HATENBOERWATER

Fresh in water since 1906.

Energy in Transition:

Reverse Osmosis and the Economics of Green Hydrogen Production

Intro

Hatenboer Water has been in the freshwater business since 1906, and Jack took over the US branch in Houston last year after 20 years in the upstream oil & gas and maritime industries. He manages the sales and market growth of Hatenboer's freshwater production, treatment, and distribution systems in the Americas.

Abstract

Green hydrogen has become a promising alternative energy source as nations seek to address climate concerns through decarbonization as well as ensure flexibility and energy security in the face of geopolitical uncertainty. But without a clear economic advantage, industry stakeholders will be reluctant to invest in the required infrastructure until it is shown that green hydrogen can generate top-line growth and bottom-line efficiency.

Both electrolysis and steam methane reformation require large amounts of fresh water, not to mention ethane cracking and other petrochemical refining processes, and this presentation will highlight how reverse osmosis and desalination can play a critical role in the economic efficiency of green hydrogen projects, as well as the transition from traditional hydrocarbons through the intermediate steps of gray and blue hydrogen.

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Fresh in water since 1906.

History

1906

Hatenboer founded as supplier of fresh water in the Port of Rotterdam

1979

4th generation starting with water quality services, advanced water products

1988

Delivery of a fully automatic Hadex disinfection measuring and control module

NAM

2006

'100 years fresh in water', being also the start of Dutch Water Ltd in Kenya

2014

750th Water Quality Risk Assessment, Inspection & Management

2020

Opening an international office in Houston, serving the Americas region

1906 | 1934 | 1979 | 1982 | 1988 | 2004 | 2006 | 2012 | 2014 | 2019 | 2020

1934

Hatenboer fleet of water supply vessels is growing to keep up with the strong growth of the port

1982

First delivery of the Hatenboer sea water membrane desalination system built for an offshore supply vessel

2004

Delivery of the 500th reverse Osmosis desalination system for the Horticulture branch

2012

Opening an international office in Singapore, serving the Asian market

2019

Opening an international office in Dubai, serving the Middle-Eastern market

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Global Footprint

Today, Hatenboer's primary focus and area of expertise is offshore and maritime applications of freshwater production by means of reverse osmosis.

Our international facilities are located near traditional hubs of petrochemical refining in the US, Asia, and even Europe, where cities like Antwerp have substantial refining capacity.

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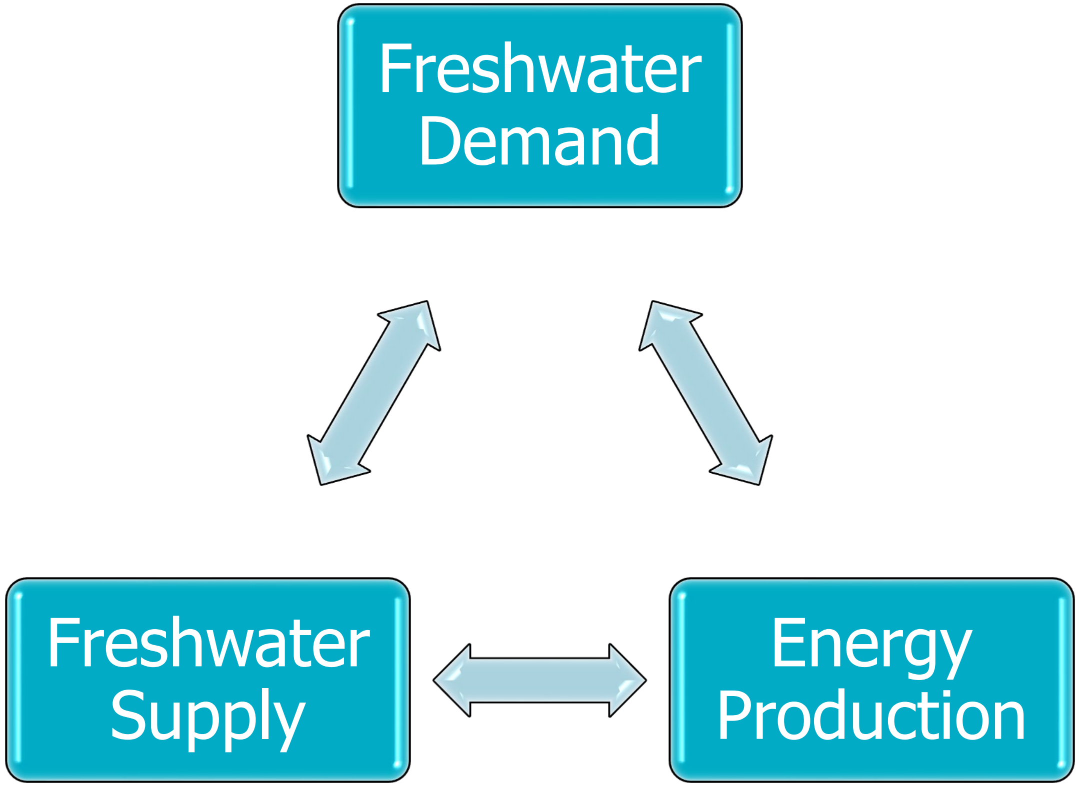
Overview

Energy and water are inextricably linked. The refining process uses a considerable amount of water, but how much largely depends on the processes employed. Global energy-related water consumption was projected to double from 2010-2035.

This will further complicate the balance between fresh water supply and demand, which will be stressed by economic growth, population growth, urbanization, and improved standards of living, along with other factors. The scarcity of water is deemed a top global risk over the next decade.

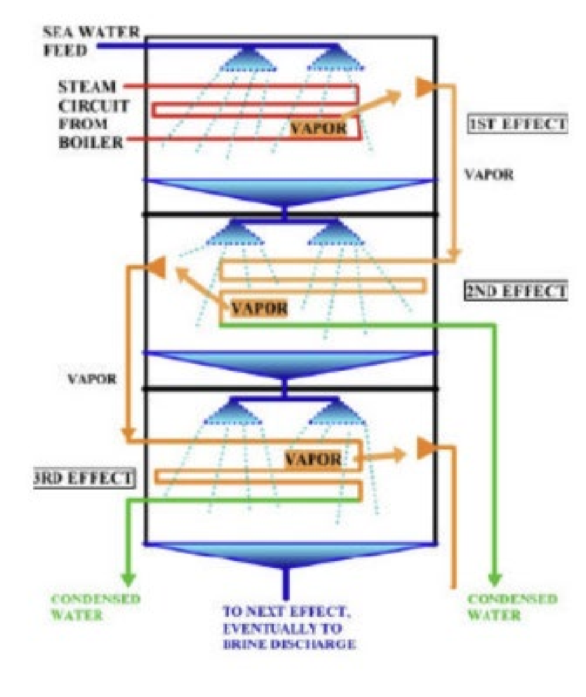


Evaporation vs. Reverse Osmosis

Evaporation is the oldest method of desalination.

- Multi-Stage Flash (MSF)
- Multiple Effect Distillation (MED)
- Vapor Compression Distillation (VCD)

Over time, improved membrane efficiency in removing salts and impurities, as well as energy requirements, have made RO units the preferred technology.



https://www.hatenboer-water.com/white-paper-ro-vs-evaporator/

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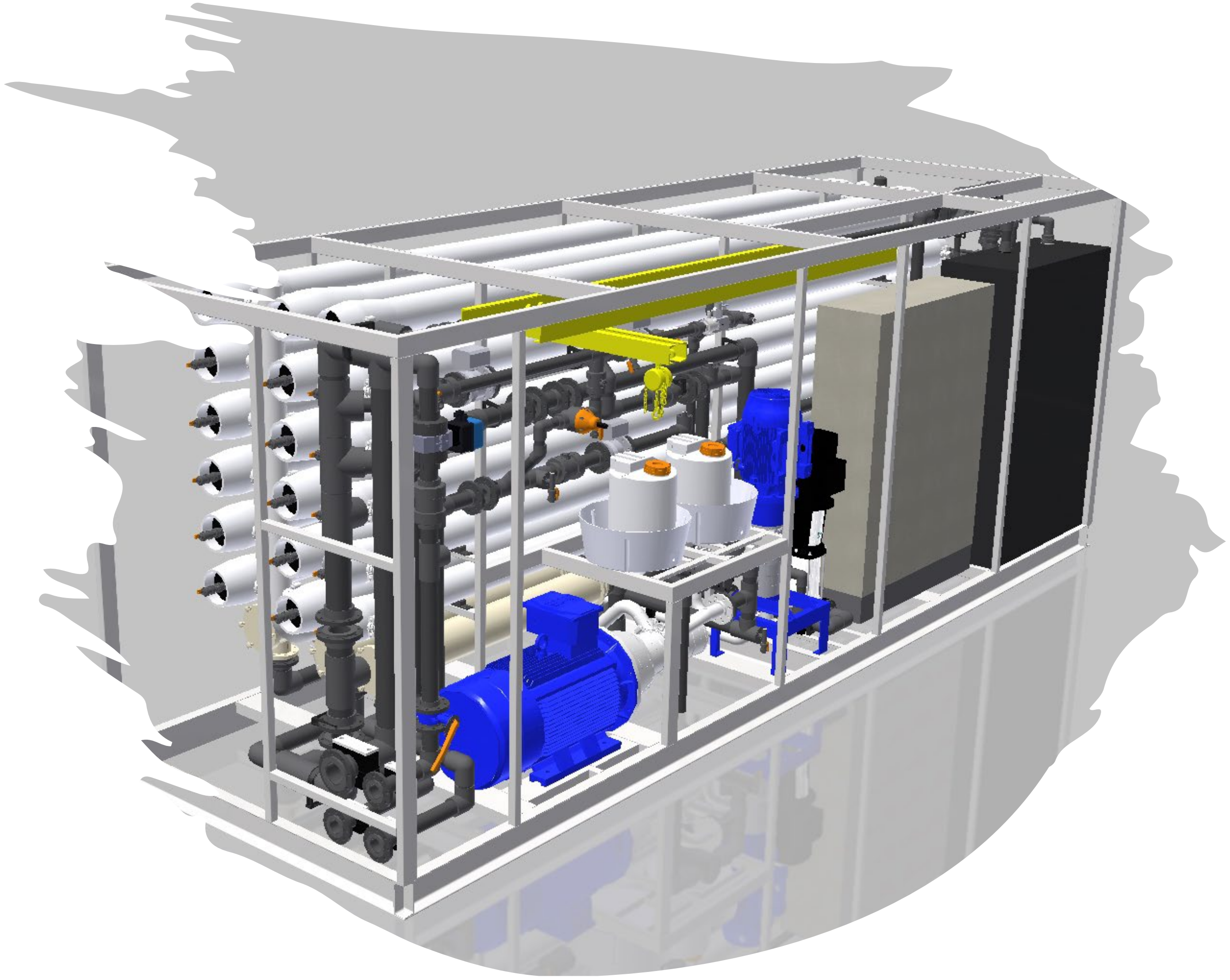
Reverse Osmosis

To begin, let's start with what reverse osmosis is. Reverse osmosis is a water purification technology that uses a semi-permeable membrane to remove ions, molecules, and larger particles from water. The membrane acts as a barrier, allowing only water molecules to pass through and blocking the passage of contaminants.

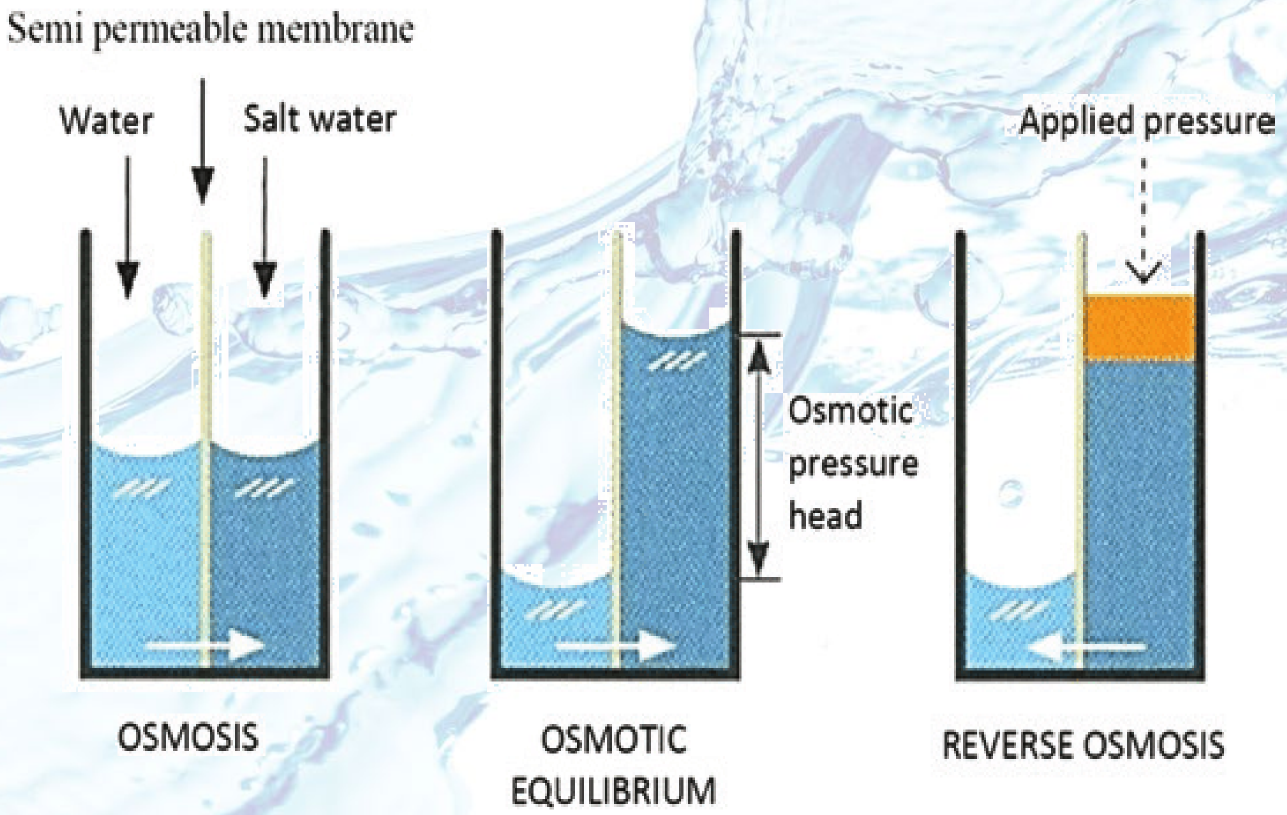


Reverse Osmosis (RO)

RO units filter dissolved salts and microorganisms from feedwater through semi-permeable membranes.

In normal osmosis, solvents naturally move from low concentration to high through a membrane, driven by osmotic pressure, and tending to equalize the concentrations on both sides.

In reverse osmosis, an applied pressure is used to overcome the natural osmotic pressure. The selective membrane allows the solvent (H_2O) to pass freely, while retaining the solutes.



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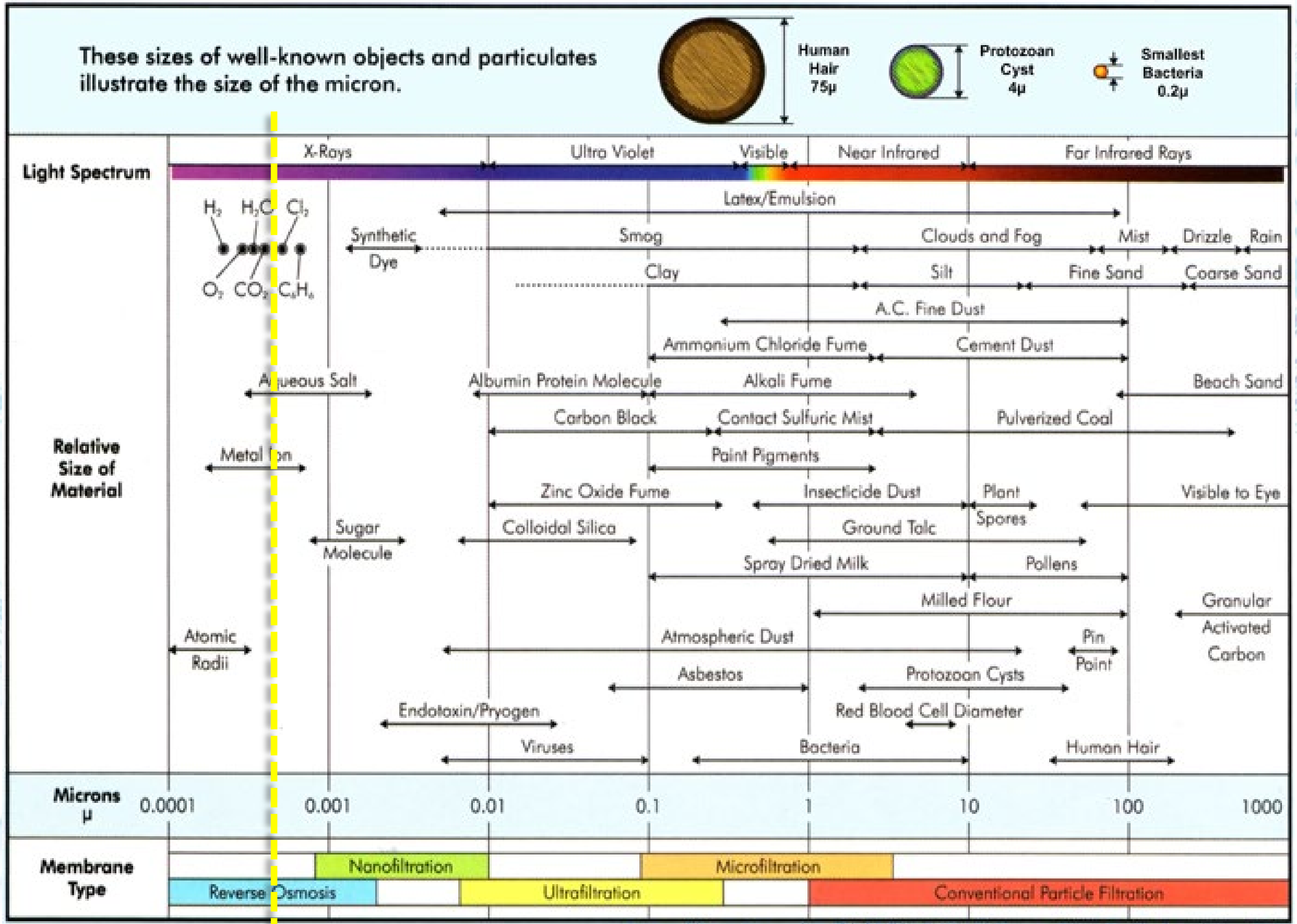
What Is Removed?

Everything.

Smaller than .001 μ



Source: "Water Processing: Third Edition", Wes McGowan, Water Quality Association, 2001

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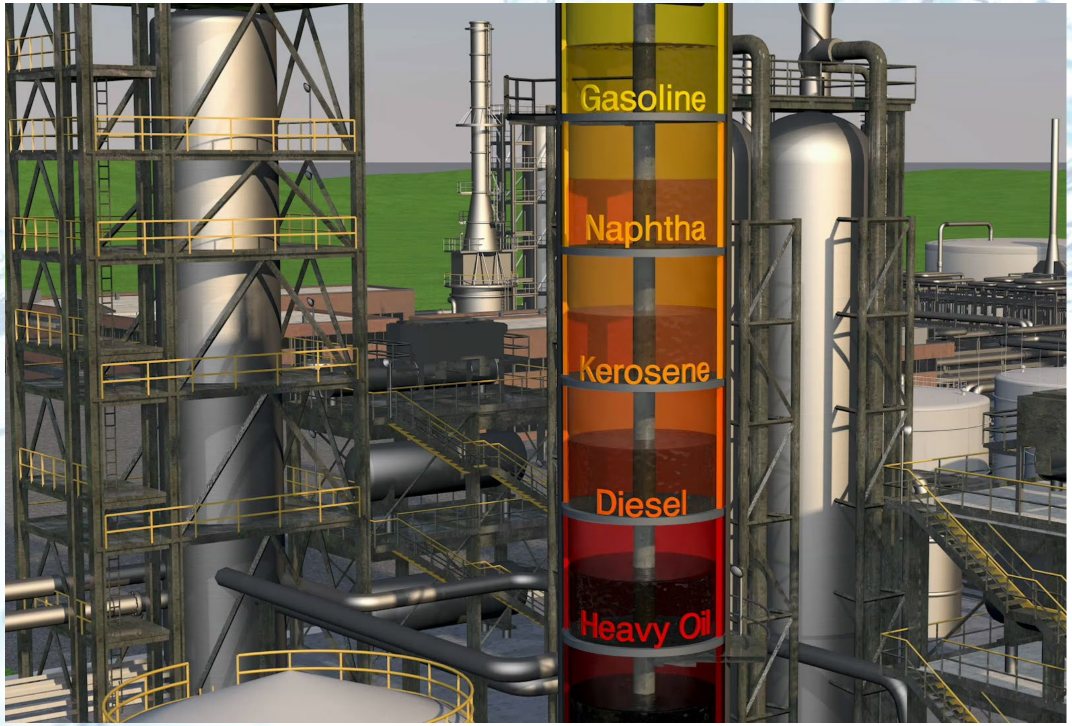
Downstream Petroleum Refineries

In traditional downstream petroleum refineries, purified water is used for various processes. For example, in steam cracking, where hydrocarbons are broken down into smaller molecules using high-temperature steam, pure water is required to prevent scaling and corrosion in the equipment. Reverse osmosis can produce high-quality water that is suitable for steam generation and other refinery processes



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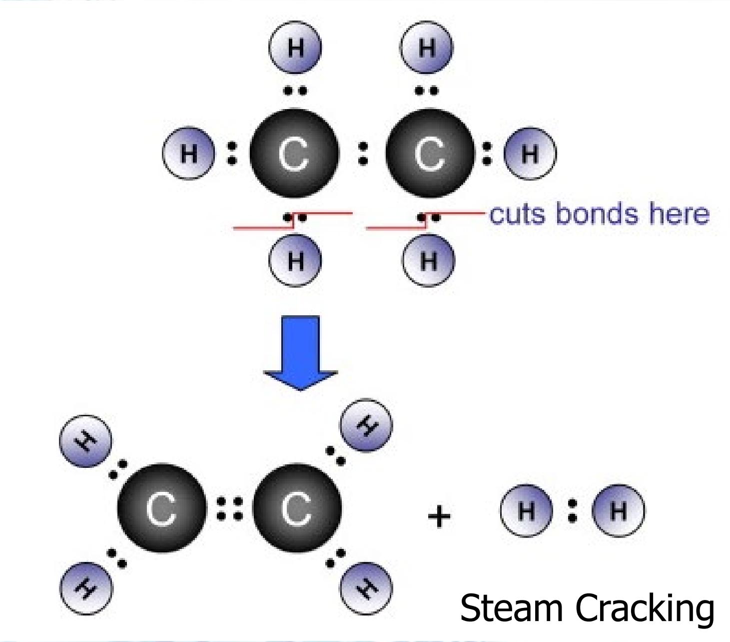
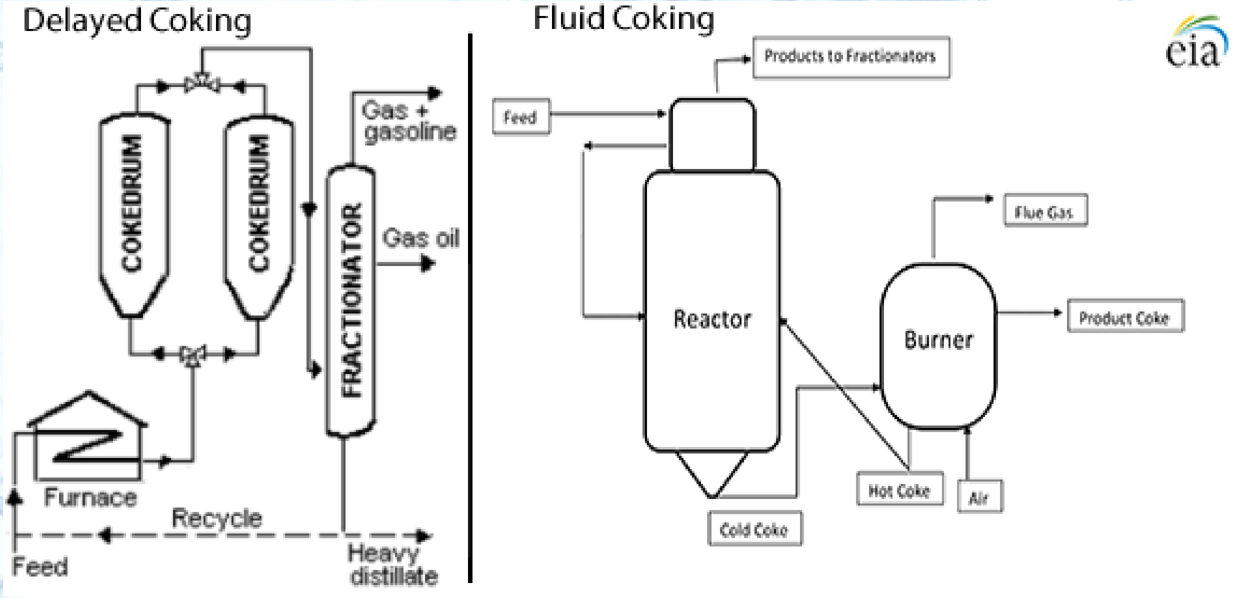
Refineries

- Steam Cracking
- Delayed Coking
- Boiler Feedwater (BFW)
- Cooling Systems
- Potable Water





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Refining Water

Requirements for water purity in refining applications are strigent, but varies and not difficult to achieve through reverse osmosis.

Water category	Contaminant specification	Potential source of re-use water
Desalter makeup	• Sulphide: < 10 mg/l • Ammonia: < 50 mg/l • Total dissolved solids (TDS): < 200 mg/l	• Stripped sour water • Vacuum tower overhead • Crude tower overhead
Coker quench water	• Total suspended solids: < 100 mg/l • Biological solids: none • H_2S and other odorous compounds: none	• Stripped sour water
Coke cutting water	• Total suspended solids: < 100 mg/l • Biological solids: none • H_2S and other odorous compounds: none	• Stripped sour water
Boiler feedwater makeup (quality required is highly dependent on the pressure of steam being produced)	• Conductivity: < 1 µS/cm • Hardness: < 0.3 mg/l • Chlorides: < 0.05 mg/l • Sulphates: < 0.05 mg/l • Total silica: < 0.01 mg/l • Sodium: < 0.05 mg/l • Dissolved oxygen: < 0.007 mg/l	• Treated and upgraded refinery wastewater
Cooling tower makeup	• Conductivity: < 6,000 µS/cm • Alkalinity: < 3,000 mg/l • Chlorides: < 1,500 mg/l • Suspended solids: < 150 mg/l	• Treated and upgraded refinery wastewater

Energy Transition

Viewing the energy transition as a zero-sum game raises hackles and misses an opportunity for the traditional petroleum industry. It might change the ends, but it doesn't change the means.

"Petroleum," "Drilling," and "Oil & Gas" companies are often calling themselves "Energy" companies now.

- Barriers
  - Economics
  - Infrastructure
  - Politics / Govt
  - Technology

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Safe water on board

From production to consumption

ISO 9001 ISO 14001 VCA*

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It’s not a zero-sum game. Hatenboer has experience putting water makers on platforms, and we can continue to do so regardless of what the platform is producing.

Hatenboer-Water to deliver RO water makers for Seafox 7 offshore platform

16 January 2018

Operator of offshore jack-up platforms, Seafox, has placed an order with Hatenboer-Water for two Reverse Osmosis (RO) systems. Hatenboer’s standard RO water makers will desalinate seawater into potable water on their Seafox 7 platform, which is used for accommodation, construction, maintenance and well services.

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Capital Idea

One thing America does well is capitalism. As the market rallies around renewables and hydrogen as an energy storage medium and alternative fuel source, American ingenuity finds a way to make money on it.

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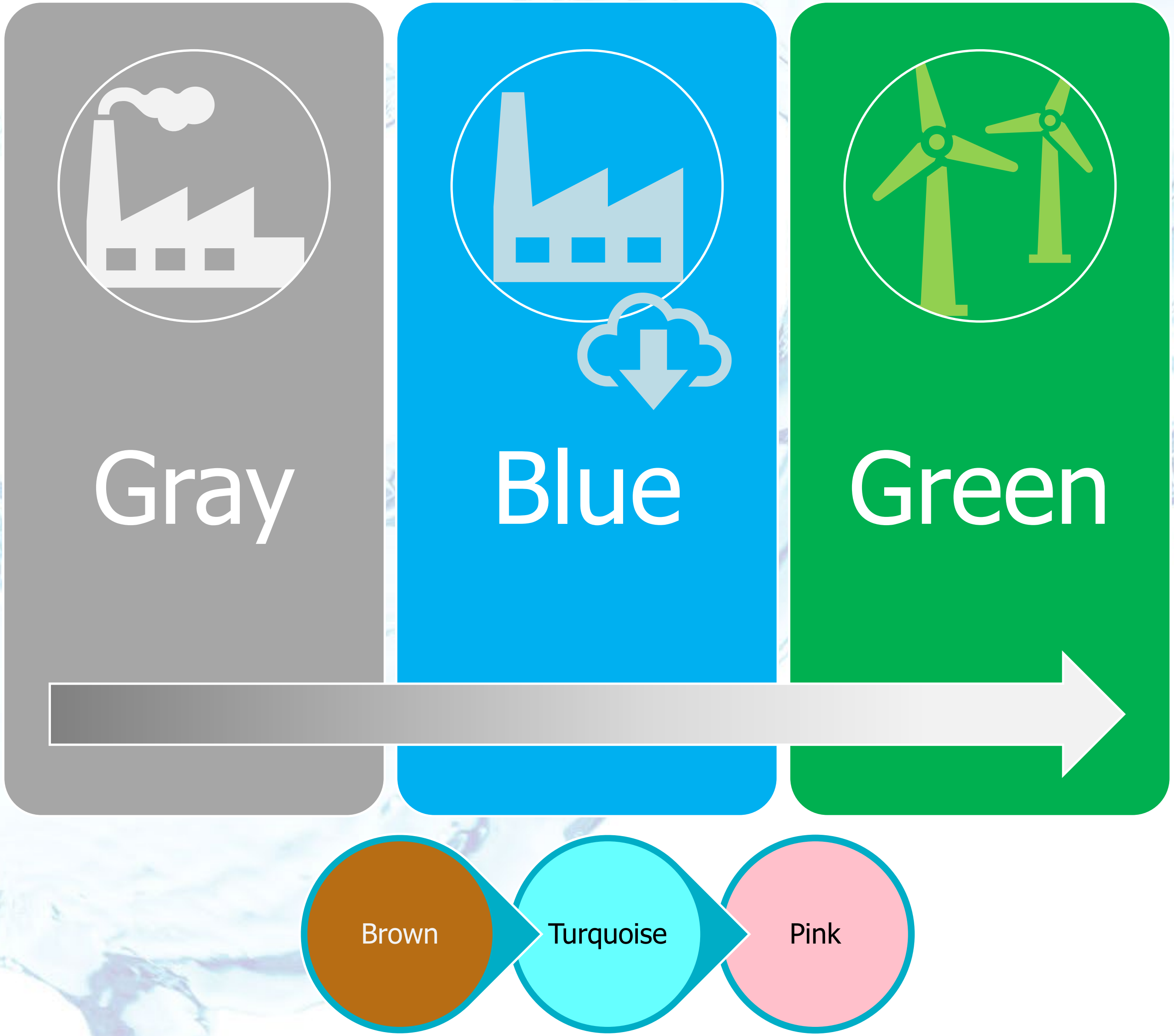
The Hydrogen Color Palette



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Hydrogen

The same knowledge base and expertise that is used for oil & gas production, refinery processes, and distribution channels can be brought to bear.

"You want hydrogen? I can get you hydrogen. Believe me. There are ways, dude. I can get you hydrogen by 3 o'clock this afternoon."

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Gray and Blue Hydrogen

Now, let's talk about the energy transition to gray and blue hydrogen production. Gray hydrogen is produced from natural gas using steam methane reforming, while blue hydrogen is produced using the same process but with carbon capture and storage to reduce carbon emissions. Both processes require large amounts of clean water for steam generation and electrolysis. Reverse osmosis technology can mitigate the input costs of clean water in these applications, reducing the overall cost of hydrogen production.

Steam Methane Reformation (SMR)

SMR

$$CH_4 + H_2O \text{ (+ heat)} \rightarrow CO + 3H_2$$

Water-Gas Shift

$$CO + H_2O \rightarrow CO_2 + H_2 \text{ (+ heat)}$$

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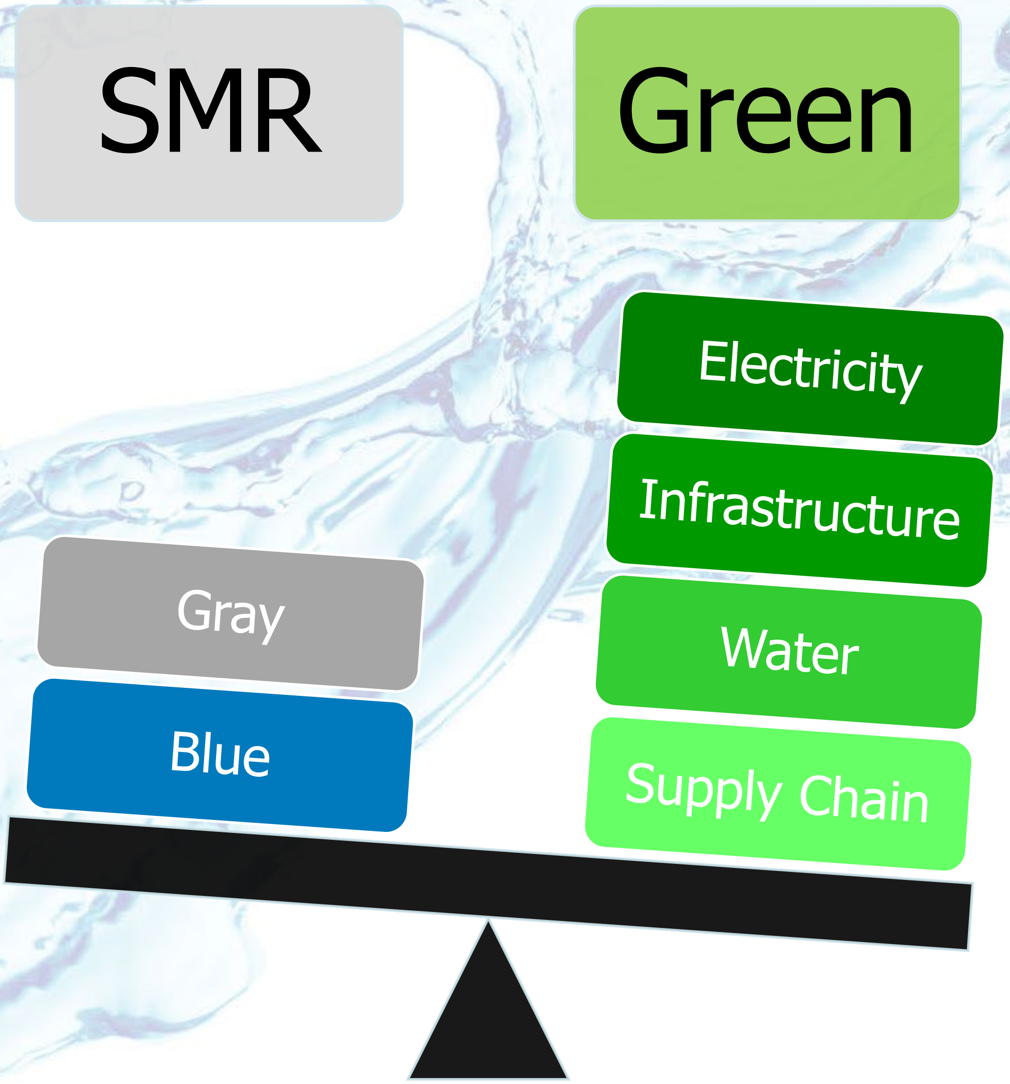
Headwinds

There are several cost input barriers that make a transition to green hydrogen more difficult:

- Electricity Costs
- Infrastructure
- Water
- Supply Chain



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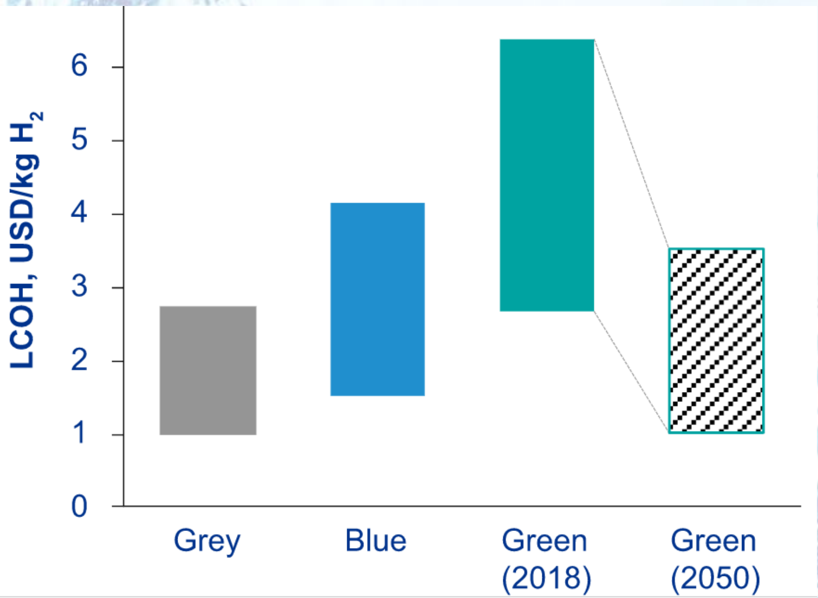
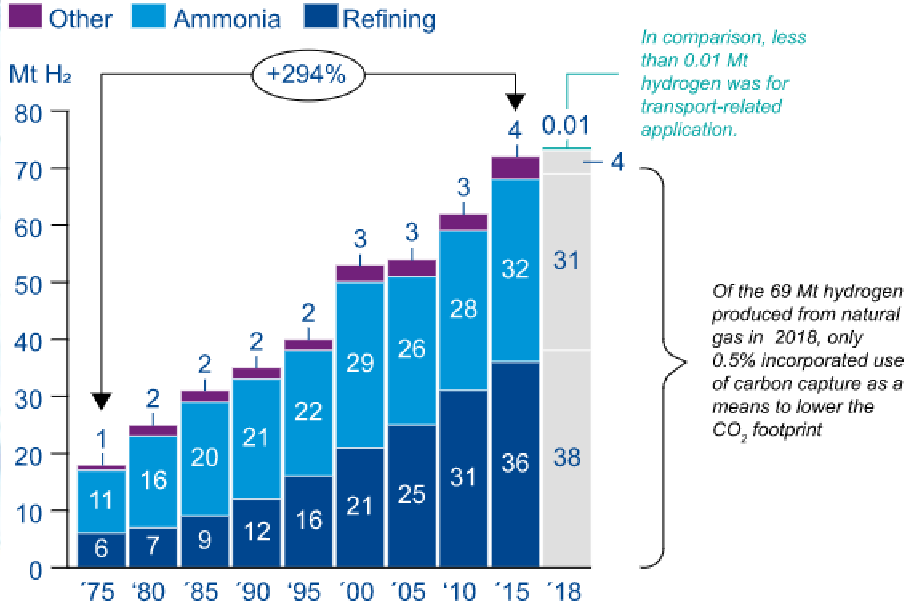
Supply & Demand for H_2

Demand for hydrogen has been steadily growing, both for refining and ammonia production.

Aside from fuel cells for small apparatus like forklifts, hydrogen does not yet account measurably for transportation.

However, hydrogen byproducts like ammonia are also seen as alternative fuels, which will only increase demand.





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Green Ammonia

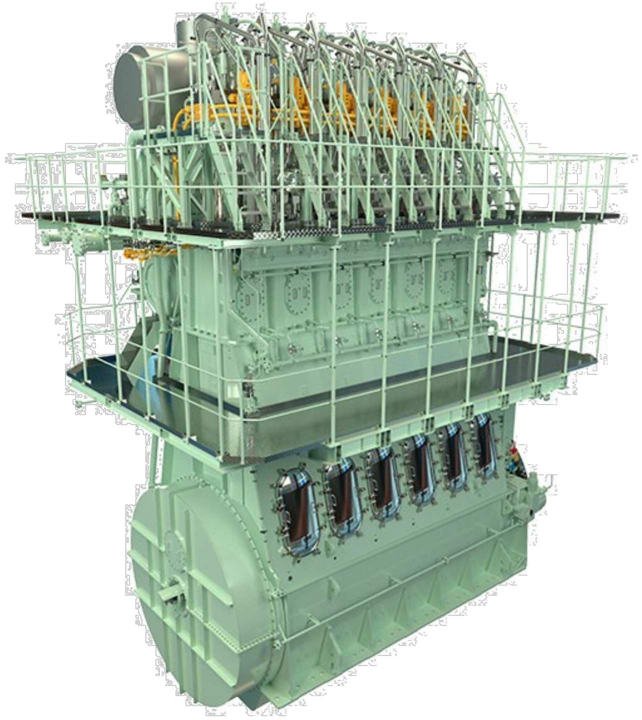
80% of ammonia today is used for fertilizer.

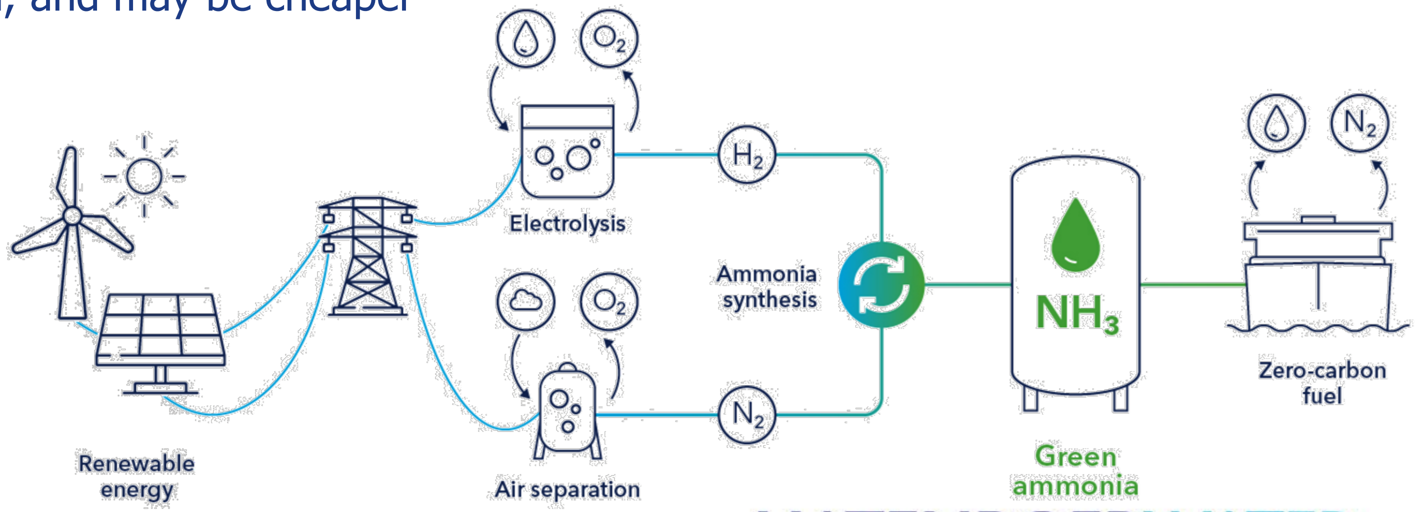
Alternative Fuel

Dual-fuel ammonia-powered combustion engines are already in development

Hydrogen Carrier

Being liquid at ambient temperature under its own vapor pressure and having high volumetric and gravimetric energy density, ammonia is considered a suitable carrier for hydrogen, and may be cheaper than direct transport of liquid hydrogen.





Source: DNV

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Public Goods

Non-rivalrous and non-exclusionary.

Streetlamps are a common example. One user doesn't exclude other users, and the good isn't consumed by individuals on a first-come basis.

Governments usually have to step in to provide or maintain these goods.

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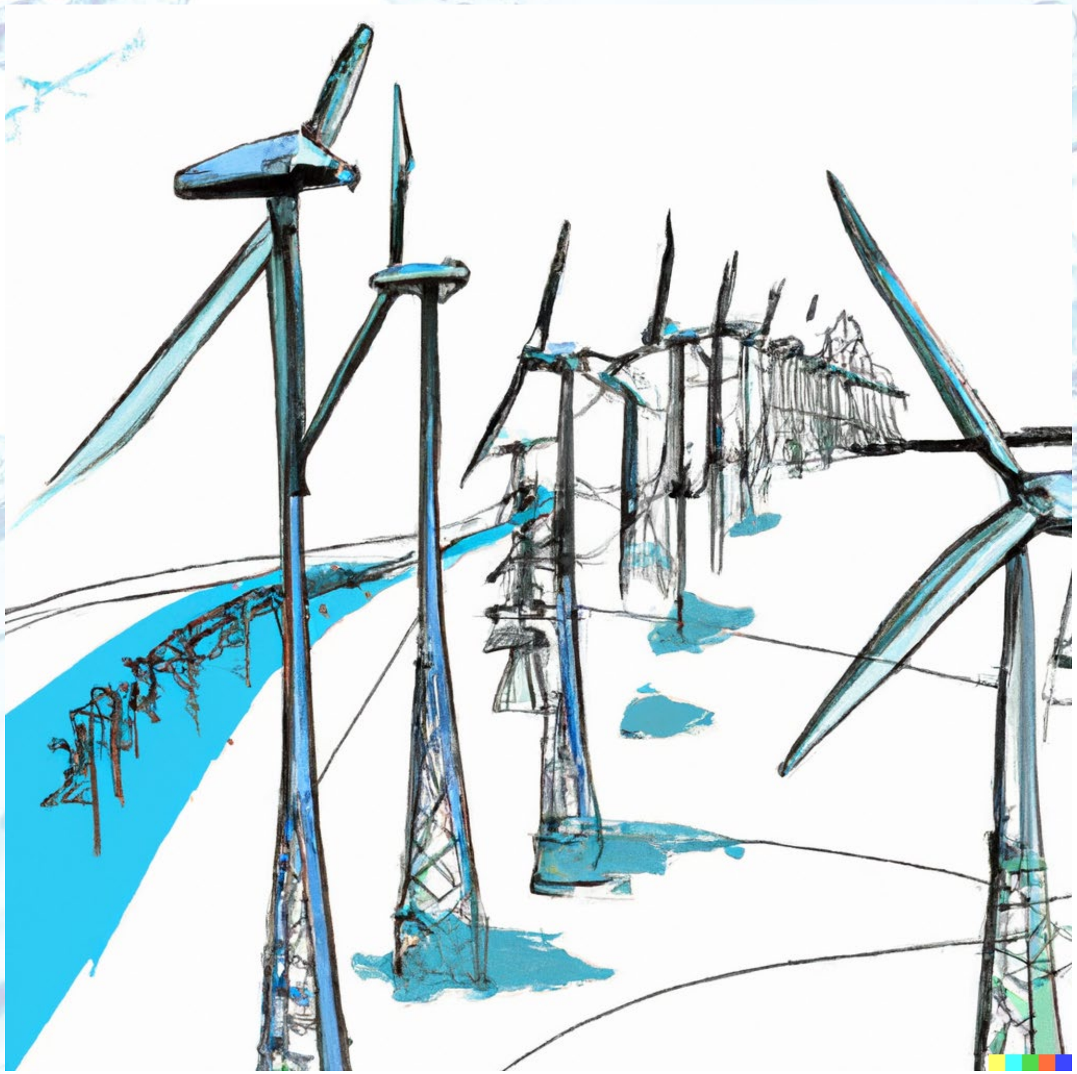
Scale

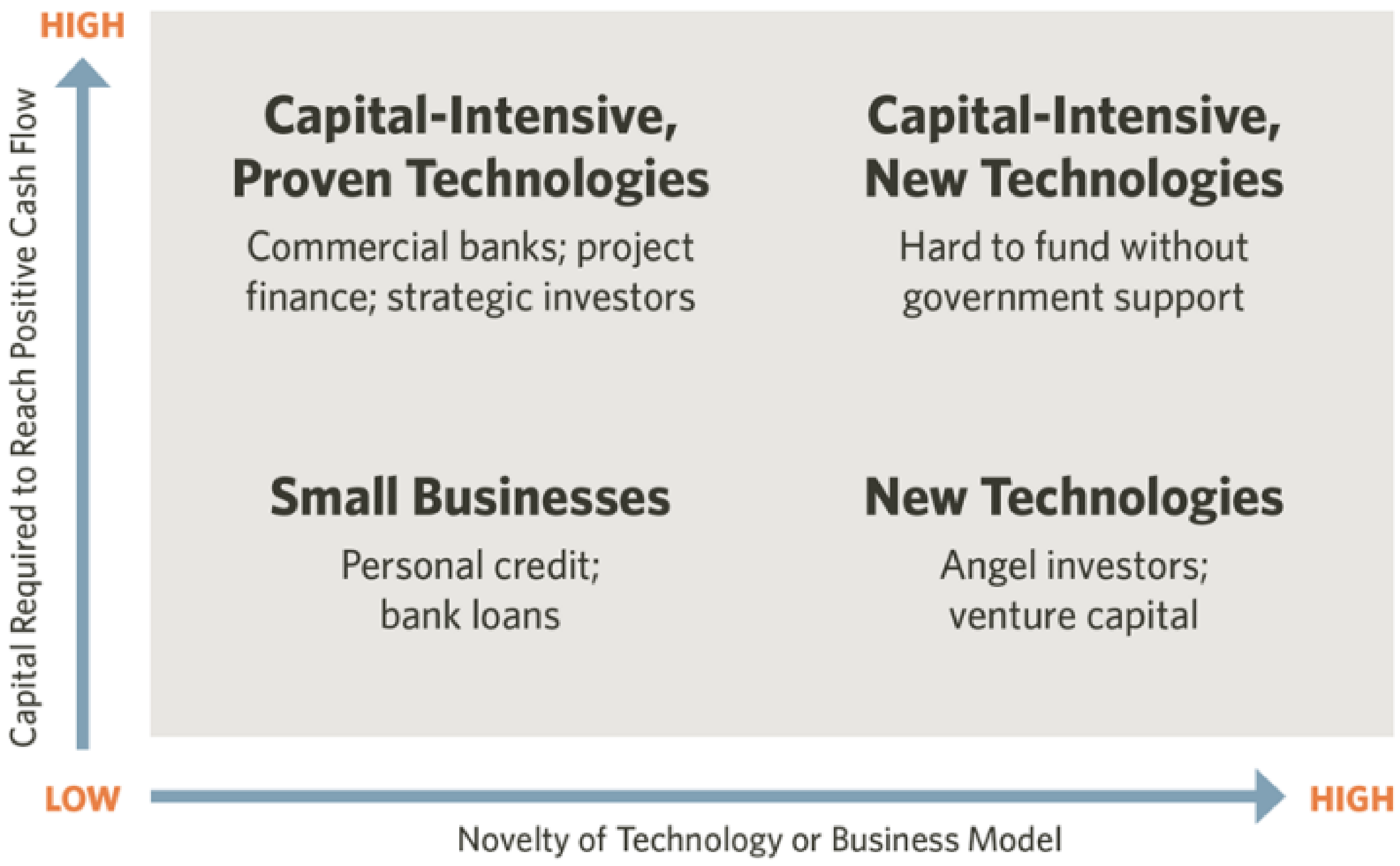
How fast can electrolyzers scale up? One useful example comes from the meteoric rise of wind and solar. During their fastest scale-up this century, utility-scale wind installations grew by an average of 42% per year, and utility-scale solar installations grew by an average of 97% per year. Even if electrolyzers are on the same path as solar, they're only on track to provide less than 20% of current hydrogen demand in ten years. Like with wind and solar, aggressive or even modest scale-up won't happen without policy support to increase the availability of green hydrogen.



Funding Sources

Depending on the characteristics of an investment, different funding sources and strategies will be required.

Scale is one of the biggest drivers.



Source: Reprinted from Harvard Business School, "Financing New Ventures," HBS No. 811-093, by William R. Kerr and Ramana Nanda.

Green Hydrogen

But what about green hydrogen? Green hydrogen is produced from water using renewable energy sources, such as wind or solar power, to power the electrolysis process. However, the input costs of clean water can still be a barrier to cost-effective production. This is where reverse osmosis comes in.

Reverse osmosis can be used to desalinate seawater for offshore green hydrogen production, reducing the reliance on freshwater sources. It can also be used to purify well or runoff water on land, further reducing the input costs of clean water.

By using reverse osmosis technology, green hydrogen can become equal or more cost-effective than gray or blue hydrogen production. This can lead to a more sustainable and environmentally friendly energy transition.

Electrolyzer Technologies

Alkaline – more mature, current standard, durable, lower cost electrodes. Higher minimum load limit (10-20%) is a difficulty for intermittent energy from renewables. Battery Energy Storage System (BESS) can levelize.

Proton Exchange Membrane (PEM) – lower minimum load limit (0-10%) means quicker ramping up and down, but components and supply chain issues make PEM 50% more expensive. Government subsidies mitigate.

Water Requirements for Electrolysis

Electrolyzers require deionized water and at minimum ASTM Type II or preferably ASTM Type I.

Water quality should also be measured in Total Silica, Total Organics, and Total Carbon for proper application assessment.

Type I - Ultrapure water is a necessity for applications such as HPLC, gas chromatography, cell culturing, tissue culturing, mass spectrometry and any endeavor involving trace elemental laboratory instrumentation, among others.

Type II - Good choice to feed to instruments and clinical analyzers because there is less calcium buildup, and it can also be used as feed water to a Type I system. Additional example applications include electrochemistry, sample dilution, radioimmunoassay and media preparation.

ASTM D1193-06	TYPE 1	TYPE 2	TYPE 3	TYPE 4
Conductivity, min. µS/cm (25oC)	0.056	1	0.25	5
Resistivity, min. MΩ-cm (25oC)	18	1	4	0.2
TOC, max. µg/l	50	50	200	No limit
Sodium, max. µg/l	1	5	10	50
Silica, max. µg/l	3	3	500	No limit
Chloride, max. µg/l	1	5	10	50
pH value (25oC)	–	–	–	5.0–8.0

$$2H_2O_{(aq)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$$

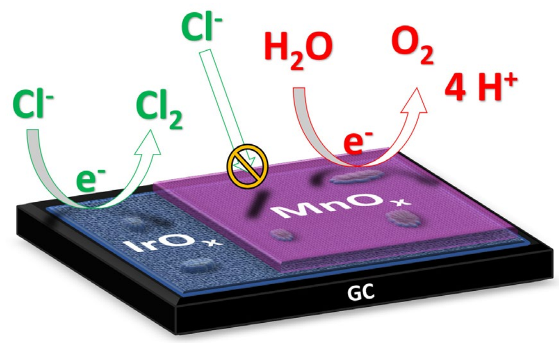
Water and Green H_2 Production

Green hydrogen production uses water as a key feedstock and renewable electricity to separate hydrogen and oxygen from water in an electrolyzer.

Water is increasingly scarce, and seawater could be a seemingly endless supply. However, direct saline splitting can cause a chlorine gas byproduct at the anode.

Impurities in the feedwater also have a major impact on the lifespan of an electrolyzer stack, increasing OPEX and LCOH. So the purest input water is therefore required.

From a stoichiometric perspective, 1 kg H_2 requires 9 kg water input, but inefficiencies can result in 18 to 24 kg. Water scarcity is regionally specific, and the water source must be explicitly addressed for large scale hydrogen production strategies. But penalties on cost and efficiency are nearly eliminated when desalination is employed, and desal can be deployed jointly for human and agricultural consumption.



Water Requirements

In 1955, 3.5 billion gallons of water was withdrawn daily for use by petroleum refineries in the US, about 3% of the total daily withdrawal for industrial purposes. An average of 468 gallons of water was required to refine a barrel of crude oil. Noncracking refineries used 375 gal/bbl, while cracking facilities used 471 gal/bbl. Almost 10x. Today it is more like 1.5x.

By 2014, researchers found that US energy required 58 trillion gallons of water, of that, 3.5 trillion was freshwater, or 10% of total US water consumption

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Traditional Water Sourcing and Distribution

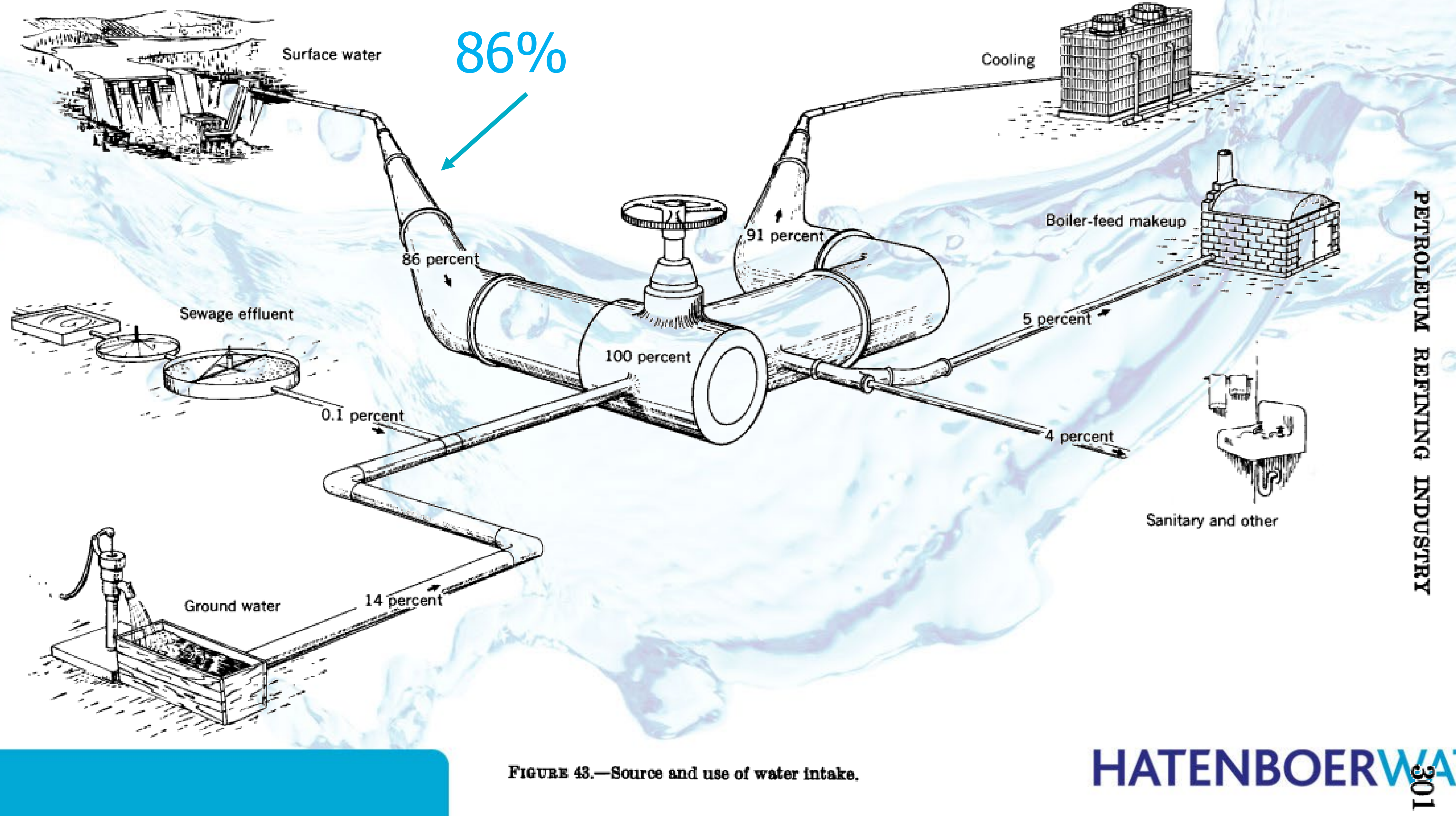

FIGURE 43.—Source and use of water intake.

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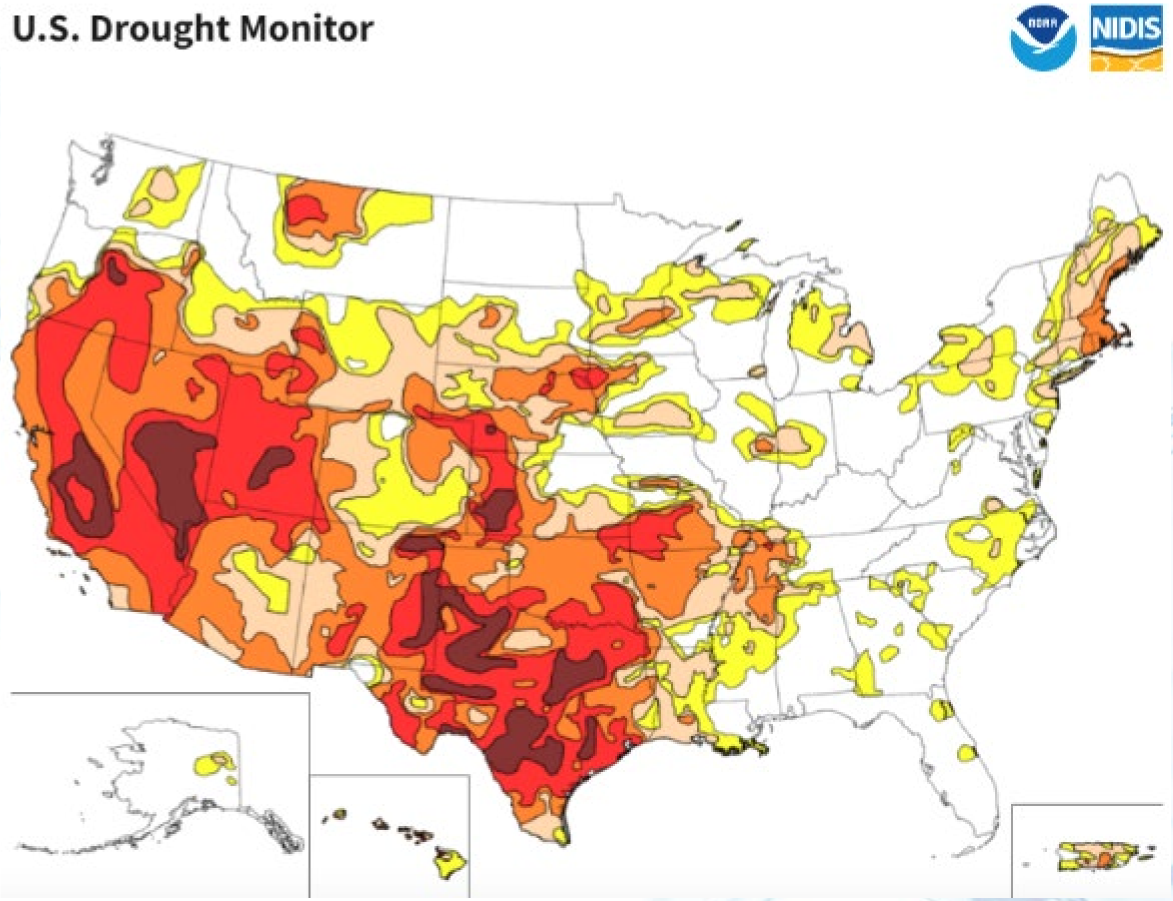
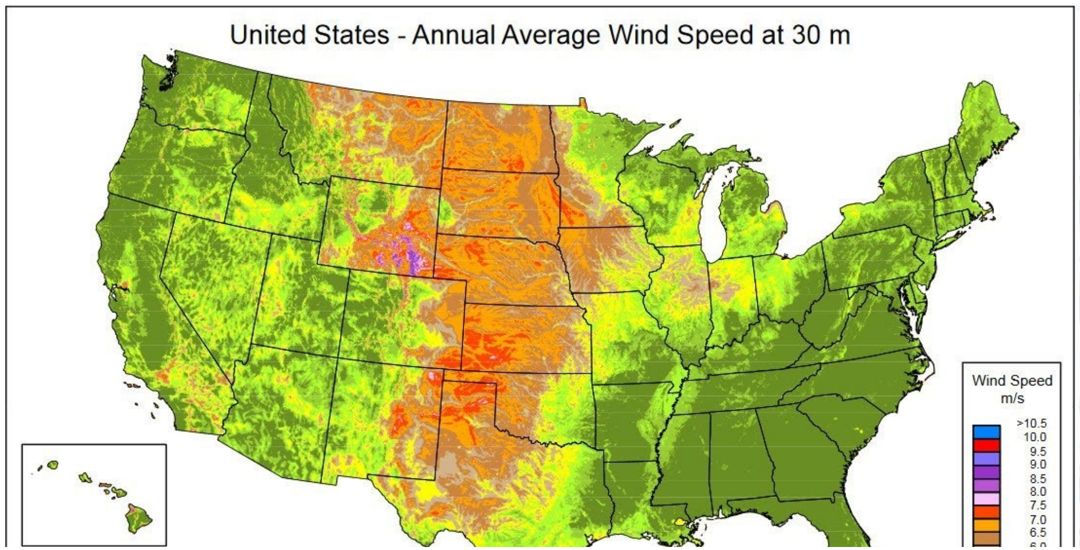
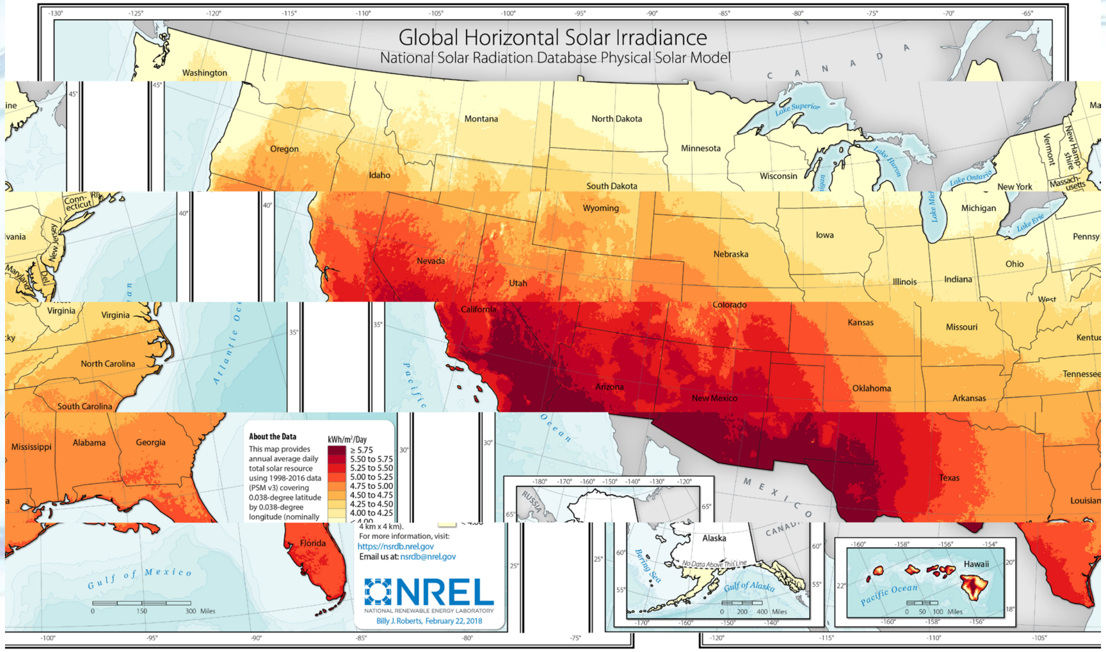
Renewable Energy vs Water







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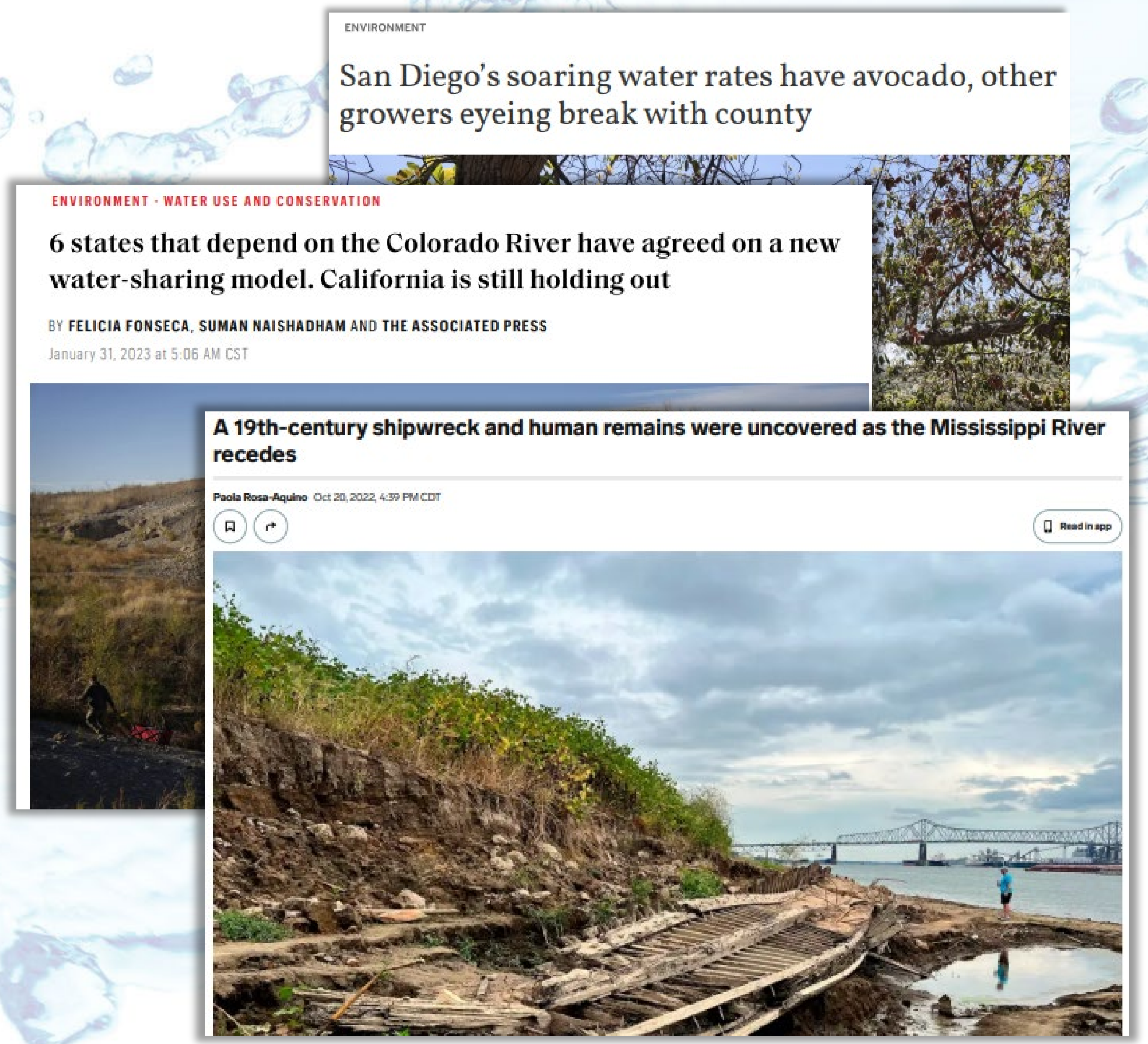
Today

Water is an increasingly scarce commodity. Not only will new projects have competing water use interests, but increasing costs if you want to take municipal or other public sources like river basins that are dwindling every year.


ENVIRONMENT

San Diego's soaring water rates have avocado, other growers eyeing break with county

ENVIRONMENT · WATER USE AND CONSERVATION

6 states that depend on the Colorado River have agreed on a new water-sharing model. California is still holding out

BY FELICIA FONSECA, SUMAN NAISHADHAM AND THE ASSOCIATED PRESS

January 31, 2023 at 5:06 AM CST

A 19th-century shipwreck and human remains were uncovered as the Mississippi River recedes

Paola Rosa-Aquino Oct 20, 2022, 4:39 PM CDT

Read in app

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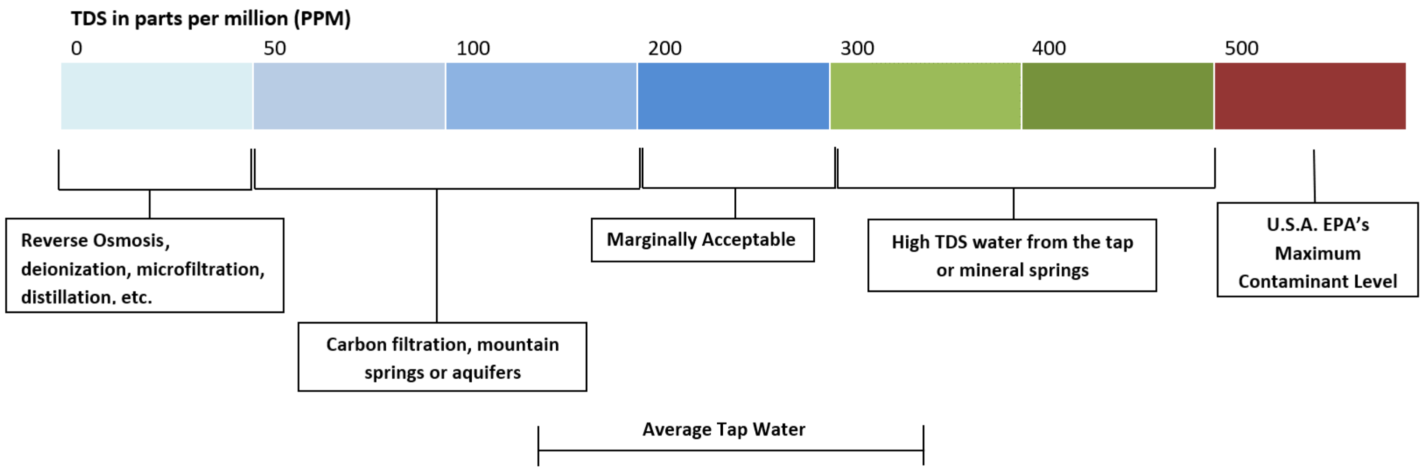
Groundwater

Typical RO recovery is anywhere from 25 to 40% of intake, so when surface or other natural water sources must be further processed, that would more than double the water consumption requirements for land-based electrolysis and hydrogen production.



Approximate Total Dissolved Solids (TDS) Values in Natural Waters	
Natural Water	**TDS (mg/L)**
Precipitation	10
Pristine Freshwater Lakes and Rivers	10 to 200
Amazon River	40
State Water Project Deliveries	275
Lakes Impacted by Road Salt Application	400
Agricultural Impact to Sensitive Crops	500
Colorado River Water	700
Average Seawater	35,000
Brines	>50,000
Groundwater	100 to >50,000

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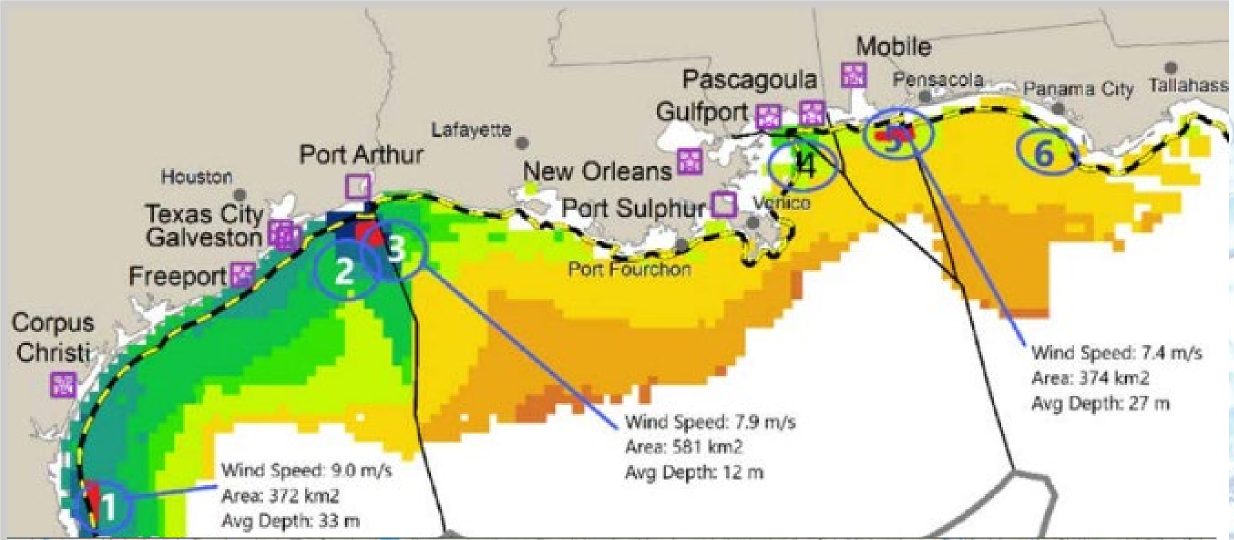
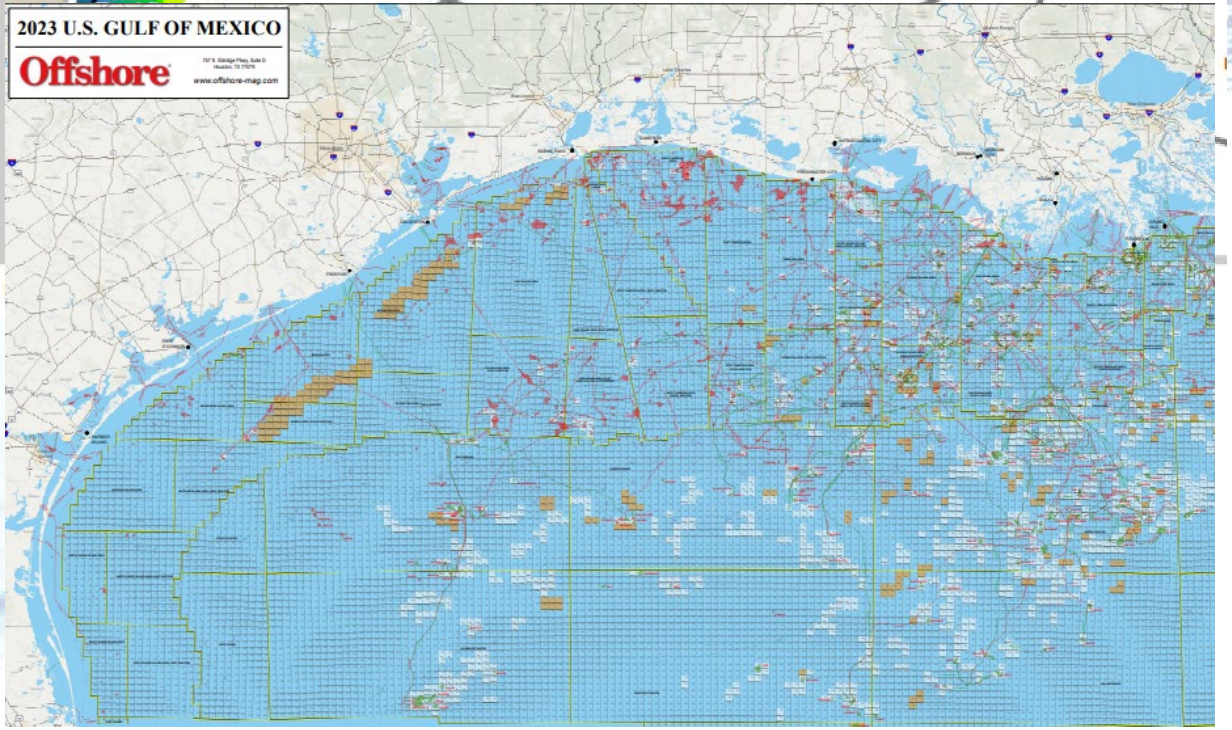
Gulf Economics

BOEM study with NREL

So what do we do, besides go buy property in Port Mansfield?

Use existing resources and infrastructure, along with the enviable knowledge and experience of people right here in this room to tackle the next energy revolution.



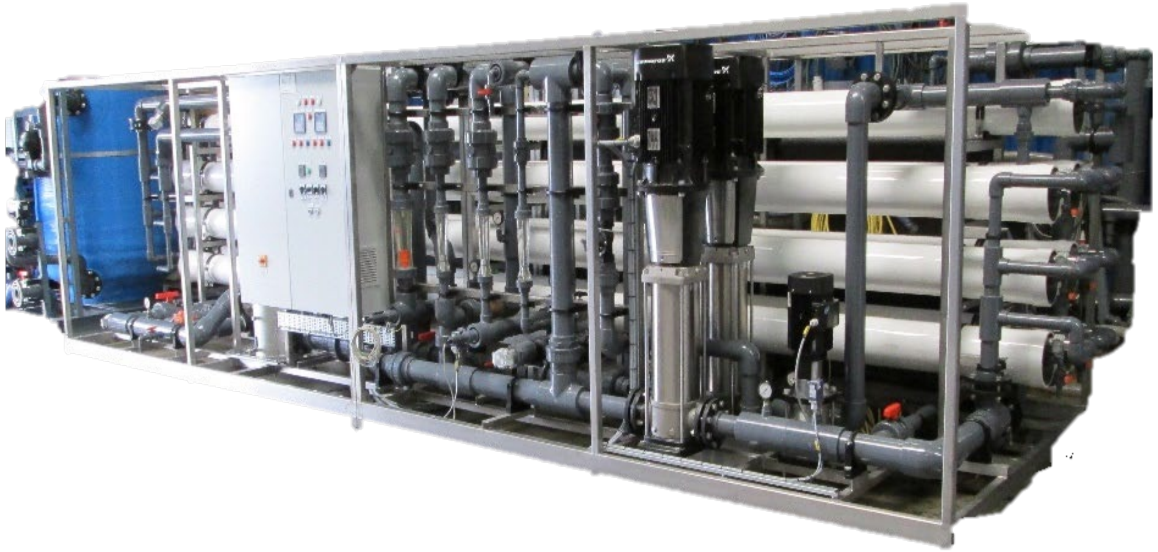


Conclusion

In conclusion, reverse osmosis technology is an essential component in water purification for traditional downstream petroleum refineries and the energy transition to gray and blue hydrogen production. Its future use in green hydrogen production can reduce the input costs of clean water, making it more cost-effective than gray or blue hydrogen. By desalinating seawater and purifying other water sources, we can achieve a more sustainable and environmentally friendly future.

Core Business

Fresh Water Production



Water makers

- Converting Seawater into Fresh water
- + 1.000 delivered worldwide
- Capacities: up to 2000 m3 per day
- Main Technique: Reverse Osmosis

Standard Range Water Makers

Fresh Water Production

Oceanus Series

Technical Details

- Water purification up to 30 m/day
- Plug & Play systems
- Microprocessor controlled
- Available from stock

- Multimedia filter
- Cleaning in Place (CIP) system for extension of membrane lifespan

Standard Range Water Makers

Fresh Water Production

Tethys Series

Technical Details

- Water production up to 6 m/day
- Plug & Play systems
- Microprocessor controlled
- Available from stock

- Multimedia filter
- Cleaning in Place (CIP) system for extension of membrane lifespan

Plastic Free @ Sea

HATENBOERWATER
Fresh in water since 1906.

THANK YOU
FOR YOUR ATTENTION

Jack Highberger

jack.highberger@hatenboer-water.com