Nov 8, 2023

Overview on international green hydrogen projects

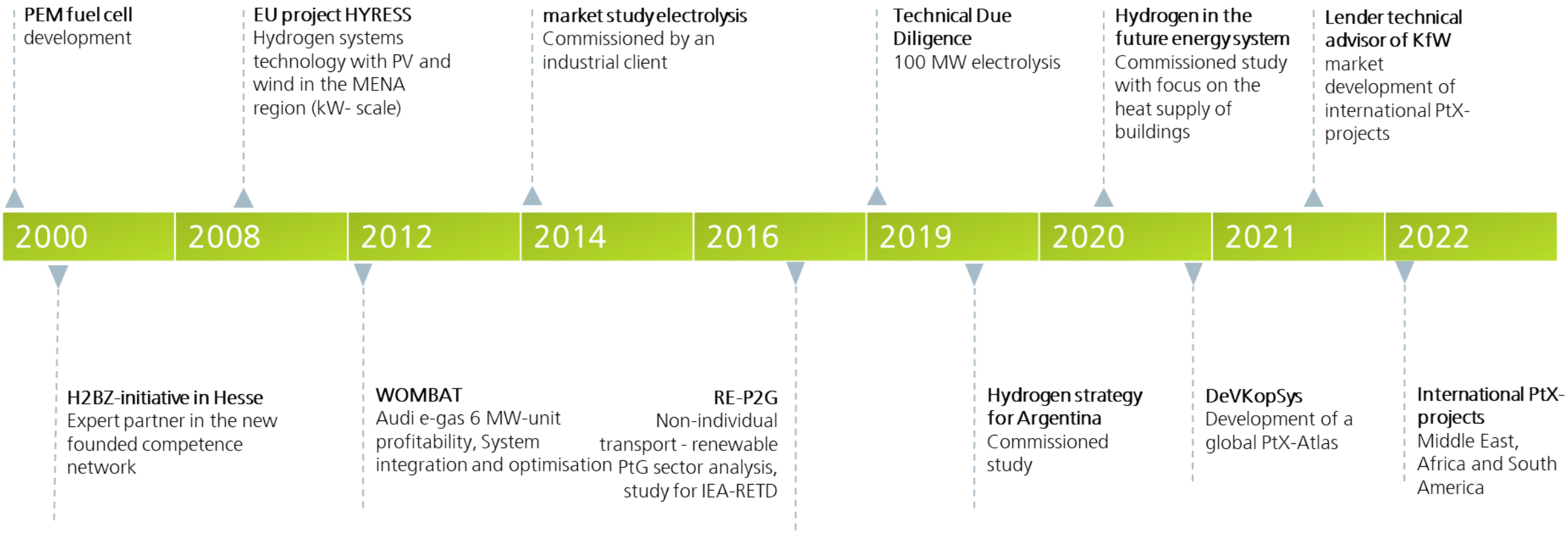
Jochen Bard

Energy Process Technology Division, Fraunhofer IEE, Kassel, Germany

H2 GIGA HyLeiT: WORKSHOP

Market development of electrolyzers under consideration of system services

H_2 @ Fraunhofer IEE
Selected References



Project scale and complexity as well as production capacity and market size have increased substantially over time!

Fraunhofer IEE

Fraunhofer IEE: Hydrogen related research and development

- **Techno-economic studies at project, regional and national level**
  - Green hydrogen resource and economic assessments:
    large scale hydrogen production, international green hydrogen applications and markets, economy of scales of production, logistics and infrastructure investments, strategy and roadmap development: Argentina, North Africa, Offshore in the North Sea, …
  - Quality Technical Advise (QTA) for Hydrogen & Power-to-X Technology Project Preparation (100 MW)
  - Regional hydrogen economy implementation i.e. for the transport sector in Germany
  - Sector analysis and policy recommendation i.e. for IEA RETD
- **R&D support of electrolyser demo and pilot projects**
  - Audi-e-Gas Plant, Wertle: 6.3 MW alkaline EL
  - Energy park Mainz: 6.3 MW PEM EL
  - Technical due diligence for a 100 MW alkaline EL (EU)
  - Design and optimisation of a 440 kW EL system (D)
- **Hydrogen system technology, electrolyser and fuel cell development**
  - Multi MW power electronics development for electrolysis
  - Hardware in the Loop systems for automotive fuel cells
  - Detailed modelling and simulation of hydrogen systems and components including lab tests, characterisation and identification of degradation

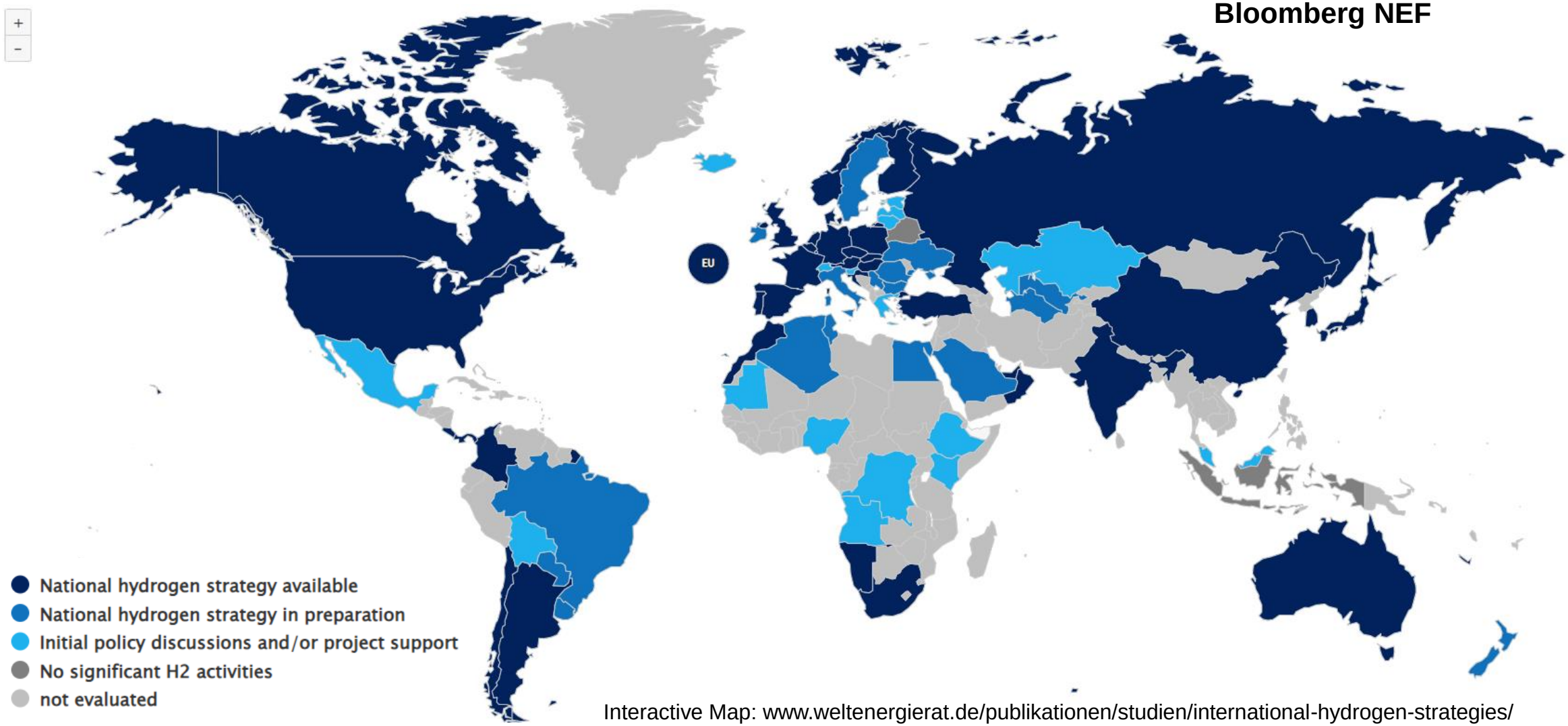
Fraunhofer IEE

International PtX project pipeline

A global race for hydrogen?

Countries with National hydrogen strategies

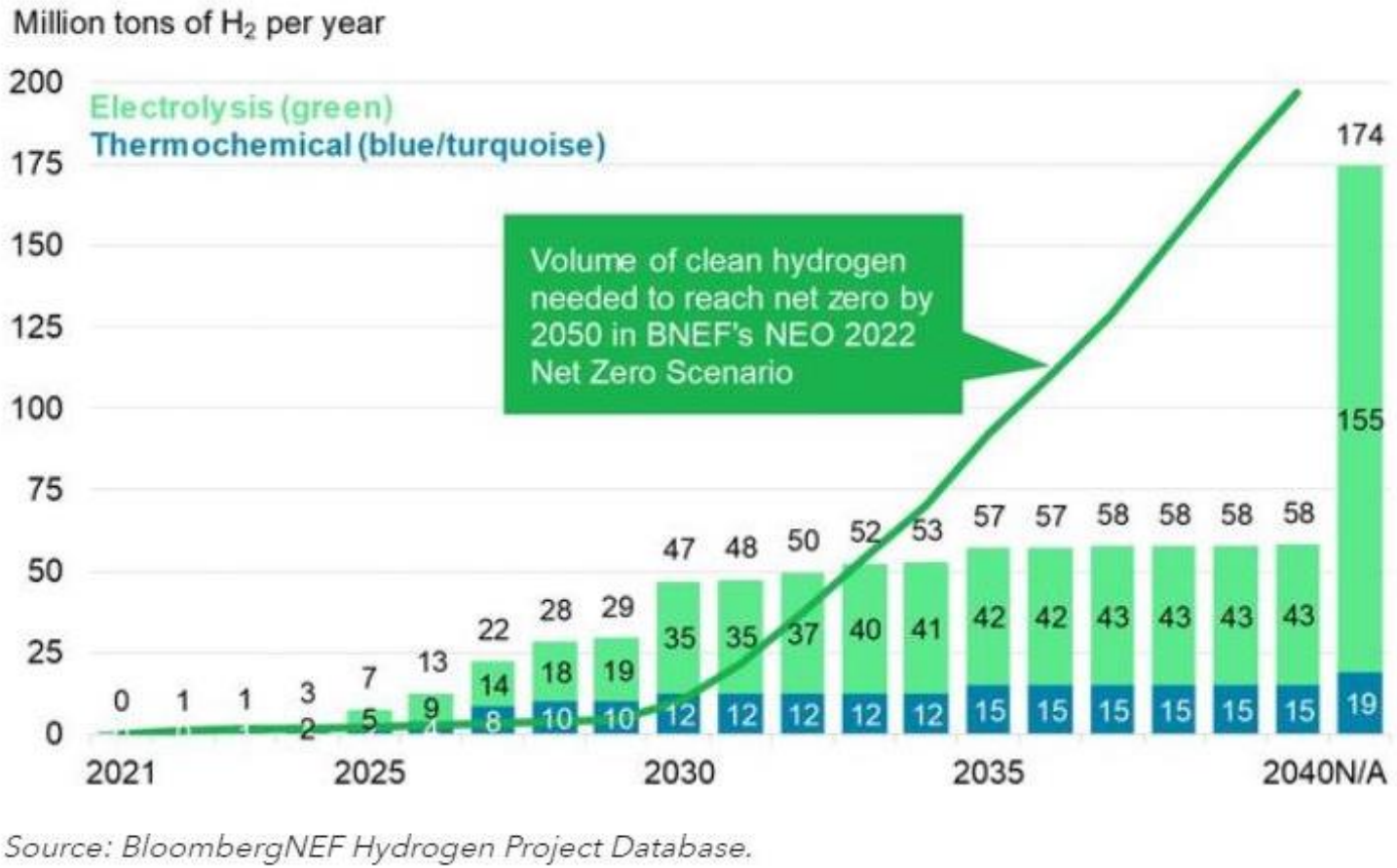
“…. what could be a $700 billion business by 2050” according to Bloomberg NEF



Interactive Map: www.weltenergierat.de/publikationen/studien/international-hydrogen-strategies/

Fraunhofer IEE

Fast ramp-up of hydrogen production globally based on “public money”

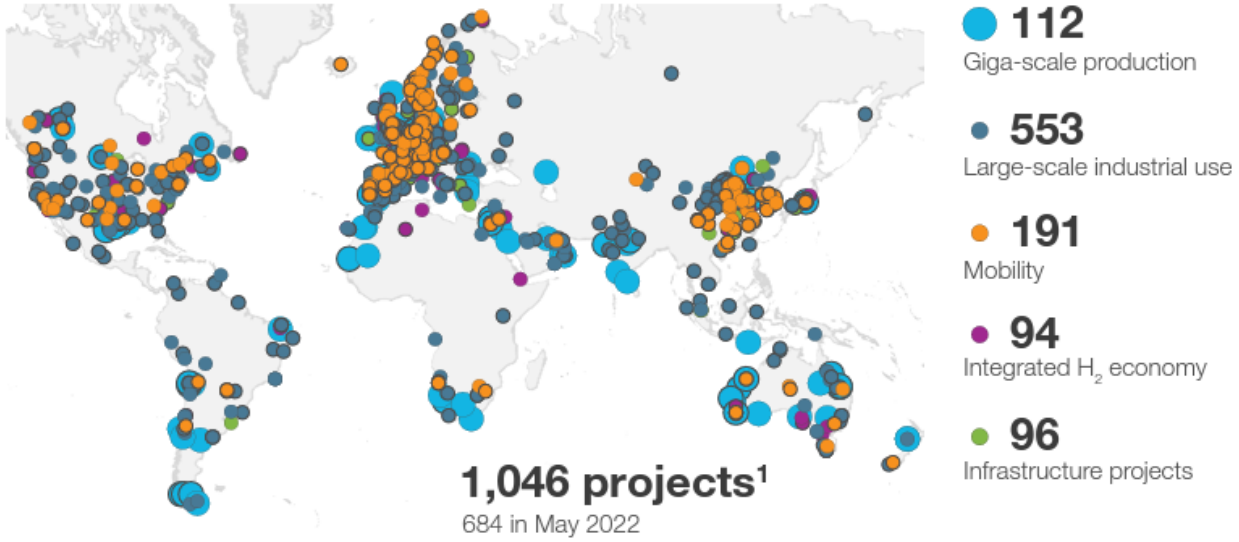


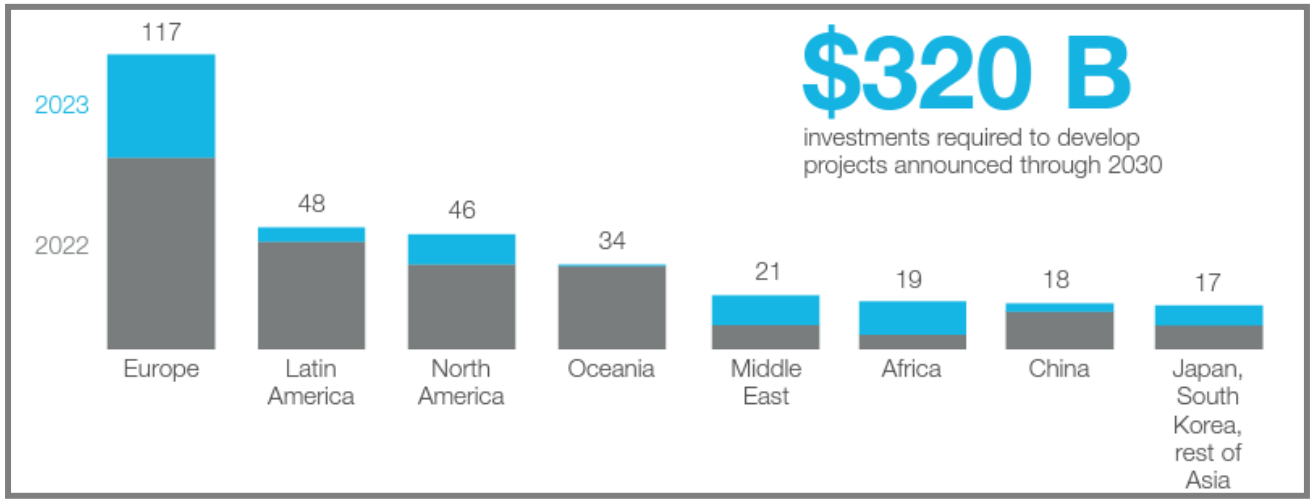
Source: BloombergNEF Hydrogen Project Database.

- **Public money available for clean H2 has climbed to $308 billion**, led by the US and Europe. But most funding programs support clean hydrogen **producers rather than users**, which will need to change if governments are to meet their hydrogen demand targets.
- The EU has set **quotas for the use of renewable H2 in industry and transport**. Germany is launching carbon contracts for difference and plans building power plants burning H2 or derived fuels. The US has announced a $1 billion plan to support clean H2 demand.
- The **pipeline of proposed clean H2 projects has more than tripled since January** to 174 million metric tons per year, close to the volume needed by 2040 in BNEF’s net-zero scenario at 197 million metric tons.

Fraunhofer IEE

International PtX project pipeline



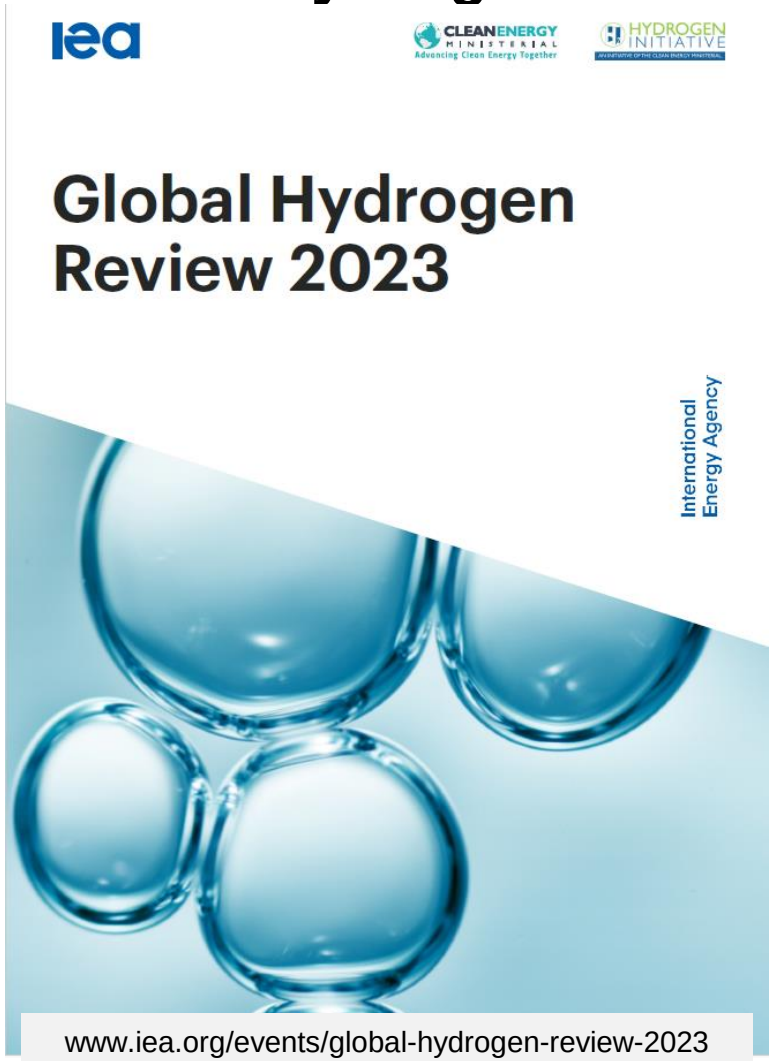


Source: Hydrogen Insights 2023, Hydrogen Council & McKinsey

- Giga-scale production: Renewable hydrogen projects >1 GW and low-carbon hydrogen projects >200 ktpa
- Large-scale industrial use: Refinery, ammonia, methanol, steel, and industry feedstock
- Mobility: Trains, ships, trucks, cars, and other hydrogen mobility applications
- Integrated hydrogen economy: Cross-industry and projects with different types of end uses
- Infrastructure projects: Hydrogen distribution, transportation, conversion, and storage

Fraunhofer IEE

Current hydrogen market: new IEA report from Sep 22 2023



Summary of main messages

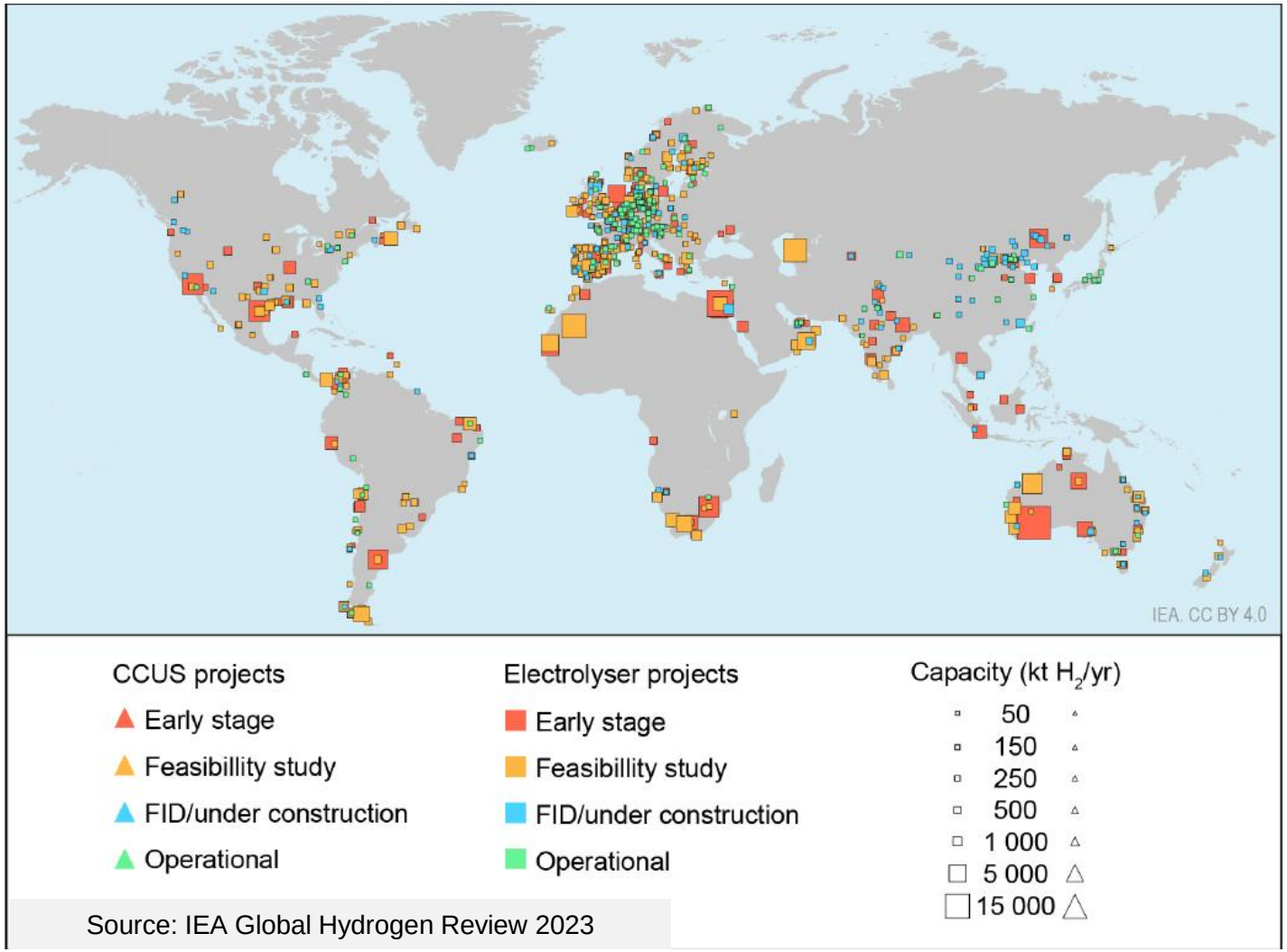
1. Low-emission hydrogen production can grow massively by 2030 but cost challenges are hampering deployment
2. Efforts to stimulate low-emission hydrogen demand are lagging behind what is needed to meet climate ambitions
3. Transforming momentum around hydrogen into deployment remains a struggle

Recommendations

1. Urgently implement support schemes for low-emission hydrogen production and use
2. Take bolder action to stimulate demand creation for low emission hydrogen, particularly in existing hydrogen uses
3. Foster international co-operation to accelerate solutions for hydrogen certification and mutual recognition of certificates
4. Quickly address regulatory barriers, particularly for project licensing and permitting
5. Support project developers to maintain momentum during the inflationary period and to extend regional reach

.TUN

Current hydrogen market overview (IEA 9/2023)

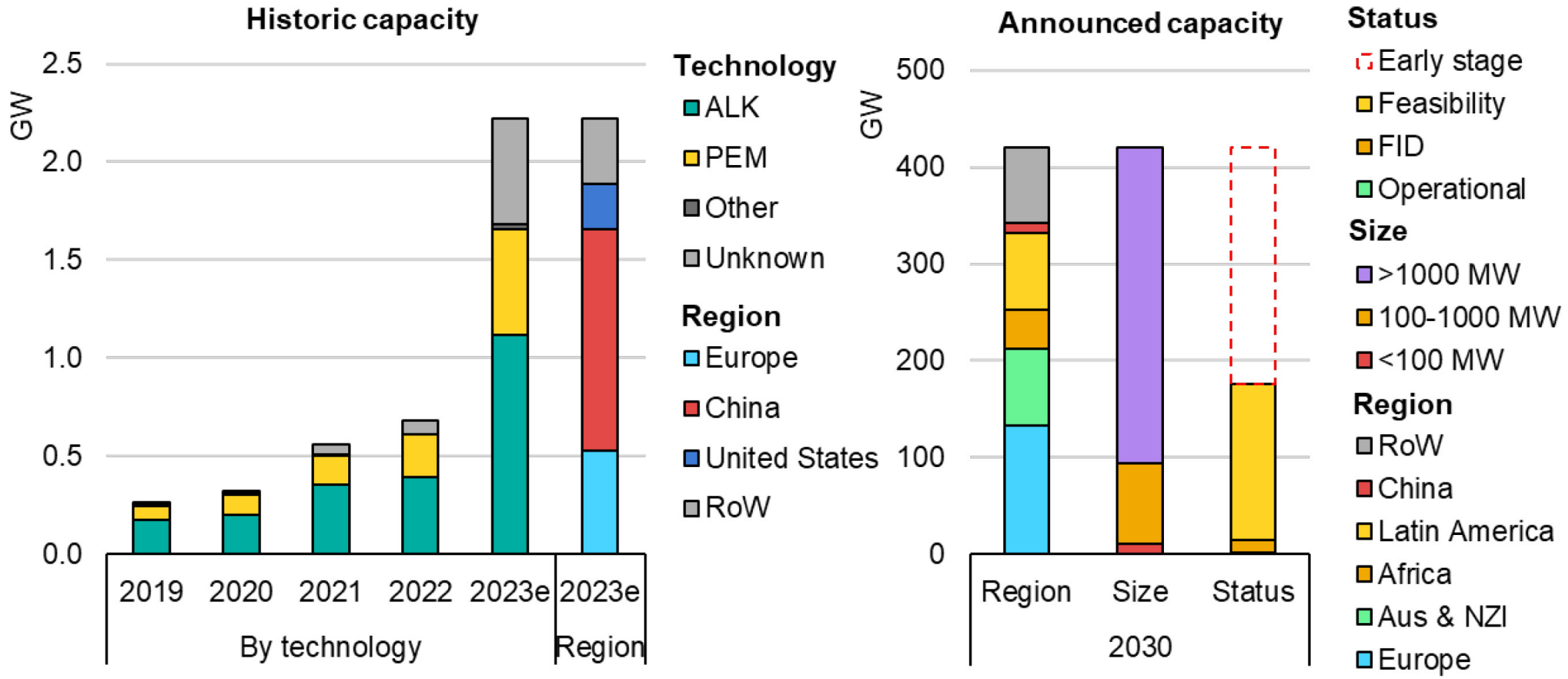


Source: IEA Global Hydrogen Review 2023

1. Announced hydrogen production capacity for 2030: 38 Mt H2 – 50% increase from 2022, 17 Mt from early stage projects
2. Only 4% of this production capacity has achieved the final investment decision
   -> now FID for 2 Mt H2/a
   -> compared to 1 Mt H2/a in 2022
3. Global installed electrolyser capacity end of 2022 around 700 MW
4. By the end of 2023 a total of more than 2 GW is expected – with 50% of that in China

Fraunhofer IEE

Global electrolyser capacity by technology, 2019 – 2023, and by region, size and status based on announced projects by 2030



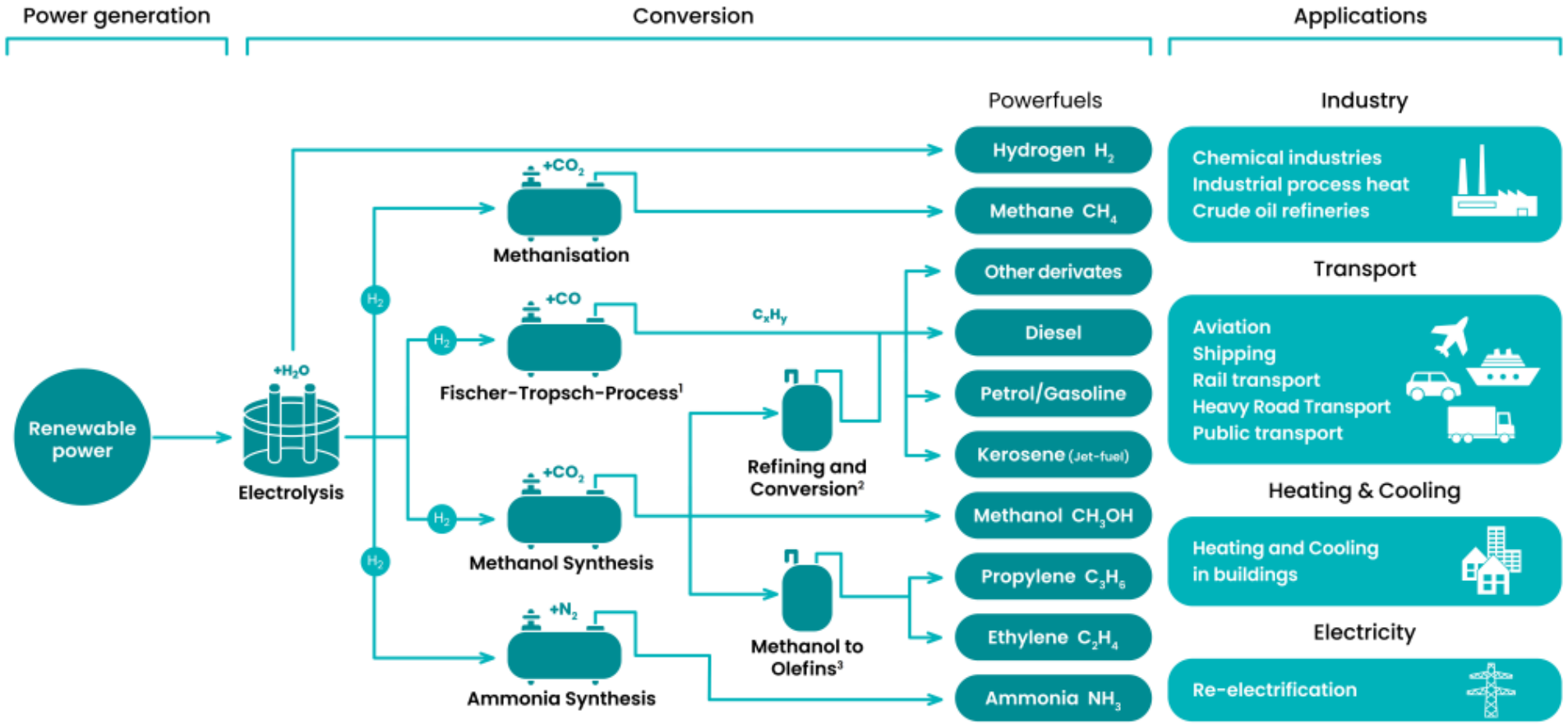
Source: IEA Global Hydrogen Review 2023

Fraunhofer IEE

Fraunhofer IEE

PtX-production: more than hydrogen

Various possible power fuel processes, end products and example applications



❶ Includes: Fischer-Tropsch synthesis, hydrocracking, isomerization and distillation.

❷ Includes: DME/OME synthesis, olefin synthesis, oligomerisation and hydrotrating.

❸ Methanol-to-olefins process.

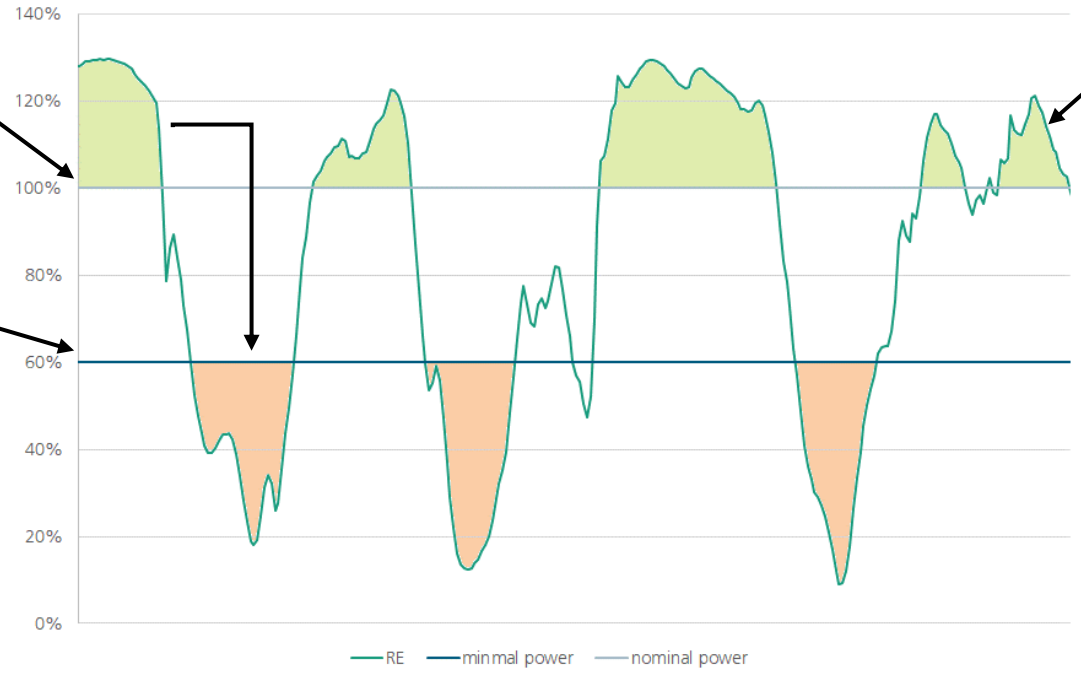
Fraunhofer IEE

Ammonia – Challenge: volatile electricity production

Haber Bosch usually operated continuously

Part load operation of the synthesis only down to 20 – 60 % of the nominal load

Complete shutdown is to avoid → long regeneration periods of the reactor (30 – 48 h)



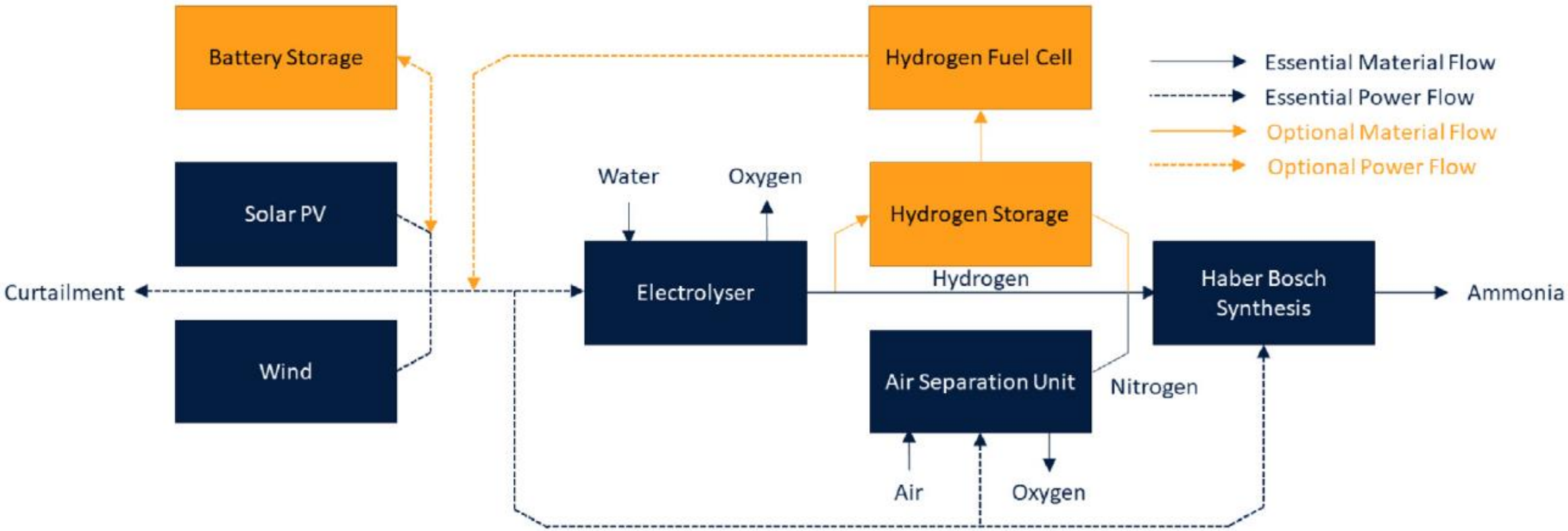
RE only provide volatile power

Excess electricity and hydrogen have to be stored to ensure minimal part load operation

- Overinstallation of RE
- Battery storage
- Hydrogen storage (combined with a fuel cell)
- Combination of the above

Fraunhofer IEE

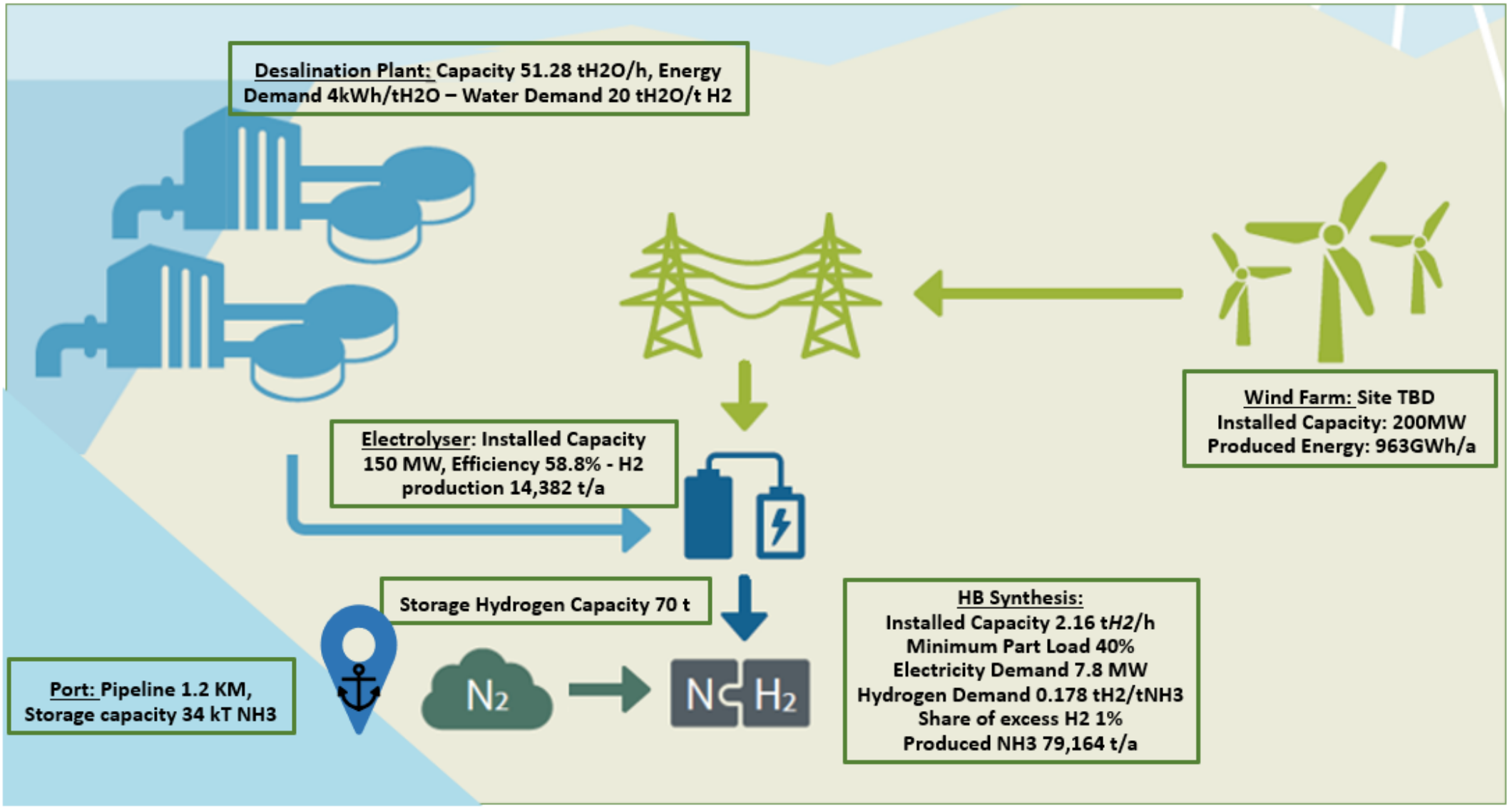
Ammonia – Production system for green ammonia



Fraunhofer IEE

IEE Project Examples
Ammonia, Methanol, E-Fuels

Ammonia – Project Example for green ammonia production in Argentina



Fraunhofer IEE

Methanol – Tunol

General information:

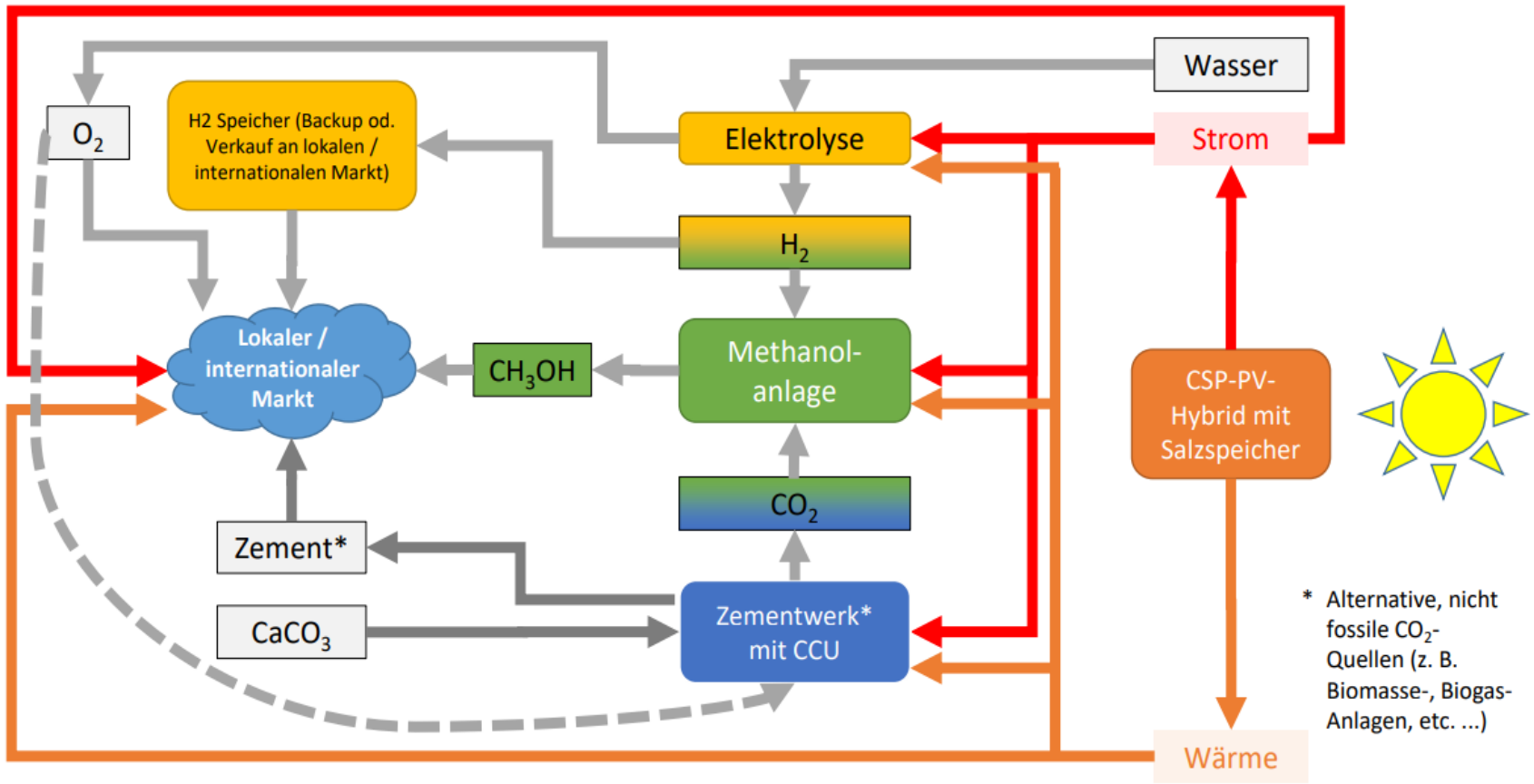
- It aims to use the solar resources of the Sahara for producing e-Methanol.
- This project is part of the SUNol consortium in Tunisia comprised by FEV, TSK Flagsol, DLR, bse Methanol, TUHH, Fraunhofer, Diwan, PtJ and Bilfinger
- This project is funded by the German Federal Ministry for Economic Affairs and Climate Protection (BMWK)
- **Motivation:** construction of an integrated production large-scale production of green methanol in Tunisia.

Fraunhofer IEE

Methanol – Tunol

Technical information:

- Integrated CSP-PV hybrid power plant:
  - Heat potential: **280 GWh/a.**
- Electrolyser with H_2 production of **20,000 tons/a** and **150,000 tons/a of O_2.**
- Methanol plant with production of **100,000 tons/a of MeOH**

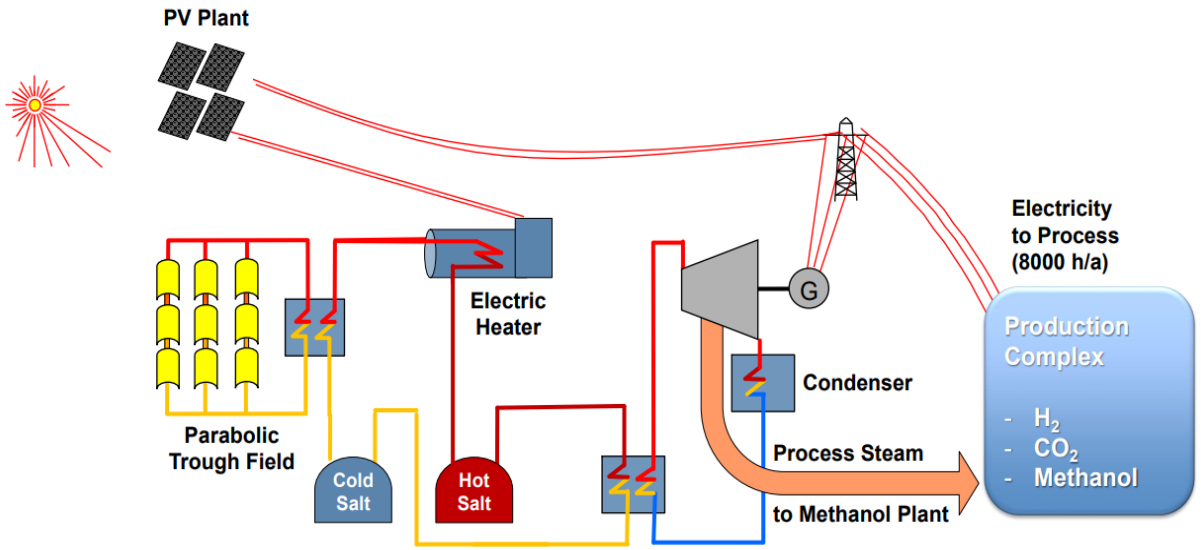


Fraunhofer IEE

Methanol – Tunol

Further key and technical information:

- CSP-PV hybrid plant: It has three stages consisting in:
  - Conversion of radiant energy into thermal energy (means the parabolic mirrors and heat transfer fluid, e.g. salt) and transfer of the thermal energy into a salt storage system and to a water-steam loop,
  - Further heat of the heat transfer fluid by electric heaters and storage of it by storage tank,
  - Thermal energy of the storage tank is used to evaporate and compress water -> steam to a turbine for producing electricity
- Electrolysis technology: Alkali Electrolysis (AEL)
- CO_2 separation: Amine scrubbing enables the capture of CO_2 -> a flue gas is required from other sources e.g. from biomass.
- Methanol synthesis: Combination of H_2 and CO_2 at 40 bar, 240°C.



Fraunhofer IEE

E-Fuels – HyshiFT Renewable Hydrogen Project

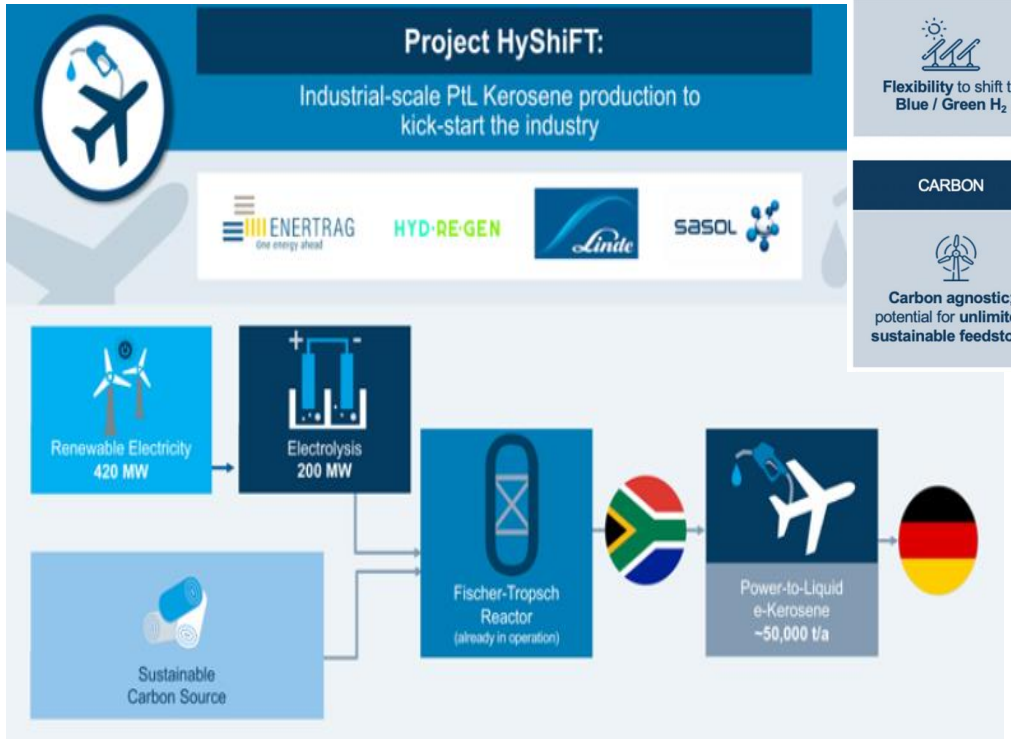
General information:

- Project aims to produce **sustainable aviation fuel (SAF) or renewable kerosene**.
- Location of the project: Secunda in Mpumalanga, South Africa
- HyshiFT consortium comprised by Linde, South Africa's chemical and energy company Sasol, Enertrag and HydRegen Energy.
  - Enertrag produces renewable power from wind and solar
  - Linde produces green hydrogen
  - Sasol (based in South Africa) supports with its expertise in the conversion into green aviation fuel.
- Funding from the German Economic Affairs and Climate Action Ministry, which is providing **€15 Mio** for the first phase of the project.
  - First stage of the project: **40 MW** electrolyser to be built.
- Sasol has commited to reducing its carbon emissions by 30 % by 2030

E-Fuels – HyshiFT Renewable Hydrogen Project

Technical information:

- The target is to produce **50,000 tons/day** of PtL Kerosene
  - This quantity can fuel 2 flights between Germany and South Africa per day.
- The PtL-Kerosene is planned to be produced through a carbon-feedstock such as biomass. The green hydrogen through powered wind and solar farms.
- The carbon and green hydrogen are converted to synthetic gas and then processed into SAF via Fischer-Tropsch (FT).
- Renewable electricity: **420 MW**
- Electrolyser capacity: **200 MW**



Fraunhofer IEE

E-Fuels – HyshiFT Renewable Hydrogen Project

Further key information:

- The group has the target to transform the OR Tambo International Airport into a global sustainable aviation hub
- Sasol's intention is to bid under the German **H2Global consortium**
- Sustainable carbon must be accounted for this product: product must be recognized by the EU Renewable Energy Directive.
- If the project receive such H2Global support:
  - HyshiFT program would seek to **displace 1 % of the grey hydrogen** currently used in Secunda with green hydrogen.

Fraunhofer IEE

Contact

Jochen Bard

Energy Process Technology Division

Jochen.Bard@iee.fraunhofer.de

Fraunhofer IEE
Joseph-Beuys Straße 8,
34117 Kassel
www.iee.fraunhofer.de