be used for investment decisions
Presentation Roadmap

• Takeaway Message

• Introduction

• Methodology

• Results

• Summary and Future Work
• Many challenges must be overcome to conduct UAM operations at scale with electric vertical takeoff and landing (eVTOL) aircraft
Takeaway Message

• Many challenges must be overcome to conduct UAM operations at scale with electric vertical takeoff and landing (eVTOL) aircraft

• Due to these challenges, Morgan Stanley’s 2021 projection of the UAM market was one-third smaller than its 2018 projection
Many challenges must be overcome to conduct UAM operations at scale with electric vertical takeoff and landing (eVTOL) aircraft.

Due to these challenges, Morgan Stanley’s 2021 projection of the UAM market was one-third smaller than its 2018 projection.

Success of UAM depends on the availability of electricity:
- Ground electric vehicles (EVs) will proliferate over time.
- The number of UAM aircraft that can charge on the grid will decrease over time.

Available electrical grid capacity may be a formidable constraint for UAM.
Introduction
The continental U.S. is part of three major electrical grids:
- Western Interconnection
- Eastern Interconnection
- Texas Interconnection
  (managed by the Electric Reliability Council of Texas)

Analysis is on the continental U.S. (does not include Alaska, Hawaii, or Canada)
Methodology
**Methodology**

**Step 1: Estimate available electrical grid power capacity**

<table>
<thead>
<tr>
<th>Data</th>
<th>Projections</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric power plant nameplate capacity</td>
<td>Generation capacity growth rate</td>
<td></td>
</tr>
<tr>
<td>Electrical grid utilization</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Methodology

Step 1: Estimate available electrical grid power capacity
- Electric power plant nameplate capacity
- Electrical grid utilization

Step 2: Estimate peak electrical power utilized for ground EV charging
- Population
- Motor vehicle ownership

Data
- Generation capacity growth rate

Projections
- Population growth rate
- Ground EV ownership, charging power, peak percentage charging

Sources
- EIA
- U.S. Energy Information Administration
- Census Bureau
- U.S. Department of Energy
- Bloomberg New Energy Finance
- IHS Markit
## Methodology

1. **Step 1:** Estimate available electrical grid power capacity
   - Electric power plant nameplate capacity
   - Electrical grid utilization

2. **Step 2:** Estimate peak electrical power utilized for ground EV charging
   - Population
   - Motor vehicle ownership

3. **Step 3:** Estimate available grid power capacity for UAM by subtracting Step 2 from Step 1

### Data
- Electric power plant nameplate capacity
- Electrical grid utilization

### Projections
- Generation capacity growth rate
- Population growth rate
- Ground EV ownership, charging power, peak percentage charging

### Sources
- U.S. Energy Information Administration
- U.S. Department of Energy
- Bloomberg New Energy Finance
- IHS Markit
Methodology

**Step 1:** Estimate available electrical grid power capacity

**Step 2:** Estimate peak electrical power utilized for ground EV charging

**Step 3:** Estimate available grid power capacity for UAM by subtracting Step 2 from Step 1

**Step 4:** Estimate maximum number of UAM by dividing Step 3 by UAM charging power

---

**Data**
- Electric power plant nameplate capacity
- Electrical grid utilization

**Projections**
- Generation capacity growth rate
- Population growth rate
- Population ownership, charging power, peak percentage charging

**Sources**
- U.S. Energy Information Administration
- U.S. Department of Energy
- Bloomberg New Energy Finance
- IHS Markit

---

400 kW for 7-minute recharge after 20-nmi flight at 130 kts

See paper for additional details!
Results
Estimated Number of UAM Charging

- **Today**
  - Ground EVs are only 0.5% of ground fleet
  - Impact on maximum number of UAM operations possible today is small

- **2050**
  - Ground EVs projected to proliferate to be 40% of ground fleet
  - Estimated to reduce the maximum number of UAM charging and operations possible by 20%

See paper for additional details and sensitivity analysis!
Estimated Number of UAM Charging

- **Today**
  - Ground EVs are only 0.5% of ground fleet
  - Impact on maximum number of UAM operations possible today is small

- **2050**
  - Ground EVs projected to proliferate to be 40% of ground fleet
  - Estimated to reduce the maximum number of UAM charging and operations possible by 20%

- This is a best-case scenario in which electricity can be transmitted and distributed within each interconnection as needed

- This may require as much as
  - $1.7T to remove distribution constraints
  - $0.7T to increase transmission capacity

See paper for additional details and sensitivity analysis!
Summary and Future Work
Summary

• Many challenges must be overcome to conduct UAM operations at scale with electric vertical takeoff and landing (eVTOL) aircraft

• Success of UAM depends on the availability of electricity
  – Ground EVs will proliferate over time
  – The number of UAM aircraft that can charge on the grid will decrease over time

Available electrical grid capacity may be a formidable constraint for UAM
Future Work

• Conduct follow-on analysis by metro area under worst-case assumption that each can only utilize the electricity generated within their borders

• Analyze exacerbating impacts of electric utilities maintaining higher reserve margin during summer when electricity demand and variation are highest

• Analyze mitigating effects of increased distributed solar photovoltaic and battery storage systems
Recommendations

• Develop comprehensive estimates of UAM energy needs under expected range of
  – Missions (e.g., speed, distance, load)
  – Operating conditions (e.g., wind)
  – Requirements (e.g., maximum charging/turnaround time)

• Reduce or eliminate the need to recharge UAM aircraft, such as by
  – Reducing structural mass
  – Increasing battery energy density

• Incorporate UAM requirements into metro area and utility company plans at least several years in advance (if additional infrastructure is needed)
Questions, Comments, Feedback

david.p.thipphavong@nasa.gov