

**twelve** | a world made from air

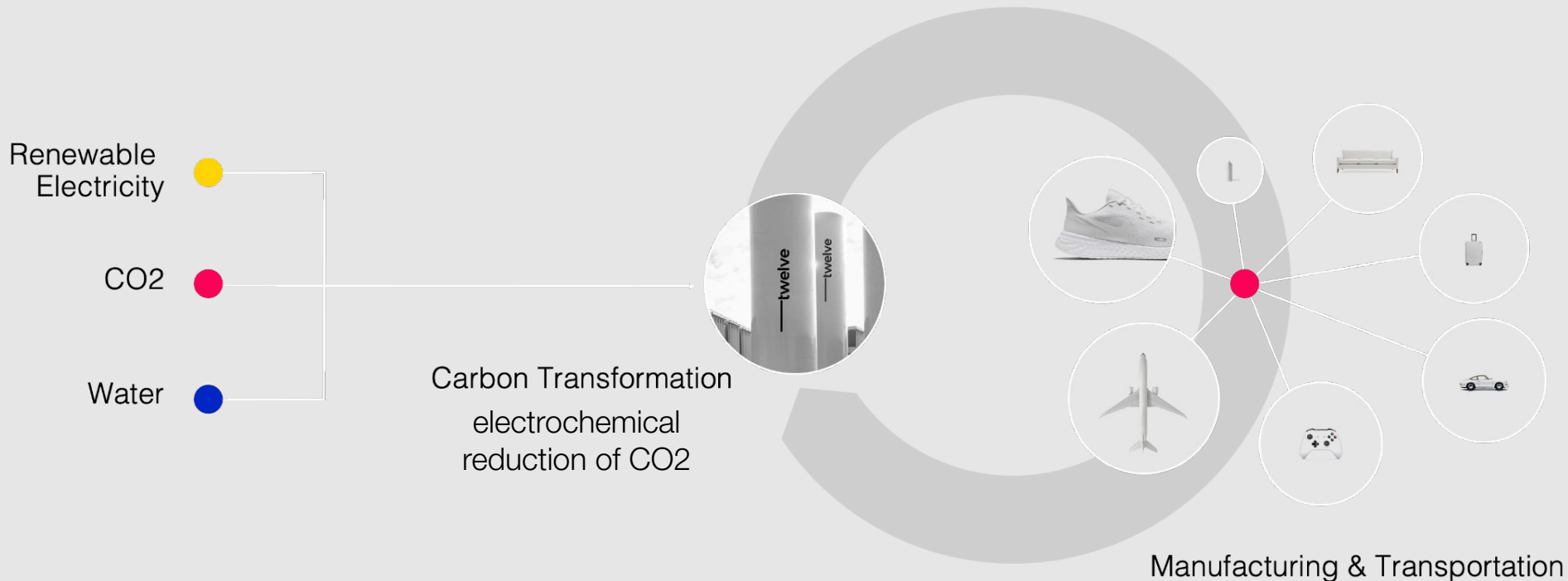
# **Twelve the carbon transformation company**

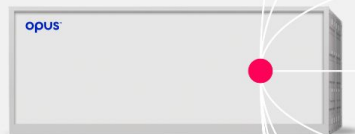


Danny Hellebusch

# Twelve: overview

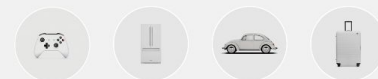
Developing and scaling a platform for a reactor that electrochemically transforms  $\text{CO}_2$  into chemicals and fuels





#### Polycarbonate

Electronics, Appliances,  
Automotive, Protective Shells

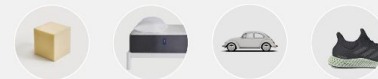


Rigid PU Foam: Insulation,  
Food Storage



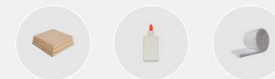
#### MDI, TDI, PMMPI

Flex PU Foam: Mattresses,  
Automotive, Footwear



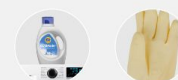
#### Methanol (from Syngas)

Wood Laminates, Adhesives,  
Insulation, Plywood



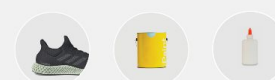
#### Formic Acid

Detergents, Natural Latex



#### Acetic Acid

Footwear, Paints, Adhesives



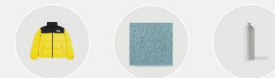
#### Oxo Alcohols

Fragrances, Flavorings,  
Solvents



#### Onsite CO

Food Packaging, Nickel  
Treatment, R&D



#### Ethylene Glycols

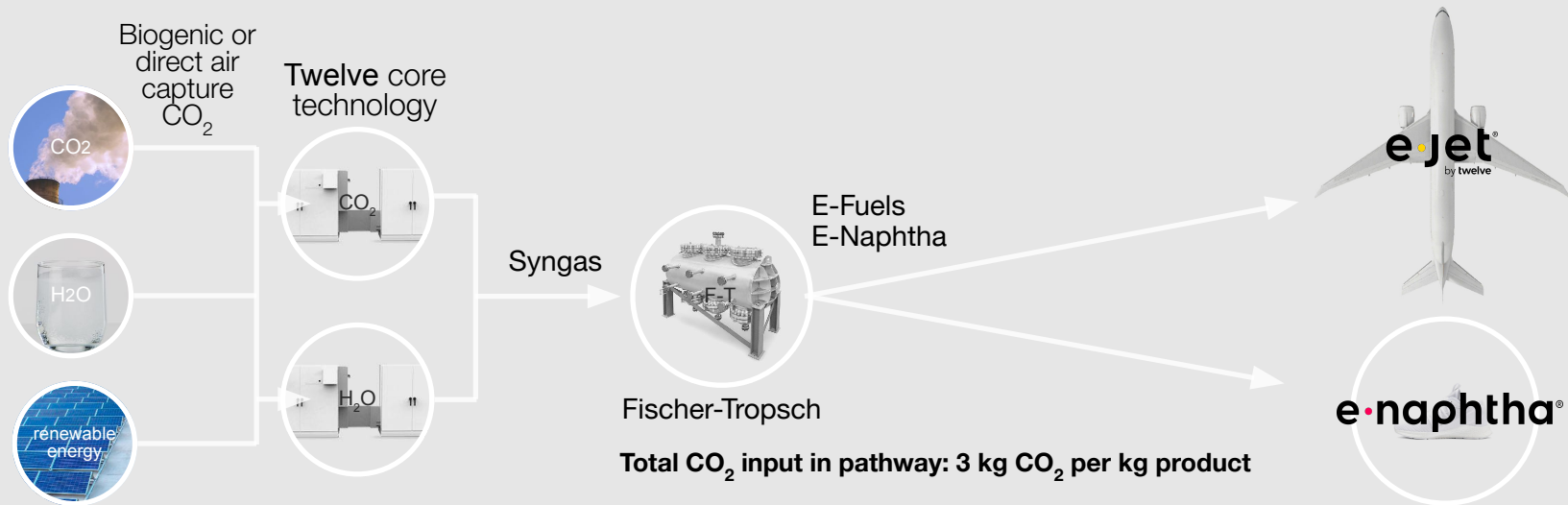
Polyethylene Terephthalate for  
Fibers, Films, and Bottles



#### Transportation Fuels

Jet fuel, Diesel

# Twelve's AirPlant™ facility turns CO<sub>2</sub> into building blocks for materials and fuels



1.

Twelve combines proprietary low temperature CO<sub>2</sub> electrolysis with H<sub>2</sub>O electrolysis to produce syngas from captured CO<sub>2</sub> and water

2.

Syngas is used to produce naphtha and drop-in fuels via Fischer-Tropsch process

3.

Twelve's products are identical to conventional products with zero new emissions, zero fossil fuels, and zero tradeoffs in quality and performance



# proton exchange membrane (PEM) electrolysis has been around since 1950

## History of Electrolyzers



PEM electrolyzers were developed. Deployment and learning were mainly driven by spaceship programs and military life-support applications

1950-1980

Solar and wind installed capacity grew, making electricity cheaper and improving the case for green hydrogen. Climate change also takes a central role.

2010-2020

Electrolyzers have been known for more than two centuries

Pre 1950

Innovators simplified the design to decrease the cost and increase the scale of the stacks to a few hundred kW so that electrolyzers would work for other industries.

1980-2010

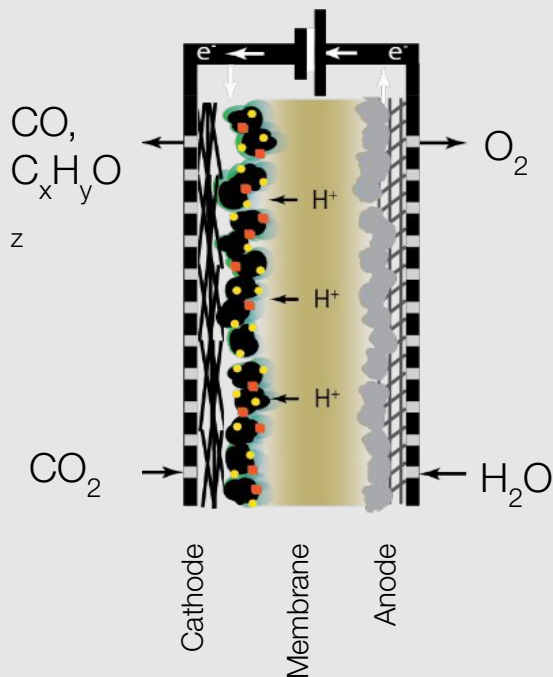
Electrolysis goes from niche to mainstream. Electrolyzer capacity is expected to grow at an annual rate of 78% with technology advances, lower electricity prices and energy security among other reasons.

Today

# the Opus™ system is Twelve's industrial-scale CO<sub>2</sub> electrolyzer that leverages PEM technology



# Twelve's core innovation is a membrane electrode assembly (MEA) that enables CO<sub>2</sub> electrolysis



## THE METRICS THAT MATTER FOR COST-EFFECTIVE CO<sub>2</sub> ELECTROLYSIS

### 1. FARADAIC YIELD

The percent of the electrical current through the system that goes to producing the desired product.

### 2. VOLTAGE EFFICIENCY

The thermodynamic minimum voltage divided by the actual voltage.

### 3. CURRENT DENSITY

The amount of current per electrode area needed to convert CO<sub>2</sub> to CO and other hydrocarbons.

### 4. LIFETIME

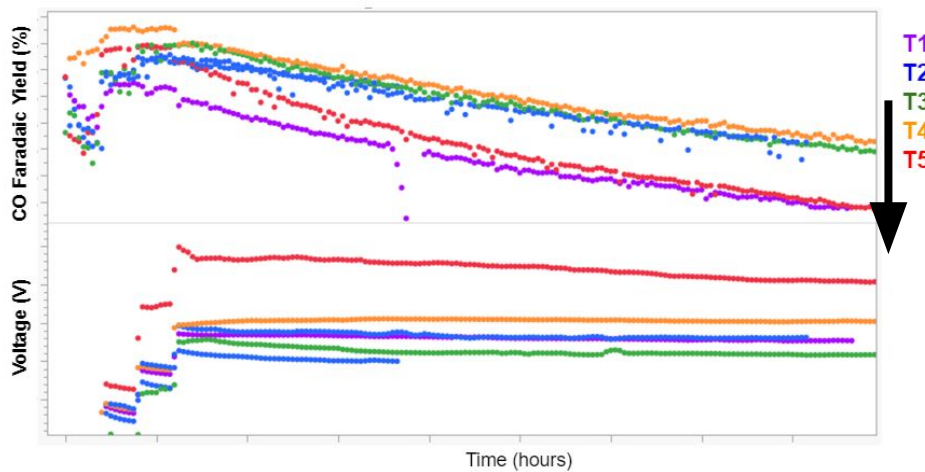
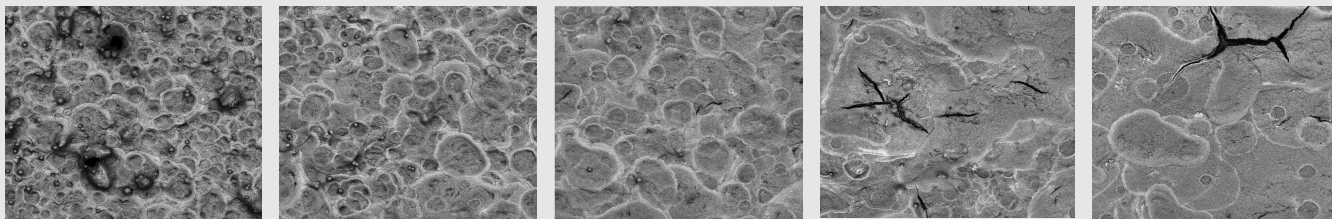
How long the electrochemical reactor runs without a loss in energy efficiency or current density.

### 5. CO<sub>2</sub> UTILIZATION

How much of the input CO<sub>2</sub> to the reactor is converted to product in a single pass.

Improving technical performance metrics that dictate  
system **OpEx** and **CapEx**

# optimizing electrolyzer performance by tuning MEA morphology and operating conditions

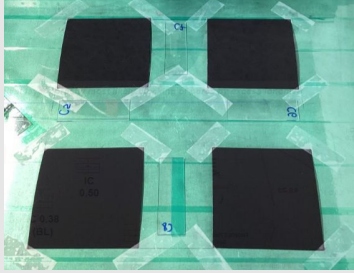


Fabrication parameters:

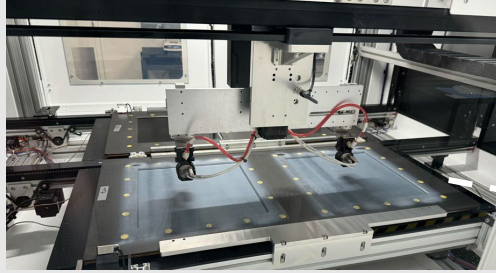
- Temperature
- Nozzle type
- Nozzle frequency
- Flow rate
- Distance of nozzle to substrate
- Speed
- Solvents
- Solids wt. %

# scaling our MEAs towards commercial-scale electrolysis

MEA size and  
fabrication scaleup  
(2022-2023)



MEA active area scaleup

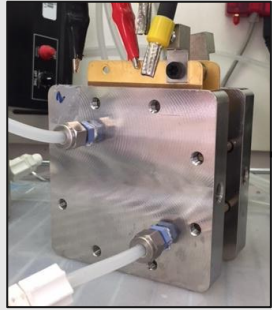


fabrication system scaleup

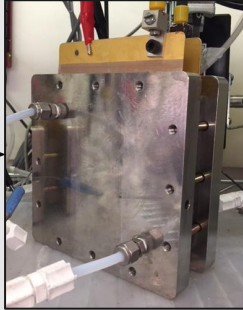




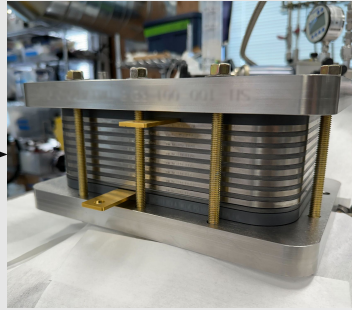
# Twelve is developing stack hardware and the balance of stack in parallel with the MEA



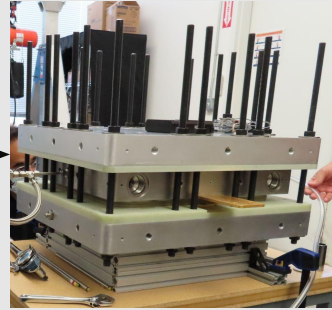
1-cell



1-cell



10- to 30-cell



1-cell



Many cells



Multi-stack

25 cm<sup>2</sup>

100 cm<sup>2</sup>

>750 cm<sup>2</sup>

twelve

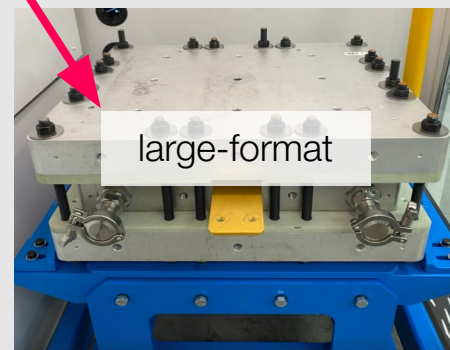
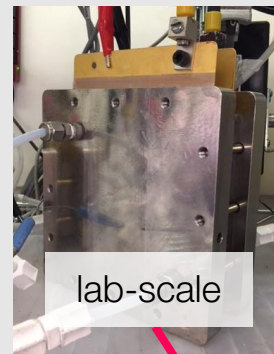
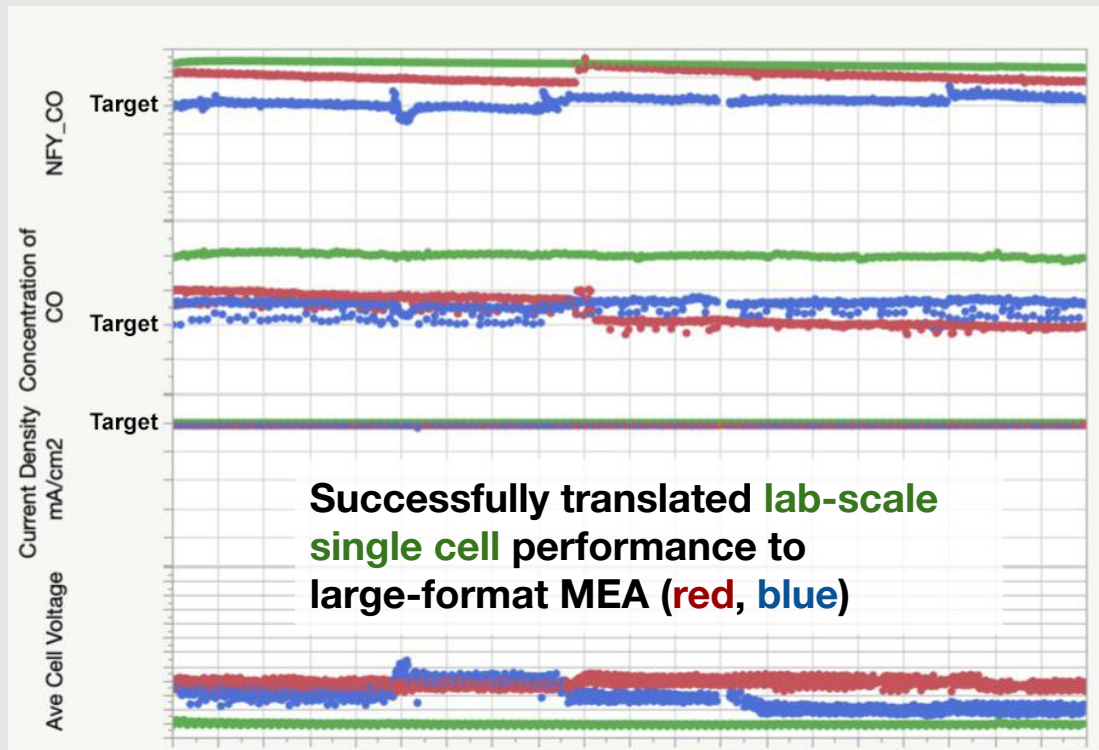
a world made from air



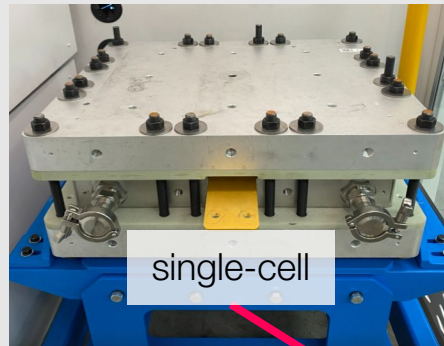
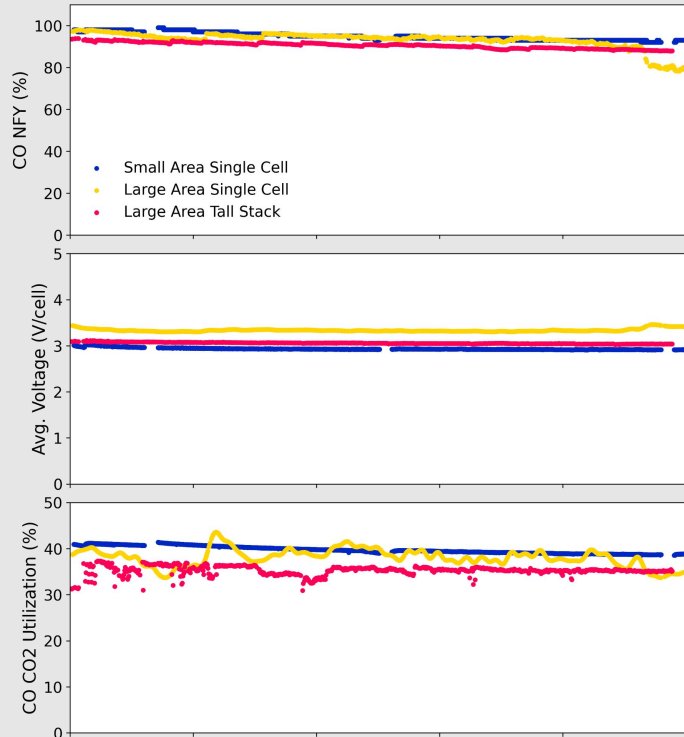
Twelve's 1st E-Jet® fuel facility under construction in Moses Lake, WA



# translating subscale performance to large-format MEAs



# translating single-cell performance to commercial-sized stacks



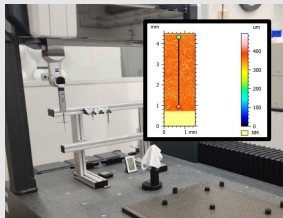
# quality control is critical to performance

## Supply Chain



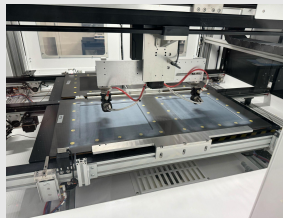
- Stack parts are received, serialized, and sorted into inventory bins
- Materials are received and put in temp and humidity appropriate storage

## Quality Control



- Received parts and materials undergo quality control
- Qualified materials are released for fabrication and assembly
- Low quality parts are placed in quarantine and investigated on a rolling basis

## MEA Coating



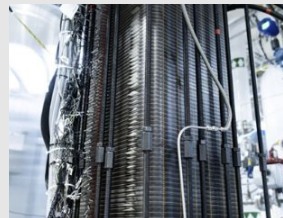
- Scalable, ink-based process
- Cleanroom fabrication
- In-line quality control
- Nine-step post-fabrication evaluation

## Stack Assembly



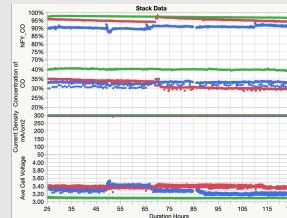
- Stacks are assembled in a cleanroom with high quality parts
- Leak testing and other pre-operational testing is performed

## Stack Installation



- Stacks are installed into Opus units after pre-operational testing

## Electrochemical Testing



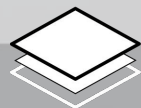
- The stack performance is monitored throughout operation
- Novel operating methods are used to maximize the performance of the stack



# the Opus™ system is scaled and ready for demonstration-scale deployment



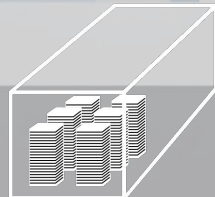
our AirPlant™ facilities scale our core technology to produce E-Jet® and E-Naphtha™ at industrial scale



1 Single Cell



2 Stack



3 Electrolyzer



4 AirPlant™ facility  
*Produces both E-Jet®  
and E-Naphtha™*

# jet fuel made from air

E-Jet® has up to 90% lower CO2 emissions than conventional jet fuel

Agreements with Alaska Airlines, IAG, Etihad Airways

No land or water issues

Drop-in Ready and US Air Force validated



# launching a new industry

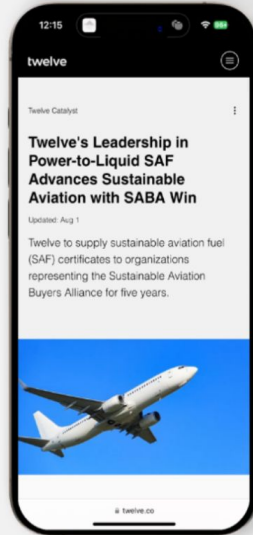


# contact us



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## Press Releases

[International Airlines Group \(IAG\) signs historic 14-year SAF agreement with Twelve](#)

[Twelve breaks ground on Power-to-Liquid SAF Production in Moses Lake, WA](#)

[Sustainable Energy: Decarbonizing Aviation](#)

[Sustainable Aviation Buyers Alliance purchases SAF certificates to grow investment in clean fuel technologies](#)