Project 001F (MIT)

Alternative Fuel Supply Chain Analysis

Massachusetts Institute of Technology

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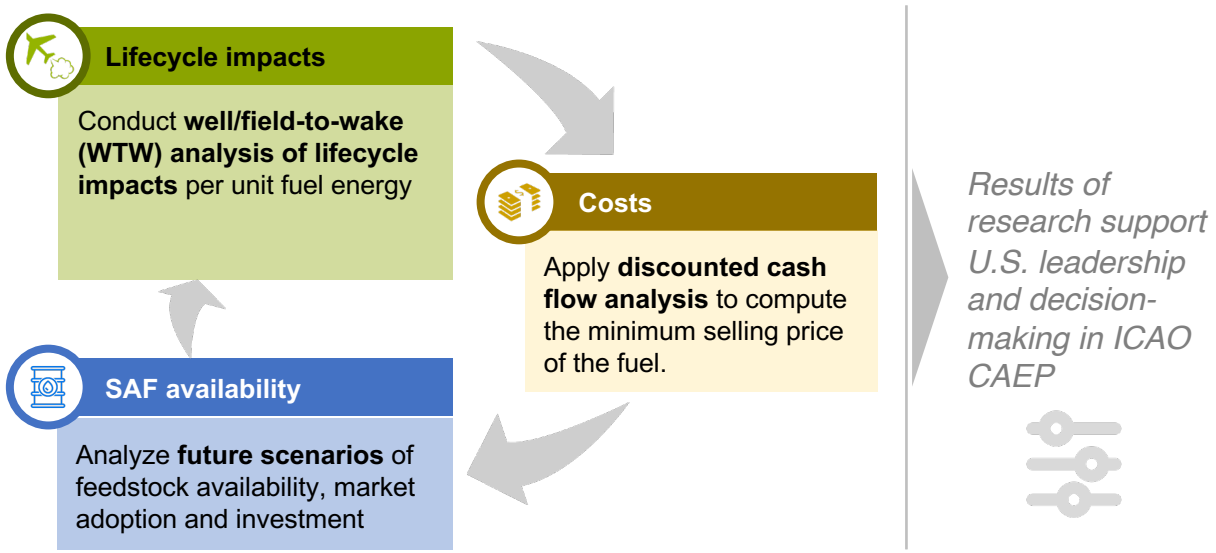
Objective:

Analyze lifecycle impacts, costs, and availability of Sustainable Aviation Fuels (SAF), considering a range of production pathways and feedstocks. Research is conducted in support of efforts under the International Civil Aviation Organization's Committee for Aviation Environmental Protection (ICAO CAEP).

Project Benefits:

1. Analysis of current and future lifecycle impacts from SAF and economic analysis of SAF
2. Understanding of supply chains for SAF production
3. Analysis of potential SAF uptake scenarios over the coming decades
4. Provide expert support on SAF to the U.S. delegation to ICAO CAEP, esp. WG5 – Aviation Fuels

Research Approach:



Major Accomplishments (to date):

- Applied lifecycle analysis (LCA) for numerous SAF pathways to obtain LCA values;
  recently: SAF production with significant electricity inputs
- Developed stochastic methods for assessing lifecycle impacts and economic viability
- Studied global SAF production scenarios and associated lifecycle impacts reductions out to 2050, incl. current and future SAF pathways
- Analyzed US-based SAF production scenarios

Future Work / Schedule:

- LCA/TEA for additional SAF pathways
- Future fuel scenario analysis
- U.S. SAF uptake

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 01 through FAA Award Number 13-C-AJFE-MIT under the supervision of Prem Lobo. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Alternative jet fuel supply chain analysis – Project 001F (MIT)

A method to enable consideration of SAF produced with significant electricity under CORSIA

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Project manager: Prem Lobo, FAA

October 15th, 2025
Alexandria, VA

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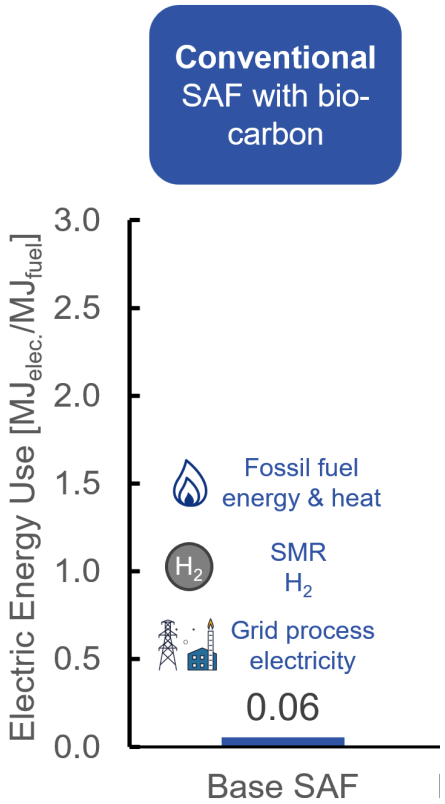
Electricity can be used as a major input to the production of Sustainable Aviation Fuels

Electricity utilization can vary across Sustainable Aviation Fuel (SAF) production pathways



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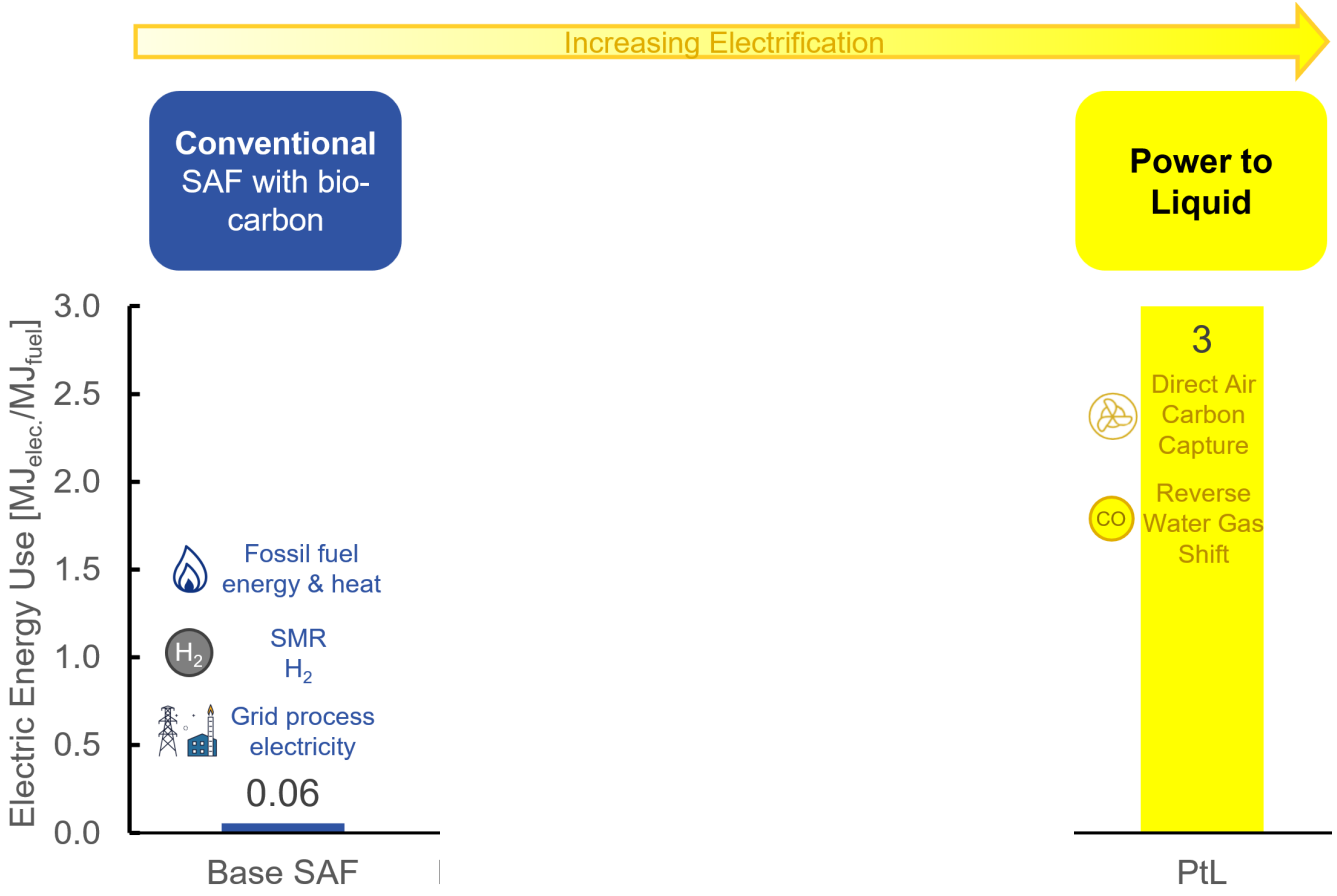

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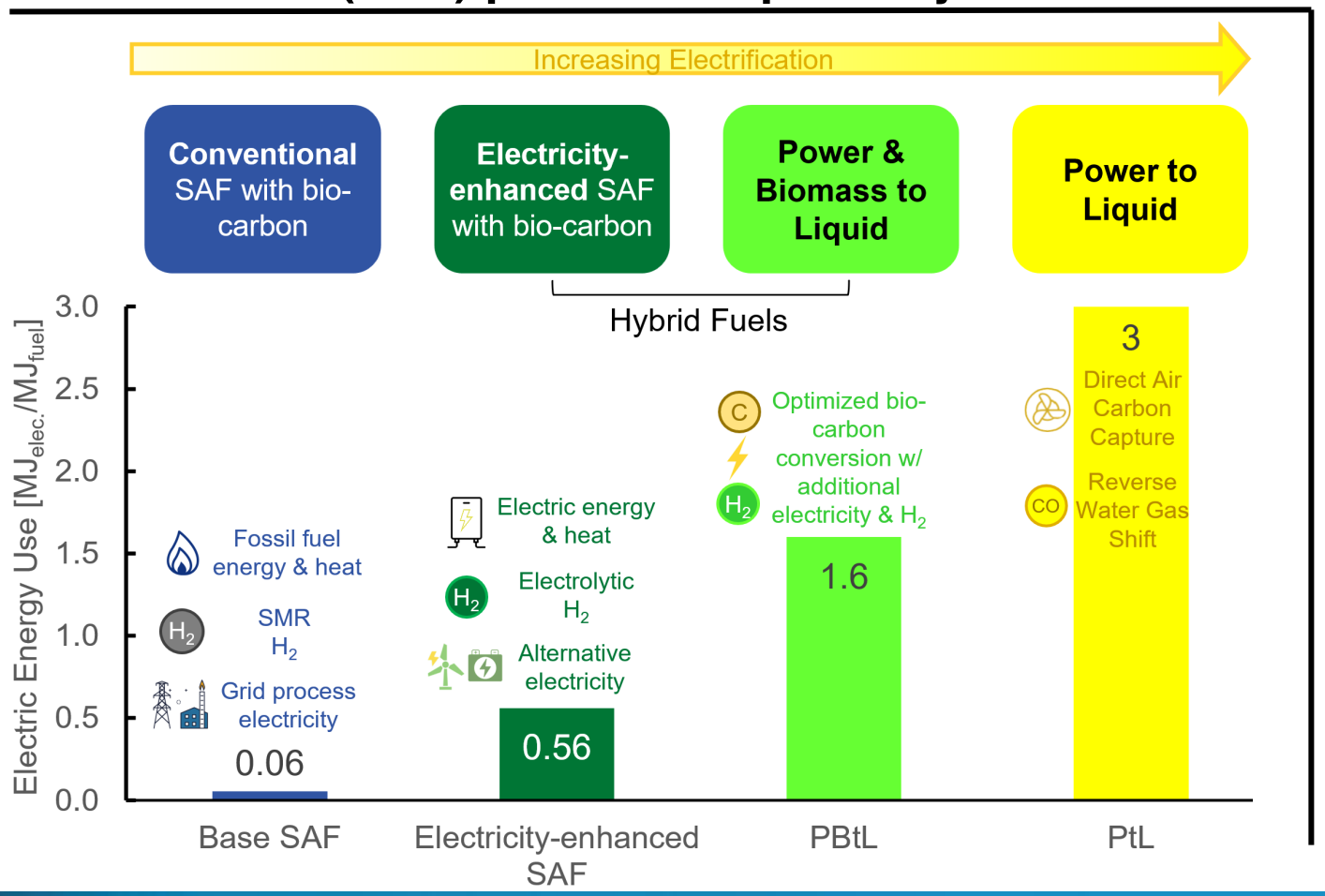

For schemes such as CORSIA*: *Methods needed to:*

1. Track electricity used for CEF production
2. Assess the attributes of electricity used for SAF production (grid, costs, impacts on atmosphere)

*During CAEP** 13, ASCENT 1 experts provided technical leadership to develop such methods for CORSIA!*

Overview of approach and underlying research presented today.

* *Carbon Reduction and Offsetting Scheme for International Aviation*
** *Committee for Aviation Environmental Protection*

Sourcing arrangements are required to enable tracing of electricity to a generation source

Key challenge:
Electricity tracing is not possible using physical tracing (like it is done for biogenic feedstocks), especially for facilities connected to the grid

Electricity sourcing will have to rely on **factual (no grid connection) or contractual (grid connection) sourcing arrangements** for a specific fuel production facility

Potential contractual arrangements

(if electricity is not self-produced with direct connection)

Power Purchase Agreements -

Contractual arrangement between power generation facility and CORSIA Eligible Fuels (CEF) producer (or producer of an intermediate) to take ownership of the electricity and its non-energy attributes at the source.

Environmental Attribute Certificates

Certificates establishing ownership of the non-power (e.g., environmental) characteristics of a unit of electricity produced and made available for use. EACs in verified systems can be traded separately from the electricity itself ("unbundled EACs").

Additional criteria for robust EACs.

From 2033, limited to 30% of electricity used.

Sourcing arrangements are required to enable tracing of electricity to a generation source

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Additional requirements for sourcing arrangements to establish chain of custody

Temporal matching	*Ensures that the electricity is generated (or released from storage) at the time when it is used.*
Deliverability	*Ensures that the electricity can be transported from where it is produced to where it is used.*
Additionality	*Ensures new energy generation capacity is added to the system to meet the extra electricity demand.*

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Additional requirements for sourcing arrangements to establish chain of custody

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- *Deliverabil…* — *… electricity can be … from where it is … to where it is used.*
- *Additionality* — *Ensures new energy generation capacity is added to the system to meet the extra electricity demand.*

When is the introduction of these additional requirements necessary?

Assessing the need for additionality requirements (1/2)

Hypothesis why additionality requirements are needed:
Addition of demand can displace other demand from preferred power generation sources and can lead to activation of less advantageous back-up capacity at grid-level.

Analysis

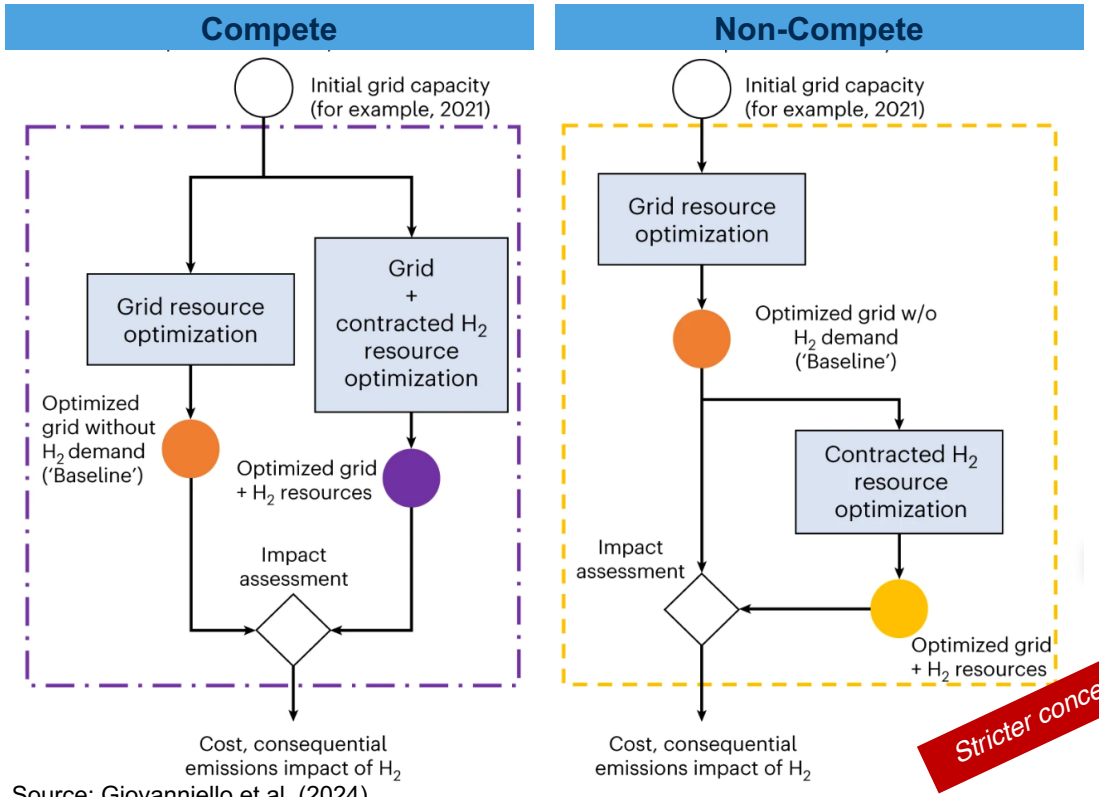
Step 1: *Interpretation of additionality in scientific analyses*

'Compete' Interpretation-
Any generation is additional which is not operating in the system before the addition of demand (e.g., electrolyzer).

"The grid is always optimized as a full system to meet all demand."

'Non-Compete' Interpretation –
Any capacity that would not have been deployed in an otherwise "optimal" grid in the absence of additional demand is additional.

"Separate resources, optimized separately"



Source: Giovanniello et al. (2024)

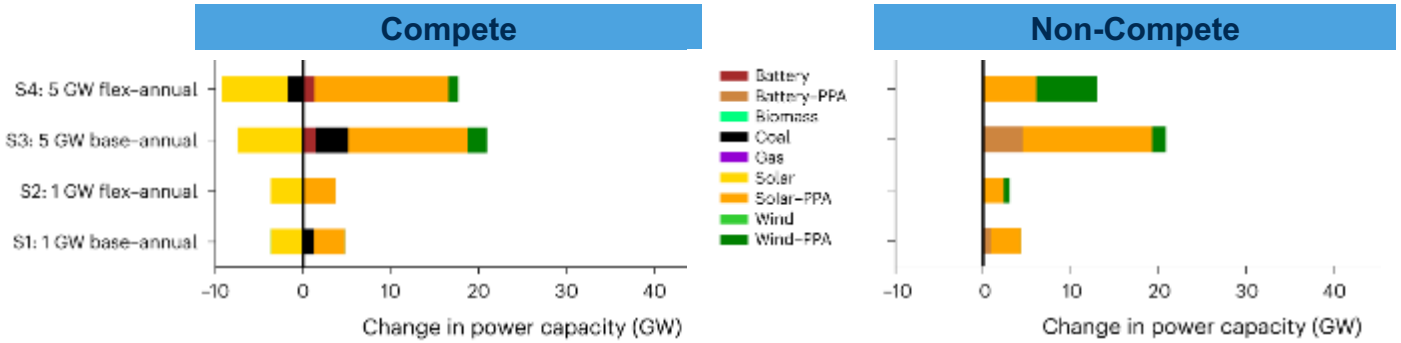
Assessing the need for additionality requirements (2/2)

Hypothesis why additionality requirements are needed:
Addition of demand can displace other demand from preferred power generation sources and can lead to activation of less advantageous back-up capacity at grid-level.

Analysis

Step 2:
Findings in scientific literature

Giovaniello et al.: Capacity response in the U.S. grid (ERCOT) to additional demand for electrolytic H_2 production: Indication of displacement of grid loads and need to expand fossil capacity under "compete" scenario



Ricks et al. (2023): Electrolytic H_2 production in the U.S.:
Marginal electricity production capacity from fossil sources effectively used for H_2 production

Zeyen et al. (2023): Electrolytic H_2 production in Germany and Netherlands:
Lack of additionality would divert wind and solar resources from grid use

Literature points towards the need for additionality criteria to ensure addition of power generation capacity.

Additionality implementation – CORSIA actual values

New Section 10.4: Additionality of power generation and storage capacity

General principle

CEF producers must show additionality of electricity generation and storage capacity. CEF producers cannot use electricity generation and storage capacity which would otherwise be used for decarbonizing the grid and/or other parts of the economy.

Criteria:

- Capacity did not go into operation more than 36 months before the operational date of the CEF facility, *and*
- Facility did not receive subsidies intended to support decarbonization of other purposes (excl. general grid expansion subsidies)

Exceptions

- Use of otherwise ”stranded” capacity
- Curtailed electricity (at grid-average levels over up to past 3 years)
- Use of electricity <30% of total energy input and claim of grid average
- Electricity use <7.5% of input energy

Rules do not apply to CEF production facilities coming into operations before 2028 (through 2035)

Researcher interpretation.
Authoritative guidance only in official ICAO documents.

Assessing the need for deliverability requirements

Hypothesis why deliverability requirement is needed:
Lack of deliverability can lead to a mismatch of the electricity claimed for CEF production and the electricity displaced elsewhere (even with additionality); lack of deliverability may induce stability risks, potentially both in the grid where capacity is added and where demand is added.

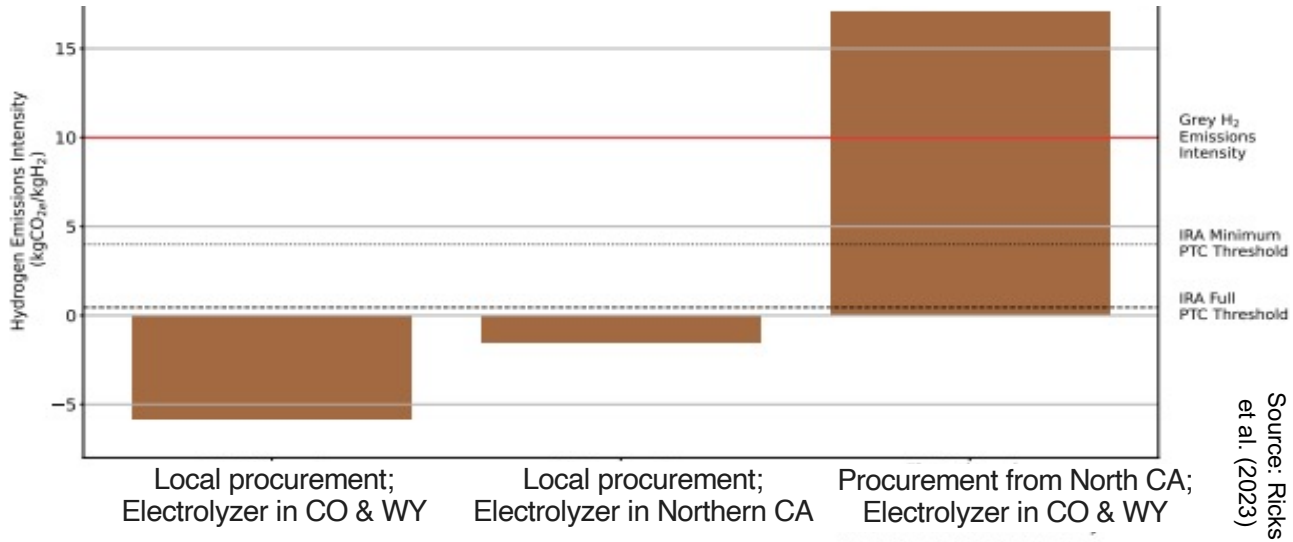
Analysis

Ricks et al. (2003): Impacts for electrolytic H_2 production in the U.S.

- Investigates the impacts of time matching and deliverability
- Assumes "compete" additionality
- Consequential impacts of H_2 production (at grid-level) used as indicator of mismatches.

- Transmission constraints can lead to differing marginal generating units which can lead to substantial mismatches.
- Congestion can further affect capacity retirements

Impact of H_2 production under different scenarios differs by sourcing scenario, *Procurement of all-solar electricity for electrolyzer, Hydrogen CI [gCO_2e/kgH_2]*



Source: Ricks et al. (2023)

Implementation deliverability – CORSIA actual values

New Section 10.2: Deliverability

General principle

Deliverability of electricity is assumed if:

1. Location on the same network (area served by an integrated grid managed by a single Transmission System Operator)

OR

2. Location in the same electricity market region, an interconnected offshore electricity market region or neighboring interconnected electricity market region (with equal or higher cost)

Exceptions

- Claim of grid average electricity (proof of grid connection sufficient)
- Direct physical connection (without other connected users)
- Grid connection and direct connection: deliverability only needs to be shown for electricity sourced from the grid

Researcher interpretation.
Authoritative guidance only in official ICAO documents.

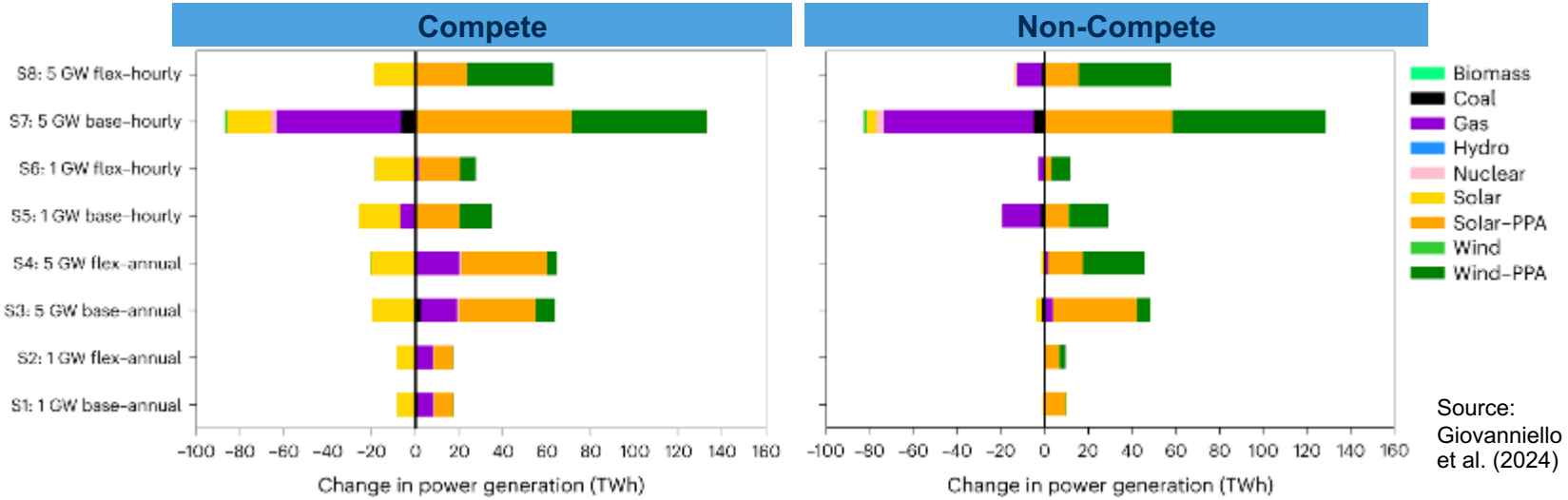
Assessing the need for temporal matching requirements

Hypothesis why temporal matching requirement is needed:
Lack of temporal matching can lead to a mismatch of the electricity claimed for CEF production and the electricity availability at any given point in time which can trigger use of substantially different marginal power generation and can induce curtailment risks at specific points in time

Analysis

Example: Giovaniello et al. (2024) - Impacts for electrolytic H_2 production in the U.S.

- Higher expansion of contracted sources (wind and solar) to buffer intermittent supply with hourly matching (adds back-up capacity, but leads to higher costs)
- Annual matching leads to expansion of utilization for non-contracted sources under “compete”



Source: Giovanniello et al. (2024)

Hourly matching necessary, esp. as long as grid is in a compete context.

Hourly matching comes at additional cost to buffer intermittency.

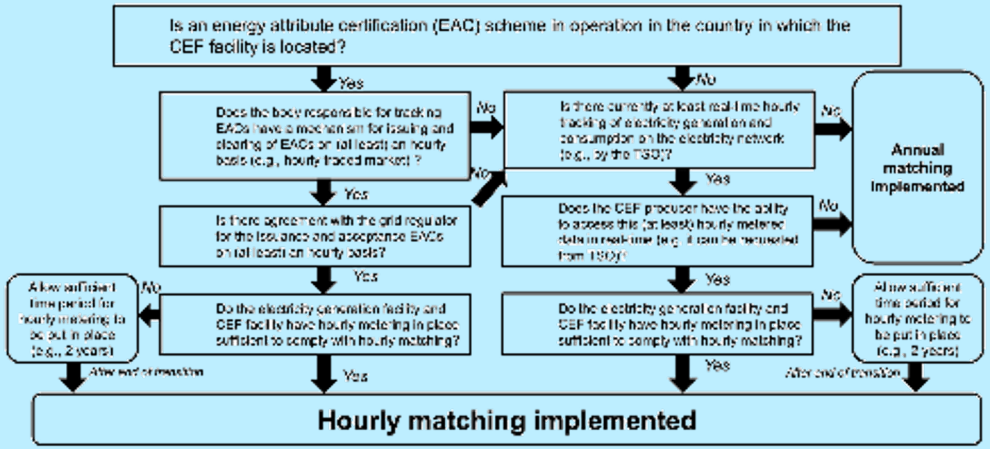
Implementation temporal matching – CORSIA actual values

New Section 10.3: *Temporal Matching*

General principle

Through December 31, 2029:
Annual matching of electricity supply and demand

From January 1, 2030:
Hourly matching of electricity supply and demand, *except:* grid readiness criteria for hourly matching are not met:



Exceptions

- Claim of grid average electricity
- Electricity use <7.5% of energy input: lifetime of sourcing arrangement or annual

Researcher interpretation.
Authoritative guidance only in official ICAO documents.

Summary

- Electricity sourcing arrangements are to be complemented by additional sourcing requirements to enable accurate tracing:
  - ***Additionality requirements*** ensure that new energy generation capacity is added to the system to meet the extra electricity demand of the SAF producer. This prevents double counting or diversion of generation capacity deployed for other uses.
  - ***Temporal matching requirements*** ensure that the generated electricity matches the electricity consumed by the SAF producer over a designated timescale. Hourly matching leads to more accurate matching than annual matching.
  - ***Deliverability requirements*** ensure the procured electricity can be delivered to the fuel production facility, considering the extent to which the electrical path is physically connected over its lifetime.
- Sourcing arrangements, additionality, temporal matching and deliverability criteria for electricity have been implemented in the CORSIA Actual Value Document (alongside a novel Sustainability approach not discussed today)