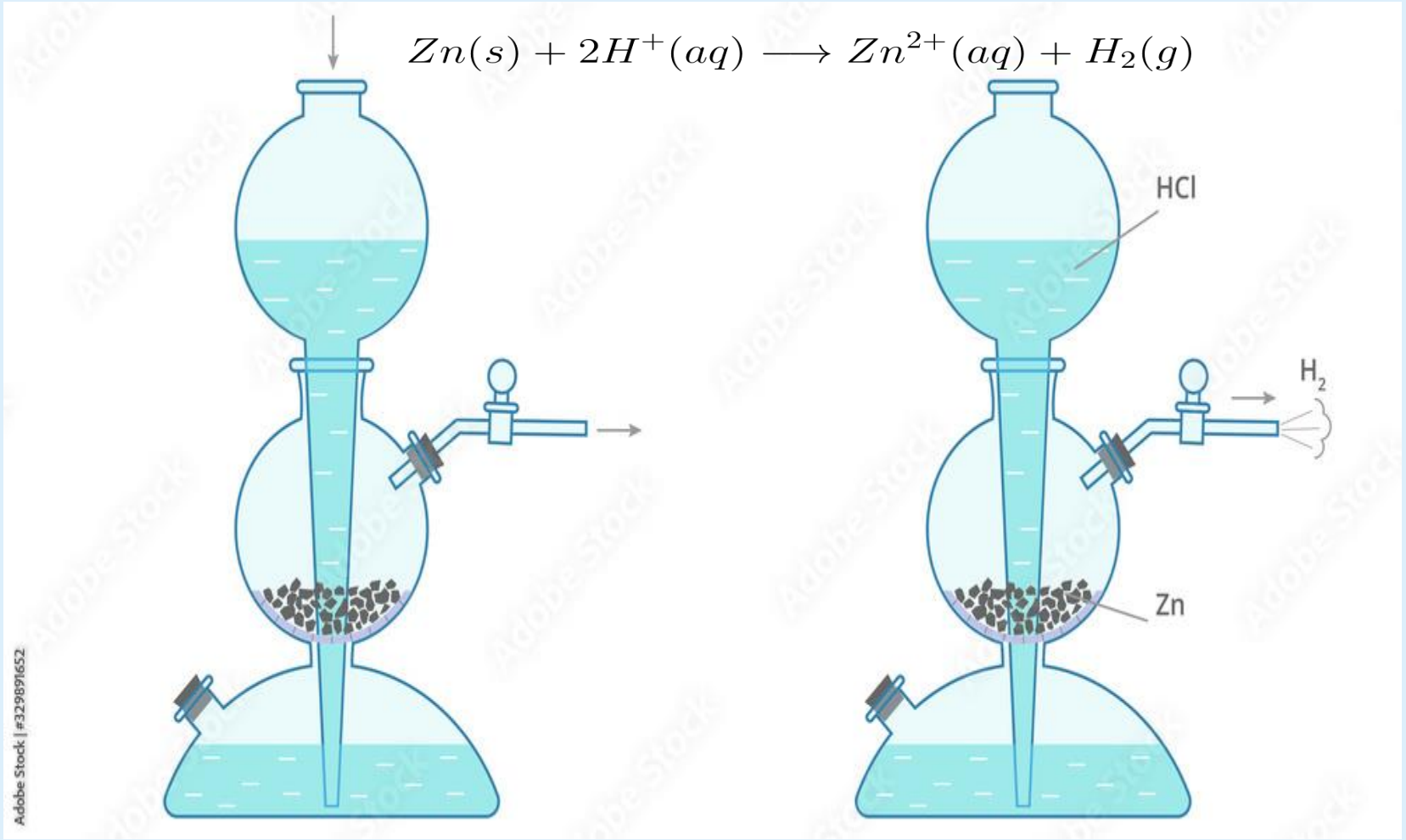
KIVI KRING CARIBBEAN – ARUBA

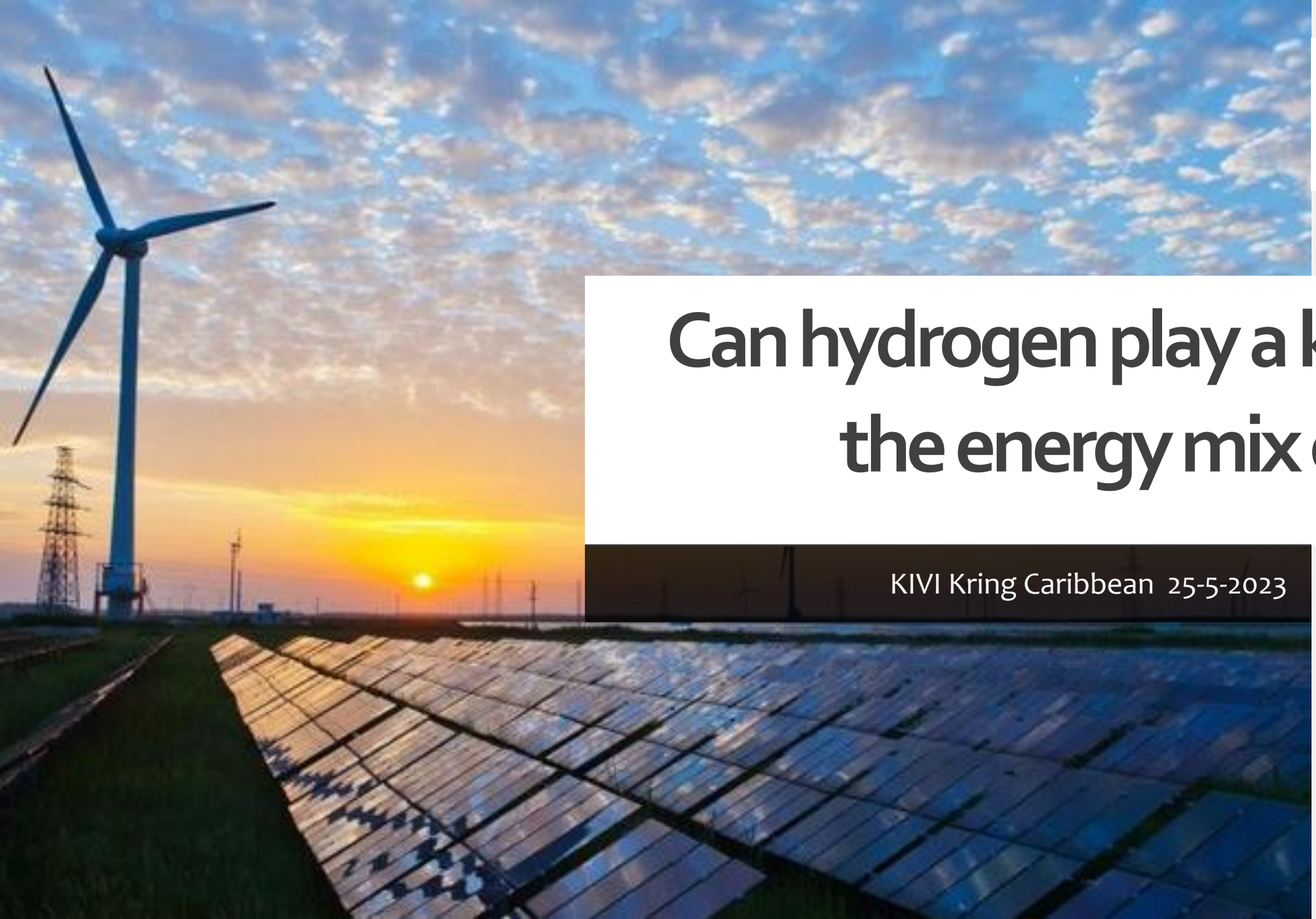
MORE INFO ON

Kring Caribbean | KIVI

KIPP'S APPARATUS

1844 PETRUS JACOBUS KIPP





Can hydrogen play a key role in the energy mix of aruba?

KIVI Kring Caribbean 25-5-2023

TODAY'S PRESENTATION
ABOUT THE PRESENTER

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- Mech eng. (BSc) & Sustainable Energy Technology (MSc) @TU Delft
- Energy Advisor at Van Dorp Installaties since 2017

Specialized in:

- Feasibility studies on Sustainability
- Renewable energy: Solar PV & thermal, heat pumps
- ATES- specialist (Aquifer Thermal Energy Storage)

Experience with Green Hydrogen project: Innovahub

TODAY'S PRESENTATION

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4. Aruba & Green Hydrogen

IN THE NEWS

ARUBA'S HYDROGEN VALLEY

ARUBA TODAY
Aruba's only English newspaper

Aruba's refinery zone to transform into Energy Valley

ARUBA NU
Altijd het laatste nieuws

Aruba is taking the next step to transform Valero refinery into a hydrogen plant

Apr 12, 2023 Editorial 924

IN THE NEWS

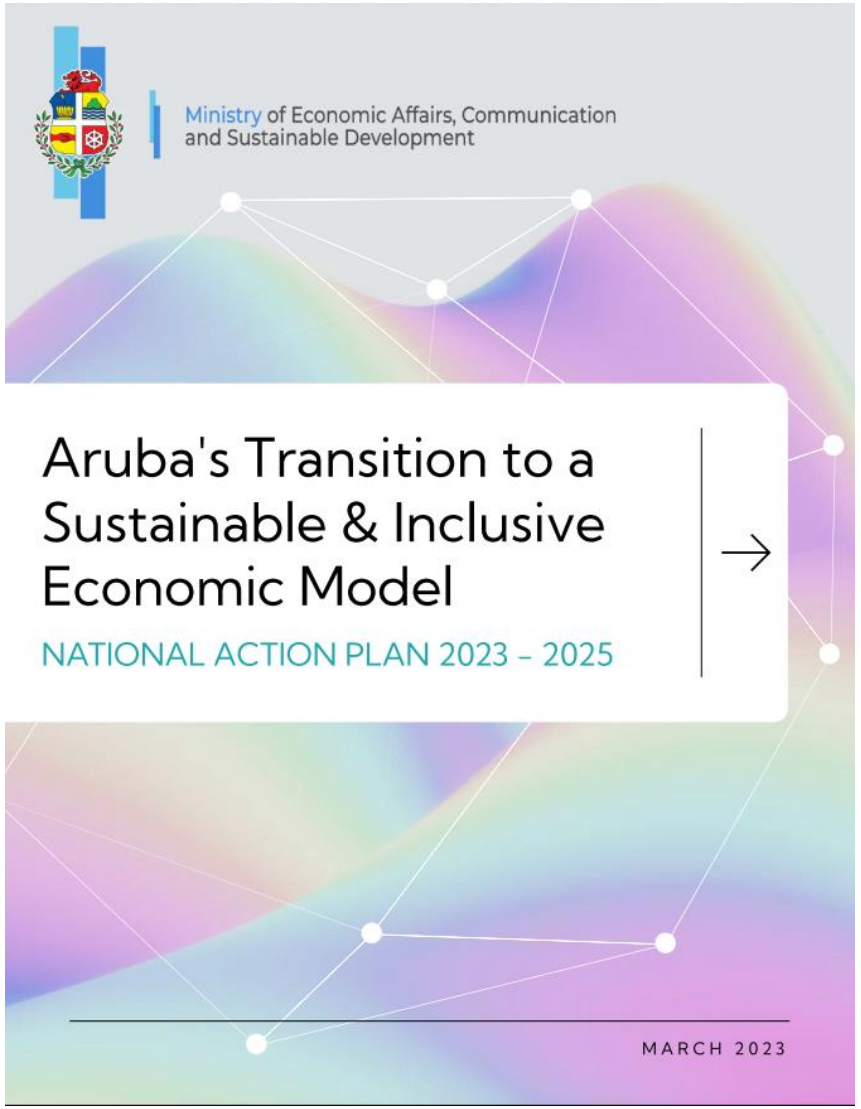
ARUBA'S HYDROGEN VALLEY

3.2.3 TRANSNATIONAL GREEN HYDROGEN CHAIN

"Countries with an abundance of renewable energy, access to water, and trade routes to major demand centers (such as Europe) have the ***opportunity to become producers and exporters of green hydrogen****"*

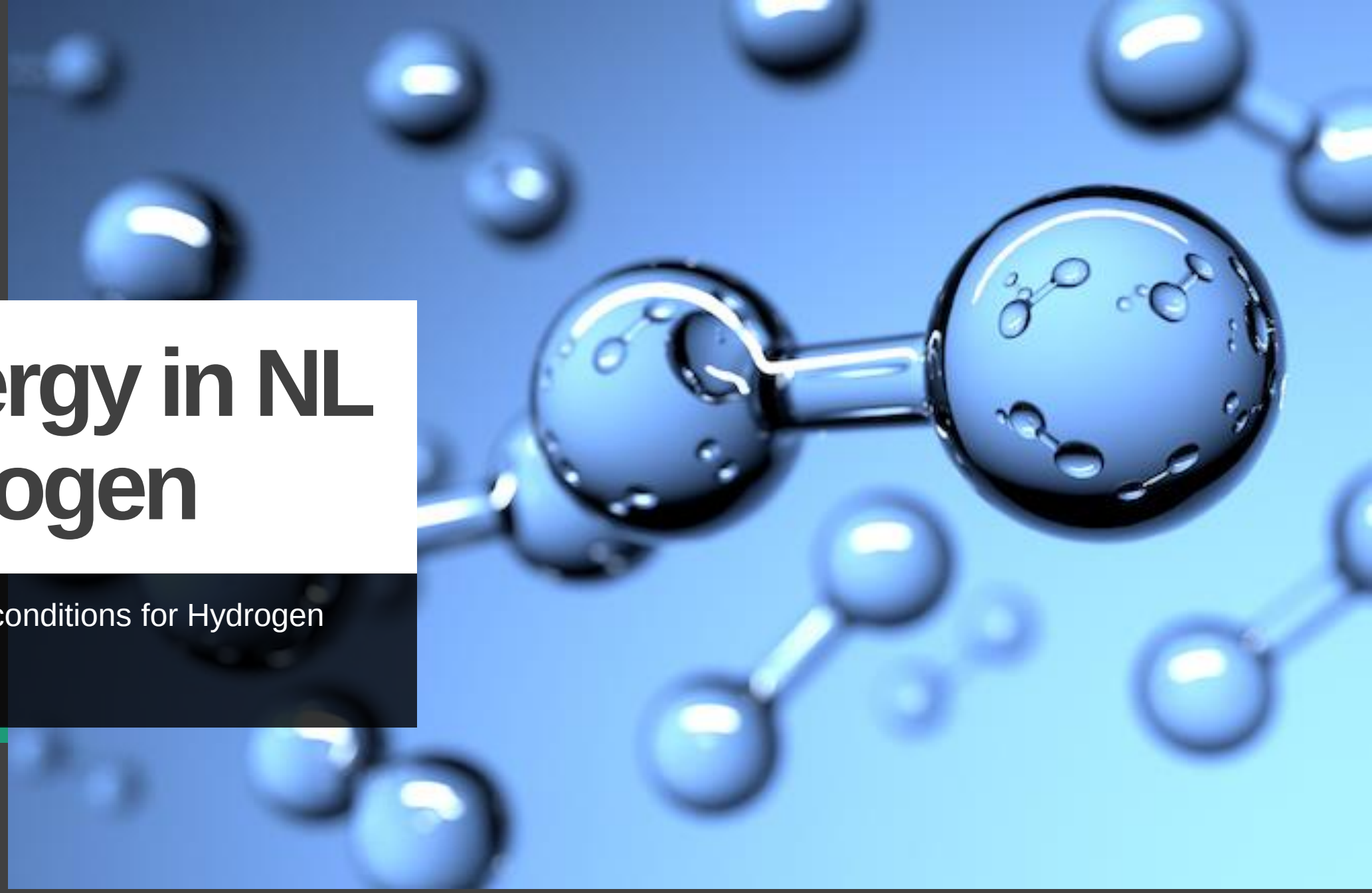
"..assess the feasibility of a ***transnational value chain for green hydrogen*** *in Aruba."*

Can Hydrogen play a key role in the energy mix of Aruba?



1 – Energy in NL & Hydrogen

Energy system and conditions for Hydrogen



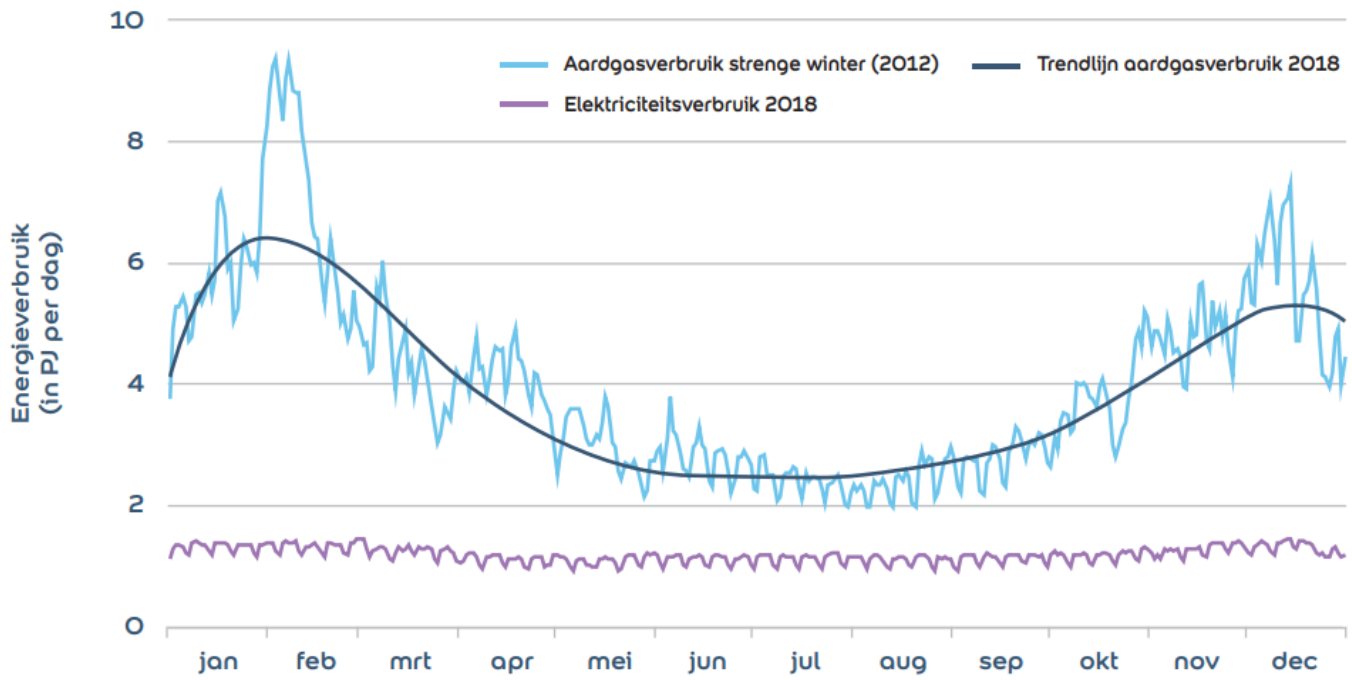
ENERGY & HYDROGEN

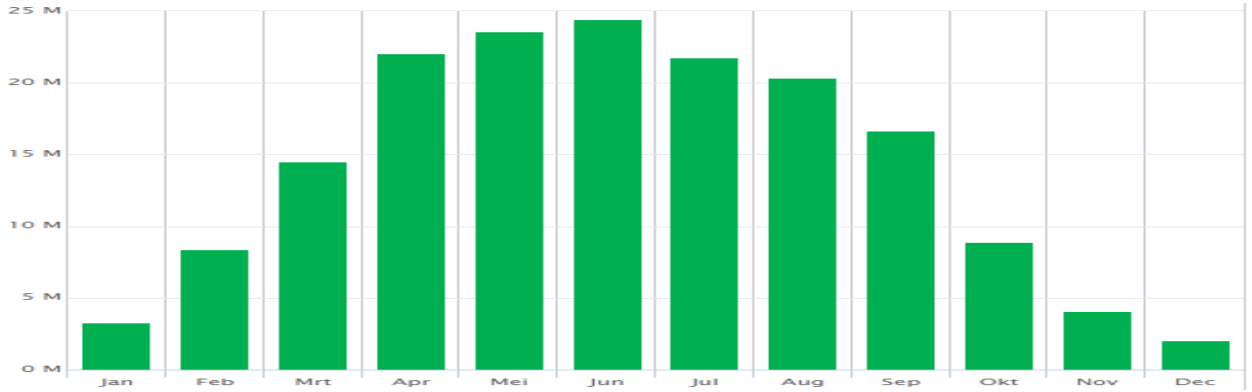
ENERGY SYSTEM NETHERLANDS

Dutch energy transition:

- Phase out fossil fuels - natural gas
- Replace by wind & solar
- Displacing the energy of gas by electrification is a challenge
- Electricity grid reinforcement very costly
- Seasonal mismatch between production and demand

Solution: Seasonal energy storage





ENERGY & HYDROGEN

ENERGY STORAGE METHODS

Given the geographic characteristics of the NL

For NL grid system:

- Batteries: short term storage -> day/night
- **Hydrogen: long term storage -> several weeks/months**

ENERGY & HYDROGEN

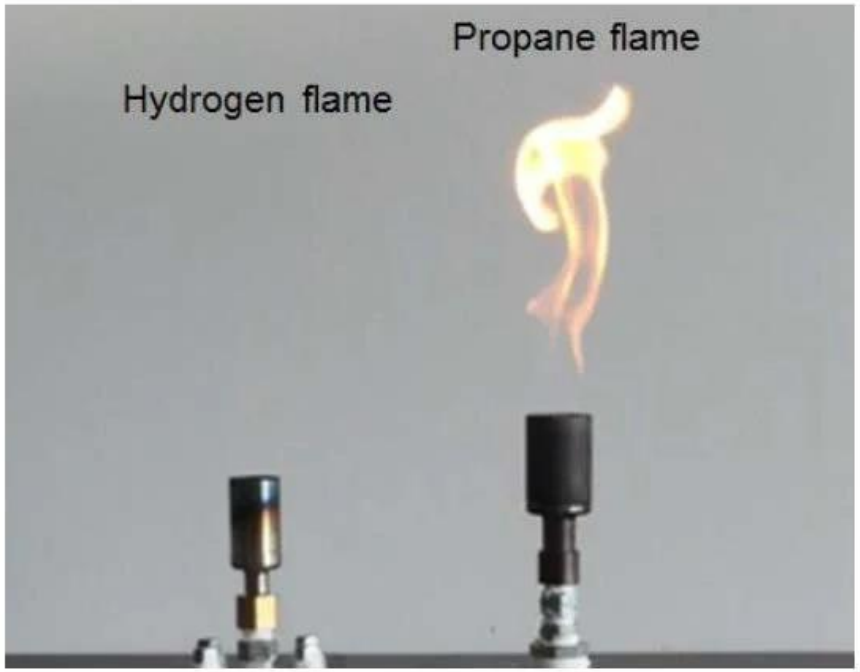
PERFECT ECOSYSTEM FOR HYDROGEN

- Existing Gas infrastructure to re-use
- Large Offshore wind capacity
- Reduce electricity grid congestion
- Long distance Transport sectors
- Energy intensive industry: Steel, glass, fertilizer, Horticulture

ENERGY & HYDROGEN

HYDROGEN: SOME INTERESTING PROPERTIES

- Lightest element of Periodic Table
- Energy carrier, not a source
- High energy density capacity
- Highly flammable! Needs only 4 % vapor concentration in air to form explosive mixture
- 14x lighter than air. Rises with 17 m/s



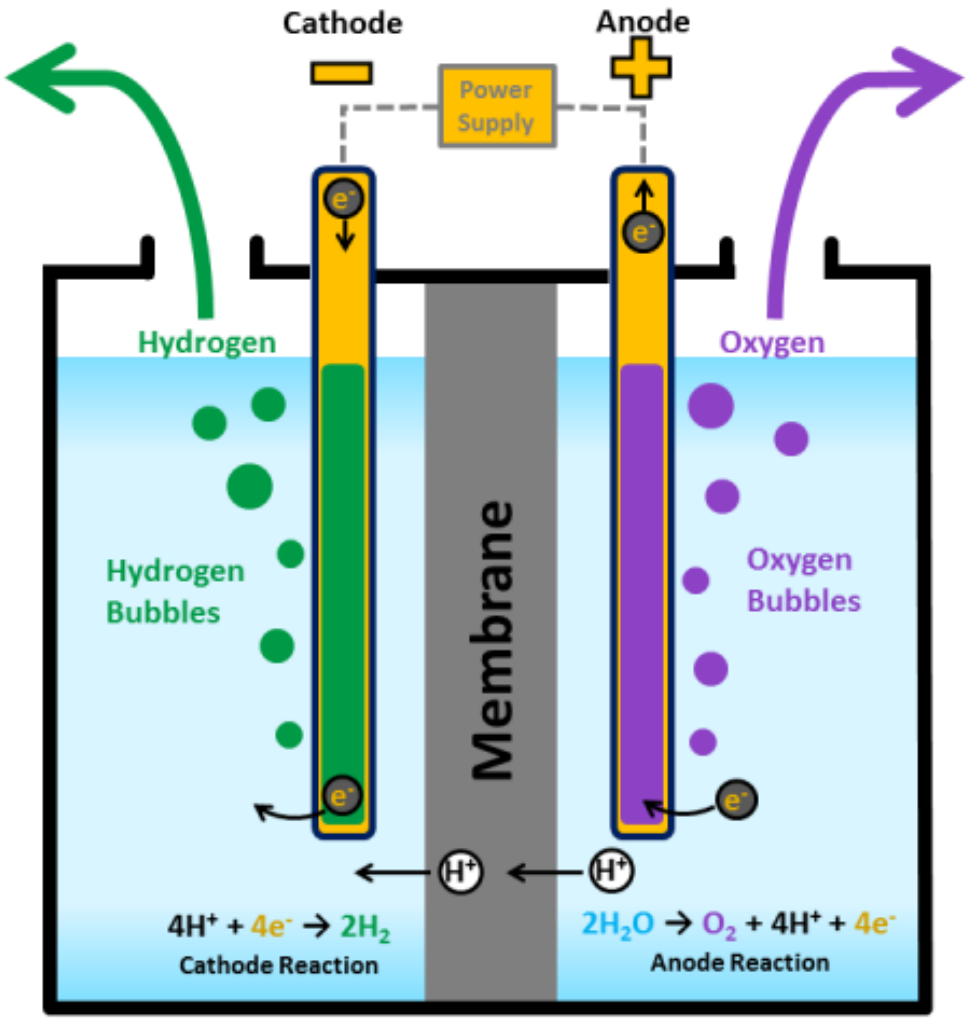
HYDROGEN
PRODUCTION METHODS

Most relevant:

- **Steam reforming of Methane**
- **Electrolysis**

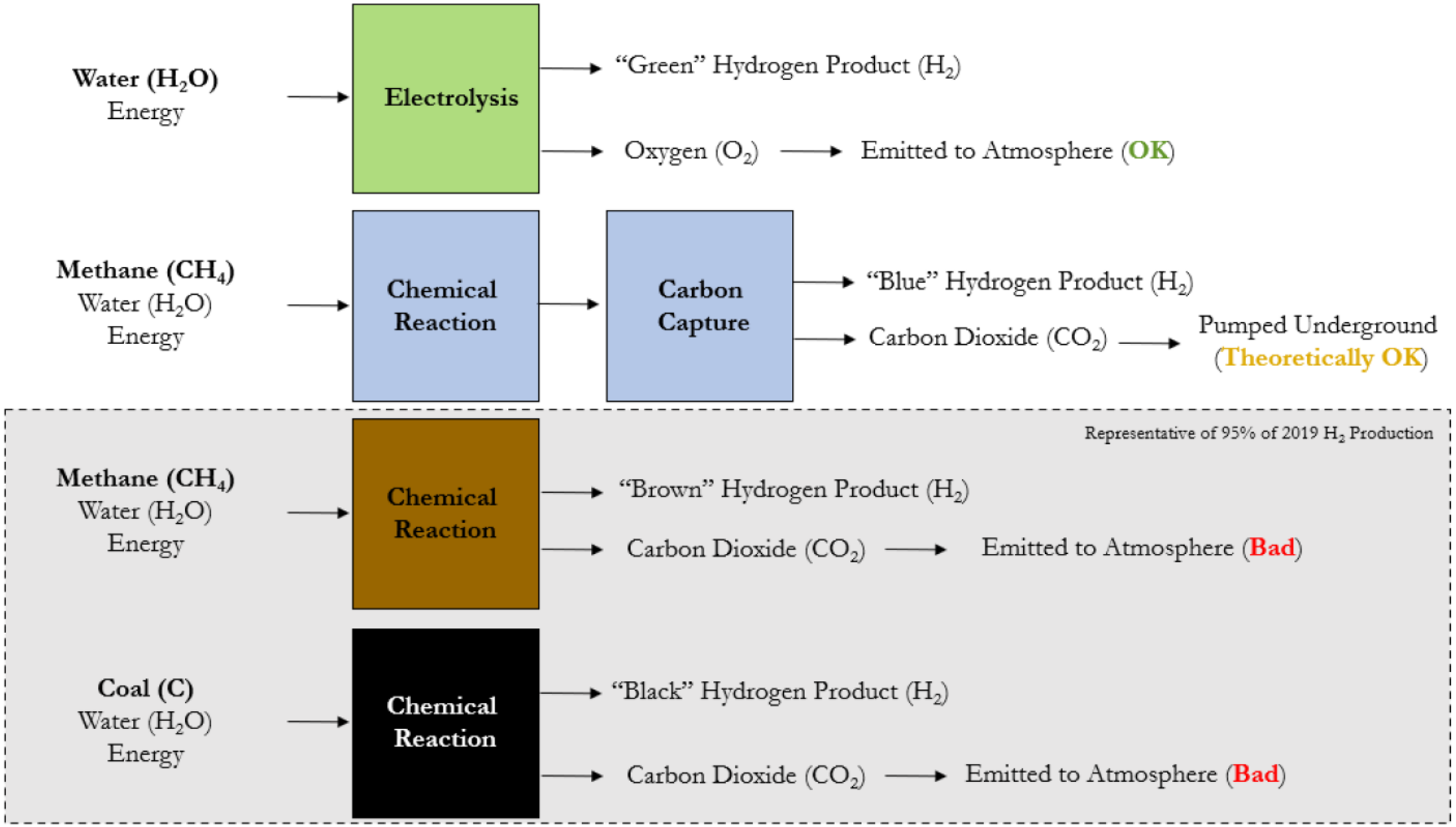
Other:

- Thermolysis
- Photochemical separation



Source: https://newatlas.com/energy/hysata-efficient-hydrogen-electrolysis: 20-5-2023

HYDROGEN
PRODUCTION METHODS



Main Pathways for Producing Hydrogen (Actual and Proposed)

HYDROGEN

ELECTROLYSIS: TECHNOLOGIES

Splitting water into H_2 and O_2 by input of electricity

Currently mainly used:

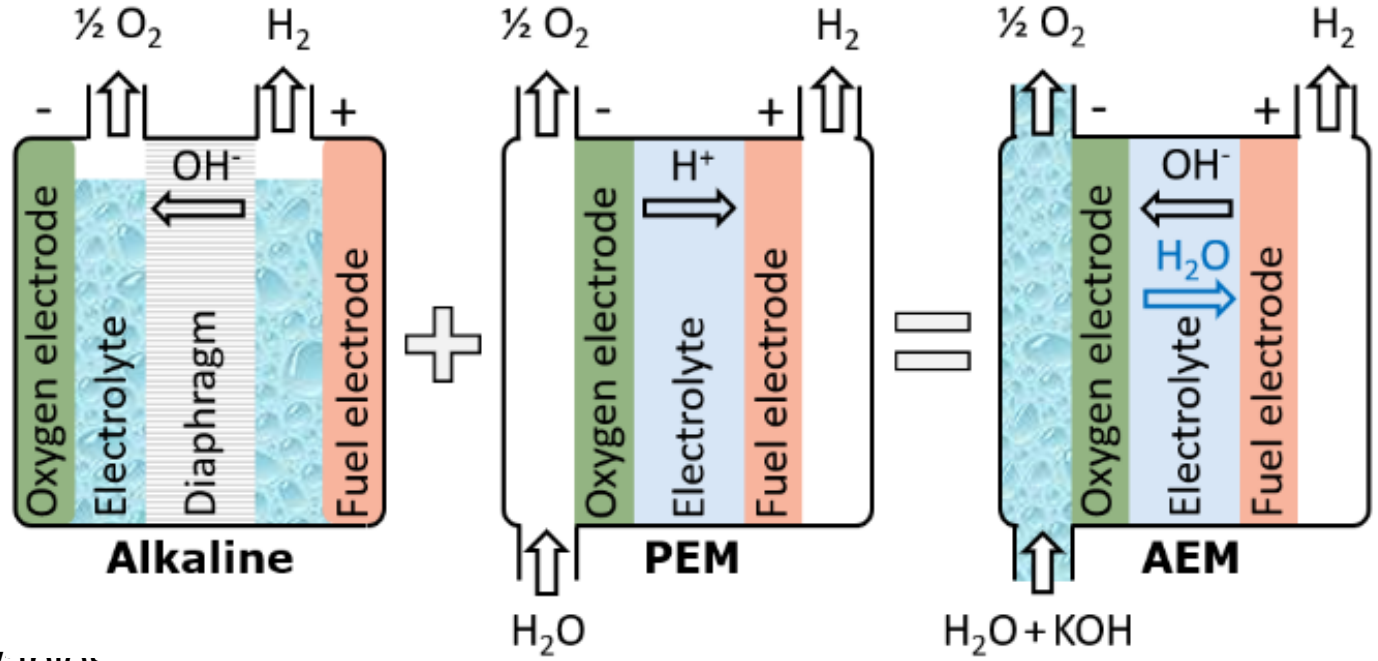
- Alkaline: Liquid electrolyte: KOH
- Polymer Electrolyte Membrane

Challenges:

- Increasing electric current density
- avoiding scarce and expensive materials
- compatibility with intermittent electricity of renewables

Current solution:

- Anion Exchange Membrane



Source: https://www.differ.nl/news/SCALE 20-5-2023

HYDROGEN
AS STORAGE AND TRANSPORT MEDIUM

- Liquified: Cryogenic storage at -253 °C
- As chemical bond: Methanol, Ammonia
- Metal Hydrides
- Pressurized gas: 250 – 1000 bar (!)

Energy Density of Hydrogen	Volumetric Density (kg / m^3)	Energy per Liter (kWh / L)
Liquid Hydrogen @ -252.9 °C	70.9	2.361
Gaseous Hydrogen @ 70 MPa	42.0	1.400
Gaseous Hydrogen @ 35 MPa	26.1	0.870
Gaseous Hydrogen @ STP	0.09	0.003
Gravimetric Energy Density (kWh per kg)	33.33	
Density of Liquid Hydrogen (g/L)	70.9	

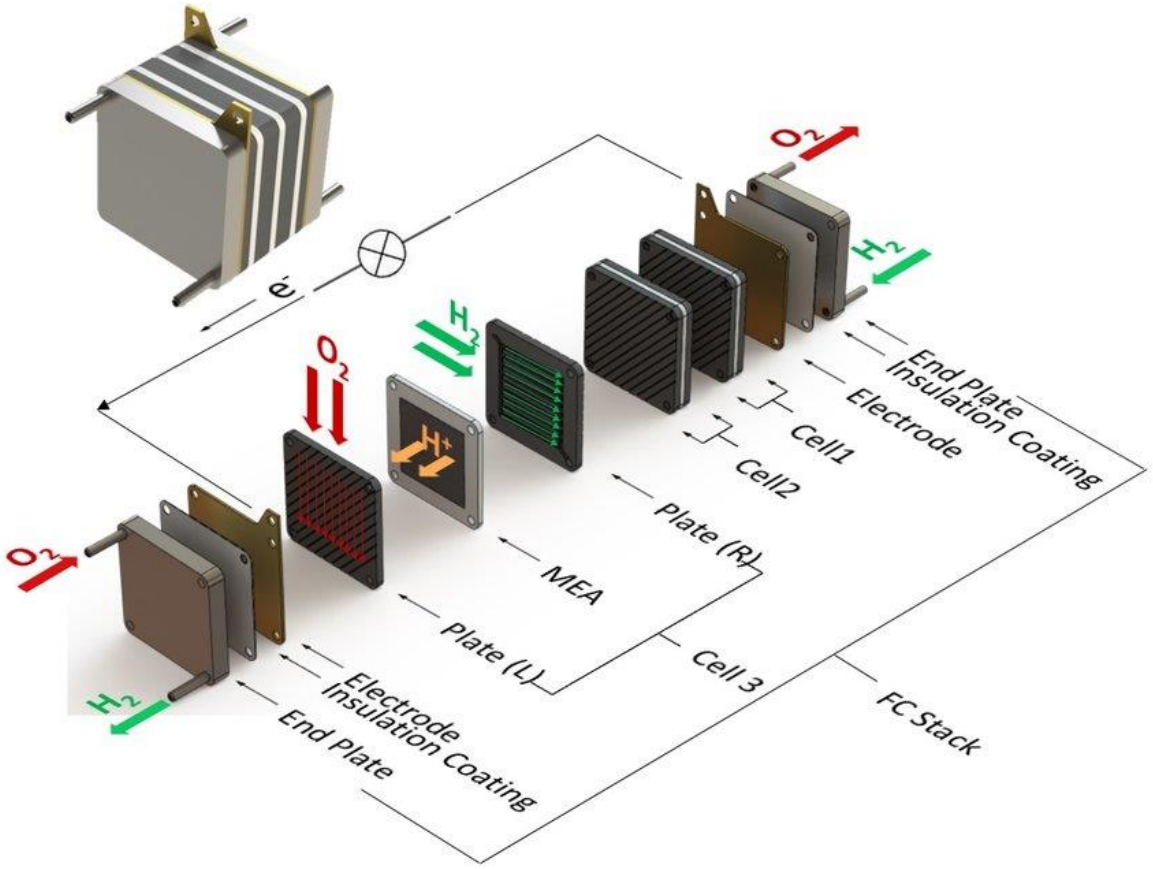
Source: https://www.quora.com/If-we-could-store-hydrogen-in-liquid-form-how-does-the-energy-density-of-liquid-hydrogen-compare-to-typical-gasoline 20-5-2023

HYDROGEN
APPLICATION

- Direct combustion
  - Heat applicatons: boilers for space heating
  - Combustion engines: mobility & electricity generation

- Fuel Cells-> Direct generation of electricity
  - Heat as ‘waste product’
  - Cogeneration efficiency up to 85%

- Feedstock
  - Methanol
  - Ammonia



Source: https://www.researchgate.net/figure/Schematics-of-a-fuel-cell-stack-operation-and-components_fig2_309898224 20-5-2023

HYDROGEN
ECONOMICS

- Current cost/kg:
  - Gray hydrogen: 2 - 4 $/kg
  - Green hydrogen: 8 - 10 $/kg
- US DOE 2021: Hydrogen Shot: 111
- Estimation for 2050: $0,80 /kg *
- Swansons Law: (power)x2 = 20% cost reduction
- CO2 tariffs need to be applied to level the playing field

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Bloomberg New energy finance 2019

Source: www.sgh2energy.com : 20-5-2023

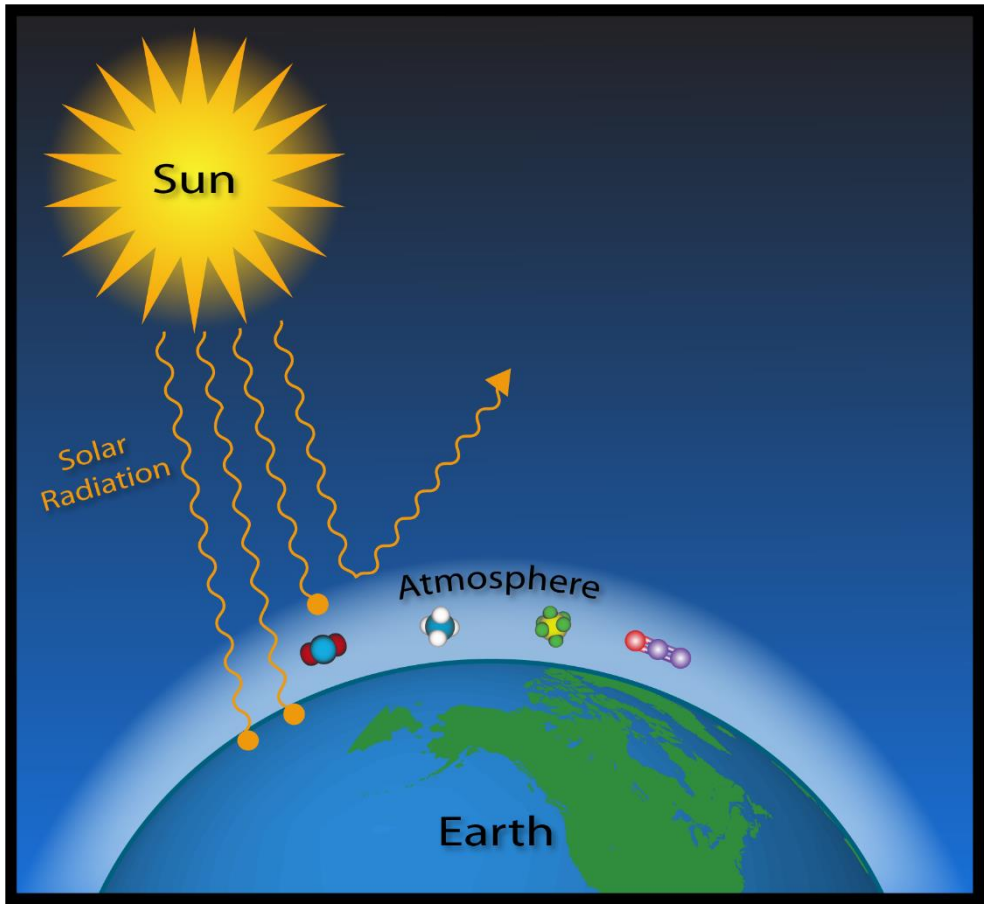
ENERGY & HYDROGEN

HYDROGEN: GREENHOUSE GAS!

Hydrogen is a Greenhouse Gas!

Leaked hydrogen:

- reacts with pollutants to extend their lifetime in the atmosphere.
- can impact ozone concentrations
- creates water vapor in the atmosphere, enhancing the GG effect.

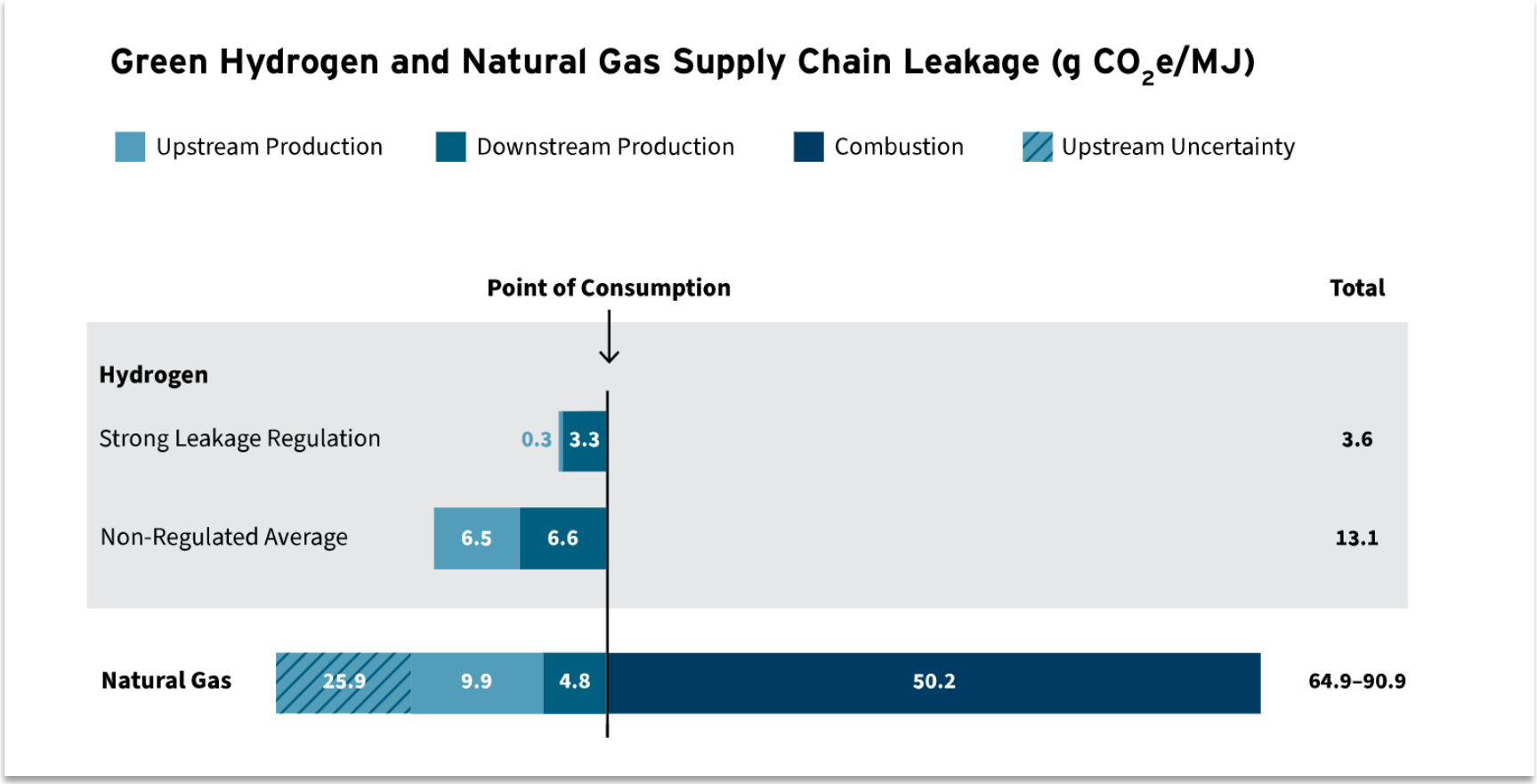


Source: https://rmi.org/hydrogen-reality-check-1-hydrogen-is-not-a-significant-warming-risk/ 20-5-2023

ENERGY & HYDROGEN

HYDROGEN: GREENHOUSE GAS!

Benefits of Hydrogen in the energy transition strongly outweigh the possible negative impact!



Source: https://rmi.org/hydrogen-reality-check-1-hydrogen-is-not-a-significant-warming-risk/ 20-5-2023

2 – Innovahub Project

Local Green hydrogen production, storage and consumption

HYDROGEN

INNOVAHUB PROJECT: PILOT PROJECT NEAR ROTTERDAM

The main objective: to supply renewable heat, cold and electricity to residencies all year round.

To reach this goal: apply seasonal energy storage in the form of green hydrogen

which enables:

- Creating daily energy balance
- Creating yearly energy balance
- Reducing congestion of the local electricity grid
- Maximizing the utility of locally produced renewable energy

HYDROGEN

INNOVAHUB PROJECT: PARTNERS AND ROLES

Hylife Innovations:

- Project owner
- Hydrogen component selection, in cooperation with suppliers
- EMS – Energy management System

Giacomini:

- Preliminary system design & supplier of hydronic components & Hydrogen boiler

Van Dorp:

- System designer of hydronics and HVAC
- System integrator on mechanical side: hydronic & Hydrogen

VHE:

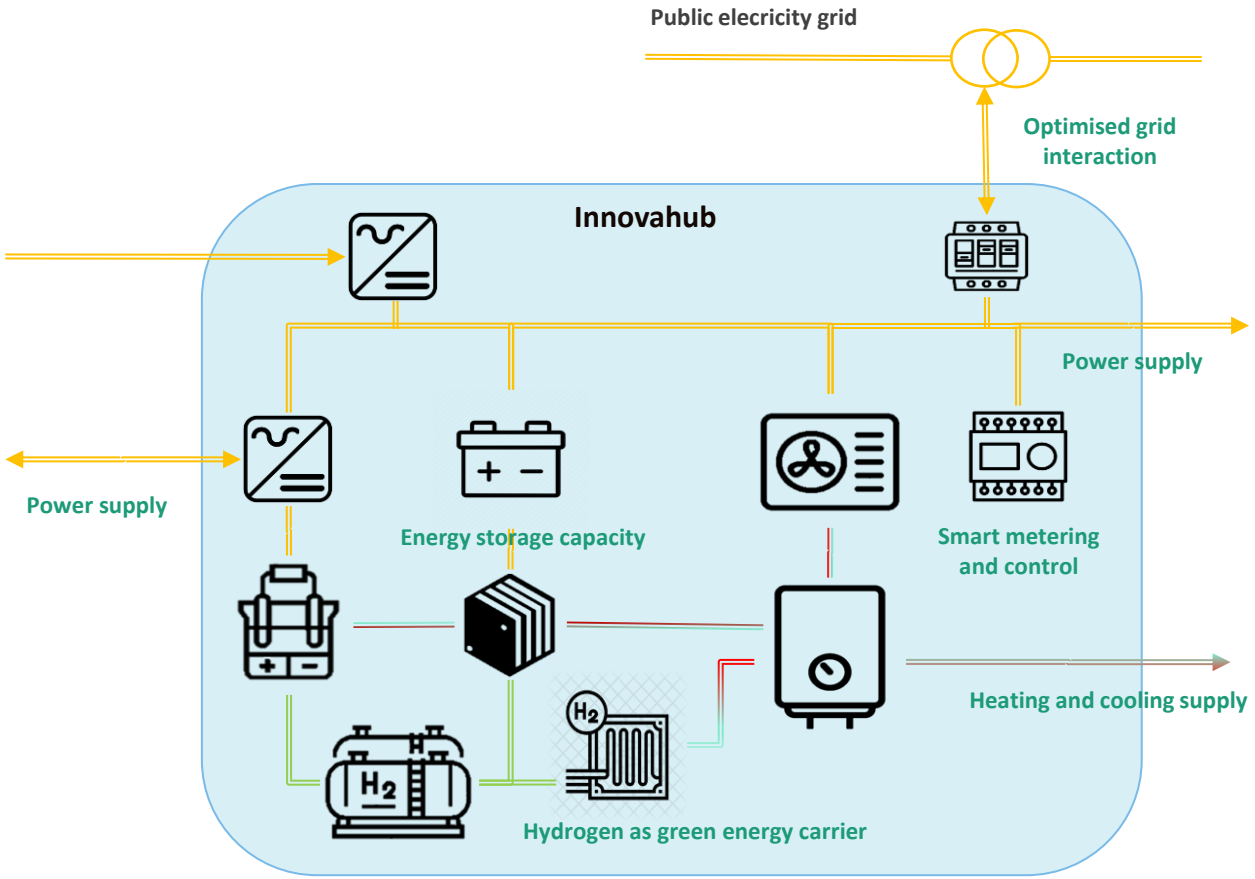
- ECS – Energy control system

HYDROGEN

INNOVAHUB PROJECT: OVERALL SYSTEM SCHEMATIC FOR PILOT

Local renewable energy

V2G electric mobility



Large scale production

Built environment

Heat networks

HYDROGEN

INNOVAHUB PROJECT: MAIN COMPONENTS

Heating:

- Heat pumps
- Fuel cell
- Catalytic boilers

Cooling:

- Heat pumps

Storage:

- Thermal buffers 4000L & 2000L
- Batteries
- Low pressure H2 storage (35 bar)
- High pressure H2 storage (270 bar)

Other Hydrogen components:

- AEM Electrolyzers (30x)
- Hydrogen compressor

HYDROGEN

INNOVAHUB PROJECT: CONTROL SYSTEMS

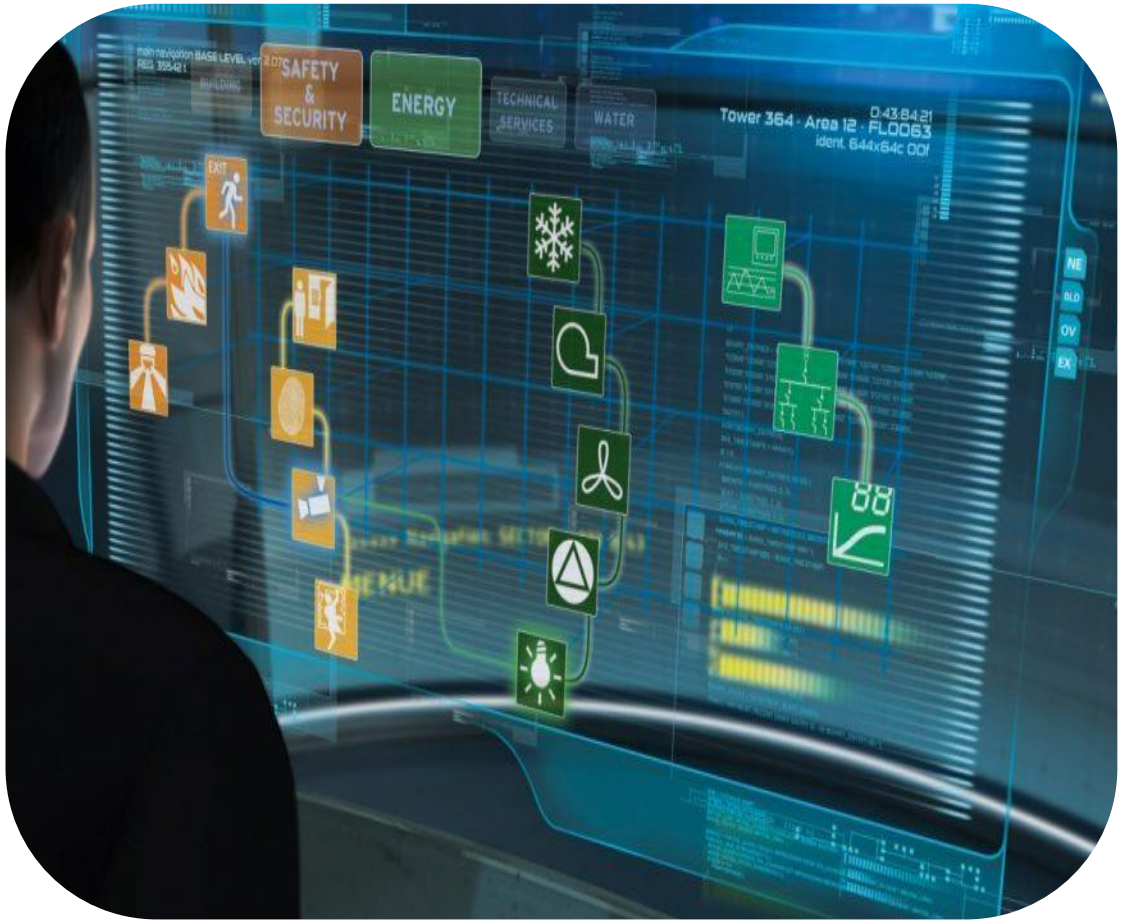
Two layers of control:

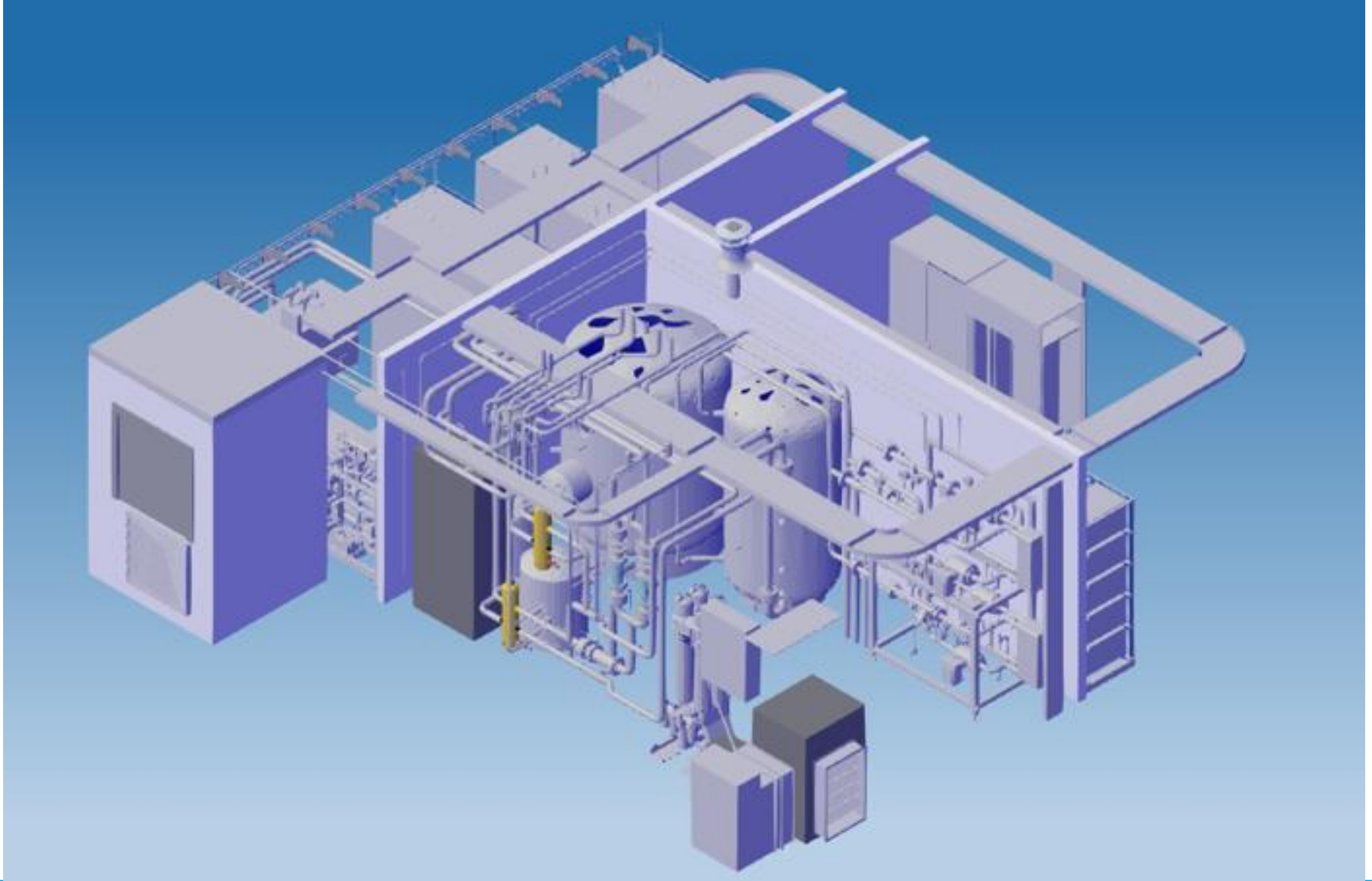
ECS – Energy control system

- Basic functionalities
- Safety systems

EMS – Energy monitoring system – layer on top of ECS

- Automated decision making
- Forecasting:
  - Weather -> sun & wind predictions
  - energy prices
  - utility net pricing (congestion pricing)





HYDROGEN

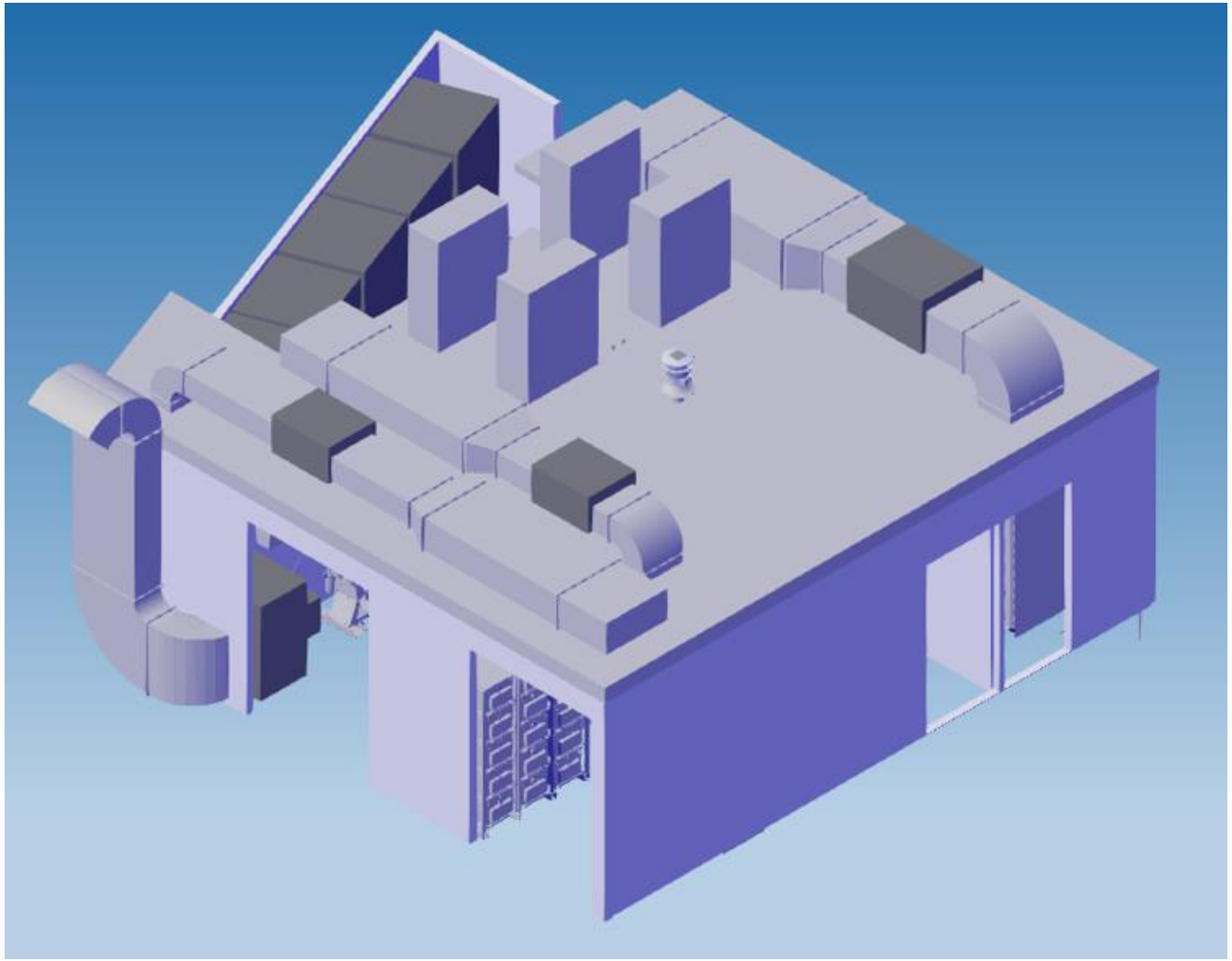
INNOVAHUB PROJECT: ENGINEERING CHALLENGES

Hydrogen Safety:

- HAZOP & HAZID analyses
- Redundancy on safety valves
- Venting systems

Noise limits -> residential neighborhood

- Air cooled equipment:
  - compressors: Hydrogen and air
  - electrolyzers




GRUNDFOS


MADE BY SANDVIK IN CZECHIA *OA-TUBE*

3- Aruba's energy system

Demand, Production and Renewable Energy

ARUBA'S ENERGY SYSTEM

INSTALLED CAPACITY ELECTRICITY GENERATION

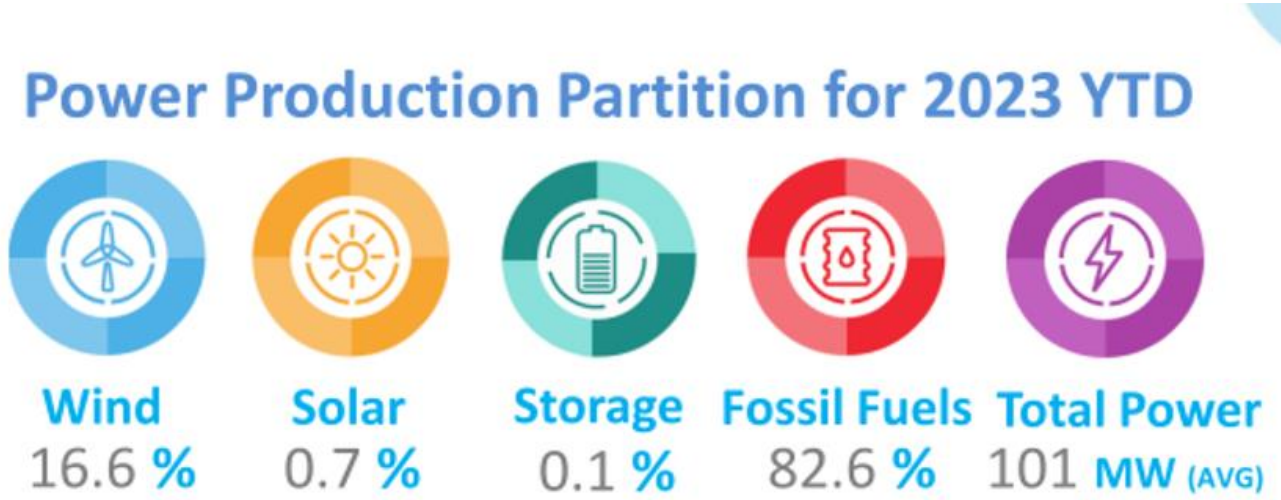
EQUIPMENT	INSTALLED CAPACITY
RECIP Phase 1+2 (6 Engines)	46.8 MW
RECIP Phase 3 (4 Engines)	45.2 MW
RECIP Phase 4 (6 Engines Dual Fuel)	102 MW
GAS TURBINES	22.00 MW
WIND TURBINES	30.00 MW
SOLAR PV	6.5 MW
ENERGY STORAGE	1 MW
AVERAGE ARUBA DEMAND	**108 MW**
MAX DEMAND PEAK	**155 MW**

Source: www.webaruba.com 20-5-2023

ARUBA'S ENERGY SYSTEM
ENERGY PRODUCTION

2023 YTD production:

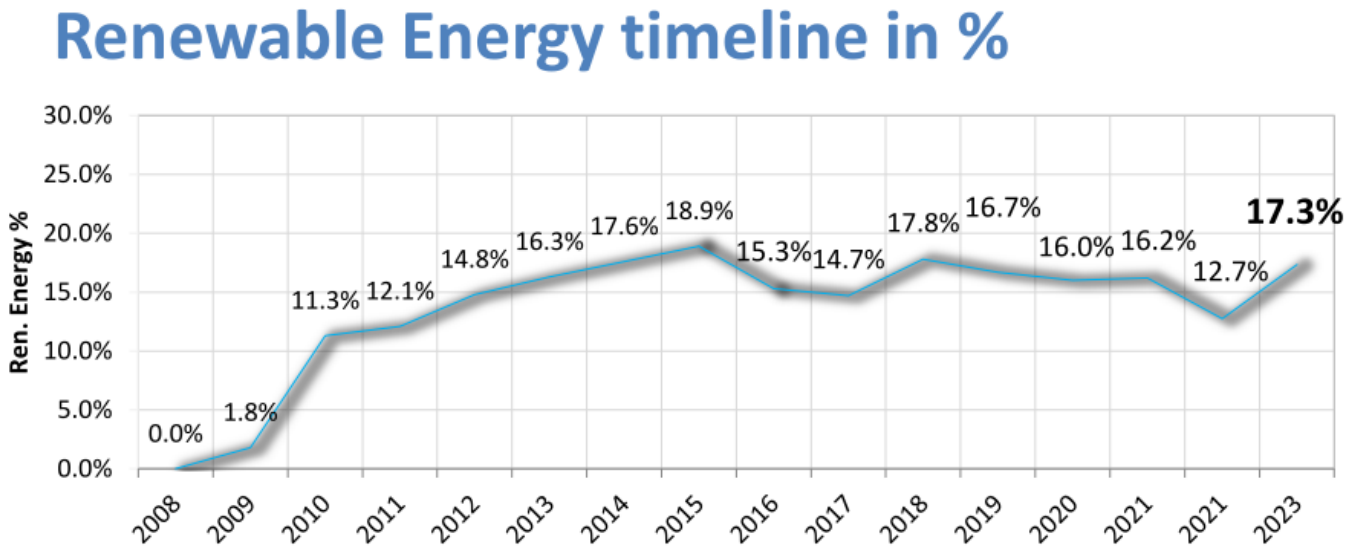
- Fossils: 82,6%
- Renewables: 17,3%
  - 16,6 % wind
  - 0,7 % solar

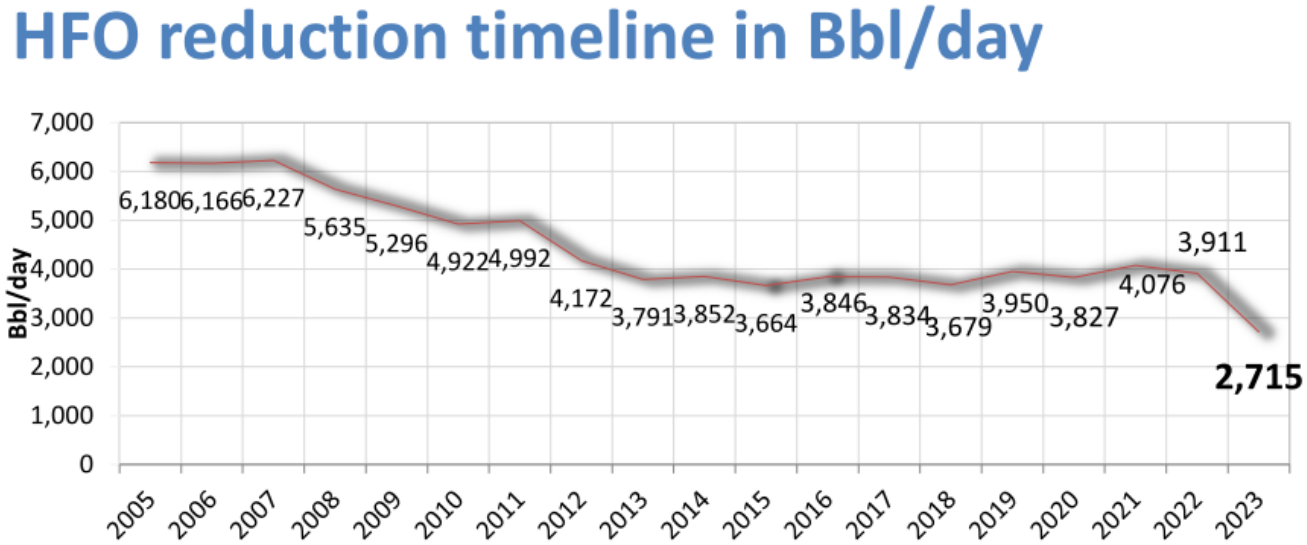


Source: www.webaruba.com 20-5-2023

ARUBA'S ENERGY SYSTEM
RENEWABLE ENERGY

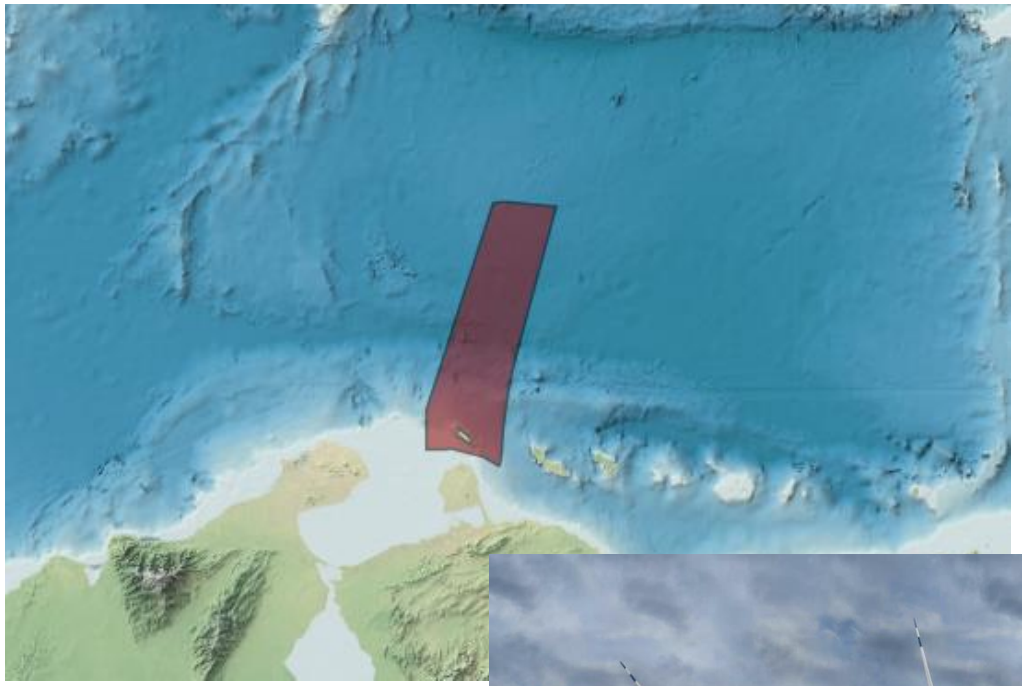
- Current renewable production:
  - 16,6 % wind
  - 0,7 % solar
- HFO reduction;
  - 2007-2013: steady decline
  - Stagnation in decline as of 2013
- SDG - Targets for 2030: 45% reduction of emissions (compared to 2010)





Source: www.webaruba.com 20-5-2023

ARUBA'S ENERGY SYSTEM
RENEWABLE ENERGY



Renewable energy potential is very high

- Current renewable installed capacity:
  - 30 MW onshore wind
  - 6,5 MW solar

- Most obvious assets to add:
  - Onshore wind
  - Solar

- Near future: Offshore wind

ARUBA'S ENERGY SYSTEM
STORAGE

Storage is necessity:

- For grid balancing purposes
- Given intermittent character of renewables,

Current storage:

- 2017: 1 MW BESS

- 2018: Pilot - > 20 underground Flywheels
  - 5MW for 12 minutes
  - Currently not grid connected

Battery Energy Storage (BESS)

Flywheel Park

Source: www.webaruba.com 20-5-2023

ARUBA'S ENERGY SYSTEM

STORAGE

For 100% renewable energy, Aruba needs more storage capacity.

Obvious choice: Batteries

- Good option for day/night and grid balancing,
- Batteries have some drawbacks
- Other storage means are welcome!

ARUBA'S ENERGY SYSTEM
CURRENT PLANS

- Expansion of current windpark: up to 35% RE
- Current short term plans for refinery terrain: LNG terminal
  - 2025: LNG as replacement for HFO in RECIP's
  - Reduction of CO2 and emissions
- LNG can be used as feedstock for grey (or blue) hydrogen.

  But this is not Green Hydrogen!

4 – Aruba & Hydrogen

Hydrogen valley for Aruba?

ARUBA & HYDROGEN

HYDROGEN OPPORTUNITIES

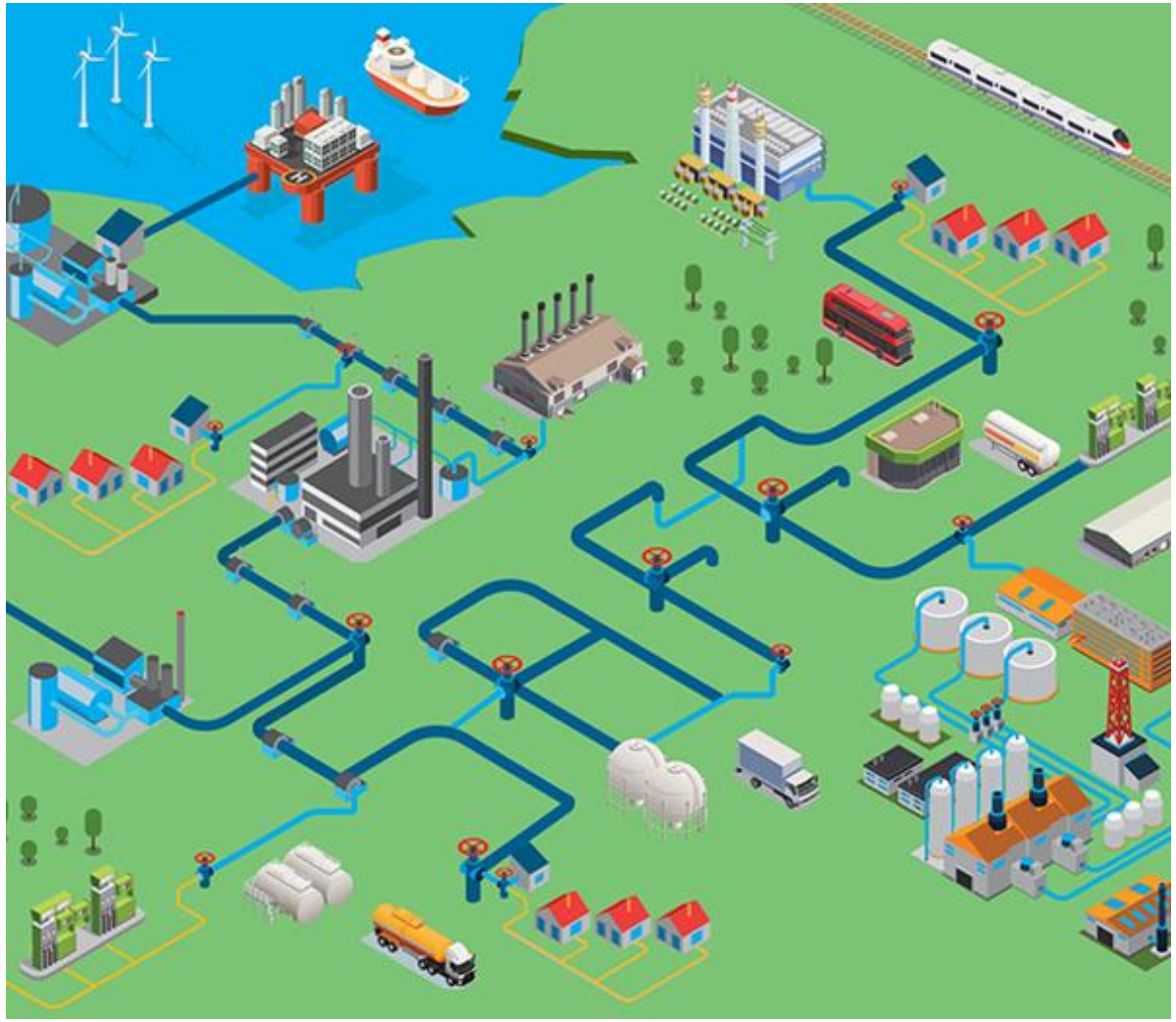
Hydrogen is growing fast worldwide!

ENERGY & HYDROGEN

WHAT IS A HYDROGEN VALLEY?

“Hydrogen Valley”

- geographical area: a city, a region, an island or an industrial cluster
- where several hydrogen applications are combined together into an integrated hydrogen ecosystem
- consumes a significant amount of hydrogen, improving the economics behind the project.
- should ideally cover the entire hydrogen value chain: production, storage, distribution and final use.



Source: www.thechemicalengineer.com 20-5-2023

ARUBA & HYDROGEN

CAN HYDROGEN PLAY A KEY ROLE IN THE ENERGY MIX OF ARUBA?

Negative perspective

Aruba

1. has little industry that uses a high-T process (no steel or glass) or needs hydrogen as feedstock (fertilizer)
2. has no significant seasonal mismatch between demand and supply of energy
3. has no significant gas infrastructure to become worthless (like in NL)
4. is a small island where the average battery electric vehicles won't give range anxiety issues.
5. Production of green hydrogen needs capital intensive assets and infrastructure

From these arguments it seems that Hydrogen is not an obvious choice for Aruba.

ARUBA & HYDROGEN

CAN HYDROGEN PLAY A KEY ROLE IN THE ENERGY MIX OF ARUBA?

Positive perspective

Aruba

1. has very high renewable energy potential to produce green Hydrogen
2. can become energy independent and self sufficient
3. can prevent future congestion by implementing strategically placed hydrogen hubs
4. can develop new industries using green hydrogen (recycling metals and glass!)
5. can apply Green Hydrogen in their existing RECIP's blended with natural gas
6. has high airplane traffic intensity
7. has high visiting cruiseship traffic
8. has waste disposal challenges that green Hydrogen will <u>not</u> excacerbate

Combining the above: Green Hydrogen can play a big role in the energy mix!

ARUBA & HYDROGEN

CAN HYDROGEN PLAY A KEY ROLE IN THE ENERGY MIX OF ARUBA?

Green Hydrogen can play a key role in Aruba!

Preconditions to be able to implement a green Hydrogen economy:

- Implement more renewable energy generation
  - Solar
  - Wind
- Use stakeholder approach to create acceptance in all communities
- Phase out HFO a.s.a.p. and apply LNG wisely: Gray or blue Hydrogen are not Green!

- Recommendations:
- Talk with local industries to assess interest and feasibility
- Establish long term partnerships for technology transfer and trade routes

ARUBA & HYDROGEN

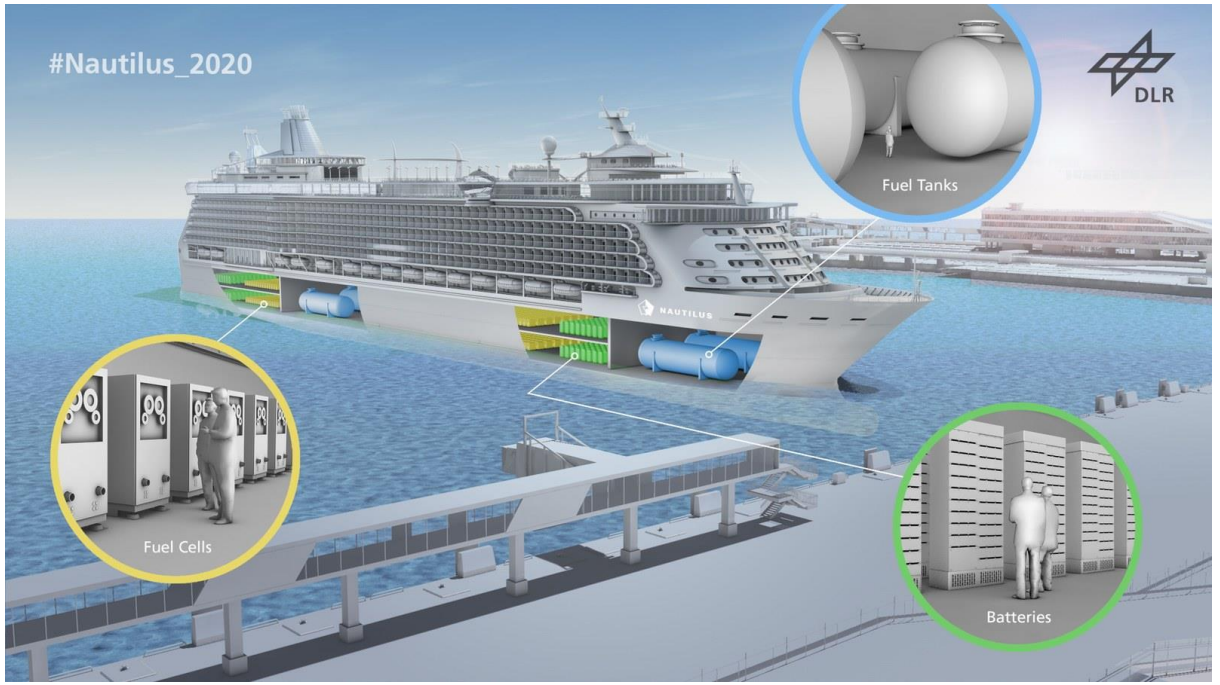
POTENTIAL HYDROGEN OPPORTUNITIES

Blending with LNG in existing RECIP’s:

- Use overproduction for day/night balancing

Refueling (cruise)ships and/or airplanes

- Needs ships/airplanes running on Hydrogen
- Needs significant more Renewable production
- Needs much larger Hydrogen production/storage capacity



ARUBA & HYDROGEN
POTENTIAL RISKS

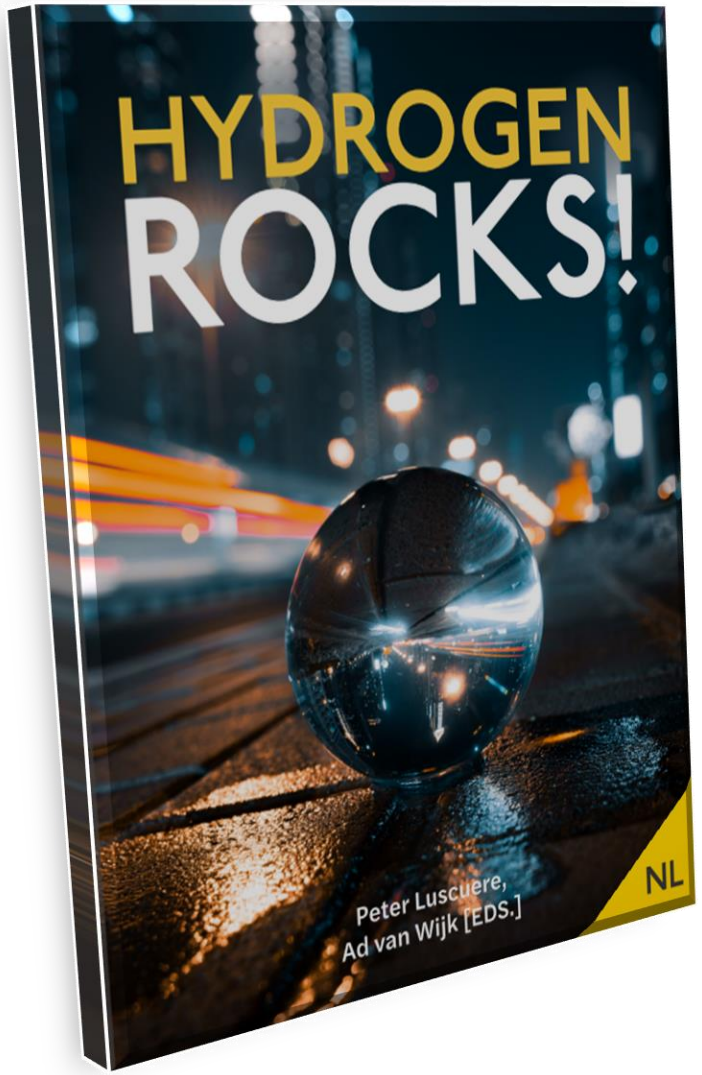
- Competition of other nearby Caribbean islands / countries
  - Curaçao
  - Dominica: has Geothermal potential
  - Trinidad & Tobago
  - Venezuela?
- Land scarcity: Trade-off between land/sea use for producing excess renewable electricity for green hydrogen

ENERGY & HYDROGEN

HYDROGEN ROCKS: VAN DORPS VISION ON HYDROGEN

- Energy will be ‘free’ - Energy abundancy theory (Jeremy Rifkin)
- Use deserts and ocean space for cheap renewable energy
- Don’t spend billions reinforcing the electricity grid
- Skip Carbon Capture and Storage – too expensive and benefits fossil fuels
- CO2 tariffs need to be applied to level the playing field for green hydrogen
- Energetic Efficiency/exergy is not the main comparing factor. It is energy cost!

Download here: https://books.bk.tudelft.nl/press/catalog/book/795



Thank you for your attention!

KIVI Kring Caribbean 25-5-2023