National Aeronautics and
Space Administration




# Airport Power for Aircraft Operations

## Panel Discussion on Smart Airport Integration of UAM / AAM

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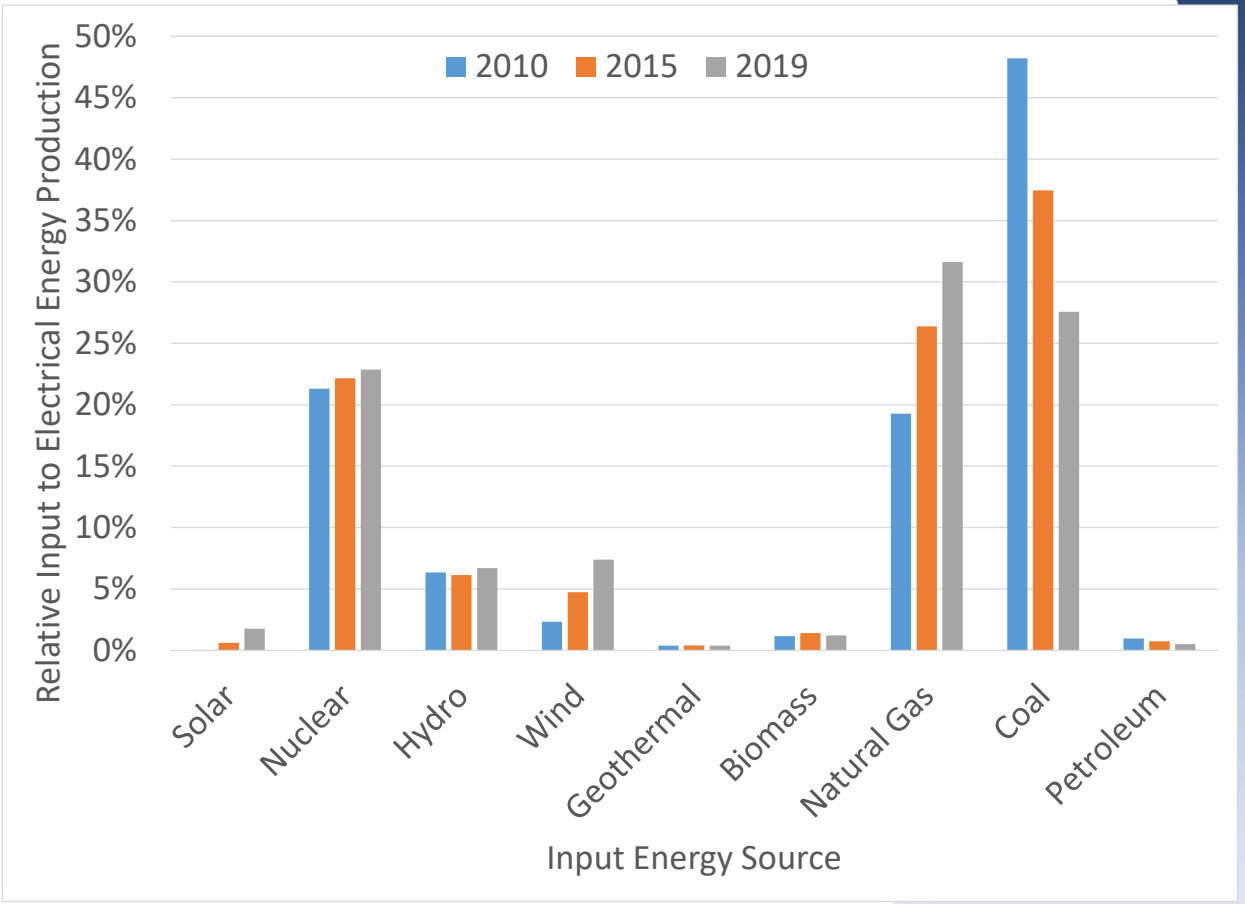
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# Disclaimer

- The views and opinions expressed in this presentation and subsequent discussions are those of the author and do not necessarily reflect the official policy or position of any agency of the U.S. government, unless noted otherwise.

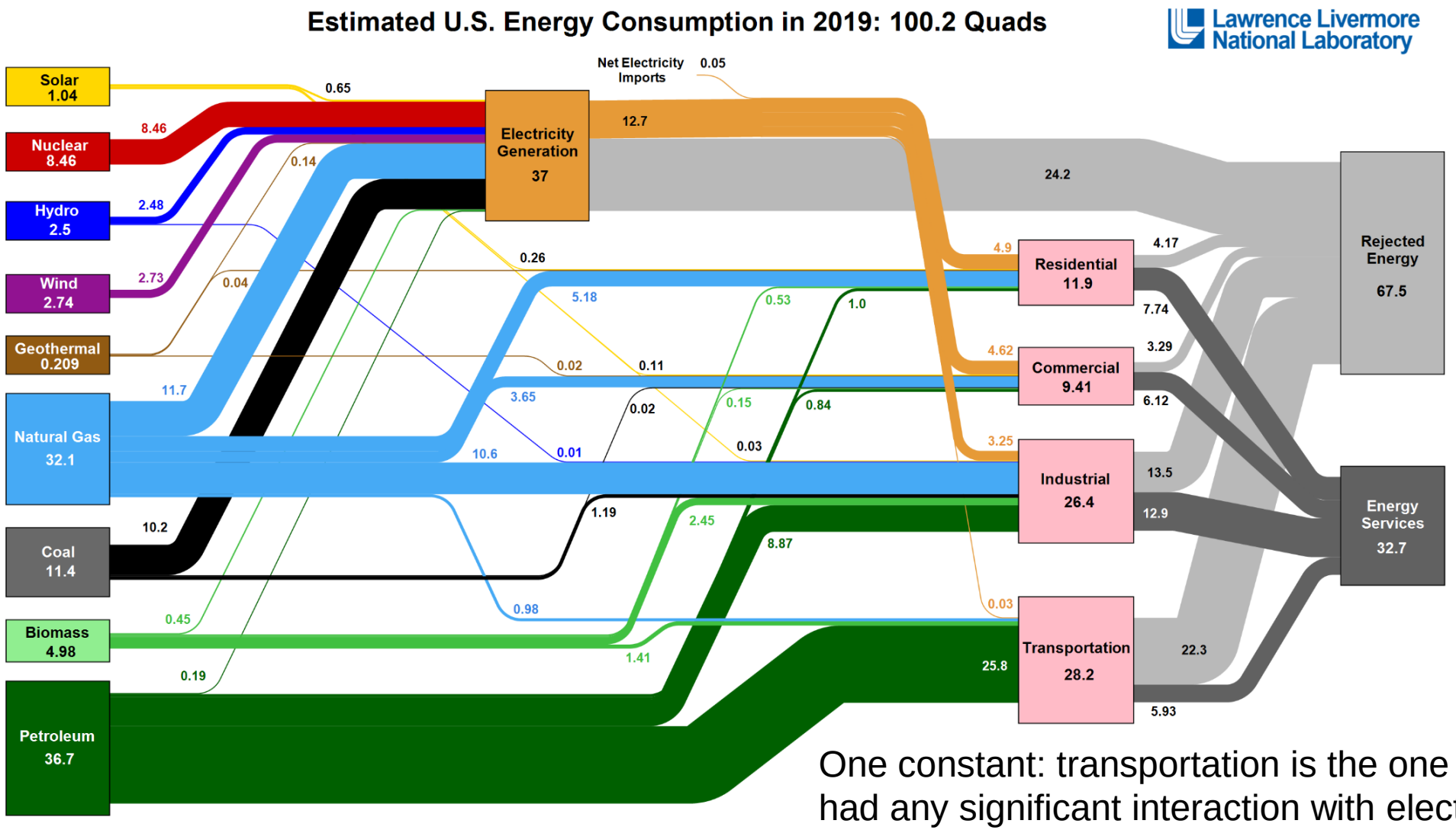
# Coal-Burning Aircraft?






*Data from Lawrence Livermore National Laboratory*

# U.S Energy Consumption & Waste




2010-2019:

- 6% increase in US population
- 8% reduction in input electrical energy
- 2% reduction in useful output electrical energy
- 4% increase in input transportation energy
- 2% increase it useful output transportation energy

One constant: transportation is the one sector that has not had any significant interaction with electricity generation

Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

# Energy & Power Requirements

**33 kWh:** electricity for a 10-minute UAM journey



… approximately the daily electricity use of a U.S. home



**400 kW:** power required for fast-charge "surge" capability per UAM aircraft




… more power than required to run an average U.S. grocery store



# Airports as Renewable Energy Sources

- The United States has over 5,000 public use airports, and over 3,000 as part of the National Plan of Integrated Airport Systems
- Several U.S. airports have installed solar facilities (information may be dated):
  - Chattanooga, TN: 2.64 MW, 12 acres
  - Denver, CO: 10 MW, 56 acres
  - Indianapolis, IN: 20 MW, 183 acres
  - Fresno, CA: 4.2 MW, 9.5 acres
  - Brunswick, ME: 1.5 MW, ? acres (but 74 "available for development")
- U.S. Department of Defense using land for renewable power
  - U.S. Navy 2015 goal for 1GW of renewable energy




93 acre site leased for NAS Oceana for 21 MW solar facility (online in 2017)

*Source: U.S. Department of the Navy Renewable Energy Program Office*

# Some Tortured Extrapolations

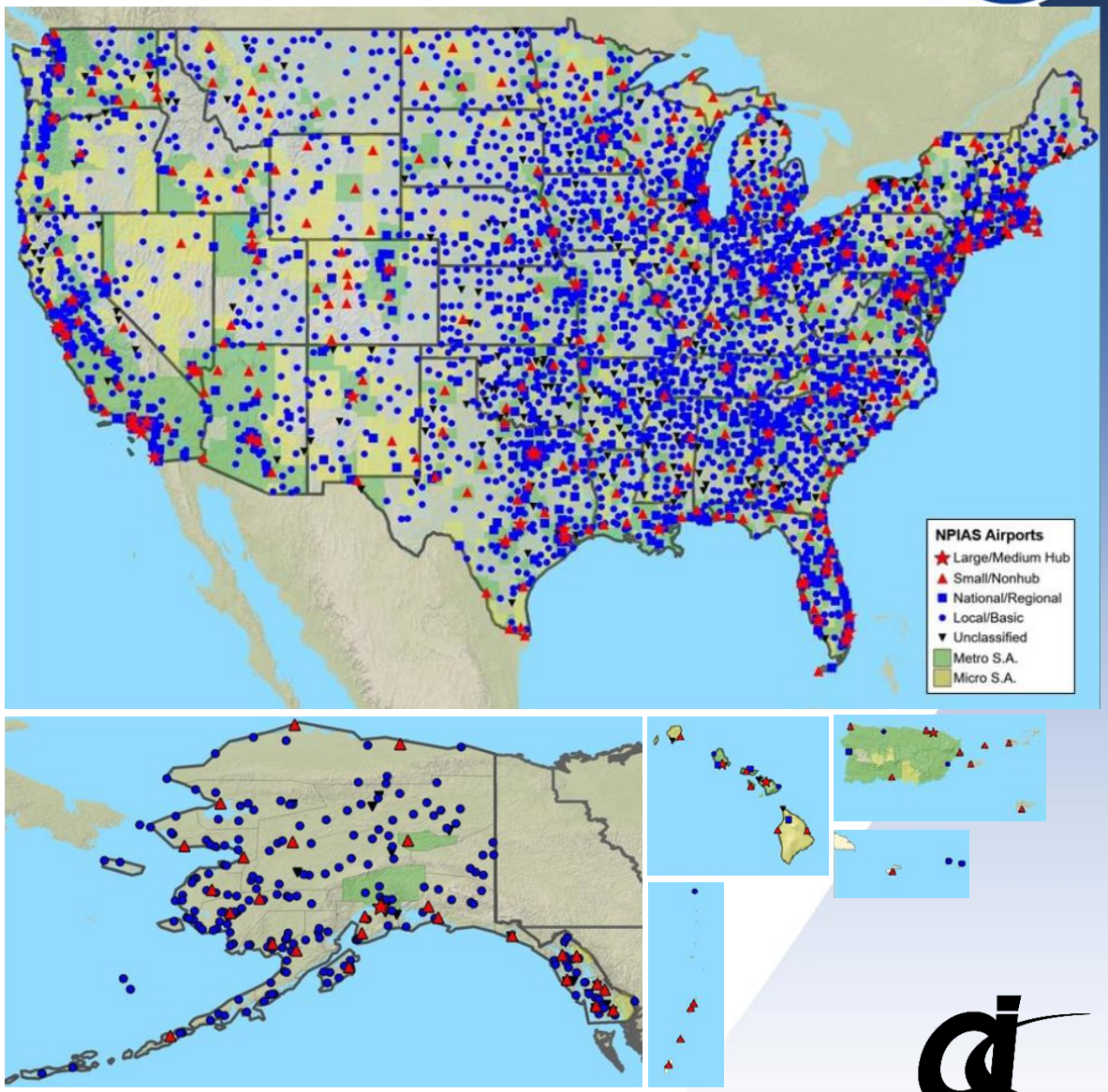
- Datasheet power generation (max capability) vs. real-world results
  - Example: CHA – 2.64 MW system, average energy generation ~1.1 GWh/year* (125kW, ~5% peak load)
- Back-of-the-envelope…
  - 5.93 Quadrillion BTUs = 1740 TWh transportation *useful* work in 2019, ~10-15% for aircraft** (174-261 TWh)
    - Assume ~65% efficiency from renewable electrical energy harvested to useful transportation work (95% power transmission efficiency, 95% charge efficiency, 90% powertrain efficiency, 80% propulsive efficiency)
  - 3,000 CHAs (12 acres ea.): 3000 x 1.1 GWh yearly x 65%; can generate ~0.8-1.2% of total existing aviation needs
  - 3,000 INDs (183 acres ea.): 3000 x (20 MW/2.64 MW) x CHA; can generate ~ 6-9% of total existing aviation needs
- However #1: UAM and RAM are not about replacing existing aviation needs, but rather replacing other forms of transportation or capturing latent demand
  - Consider that 1x CHA could power (offset) 1.1 GWh/year / 33 kWh/10 minute trip x 95% transmission efficiency x 95% charge efficiency ~ 30,000 10-minute UAM trips/year, or ~80 10-minute UAM trips/day
  - Typical electric RAM aircraft may use ~200-500 kWh/trip, so 1x CHA could power (offset) 6-13 RAM trips/day
- However #2: Current airport solar power systems are sized to return revenue based on existing electrical demands, infrastructure, rates, and policy, not for future transportation needs

**Estimated from Inman Solar's Chattanooga Airport data @ https://pubdisplay.alsoenergy.com/kiosk/1801439850952260 5?dashkey=2a5669734966472f4341413d3d&tag=3915579*
***2015 U.S. Transportation Sector Greenhouse Gas Emissions (EPA, 2017) estimates 9% of total transportation emissions due to aircraft. This assumes that aircraft consume energy at approximately the same efficiency as other forms of transportation, which likely underestimates the total share of useful energy required for aviation.*

# Upcoming Work

- NASA is sponsoring a study on *Advanced Regional Air Mobility* that includes all NPIAS airports in the mid-Atlantic corridor
- Estimate benchmark values for demand, economics, and emissions for regional operations
- Estimate impact of advanced technologies on these benchmarks
- Estimate impact of these airports as local power generation facilities on regional aircraft operations and economics

*National Plan of Integrated Airport Systems, 2019-2023 (FAA)*





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