ICAO ENVIRONMENT

ACT-SAF #9 SERIES

Green Hydrogen for Aviation

ICAO ENVIRONMENT

ACT SAF

ACT SAF

Assistance, Capacity-building and Training for SAF

1. Opening

Mrs. Jane Hupe
Deputy Director
ICAO Environment

Objectives

ACT-SAF
#9
SERIES

Provide participants with knowledge on Green Hydrogen for Aviation, its production and its use for SAF production processes.

ACT-SAF Series #9 Speakers

Luis Janeiro
Team lead – End use sectors
IRENA Innovation and Technology Centre

Mathias Bøje Madsen
Business Development Manager, Ventures
TOPSOE A/S

Søren Mikkelsen
Business Development Manager, Power-to-X
TOPSOE A/S

Alexandre Mombazet
Structured Market Referent
Qair Energy

ACT-SAF Series #9 Speakers

Nicolas Landrin

Hydrogen Infrastructure development

Airbus

Eiji Ohira

Strategy Architect for Fuel Cell and Hydrogen

NEDO, Japan

Luis Ignacio Castillo

Coordinator of the Green Hydrogen Area

Agencia Sostenibilidad Energética

Chile

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ICAO update on ACT-SAF programme

ICAO ENVIRONMENT

ACT-SAF updates

ACT-SAF

ACT-SAF platform provides the most recent information:

- List of Partners constantly updated
- ACT-SAF series material available online

ICAO ACT-SAF Platform

Here you will find more information on our ACT-SAF Participants*

ACT-SAF Series

Coordination with ACT-SAF partners identified that many States need conceptual training on SAF.

To address that, ICAO is developing the **ACT-SAF Series of training sessions**, to be held on a monthly basis This will allow delivering comprehensive training to ACT-SAF Partners on an array of important SAF-relatec topics, ranging from sustainability, to policy, economics/financing certification and logistics.

The ACT-SAF Series will empower the ACT-SAF Partners with training material designed with the support o Supporting States and Organisations from the air transport, fuels and finance sectors, as well as academics anc actors with niche expertise such as SAF reporting under CORSIA.

Want to participate on the ACT-SAF Series? Join ACT-SAF now (click here to access the ACT-SAF Terms and Conditions). Participation is open to all States and Organizations interested in further action on SAF.

ACT-SAF Series	Date	Topics	Contributor(s)	Abstract	Video and Presentation
#1	25 November 2022	An introduction to SAF	ICAO	• Introduction to ACT-SAF • Basics of SAF	Download Presentation
#2	25 January 2023	SAF sustainability and reporting under CORSIA	ISCC RSB Verifavia	• process for sustainability certification of SAF • Reporting and verificaiton of SAF Claims under CORSIA	Download Presentation
#3	23 February 2023	SAF technology and certification	Airbus US FAA Safran	• specifications for aviation turbine fuels • process for approval for new production pathways	Download Presentation
#4	23 March 2023	SAF policies	Brazil, European Commission,	• Practical experiences from States	

90
States

Name of State
Albania
Argentina
Australia
Austria
Bahamas

States

Acceptance to ... Pending Yes

60
Organizations

Name of Organization
WORLD TRAVEL & TOURISM COUNCIL
World Bank
Wizz Air
WEF - World Economic Forum
Verifavia
United Nations World

International Organizations

Acceptance T&C (Blank) Pending Yes

Latest news on ACT-SAF

Date	Latest news	Link
11/17/2023	SAF investor and Carbon direct joins ACT-SAF	
9/26/2023	Boeing joins ACT-SAF	
6/1/2023	4 States join ACT-SAF (Ghana, Greece, Mali, Zambia)	
5/24/2023	European Commission announces 4 million euros to support SAF development under ACT-SAF	
5/23/2023	Inter-American Development Bank joins ACT-SAF	

https://www.icao.int/environmental-protection/Pages/act-saf.aspx

ACT-SAF platform of implementation support initiatives

- **ACT-SAF tracks implementation support initiatives from our partners**
  - Easy to access resource in ICAO ACT-SAF website, with information on feasibility studies, training/outreach, and events
  - Reduces duplication of efforts across partners/stakeholders
  - Reach out to ICAO to have your initiative reflected in the platform

Many ACT-SAF partners and aviation stakeholders are supporting implementation of cleaner energies for aviation, including Sustainable Aviation Fuels.
The dashboards below provides a summary of these initiatives
(click on the drops for details)

Recently concluded SAF feasibility studies from our partners

- **SAF Feasibility Study for Colombia**
  - ➢ Developed by ISCC / World Bank
  - ➢ Assess impact of palm oil sector development on the production of SAF and Renewable Diesel
  - ➢ Positive outlook, with potential compliance with CORSIA emission reduction requirements
  - ➢ Identified follow-up action: raising awareness, development of country-specific LSf values, training, development of sustainable agricultural practices

- **SAF Feasibility Study in Ireland**
  - ➢ Developed by Sustainable Flight Solutions Ireland
  - ➢ Economic benefits from SAF industry (1,000 high-skilled jobs, generating revenue of €2.55 billion by 2050)
  - ➢ Pathway identified - biggest opportunity through PtL production of eSAF
  - ➢ Policy changes needed to help accelerate pathway for SAF production

Latest news

Recently concluded policies / roadmaps from our partners

- **SAF Roadmap for Australia**
  - Developed by Boeing
  - Builds consensus on developing an Australian SAF industry, using local feedstock
  - Roadmap estimate resources sufficient to provide almost 5b litres of SAF by 2025
  - Alcohol-to-Jet and Fischer-Tropsch identified as ideal technology pathway options

- **Singapore Sustainable Air Hub Blueprint – SAF target/levy**
  - To kickstart SAF adoption, flights departing Singapore to use SAF from 2026
  - 1% target, growing to 3-5% by 2030, subject to global developments
  - SAF levy to be introduced with estimates for direct economy flight from Singapore to Bangkok (S$3), Tokyo (S$6), and London (S$16)

Recently concluded/upcoming events by ACT-SAF Partners

SAF Investor

SAF Investor London 2024

- 27-28 Feb 2024
- Presentations, interactive panel discussions, Q&A, fireside chats, networking
- Panels covering: SAF production/ demand, Book & Claim, Removing price uncertainties, E-fuels, Finding early stage investors, Project finance

https://www.safinvestor.com/

UK ACT-SAF programme

Introductory training and SAF policy workshops

- Tanzania - 18 to 21 March 2024
- Equatorial Guinea – 25 to 28 March 2024
- Cameroon – 8 to 11 April 2024

SUSTAINABLE AVIATION FUTURES CONGRESS

Sustainable Aviation Futures Congress

- 21-23 May 2024, Amsterdam
- 40+ hours of industry content, panels / keynotes covering SAF, sustainable aerospace technologies, eFuels, Hydrogen
- Concurrent streams across Conference days to maximize content coverage
- MENA (12–14 February 2024, Dubai), North America (2 - 4 October 2024, Houston), APAC (4-6 November 2024, Singapore)

https://www.sustainableaviationfutures.com/

Request for inputs: SAF business case template/guide

- **As a follow up to the SAF feasibility study template/guide, we are currently preparing one to support SAF business case development**
  - Detail key parameters in a SAF business case study
  - Highlight approaches/assessments that may validate financial viability of a SAF project (techno-economic assessments, sensitivity analysis)
  - Explore impact on policy (grant, loans, subsidies, etc.)
  - **Support needed**: Reports for referencing, offers to support the development of template

Examples of possible references

No.	Title
1.	Advanced Sustainable BIOfuels for Aviation Deliverable D5.1: Business case (SkyNRG, RE-CORD, Total, 2019)
2.	SAF Fact Sheet 8: SAF Project Economics (IATA, 2018)
3.	The cost of supporting alternative jet fuels in the EU (ICCT, 2019)
4.	Capex deep dive – Integrating social and environmental factors into capital investment decision making (Accounting for Sustainability, 2019)

SAF feasibility studies

Scale up of SAF feasibility studies thanks to financial contributions from or cooperation with:

- Austria: to be announced.
- Cote d'Ivoire: to be announced.
- France: Business Implementation report in Ethiopia and studies in 2 or 3 other States.
- Netherlands: feasibility studies in 3 States (Jordan and Chile + 1 TBC).
- United Kingdom: 3 SAF feasibility studies + SAF training for States.
- European Union**:** 10 SAF feasibility studies (African States and India)
- Airbus : 3 Feasibility Studies (South America).

Process to select consultants will start soon – contact ICAO to suggest potential experts with suitable expertise

ACT-SAF updates

Key request - conceptual training on SAF

ACT-SAF Series - SEASON 2
#8 Green Hydrogen for aviation
#9 ICAO SAF supporting tools
#10 SAF in State Action Plans
#11 CAAF/3 Global Framework
#12 Multi-stakeholder SAF Alliances
#13 Feasibility assessments
#14 Economics and Financing (SAF projects)
#15 Updates on recent developments (policies)

Today's Session

- Future sessions on specific aspects
- Subject to review – **feedback welcome**

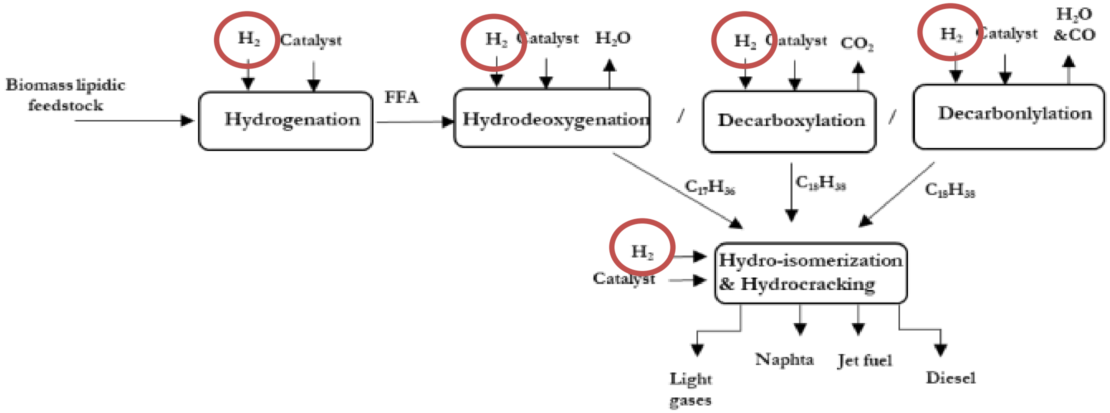
ACT SAF

Assistance, Capacity-building and Training for SAF

Green Hydrogen for SAF production

Hydrogen is a key process input in SAF production pathways

The HEFA process consists of various catalytic reaction mechanisms, where Hydrogen is required as an input



For ATJ, Hydrogen is also needed as a process input

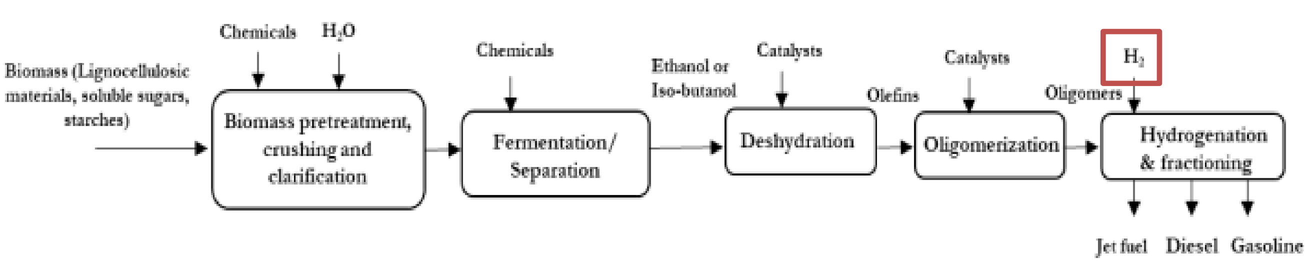


Figure 6: General process flow alcohol-to-jet pathway

Hydrogen production is considered on the life cycle emissions of these Fuels

Table 2. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels produced with the Hydroprocessed Esters and Fatty Acids (HEFA) Fuel Conversion Process

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Tallow		22.5		22.5
Global	Used cooking oil		13.9		13.9
Global	Palm fatty acid distillate		20.7	0.0	20.7
Global	Corn oil	Oil from dry mill ethanol plant	17.2		17.2

Table 3. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels produced with the Alcohol (isobutanol) to jet (ATJ) Fuel Conversion Process

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Agricultural residues	Residue removal does not necessitate additional nutrient replacement on the primary crop.	29.3	0.0	29.3
Global	Forestry residues		23.8		23.8

https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

Hydrogen and Fischer Tropsch processes

No Hydrogen input when the feedstock is biomass (e.g. forestry residues, MSW)

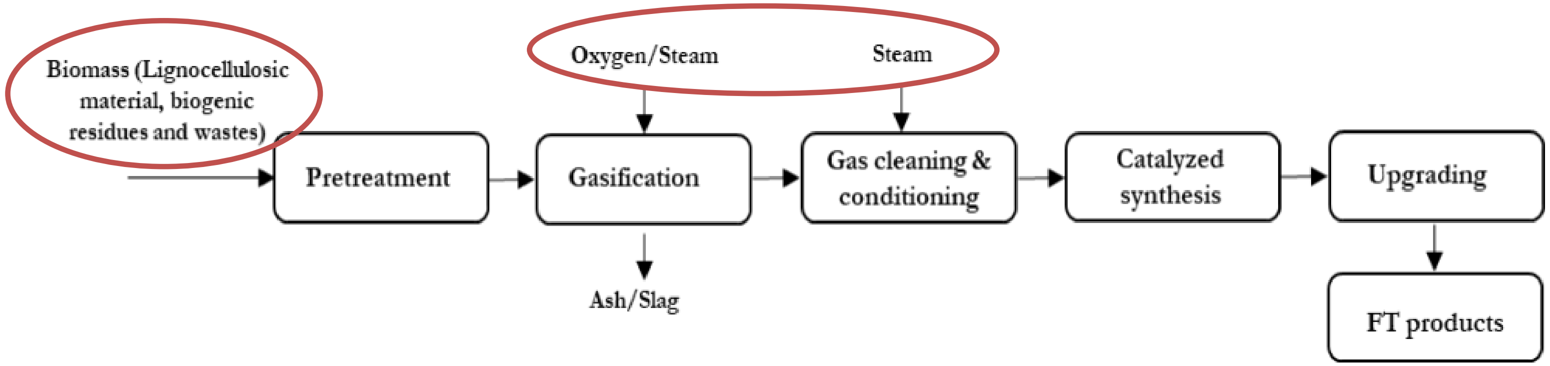
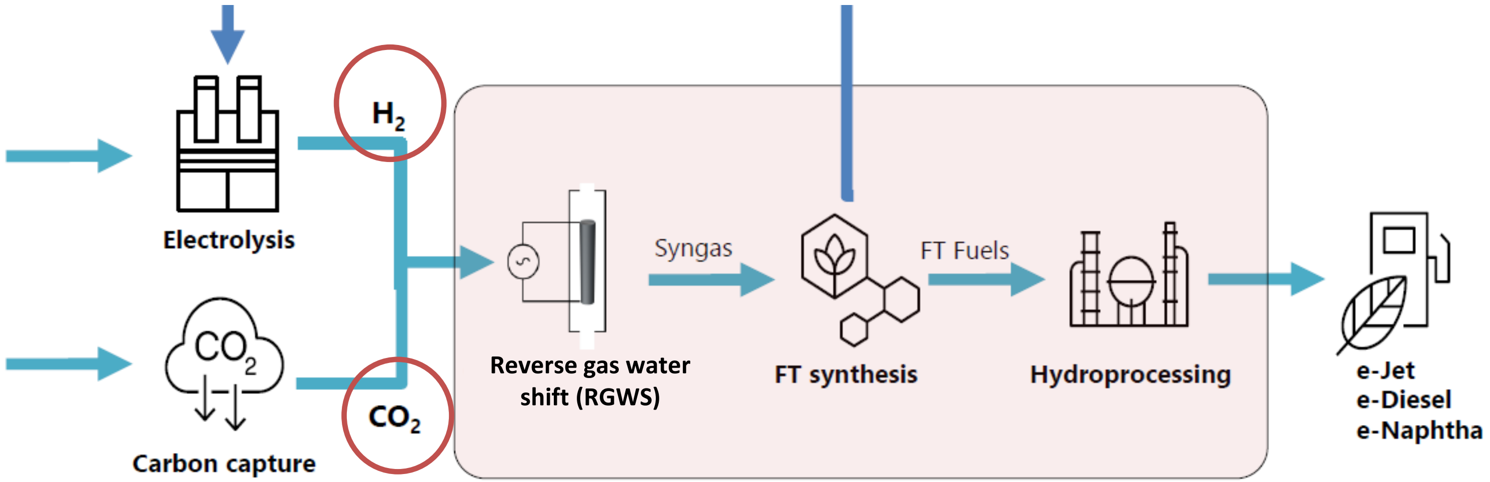


Figure 2: General process flow Fischer-Tropsch pathway

However, Hydrogen is needed when the feedstock is CO2. (e.g. direct atmospheric capture (DAC), CO2 waste streams)



Note - it is possible to have both processes implemented in a single FT facility

Types of Hydrogen and life cycle emissions

There are many ways to produce Hydrogen

Color	GREY HYDROGEN	BLUE HYDROGEN	TURQUOISE HYDROGEN*	GREEN HYDROGEN
Process	SMR or gasification	SMR or gasification with carbon capture (85-95%)	Pyrolysis	Electrolysis
Source	Methane or coal	Methane or coal	Methane	Renewable electricity

Note: SMR = steam methane reforming.
** Turquoise hydrogen is an emerging decarbonisation option.*

REDUCTION OF LIFE CYCLE CO2 EMISSIONS

The source of CO2 and renewable electricity is also important

Processing Technology	Feedstock	Life cycle emissions (gCO2e/MJ)*	Abatement Cost ($/t$CO_2$e)	
			n[th]	pioneer
FT	DAC CO2, green H2, wind electricity	7 ***	1390	
FT	DAC CO2, green H2, solar electricity	25 ***	1780	
FT	DAC CO2, green H2, grid electricity	279 ***	no CO2 abatement	
FT	waste CO2, green H2, wind electricity	31 ***	1510	
FT	waste CO2, green H2, solar electricity	49 ***	2190	

Source: ICAO SAF rules of thumb

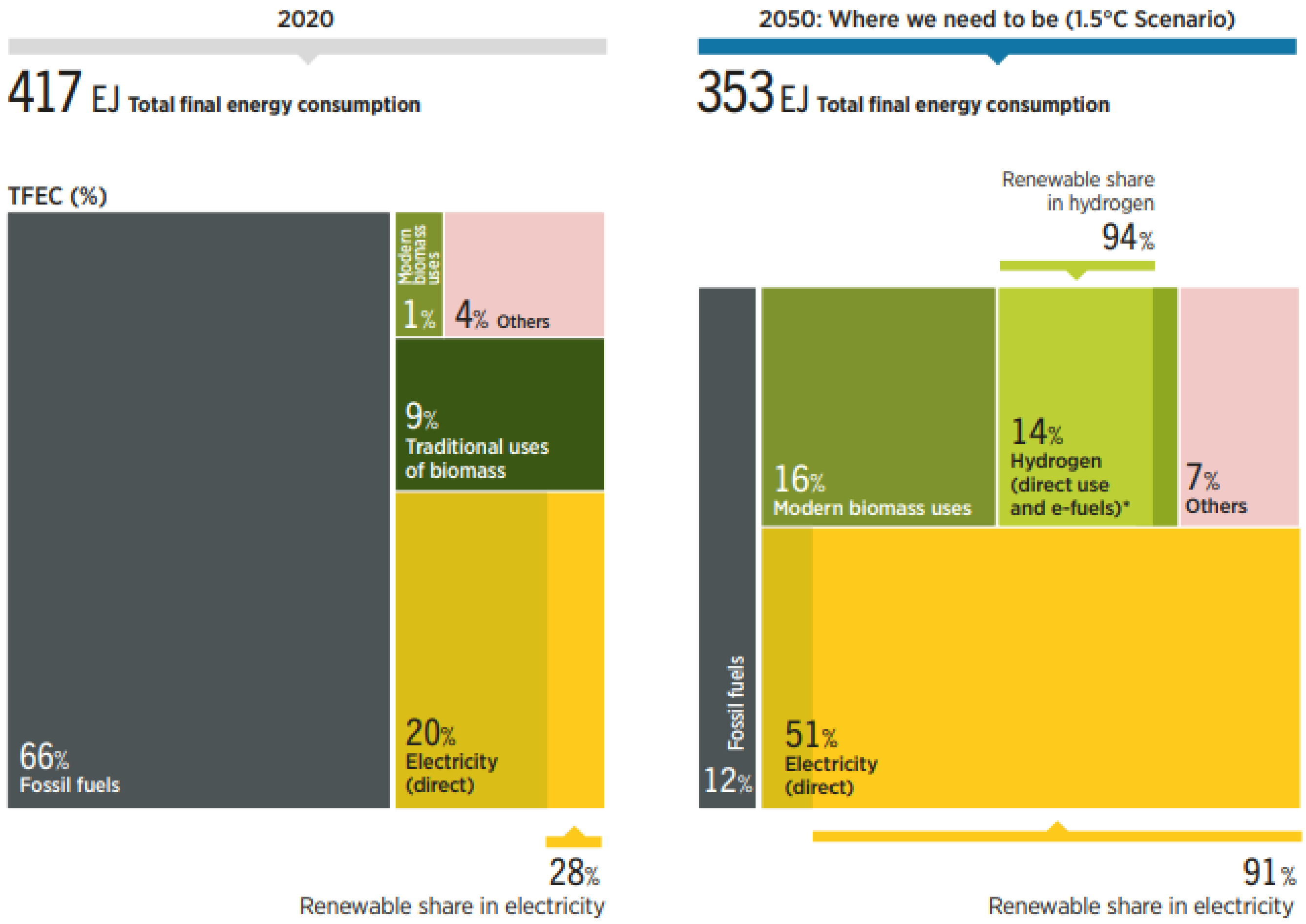
Green Hydrogen, renewable electricity, and CO2 source can reduce the life cycle emissions of the final SAF

IRENA’s perspective on SAF from green Hydrogen

Role of Hydrogen in IRENA's 1.5°C Scenario

IRENA
International Renewable Energy Agency

Breakdown of total final energy consumption by energy carrier in 2020 and 2050 under IRENA's 1.5°C Scenario:

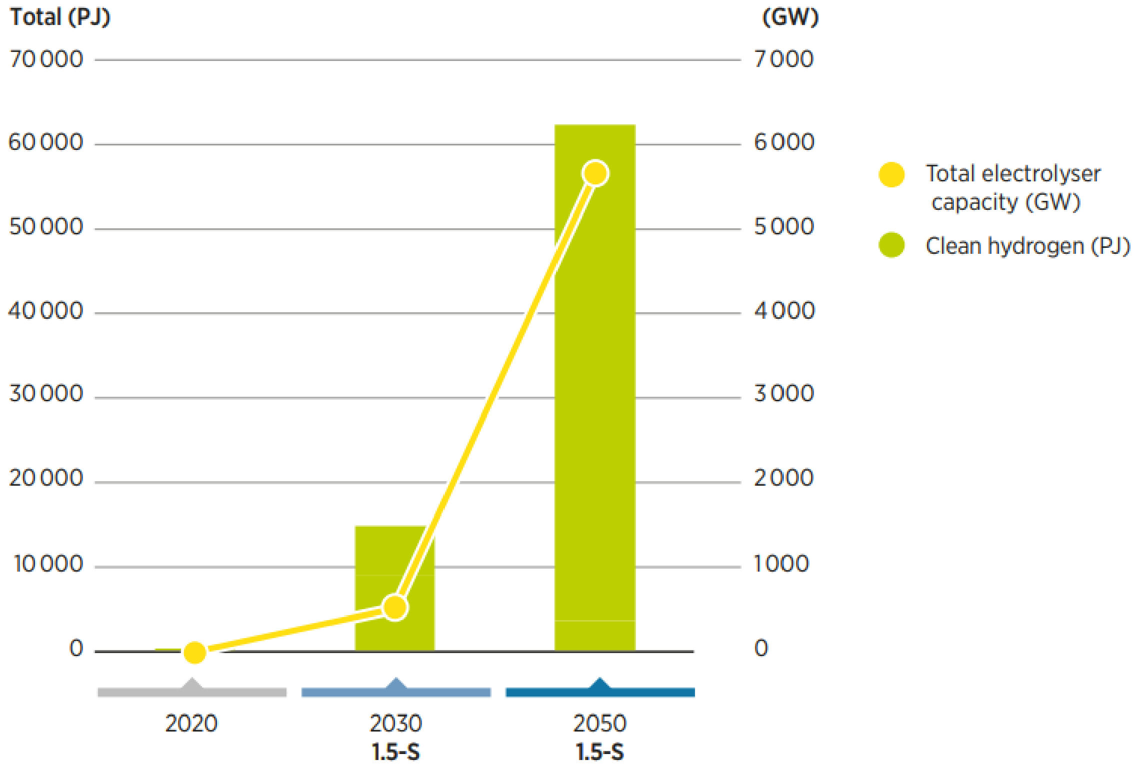


- By 2050, **electricity becomes the main energy carrier**, accounting for more than half of the global final energy consumption.
- Hydrogen and Hydrogen derivatives represent up **14% of total final energy consumption by 2050**.
- **94% of Hydrogen production** should **come from renewables.**

Scaling green Hydrogen production will be a major challenge

IRENA
International Renewable Energy Agency

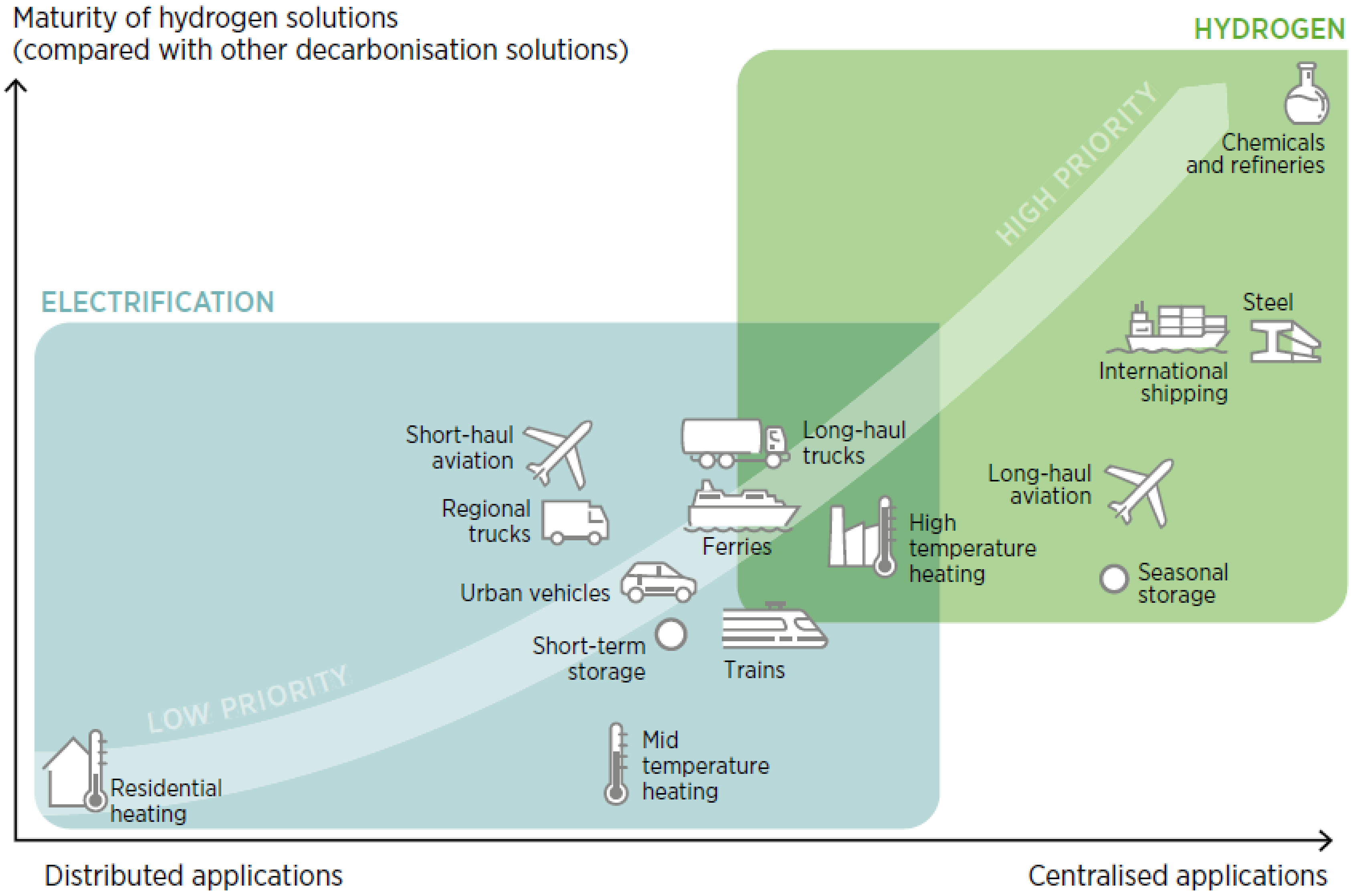
Global clean Hydrogen supply in 2020, 2030 and 2050 in IRENA's 1.5°C Scenario.



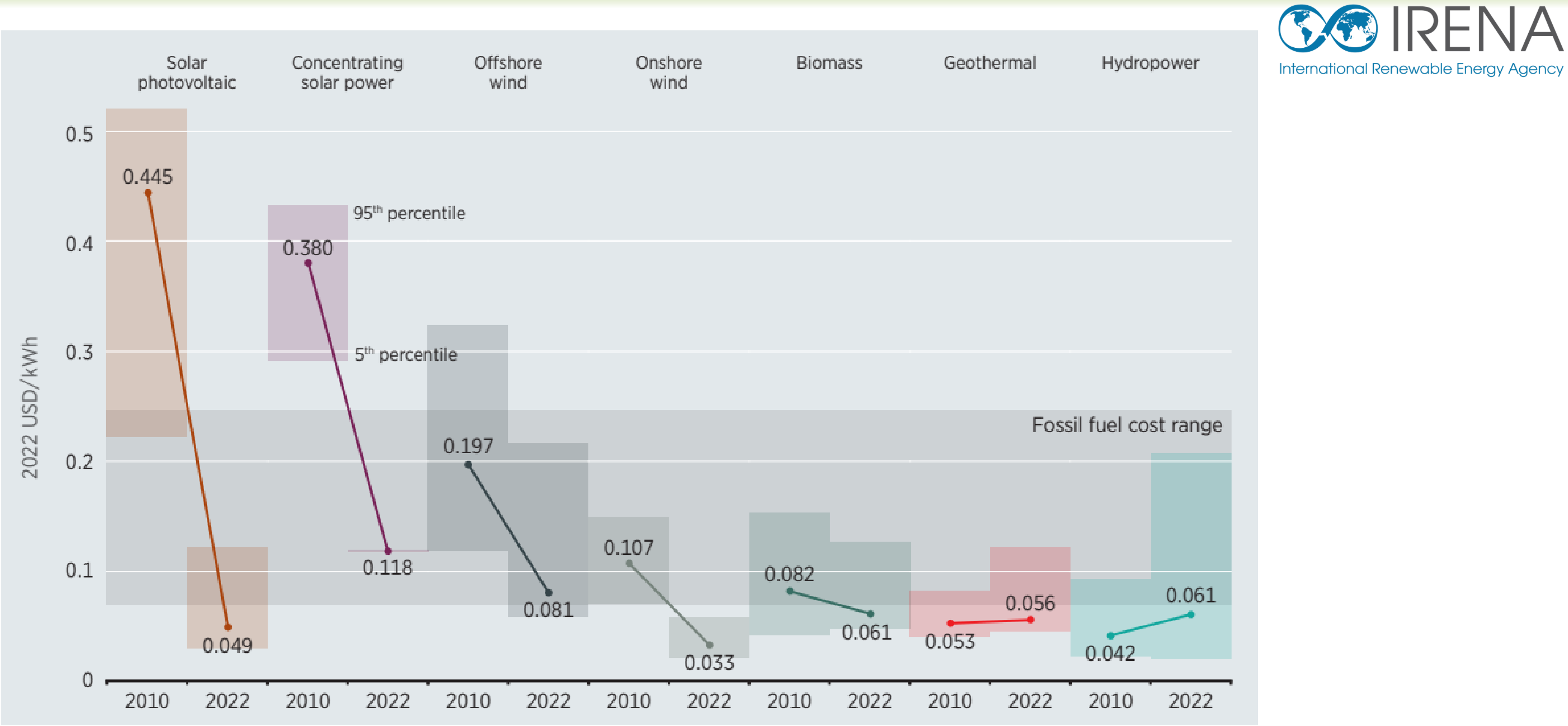
Notes: 1.5-S = 1.5°C Scenario; GW = gigawatt; PJ = petajoule.

- Bulk of **today's Hydrogen production is fossil-based** (mostly natural gas, but also coal)
- Most of global Hydrogen **production in 2050 should come from renewables**
- The electricity requirement for **green Hydrogen in 2050 is comparable to today's global electricity consumption.**
- From **~ 1 GW to >5700 GW** electrolyser capacity by 2050.

Priority uses for Hydrogen across the energy system

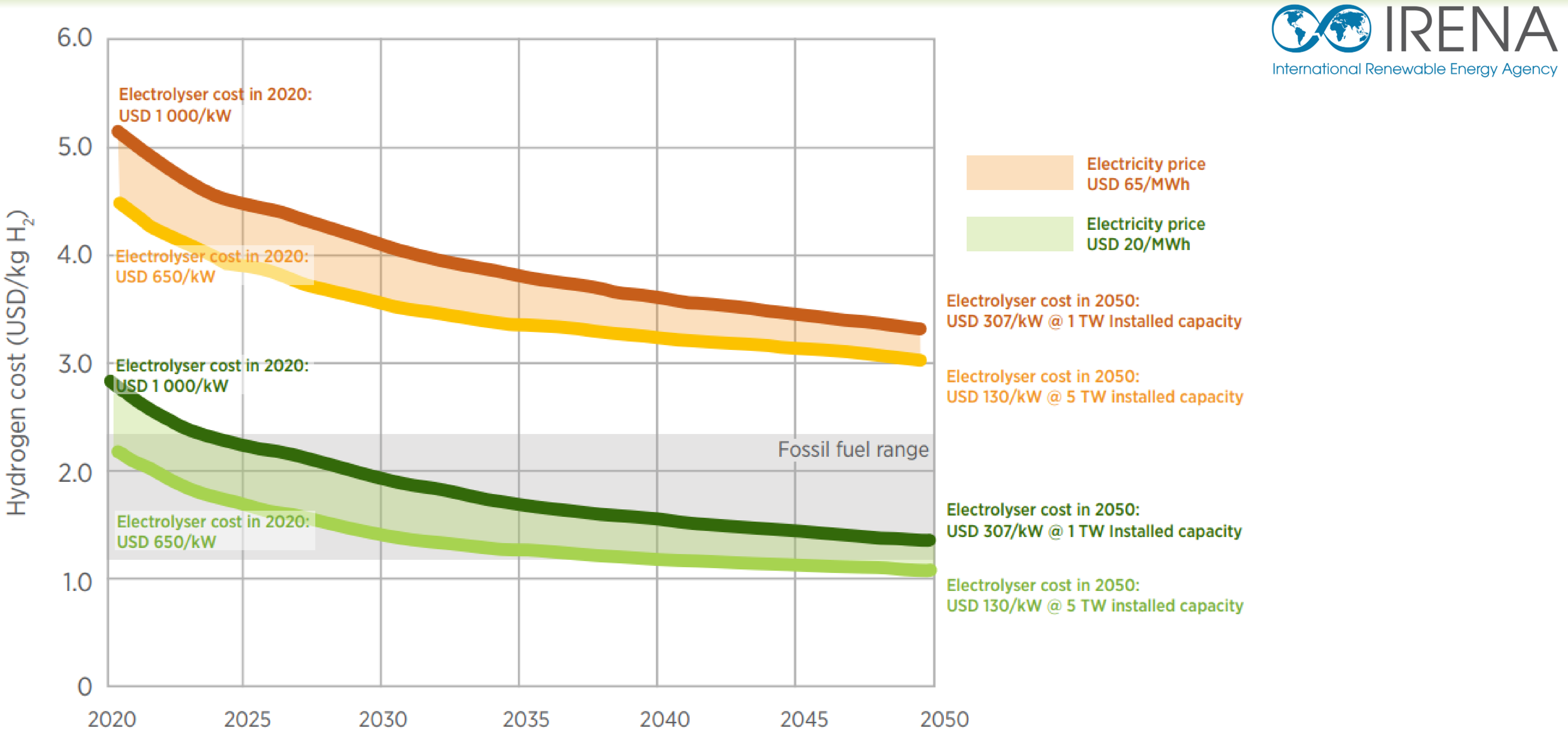


We are transitioning to a world of abundant, cheap renewables



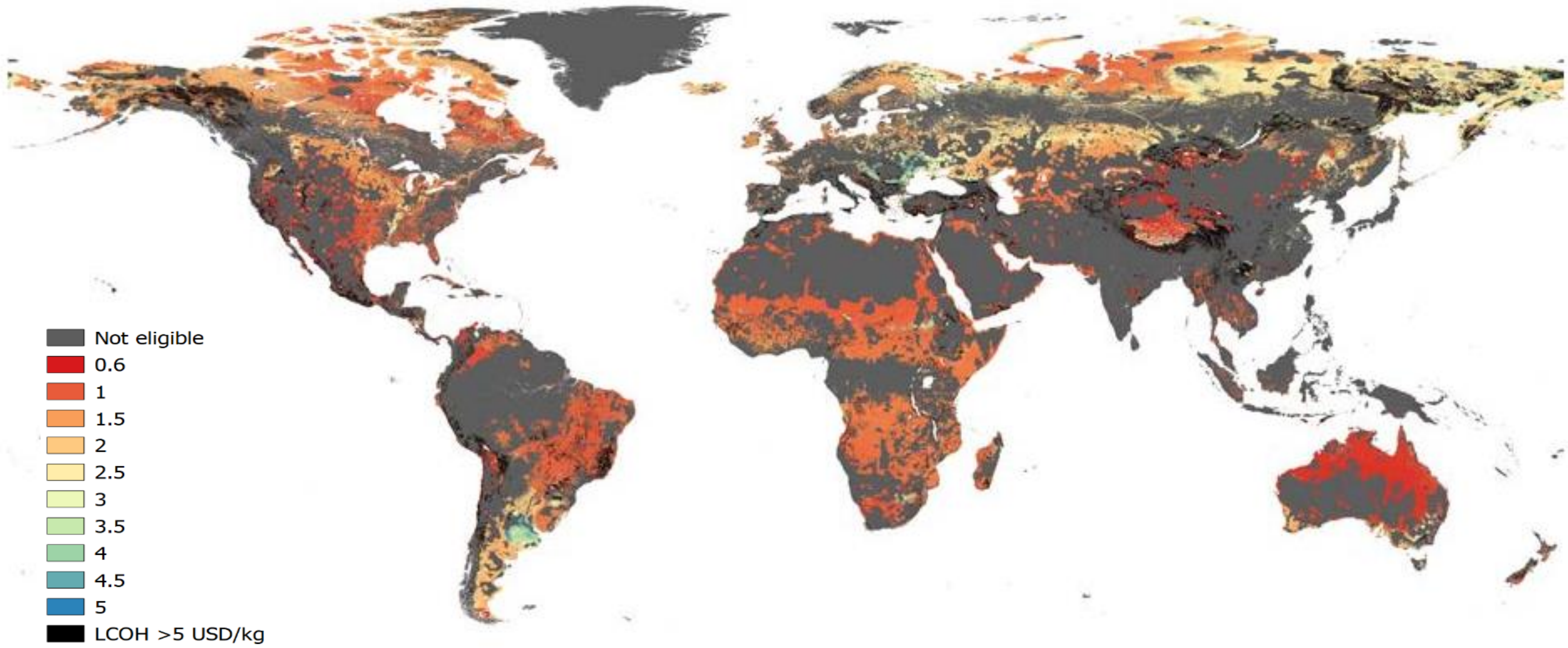
Source: IRENA, 2023. Renewable Power Generation Costs in 2022. Available from: https://www.irena.org/Publications/2023/Aug/Renewable-power-generation-costs-in-2022

Green Hydrogen costs depend on electrolyser cost and electricity cost



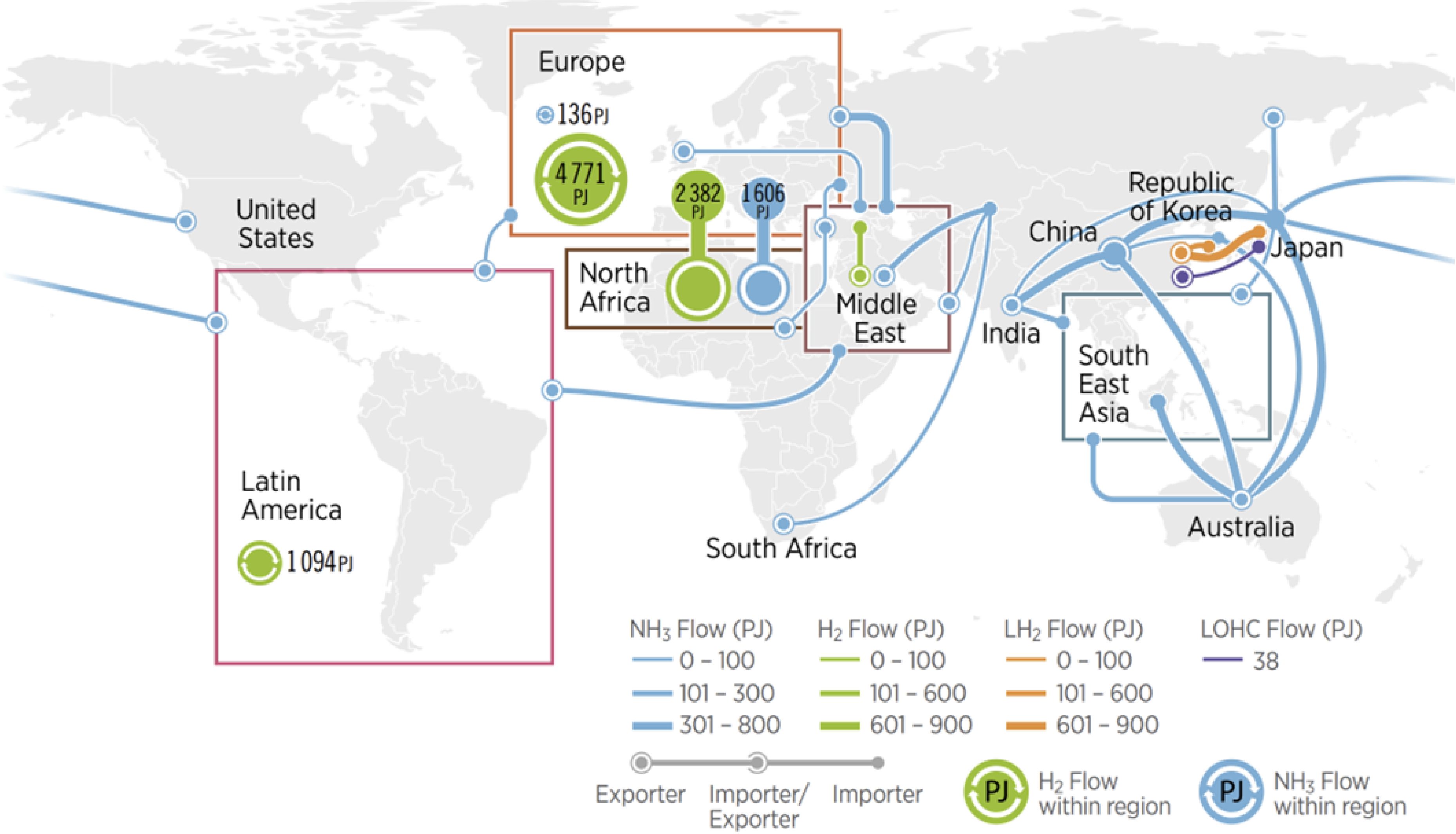
Source: IRENA, 2022. Global Hydrogen trade to meet the 1.5C goal. Part I: Trade outlook for 2050 and way forward.

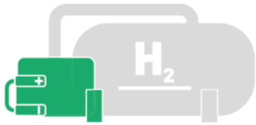
Green Hydrogen technical potential, almost 20 times the global primary energy supply in 2050



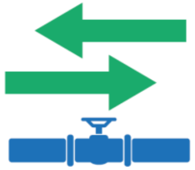
Note: Assumptions for capital expenditure are as follows: solar photovoltaic (PV): USD 270-690/kW in 2030 and USD 225-455/kW in 2050; onshore wind: USD 790-1435/kW in 2030 and USD 700-1 070/kW in 2050; offshore wind: USD 1 730-2 700/kW in 2030 and USD 1 275-1 745/kW in 2050; electrolyser: USD 380/kW in 2030 and USD 130/kW in 2050. Weighted average cost of capital: Per 2020 values without technology risks across regions. Land availability considers several exclusion zones (protected areas, forests, permanent wetlands, croplands, urban areas, slope of 5% [PV] and 20% [onshore wind], population density, and water availability). Source: IRENA, 2022. Global Hydrogen trade to meet the 1.5C goal. Part I: Trade outlook for 2050 and way forward

About a quarter of the global Hydrogen demand could be internationally traded

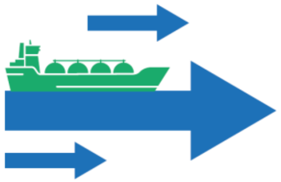




By 2050, international trade could satisfy about ¼ of the total global hydrogen demand in IRENA's 1.5°C scenario.



55% of this hydrogen would be traded via pipelines.



45% of this hydrogen would be shipped, predominantly as ammonia.

Source: IRENA, 2022. Global Hydrogen trade to meet the 1.5C goal. Part I: Trade outlook for 2050 and way forward.

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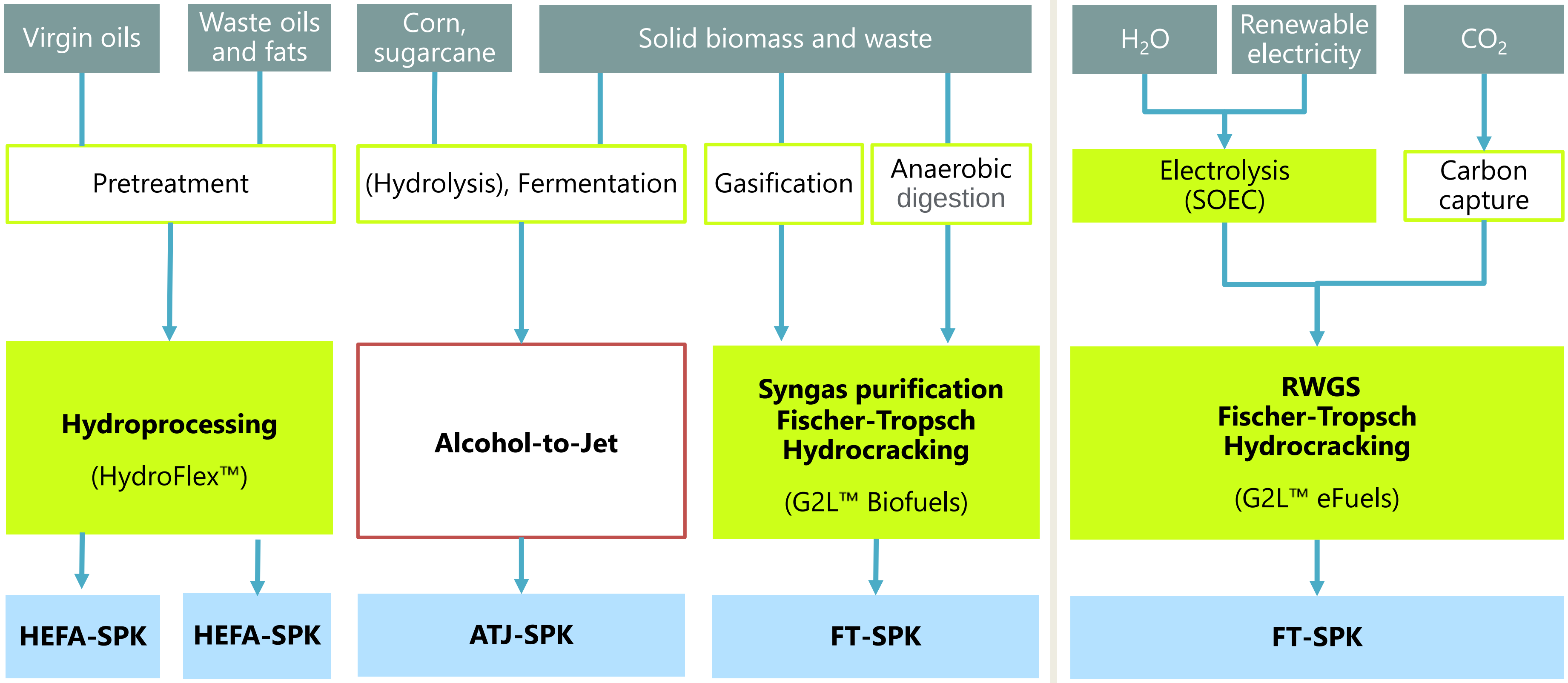
Green Hydrogen in the SAF production process

Topsoe

PATHWAY OVERVIEW

RENEWABLE FUELS

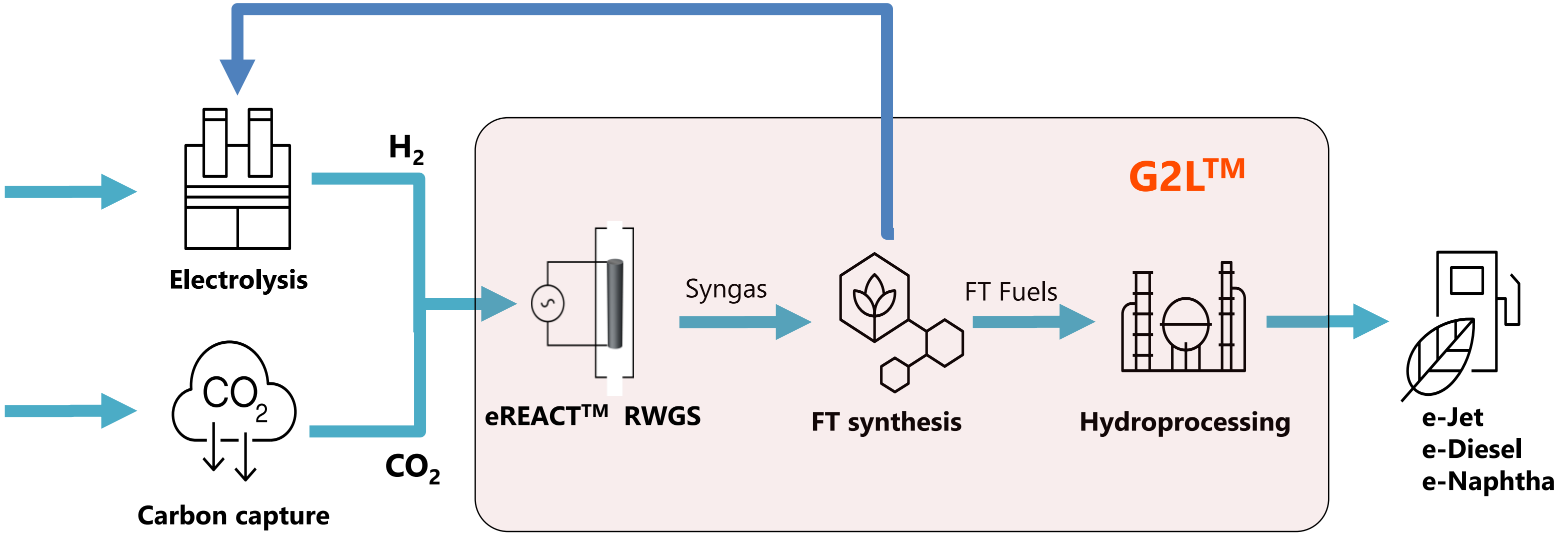
eFUELS

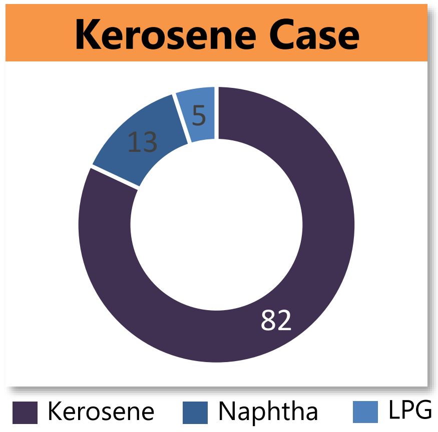


- Feed
- Process
- Process (Topsoe & Partners)
- Product

Source: CORSIA, ICCT paper 2021-11, WEF+McKinsey 2020-11

From H2 and CO2 to fuel





Solution features

- >95% overall carbon efficiency
- High SAF yield
- Flexible product slate
- High Hydrogen utilization
- Generates low-pressure steam

Status

- Ready for commercial application
- Kerosene - ASTM D7566 qualified fuel
- Diesel - ASTM D975 and EN15940 standards

Starts with synthesis gas (CO and H_2) production

Captured CO_2

Fuels from CO_2

Synthesis gas generation with eREACT™ RWGS

$$CO_2 + H_2 \longrightarrow CO + H_2O$$

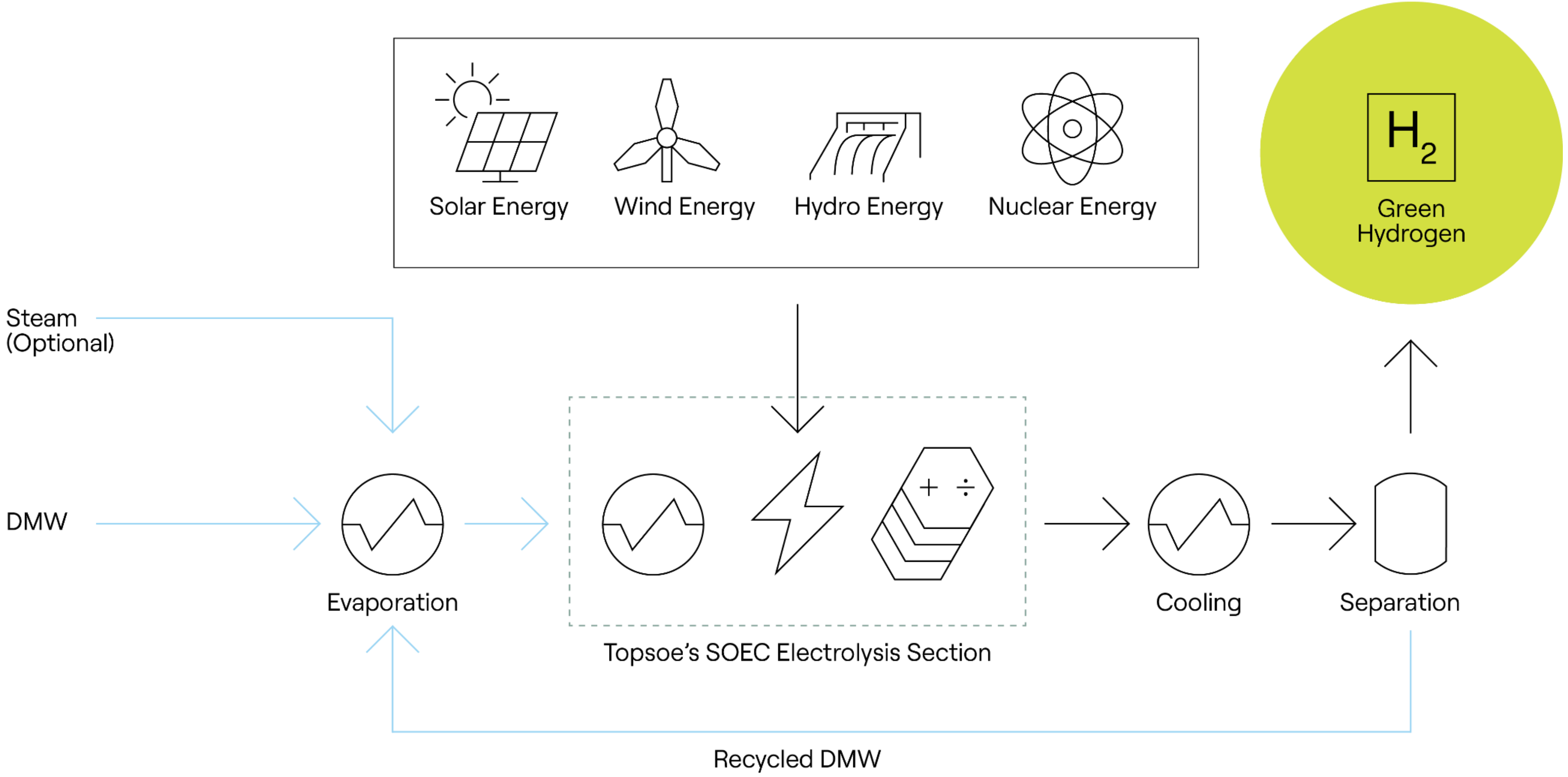
Fischer-Tropsch Synthesis

$$nCO + 2nH_2 \longrightarrow (\text{-}CH_2\text{-})_n + nH_2O$$

Hydrocracking

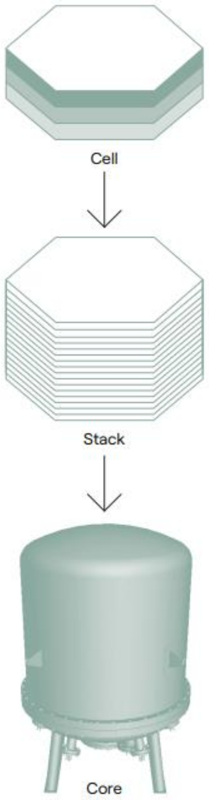
$$(\text{-}CH_2\text{-})_n + H_2 \longrightarrow 2(\text{-}CH_2\text{-})_{1/2n}$$

Example - Green Hydrogen production through SOEC



Example - chemistry behind the SOEC electrolysis process

SOEC CELL, STACK AND CORE



CONCEPTUAL DIAGRAM OF SOEC, ALKALINE, AND PEM ELECTROLYSIS,
INCLUDING HALF-CELL REACTIONS (THE OXIDIZING AND REDUCTION REACTIONS)

SOEC

H_2O → H_2

$H_2O + 2e^- \rightarrow H_2 + O^{2-}$	**Cathode**
O^{2-}	Electrolyte
$O^{2-} \rightarrow 2e^- + ½ O_2$	**Anode**

$½ O_2$

ALKALINE

$2H_2O$ → H_2

$H_2O + 2e^- \rightarrow H_2 + 2OH^-$	**Cathode**
$2OH^-$	Electrolyte
$2OH^- \rightarrow ½ O_2 + H_2O + 2e^-$	**Anode**

$H_2O + ½ O_2$

PEM

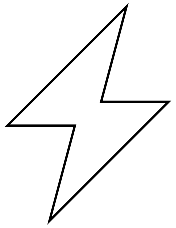
H_2

$2H^+ + 2e^- \rightarrow H_2$	**Cathode**
H^+	Electrolyte
$H_2O \rightarrow ½ O_2 + 2H^+ + 2e^-$	**Anode**

$½ O_2$ ← **H_2O**

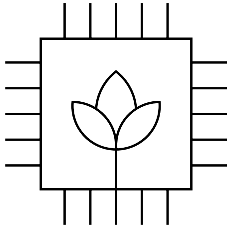
Example - SOEC electrolysis advantages

Lower power consumption



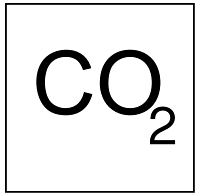
- SOEC has the highest efficiency of all electrolysers
- With heat integration, SOEC is 30 % more efficient than alkaline and PEM

Non noble materials



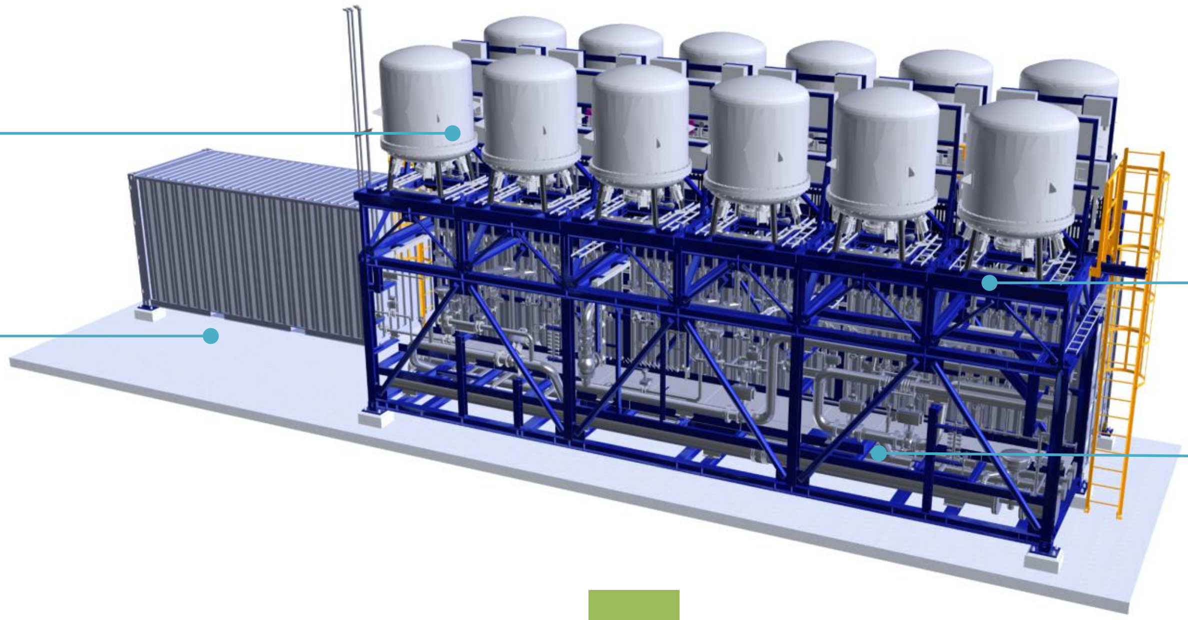
- SOEC consists of materials that are abundant in nature and can therefore easily be scaled up without material availability constraints
- The use of non-noble materials will benefit cost as the raw materials will not become more expensive due to scarcity

Syngas creation



- In addition to the electrolysis of steam, SOEC can electrolyse CO_2 and thereby generate CO (eCOs™)
- CO_2 electrolysis enables carbon capture & utilization from a point source and provides advantages for making eFuels such as eJet, eDiesel and methanol

Example - From concept to next generation



DEVELOPMENT TIMELINE

1980

Solid Oxide Fuel Cell (SOFC) developed

SOFC cell and stack can also be used as SOEC

Electrolysis of both water and CO_2

2013

Focus Shifts to SOEC

Demonstration and industrial SOEC units since 2015

Continuous optimization & innovation

Market leading efficiencies

2025

The world's biggest SOEC manufacturing facility

Initial 500 MW annual stack production capacity

Expansion to 1,2 GW Annually by 2031

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Developing Green Hydrogen

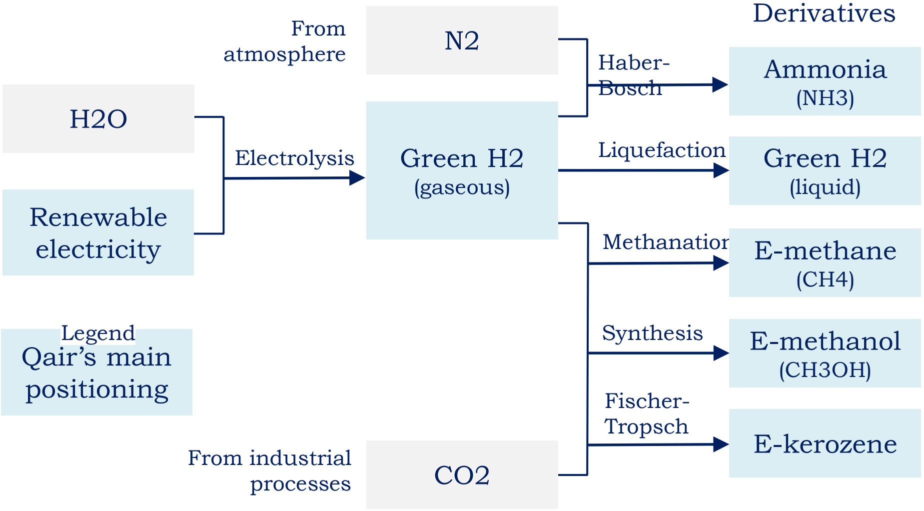
Qair Energy

Example: Qair's green H2 strategy

1 Green H2 is an important link in the ongoing energy transition

- Key to solve the intermittency issue of renewables, like wind and solar, as a way to store electrons.
- Allows for indirect use of green electrons in long-distance transportation, aviation & shipping where battery technologies cannot be deployed efficiently (as green H_2, but also ammonia, e-methanol, e-kerosene, and other derivatives).
- Way to get closer H2 is to the end-user by selling directly green molecules instead of electrons.

2 Qair intends to cover the whole H2 value chain



3 Qair identified promising geographies

- Qair's green H2 project under development / construction
- Top-priority countries for green H2 development
- Prospective countries for H2 development
- Shipping routes for export to Europe
- Expected pipelines for export to Europe

4 Qair set up ambitious yet realistic targets

By 2032

7 GW of electrolysis

1M t/yr of H2 green produced

Example: Hylann Project

2029

Location

- 23ha secured
- In Lannemezan, close to major communication axes, to the gas transport network operated by Terega, and to several industrial customers and mobility players (including airports).

Offtake

- E-kerozene production for nearby airports (Tarbes 35km, Toulouse 130km, Bayonne, Bordeaux, Bilbao)

2021 - 2022
Area secured
Resources secured
Partnerships engaged

2023
Pre-Design and Environmental studies

2024
Detailed Design
Building Permit
Financial Closing

2026
Start of construction

2029
Start of operation

300 MW – e-SAF

Renewable energy production

Qair

Solar PV to develop locally

Green H2 (& O2) production

Qair

Hylann

CO2 capture & transport

PYCASSO **(+CO2 onsite)**

300 kt of biogenic CO2

Synthesis of e-kerozene

Partnership with e-kerozene producer under discussion

70ktons of e-SAF

Storage, blending & transport of e-kerozene

TBD

Uses as aviation fuel

Offtakers under discussion with nearby airports

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Example: Project development insights 1/2

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1. Electrical Need :

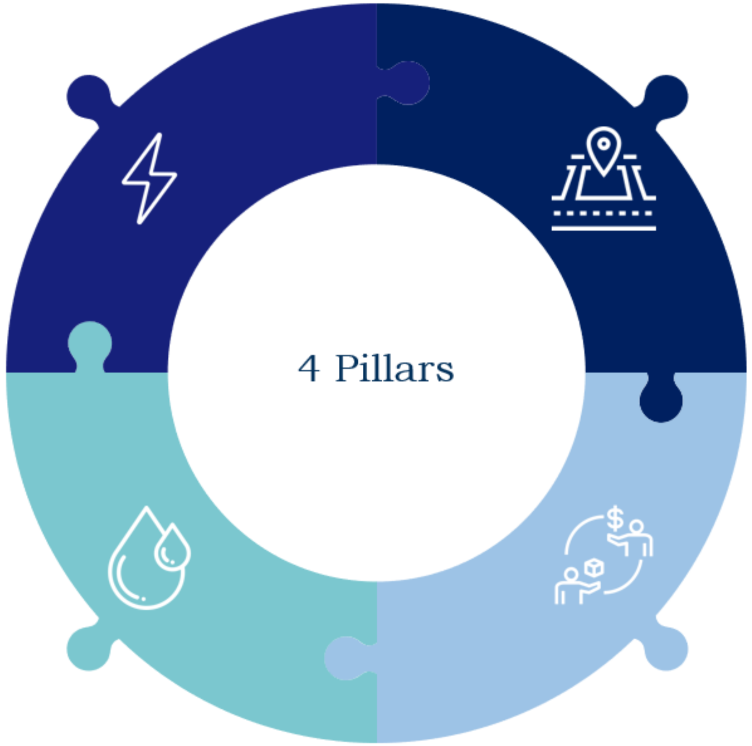
- A **substantial supply of low-carbon and renewable electricity** is accessible for production, totaling 2.7 TWh annually for 300 MW electrolysis

➢ This is equivalent to **nearly 2 GW of solar PV capacity** installed in the South of France.

- **Consequent grid connection** capacity stands at 328 MW through RTE link.

2. Water Need :

- Hydrogen electrolysis **demands large water quantities**. 600 000 m3/y for 300 MW electrolysis.
- Regions like Northern Africa or Southern Europe, **prone to drought, face water scarcity issues**.
- **Purification of water is essential** to enhance electrolysis efficiency.



3. Land Need : (French Case)

The rarification of available industrial land in France is underscored by:

1. **Regulatory constraints** such as the ZAN Law, heightening competition both within and between sectors.
2. These factors contribute to the increasing **scarcity of industrial land** and intensify the competition for its utilization within the country.

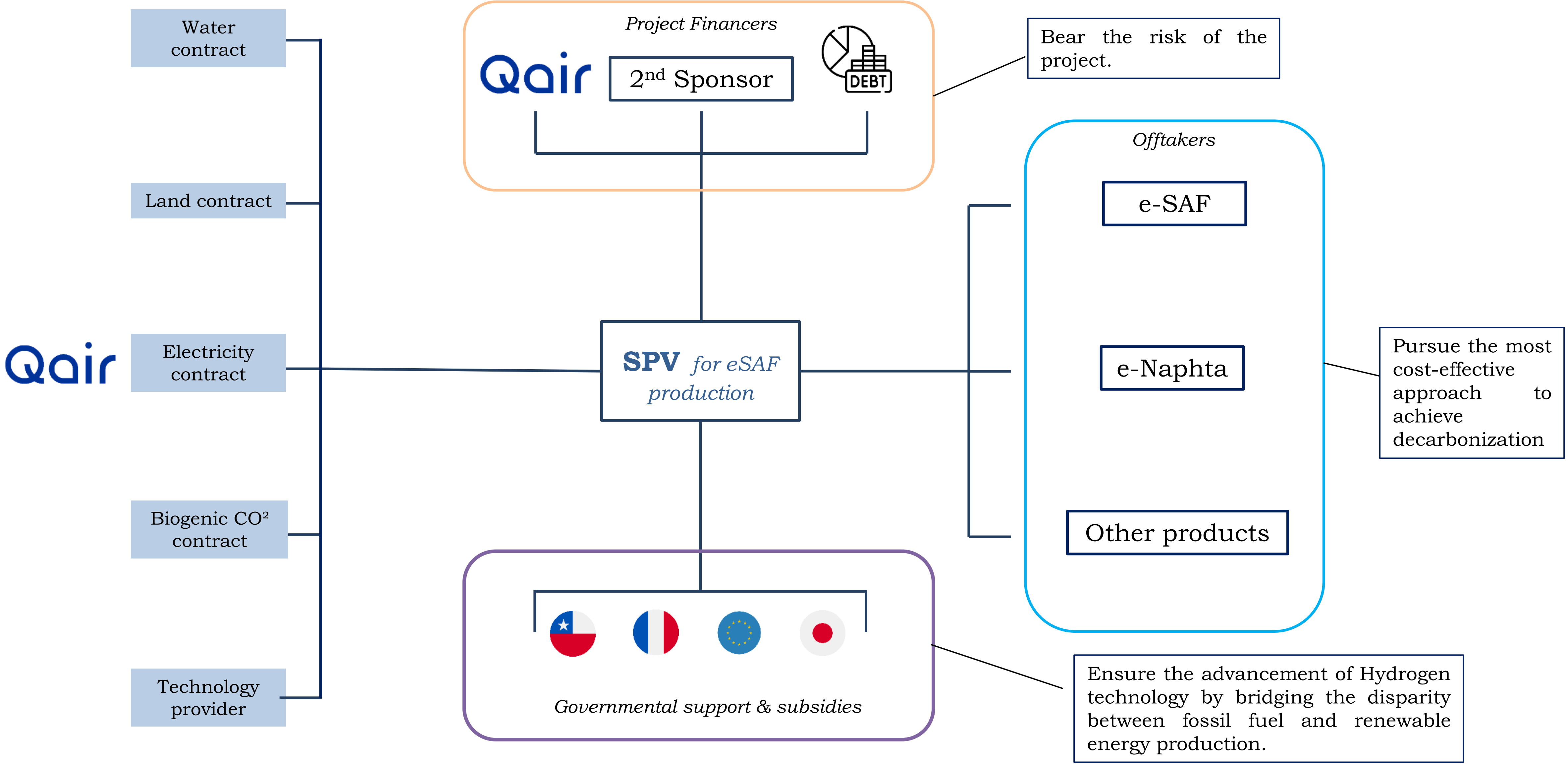
4. Offtakers :

- Securing bank financing for a highly costly project necessitates offtake contracts, typically requiring a minimum of 40% commitment.
- SAF market features :

1. 100% drop-in of SAF is currently **not permitted by regulations**.

2. **Competition exists among various types of SAF**, which are produced through three different modes: eSAF, bioSAF, and e-bioSAF.

Example: Project development insights 2/2



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Green Hydrogen from an aeroplane manufacturer’s perspective

Airbus

Why Hydrogen?

Decarbonized

H2 emits no CO_2* & has the potential to reduce non-CO_2 emissions (i.e. NO_x) & persistent contrails

(*if generated from renewable and sustainable sources)

Declining costs

The cost of producing H2 is likely to decline over the next decades as it gets widely adopted by various industries

Versatility

H2 can be used as an ingredient of Sustainable Aviation Fuel or directly on-board an aircraft through direct combustion or Fuel Cells

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Examples: Hydrogen and PtL pathways

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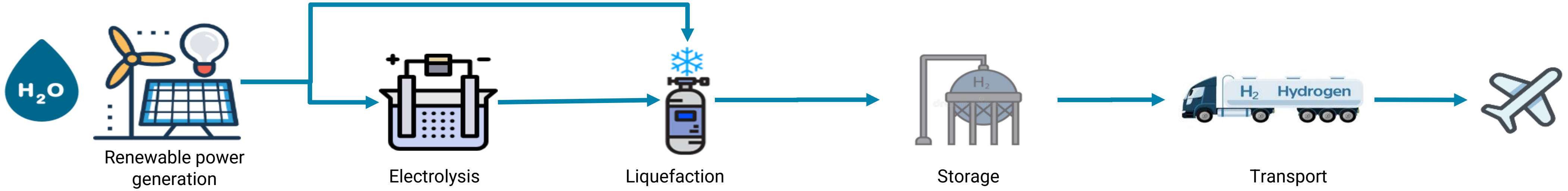
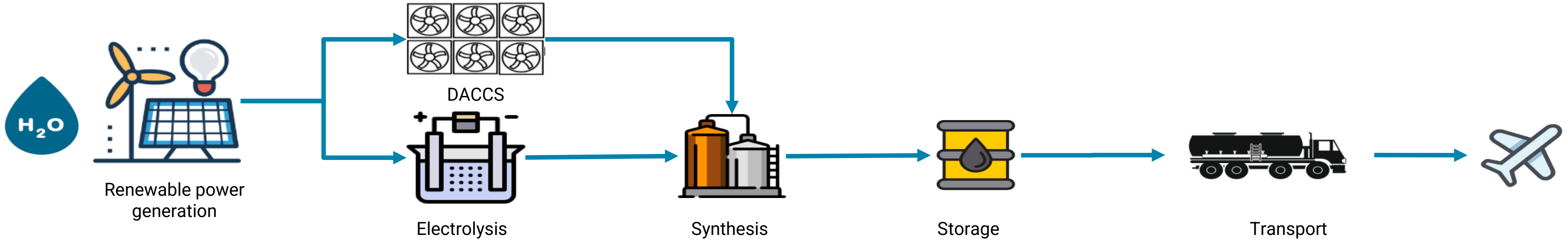
LH_2



Renewable power	**Electrolysis**	**Liquefaction**	**LH2 storage**	**LH2 distribution & transport**

PtL

Renewable power	**Electrolysis**	**Direct Air Carbon Capture**	**Synthesis**	**eSAF storage**	**eSAF distribution & transport**



High commonality and synergies between LH2 and PtL pathways

AIRBUS

Global ecosystem collaboration

Low-carbon hydrogen ecosystem development

A new ecosystem will develop to supply aviation with low-carbon hydrogen

Concerted efforts from a wide range of stakeholders are required

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Assistance, Capacity-building and Training for SAF

Chile's strategy on SAF from green Hydrogen

Policy framework: Chile's SAF Roadmap 2050

- **OCT 2022** — Launching of the SAF Round Table
- **NOV 2022 - MAY 2023** — Sessions of the SAF Round Table
- **JUN 2023 - DEC 2023** — Elaboration of the Roadmap
- **JAN 2024 - FEB 2024** — Public consultation
- **APR 2024** — Launching of the SAF Roadmap

Launching of the SAF Round Table (20/10/22)	Session 1 (24/11/22)	Session 2 (12/12/22)	Session 3 (12/01/23)	Session 4 (16/03/23)	Session 5 (31/05/23)
Ministerio de Energía; Ministerio de Transportes y Telecomunicaciones	SKY	IATA	CORMA	DGAC Chile	国土交通省 Ministry of Land, Infrastructure, Transport and Tourism
Agencia de Sostenibilidad Energética	LATAM	ENAP	Honeywell	Armada de Chile	Federal Aviation Administration
BID Banco Interamericano de Desarrollo	JetSMART	Brasil Biofuels	NESTE	Axens	Low Carbon Fuels Coalition
IATA	Agencia de Sustentabilidad y Cambio Climático	Rendering	UCSC	SGS	EASA
AIRBUS		HIF	Linde	Universidad de Concepción	BOEING
ANAC		COPEC	enex		C·A·C Always an idea ahead
			Air Liquide		

Green Hydrogen Roadmap 2023-2030

- Main Objective:
  - Define a roadmap between 2023-2030 that allows the deployment of the sustainable industry of green Hydrogen and its derivatives
- Specific objectives:
  - Sustainability
  - Coordination
  - Identify new actions
  - Define roles

Participatory Process

Consultative Council

Strategic Committee

Discussion results

Inputs and topics for discussion

Inputs and topics for discussion

Strategic guidelines

Interministerial Roundtables

Results

Inputs and topics for discussion

Citizen Workshops

Preparation of the Roadmap

Public consultation

Roadmap Actions

Lines of action	Governance	Total	2
	Market enablement and promotion		27
	Enabling infrastructure		19
	Participation, training and education		9
	Permission system		5
	Industry Sustainability		14
	Territorial deployment		13
	Development of capacities, knowledge and skills		16
	International positioning		6

Action Windows

2020

2023

Investment signals, regulations, off-takers

2026

Productive chain and decarbonization

2030+

- Efficient energy costs
- Efficient permit system
- Tax and financial incentives
- Promotion of necessary regulations
- Local demand
- Define environmental, social standards and working conditions

- Regulation implemented
- Contribution to Decarbonization
- Human capital
- Productive chain and local development

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Presentation of NEDO (Japan) work on Clean Hydrogen

Japan's Hydrogen Policy Move

- Historically Japan started Hydrogen/fuel cells R&D back in **1973** (before the oil shock started).
- **The first country to have formulated a national Hydrogen strategy (2017).**
- The Prime Minister set **"2050 carbon neutral" declaration (2020)**. **$15bn Green Innovation Fund.**
- Positioned **Hydrogen as one of the priority areas** in the Green Growth Strategy.
- **Key part of achieving green transformation economy plan (2023).**

Milestones — Japan's Policy Moves

2014	2017	2020	2021	2023
Hydrogen and Fuel Cell Strategy RM	Basic Hydrogen Strategy	PM's 2050 CN Declaration Green Growth Strategy	-Green Innovation Fund -Revised Strategic Energy Plan	**-GX Promotion Act** **-Basic Hydrogen Strategy updated**

Targets (Set in the Basic Hydrogen Strategy on Dec. 26, 2017 – updated in 2023)

- **Supply & Demand volume:**

  Current (Approx. 2Mt) → 2030 (**Approx. 3Mt**) → **2040 (Approx. 12Mt)** → 2050 (**Approx. 20Mt**)

- **Hydrogen cost (@Port)**

  2030 (**JPY30/Nm3**) → 2050 (**Less than JPY20/Nm3**)

Revised Japan's Hydrogen Strategy

Expanding Supply

(a) A new volume target at **12 Mt/p.a. by 2040**.
(b) Leading to low-carbon Hydrogen by introducing:
① **carbon intensity-based criteria, not "color" based;**
② guiding regulatory requirements.
(c) Promote domestic production and supply chain. Target share of **electrolyser** (domestic and overseas) that involve Japanese element (including parts and materials) **by 2030 is set around at 15GW**.
(d) Strengthen relationships with exporting countries, develop transportation technologies and expand financing capabilities.

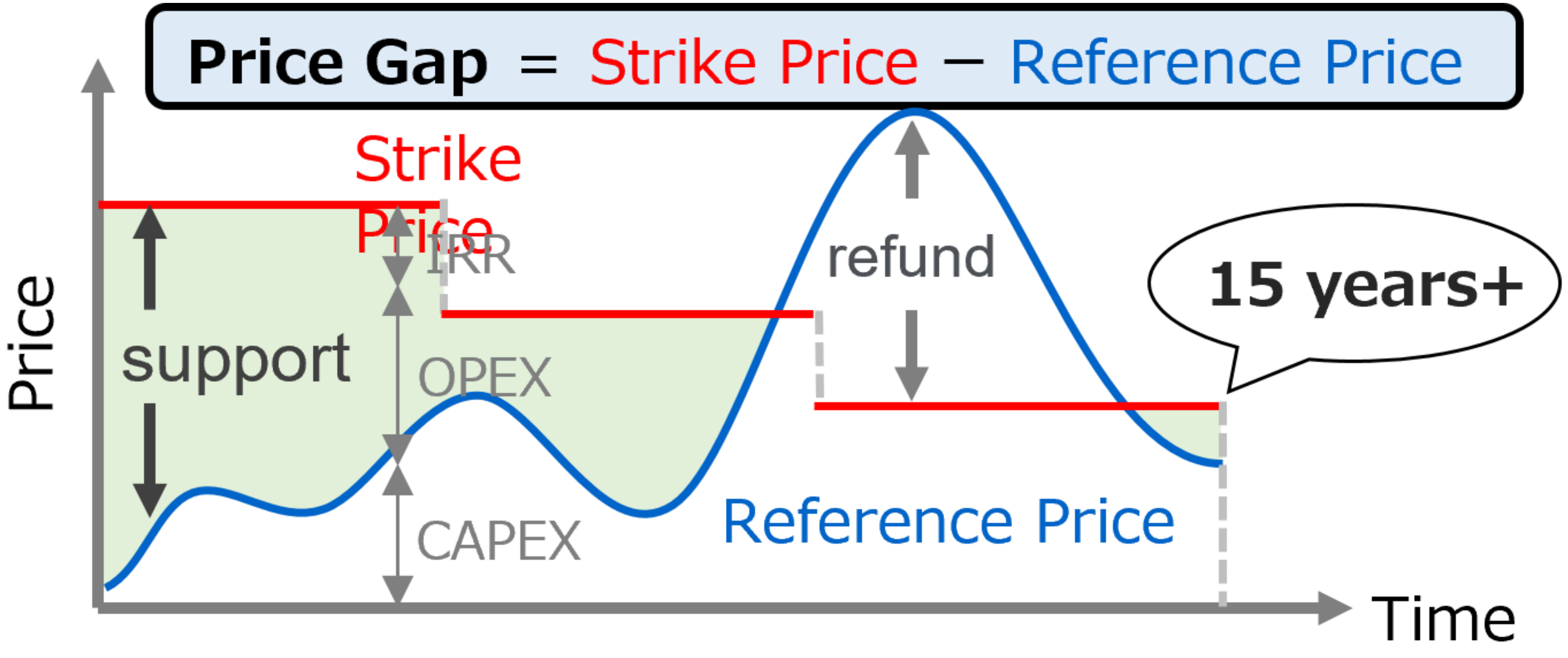
Creating Demand

(a) **Power generation**
A wide range of use in power sector, including co-firing and single-firing.
(b) **Fuel cells**
Deploy FC stack technology in a variety of applications such as commercial vehicles, material handling, vessels, heavy-duties, etc.
(c) **Industrial use**
Heat, Raw materials / in hard to abate sectors
(d) **Home use**
Promote high performance and low-cost residential Fuel Cells.

To introduce various support schemes with a view to setting up large-scale, resilient supply chains:

a. **Producer support scheme (price gap subsidy)**
b. **Cluster development support**

Supplier Support Scheme



Target by 2030
Well-to-Gate emissions ~3.4kg-CO_2/kg-H2*

(Ref.) Standards of different country or area	**Life cycle GHG emissions [$kgCO_2/kgH_2$]**
RED/RFNBO (EU)	3.4
CertifHy Low Carbon (EU)	4.4
EU taxonomy (EU)	3
Low Carbon Hydrogen Standard (UK)	2.4
CHPS (US)	4
IRA (US)	0~4

Strike Price : **Agreed price** for supply costs, including production, transportation and (if applicable) deHydrogenation costs, and return. To be **periodically reviewed** to reflect the cost-saving effects from the **technology developments** and **business expansion**.

Reference Price : **Market price of counterfactual fuels***

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NEDO’s R&D Strategy

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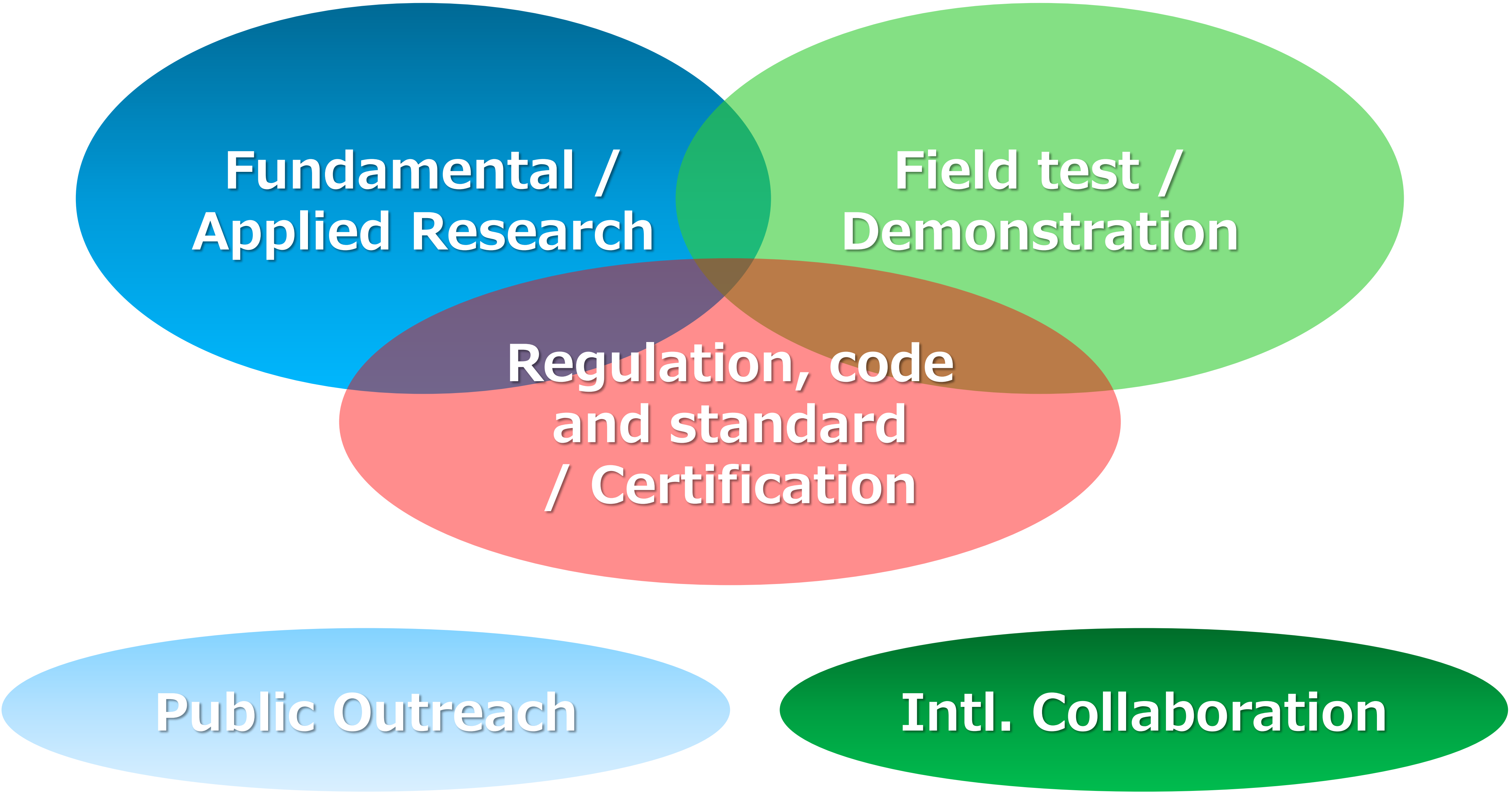
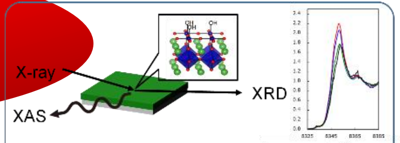


R&D on Electrolysis

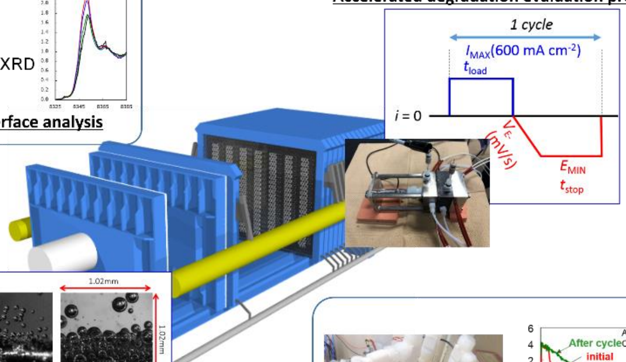
Electrolysis

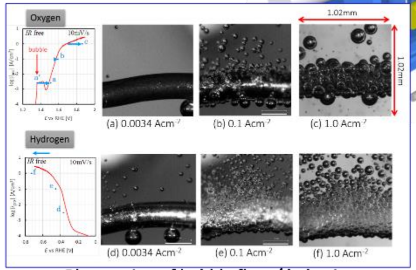
Fundamental Research



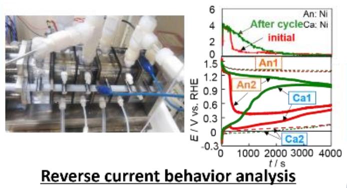
Electrode / electrolyte interface analysis

Accelerated degradation evaluation protocol





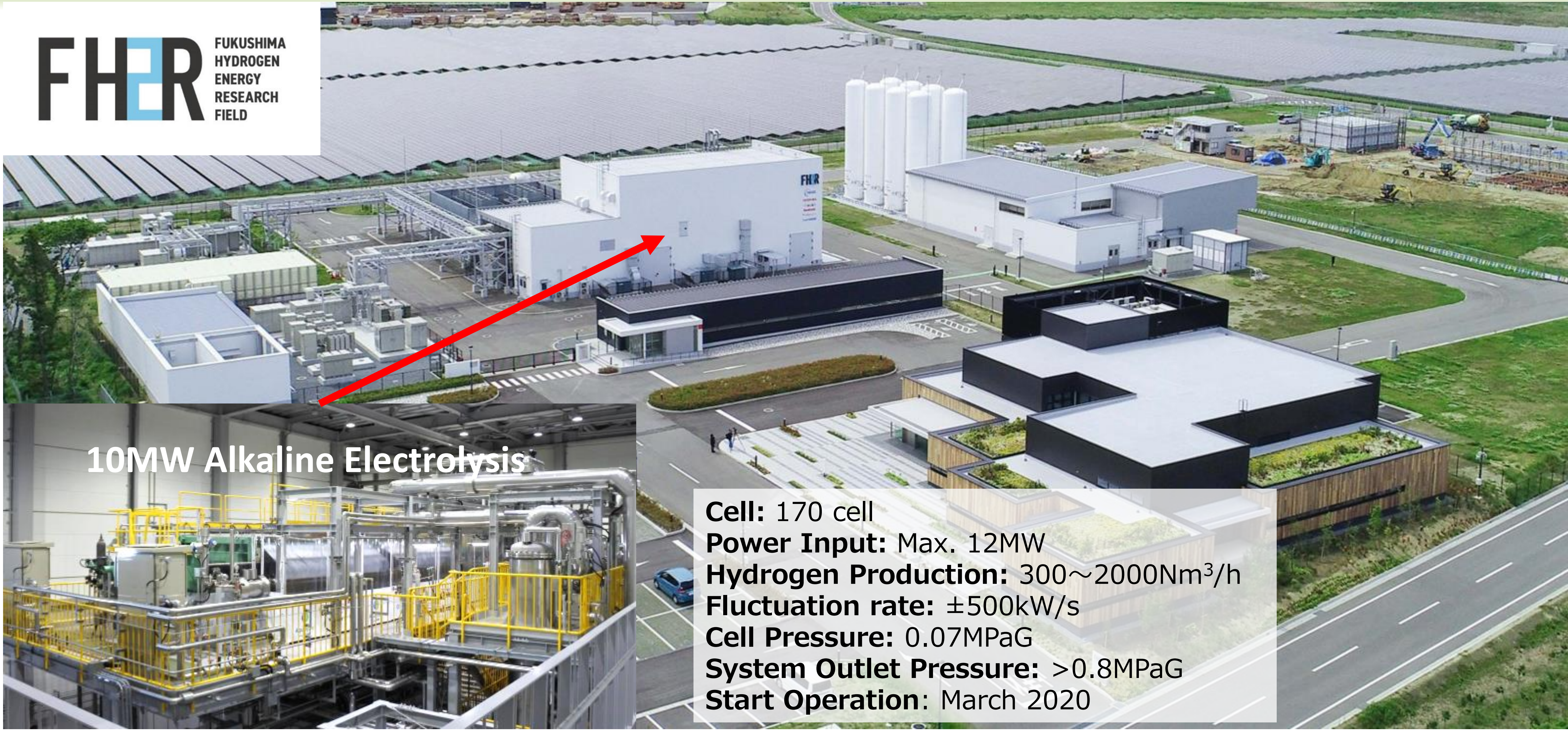
Observation of bubble flow / behavior



Reverse current behavior analysis

Scale-up / System Technology

Electrolysis Technology Development

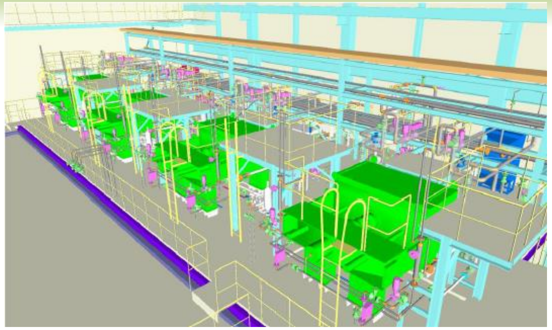


Cell: 170 cell
Power Input: Max. 12MW
Hydrogen Production: 300～2000Nm^3/h
Fluctuation rate: ±500kW/s
Cell Pressure: 0.07MPaG
System Outlet Pressure: >0.8MPaG
Start Operation: March 2020

Scaling up

Single Stack Test@FH2R (10MW)

×



Multi Module Test（0.8MW×1～4 unit(s)）

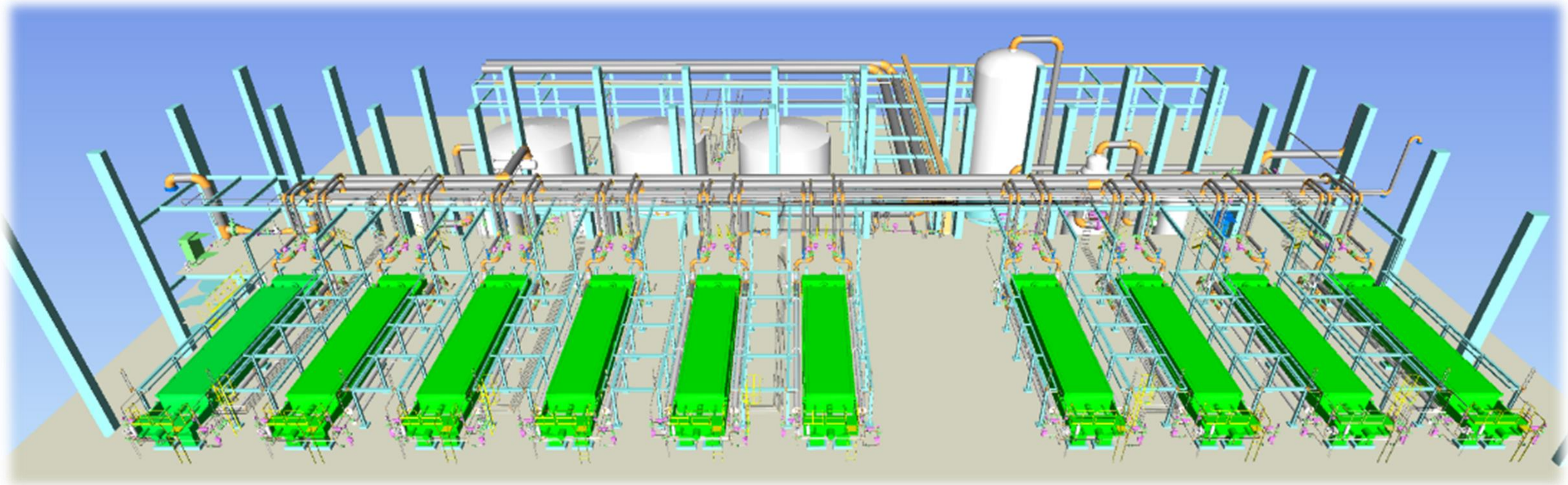


Image: Asahi Kasei

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Global Hydrogen Supply

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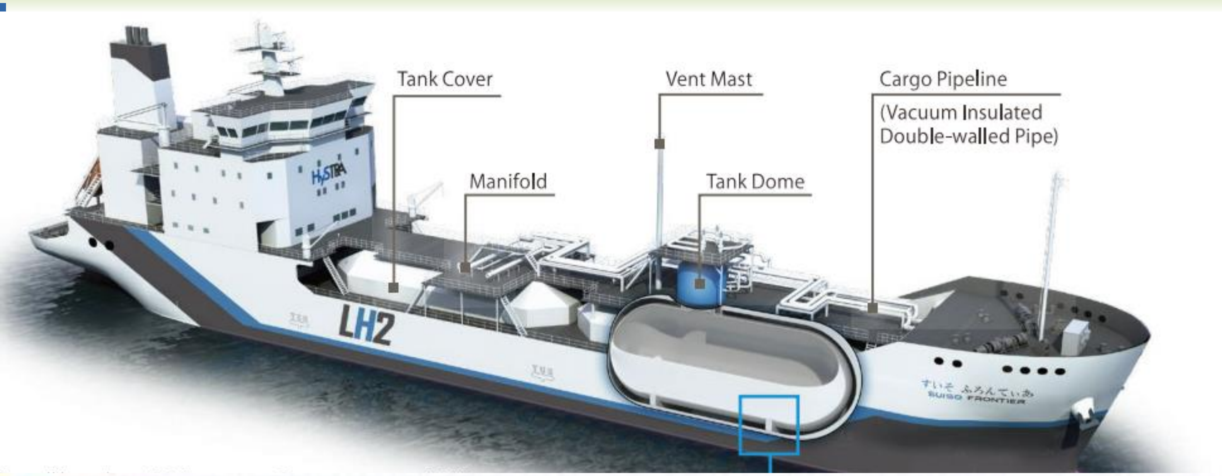
Image: Kawasaki-city



2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
FS / Concept Design			Development/Construction				Demonstration		

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Questions and Answers

Closing Remarks

Key request - conceptual training on SAF

ACT-SAF Series - SEASON 2
#8 Green Hydrogen for aviation
#9 ICAO SAF supporting tools
#10 SAF in State Action Plans
#11 CAAF/3 Global Framework
#12 Multi-stakeholder SAF Alliances
#13 Feasibility assessments
#14 Economics and Financing (SAF projects)
#15 Updates on recent developments (policies)

Today's Session

- Future sessions on specific aspects
- Subject to review – **feedback welcome**

https://www.icao.int/environmental-protection/Pages/ACT-SAF-Series.aspx

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Upcoming ICAO Events

ACT SAF

ICAO Seminar on Green Airports

18-19 April 2024, Athens, Greece

https://www.icao.int/Meetings/greenairports2024/

ICAO Symposium on Non-CO2 Aviation Emissions

30 July – 1 August 2024, ICAO HQ, Montreal, Canada

https://www.icao.int/Meetings/SymposiumNonCO2AviationEmissions2024/

ICAO LTAG Stocktaking event

7-10 October 2024, ICAO HQ, Montreal, Canada

https://www.icao.int/Meetings/LTAGStocktaking2024/

Follow up actions

We need your assistance on the following actions:

- Suggest consultants for SAF feasibility studies and business implementation reports
- Suggest references for the development of the template for business implementation plans
- Suggestions for the new session on "latest news" for the next ACT-SAF series sessions

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