Energy Transition: An Optimization Approach for Green Hydrogen and Integration of HVO

The AIChE Netherlands/Belgium Section Meeting

Burcu Ekmekci

28 June 2022

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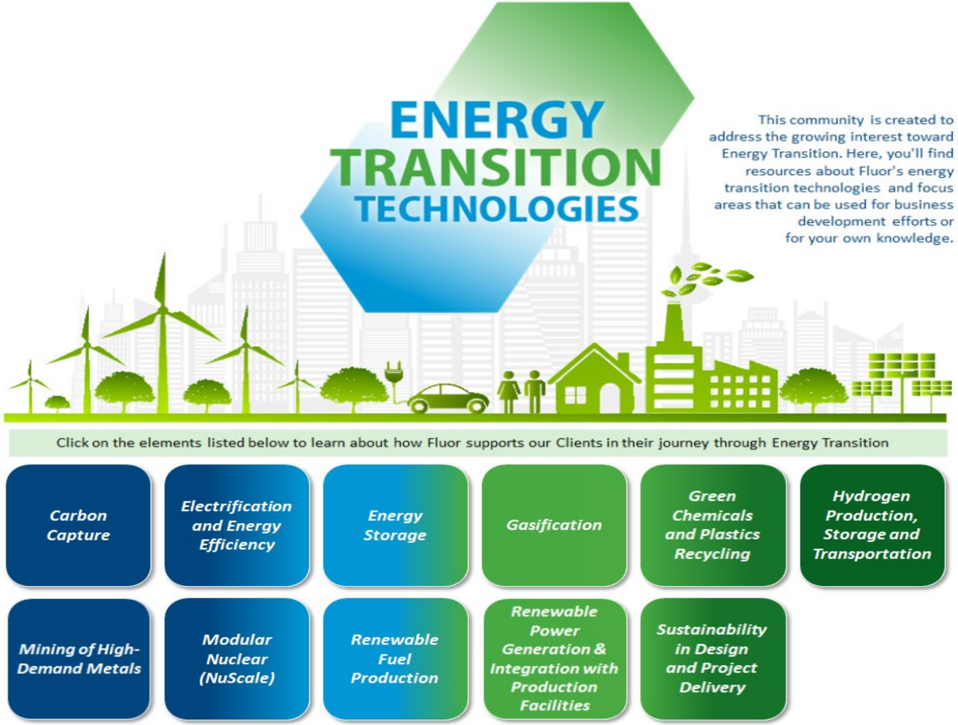
Agenda

It is **NOT** JUST Water



Water Group 2022

Burcu Ekmekci

Fluor Fellow – Water and Wastewater Treatment

IT IS NOT JUST WATER

HSE TOPIC

What Happened?

- The Omega Protein facility in Moss Point, Mississippi
- A tank explosion on July 28, 2014, killed a contract worker and severely injured another
  - The explosion blew the lid off the **30-foot/9-meters high tank**,
  - Fatally injuring a contract worker who was on top of the tank.
  - A second contract worker on the tank was severely injured.

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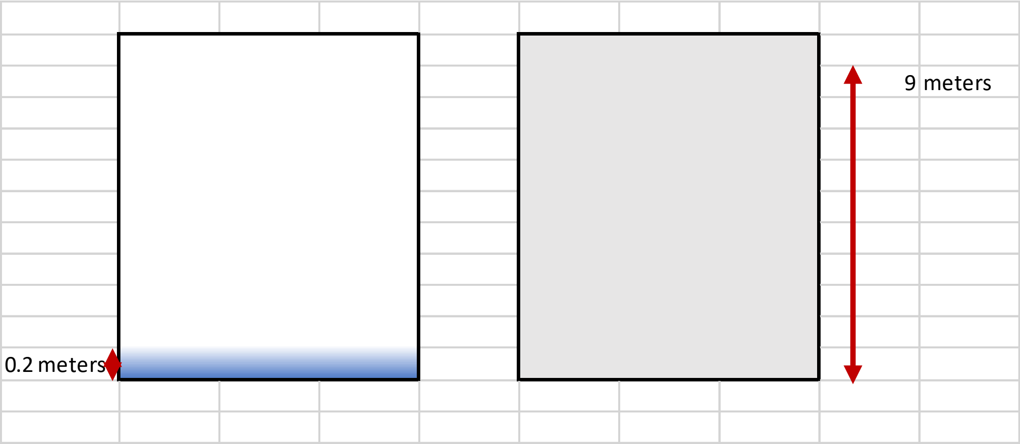
Why it happened?

The incident occurred during hot work on/near a tank containing

8 inches / 20 cm of a slurry of water



Yes, only 20 cm of a slurry of water

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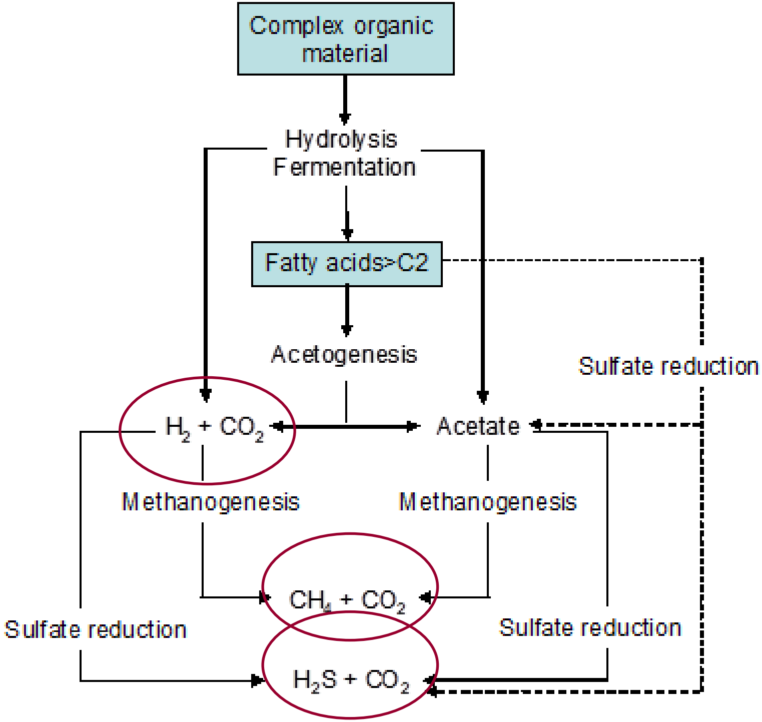
How did it happen?

- The water inside of the storage tank had been thought to be nonhazardous
- No combustible gas testing was done on the contents of the tank before the hot work commenced.

- Signs of microbial activity in the samples
- Presence of volatile fatty acids in the liquid samples
- Off gassing of flammable methane and hydrogen sulfide

How did it happen?

Anaerobic Conversion



Results in

- H_2S Emission
- Hydrogen
- Methane

- Technical Expertise
  - Oxygen Transfer Rate
  - Tank Sizing
  - Understanding of Reaction Kinetics

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TAKE AWAYS – IT IS NOT JUST WATER

IT IS NOT JUST WATER

- Extreme importance of careful hot work planning
- Danger of Hot Work on Tanks Containing Biological or Organic Material
- Hazard evaluation
- **Procedures for all storage tanks**
- Hot work dangers are not limited to the oil, gas, and chemical sectors where flammability hazards are commonplace

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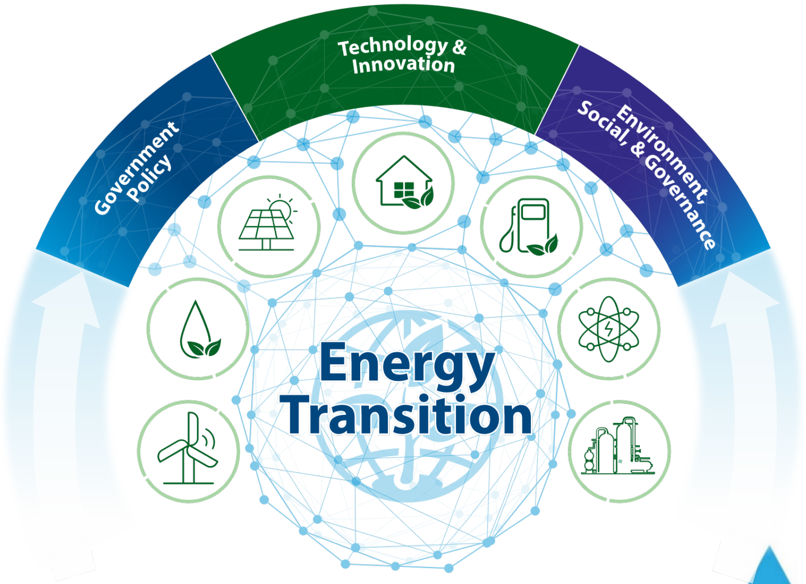
Energy Transition Linking with Water

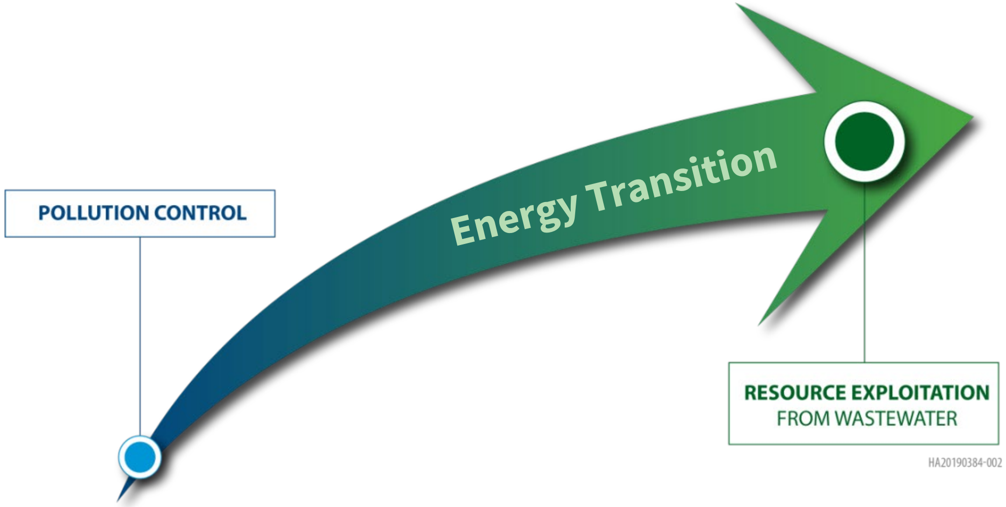


- Electrolysis: Green H_2 ⟷ **WATER**
- HVO

Is water becoming “the new oil”?

- Large amount and stringent quality requirements
- Reuse of treated water effluent
- Integrated water management

Integration of Water Solutions



- Remediation of Wastewater
- An energy-intensive process
- Increases the economic burden on industry
- A regulatory need for wastewater treatment before disposal

- Water Reuse
- Produce value-added products
  - BioPlastic
- Product Recovery (Metals Li)
- Waste to Energy
  - Biogas
- Ultra Pure Water

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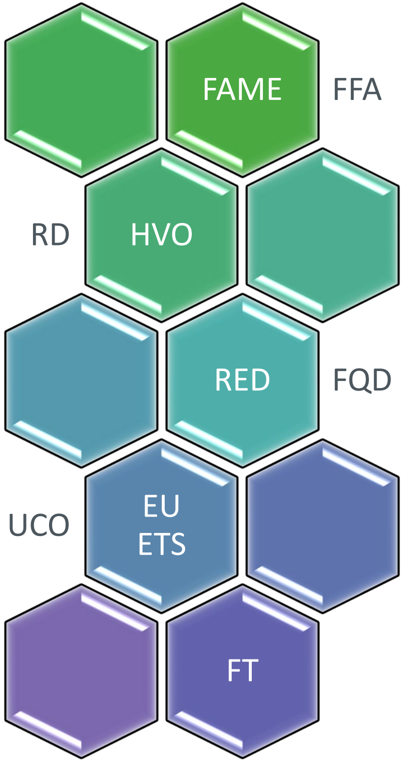
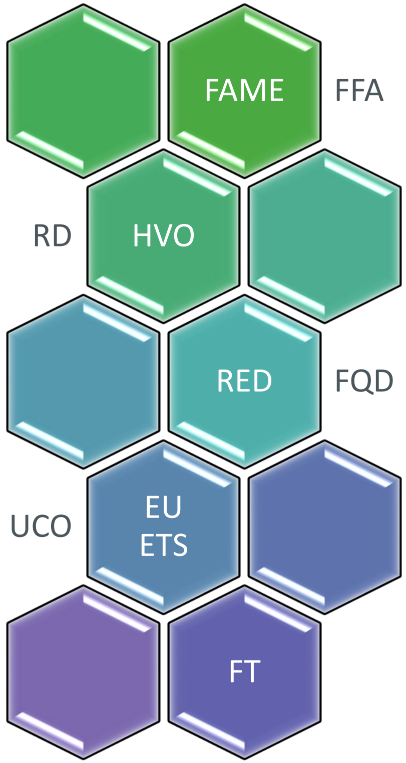
Introduction and Background

- **Well-known:**
  - Technology Selection
  - Legislation
  - Facility Match



Introduction and Background

- **Well-known:**
  - Technology Selection
  - Legislation
  - Facility Match
- **How about:**
  - Implication of Utilities
  - Implication of Environmental Permits



Case Study

Co-processing Hydrogenated Vegetable Oil (HVO)

- Utility Footprints
- Wastewater Treatment Plant Footprint

Co-Processing

MAIN FEEDSTOCK

- Plant Oils
- Animal Fats
- Algae

ROUTE 1

Methanol and Caustic → Transesterification → **Biodiesel [FAME]** + Glycerol

What is Co-Processing and how does it impact the existing process units

ROUTE 2

Hydrogen and Catalyst → Hydrotreating / Hydroprocessing → **Renewable Diesel** + Propane, CO, CO_2

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Case Study

Co-Processing

MAIN FEEDSTOCK

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ROUTE 1

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ROUTE 2

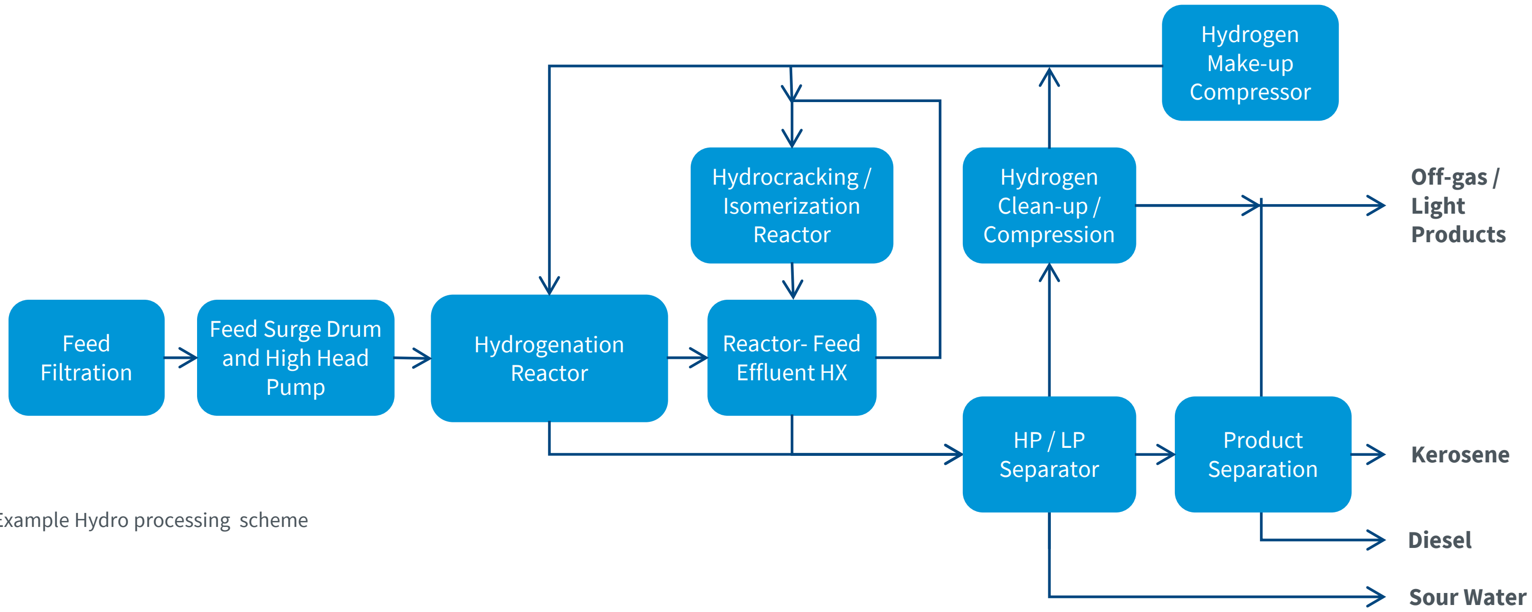
Hydrogen and Catalyst → Hydrotreating / Hydroprocessing → **Renewable Diesel** + Propane, CO, CO_2

Hydrogenated Vegetable Oil

- Specific needs of each refinery
- Quality of the end product
- Availability of hydrogen
- Ease of integration with existing refinery unit
- Nature of available feedstock
- Various pre-treatment requirements and options

Case Study

Co-Processing Impacts on Utilities



Legend:
Example Hydro processing scheme

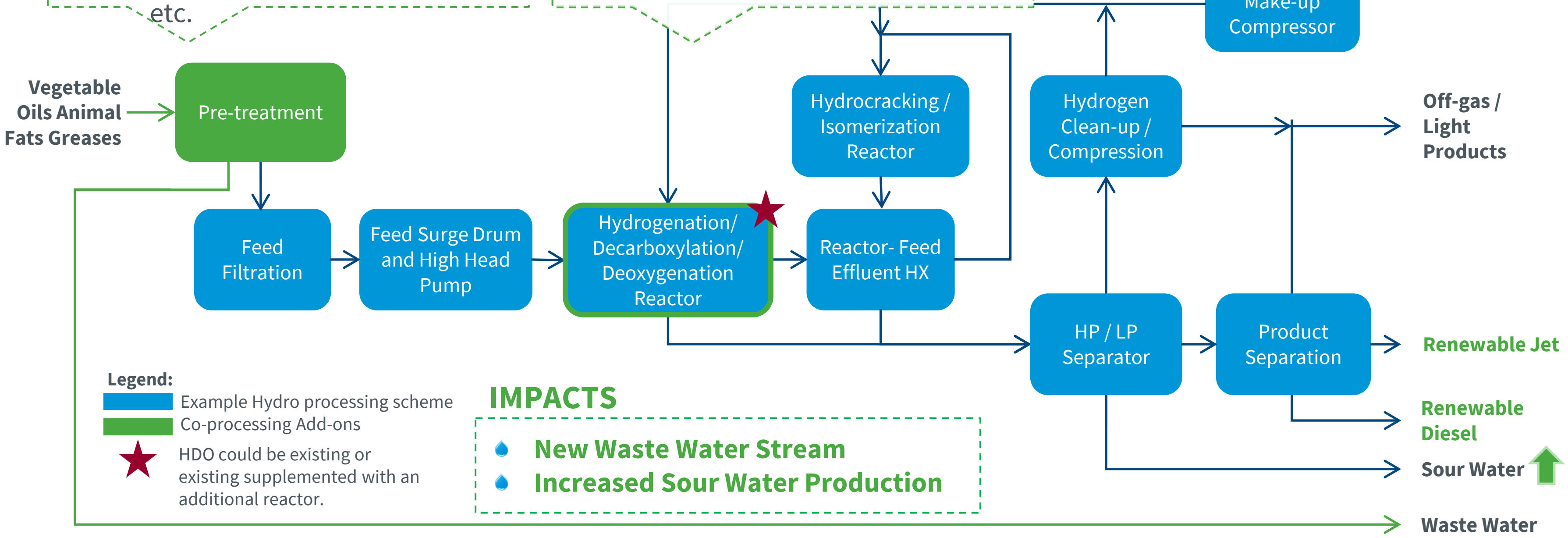
Co-Processing Impacts on Utilities

Pre-treatment:

- Characteristics of feedstocks
  - Alkali metals, phospholipids etc.

Higher Exothermic:

- Provision of Quench gas lines and distributors



Legend:

- Example Hydro processing scheme
- Co-processing Add-ons
- ★ HDO could be existing or existing supplemented with an additional reactor.

IMPACTS

- **New Waste Water Stream**
- **Increased Sour Water Production**

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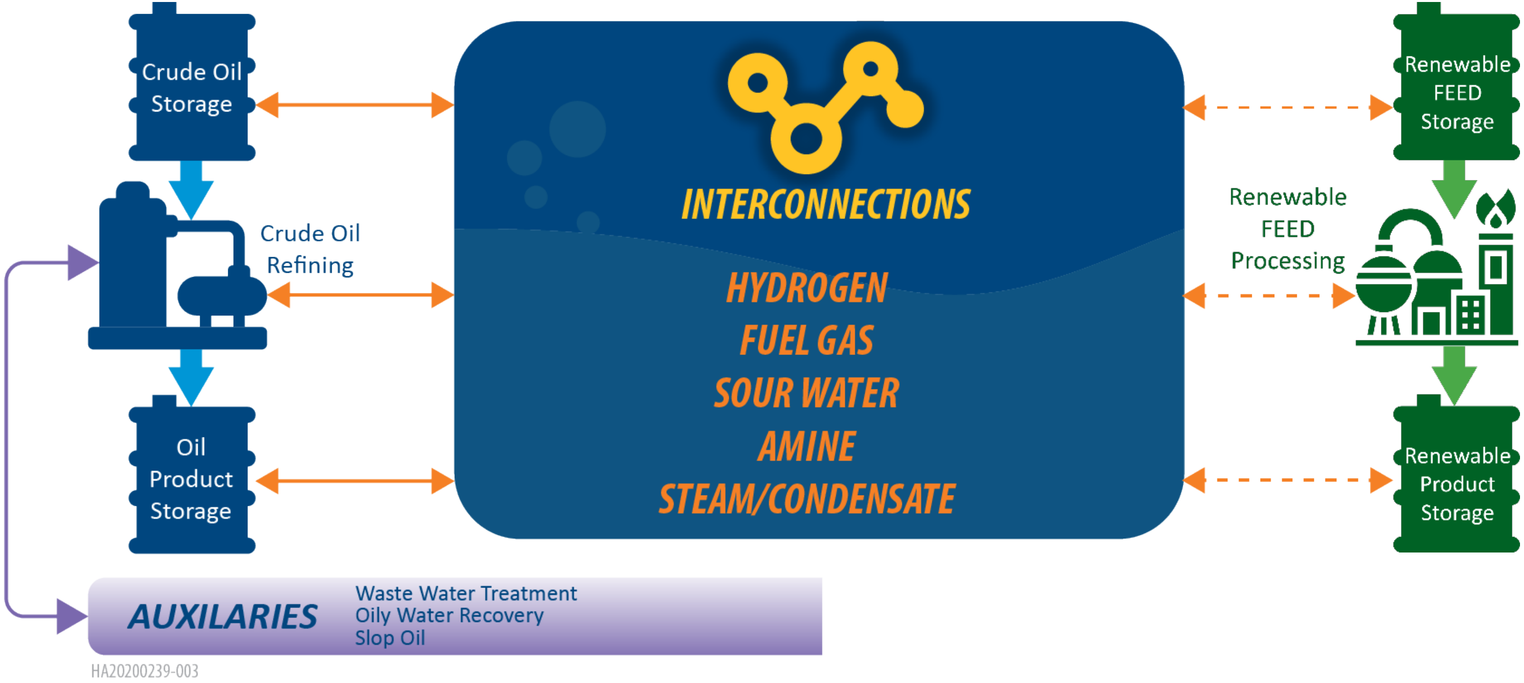
Case Study

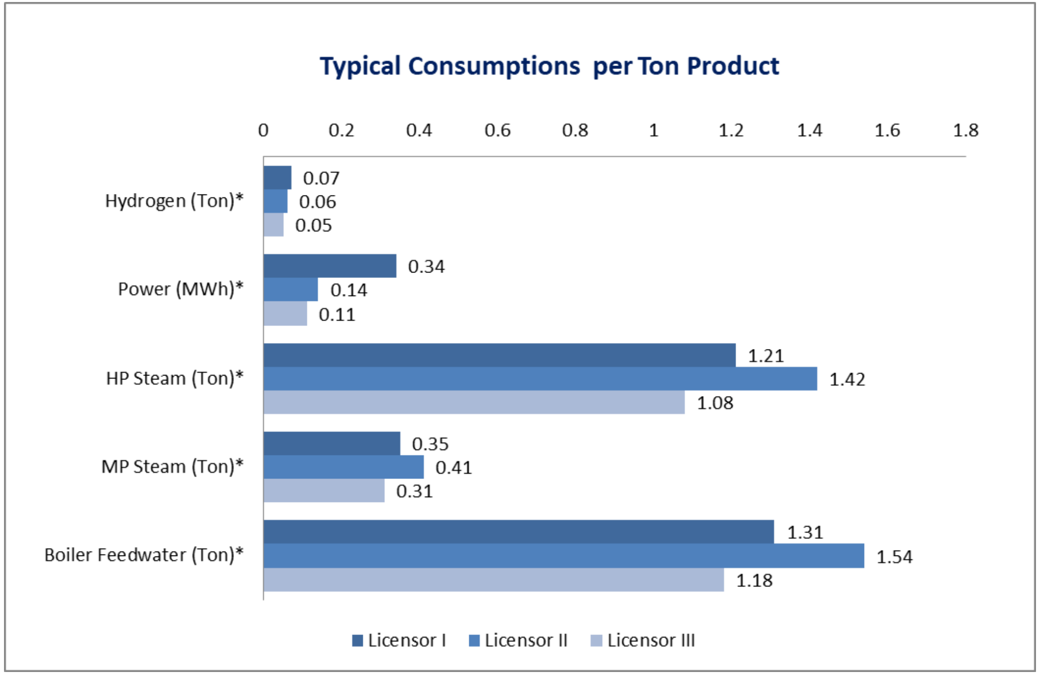
Utility Footprints



Case Study

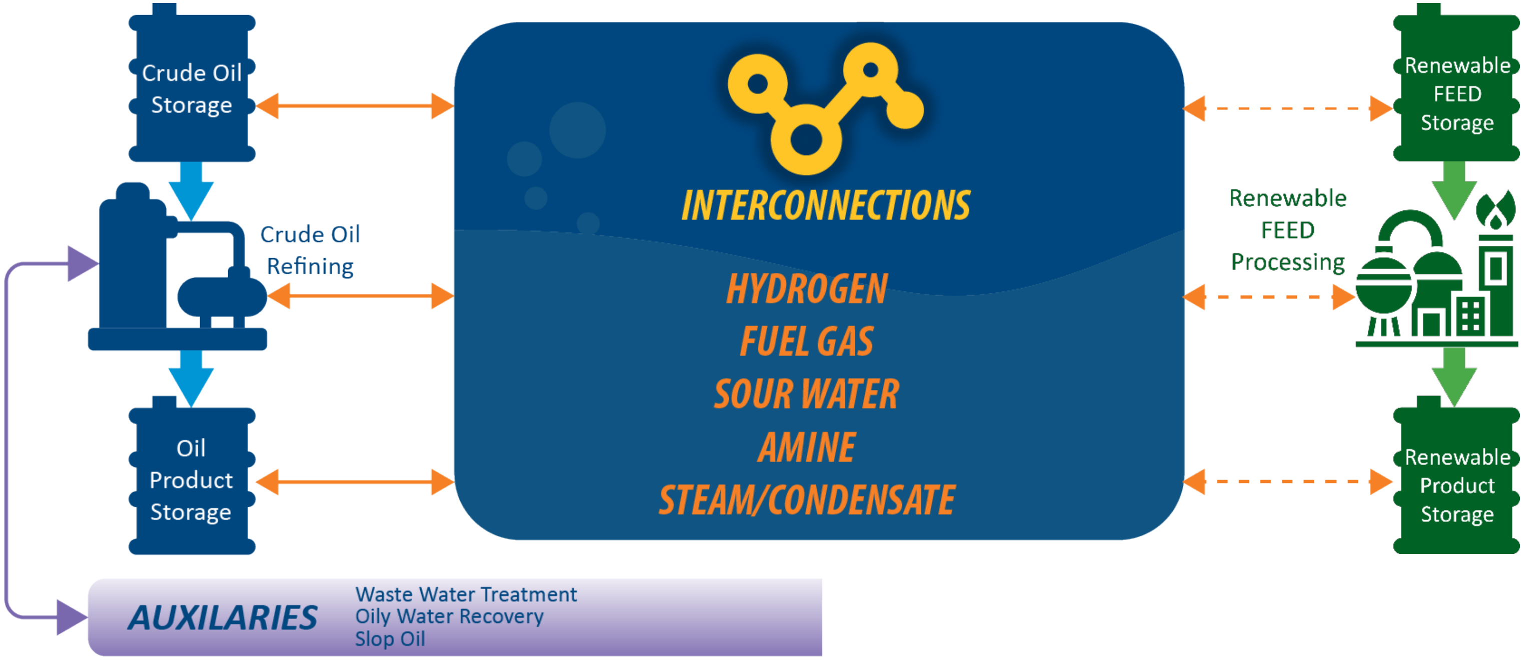
Utility Footprints

- Quick Scan for the existing utility capacities
- Main Differences Power Consumption and Boiler Feedwater



**Data Source: Nexant Bio renewable Insights: Non-Ester Renewable Diesel, September2019.*
UOP Ecofining, Haldor Topsøe Hydroflex, Neste NeXBTL

Utility Footprints



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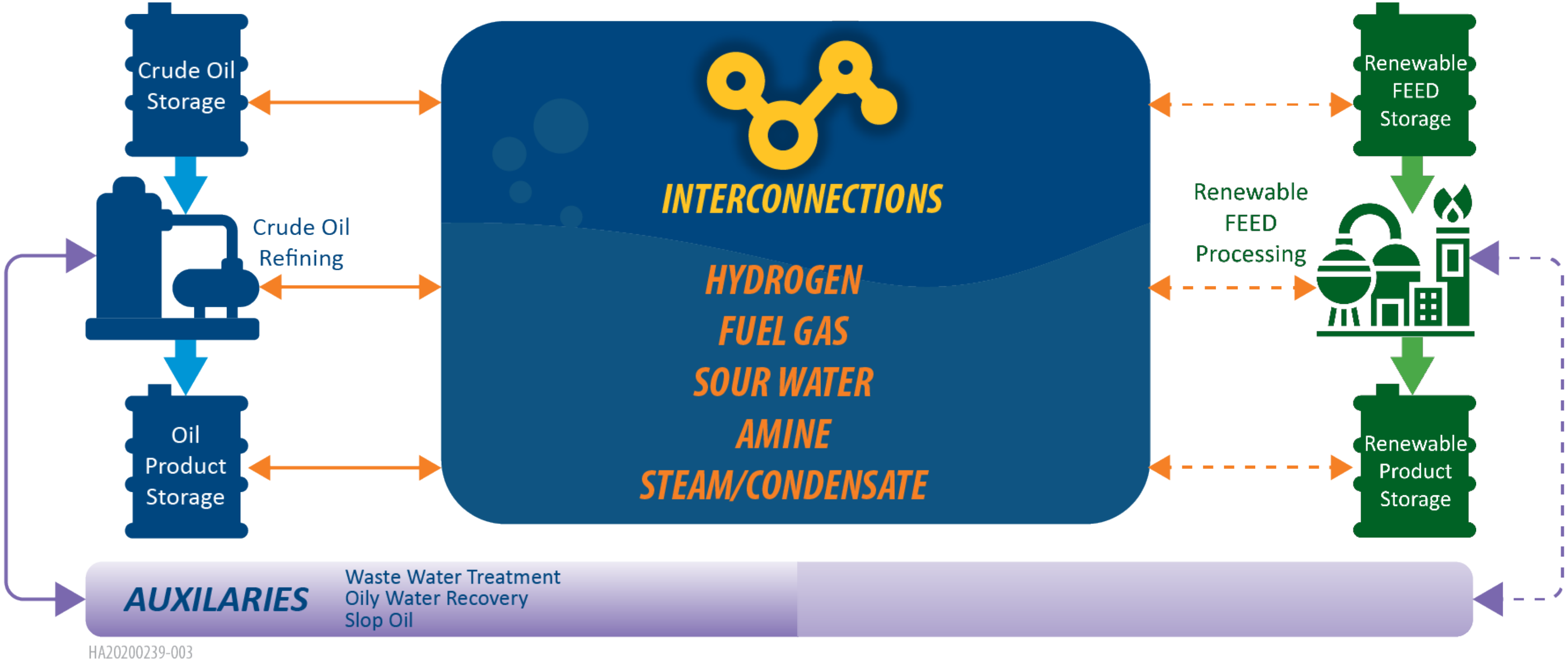
Case Study
Utility Footprints



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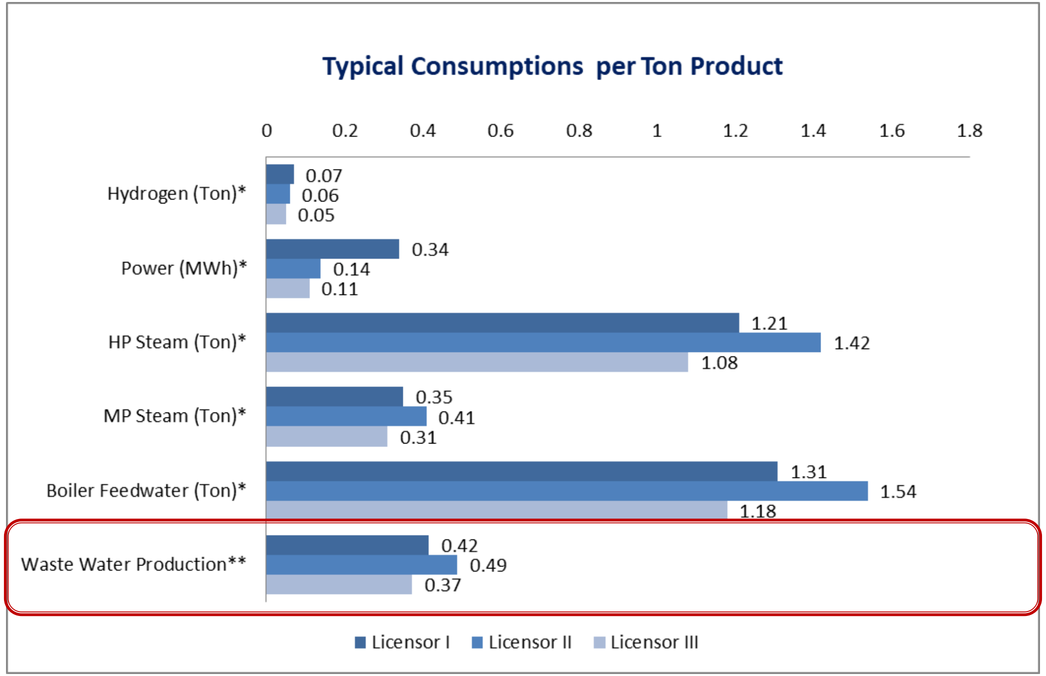
Case Study

Utility Footprints

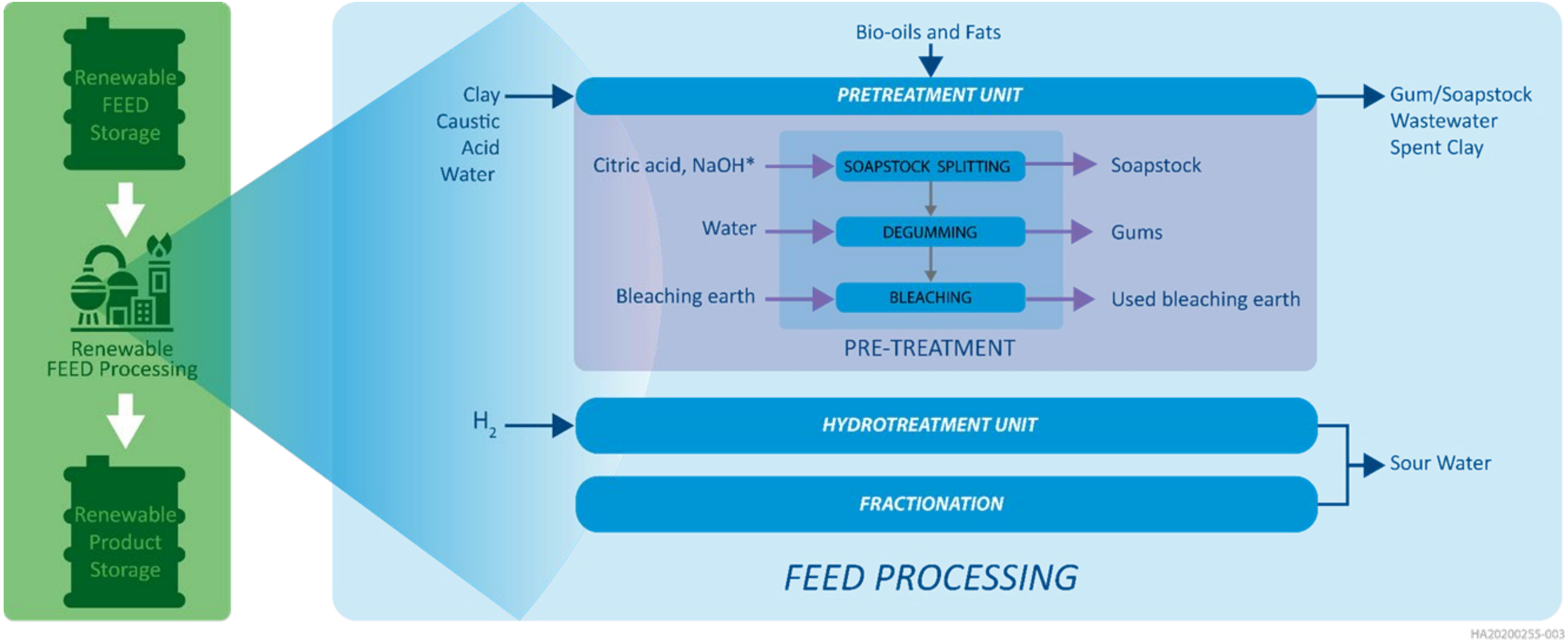
- Quick Scan for the existing utility capacities
- Main Differences Power Consumption and Boiler Feedwater
- The wastewater originated from the processing at least 10 – 30 % of the feed flow
  - ~ 10% for pre-treatment
  - ~ 20% for sour water draw



**Data Source: Nexant Bio renewable Insights: Non-Ester Renewable Diesel, September2019.*
UOP Ecofining, Haldor Topsøe Hydroflex, Neste NeXBTL
*** in-house Information*

Case Study

Wastewater Treatment Plant Footprint



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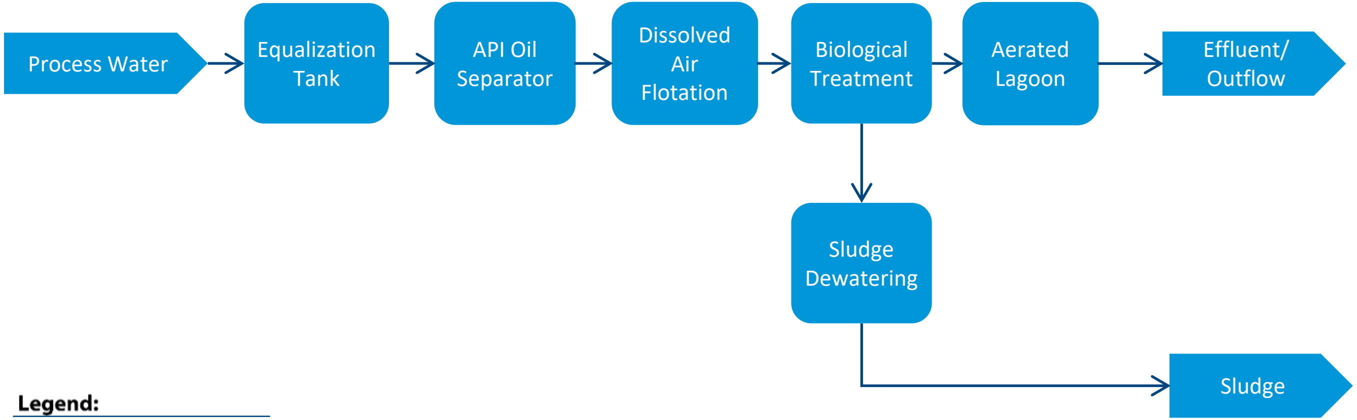
Case Study

Wastewater Treatment Plant Footprint



Legend:

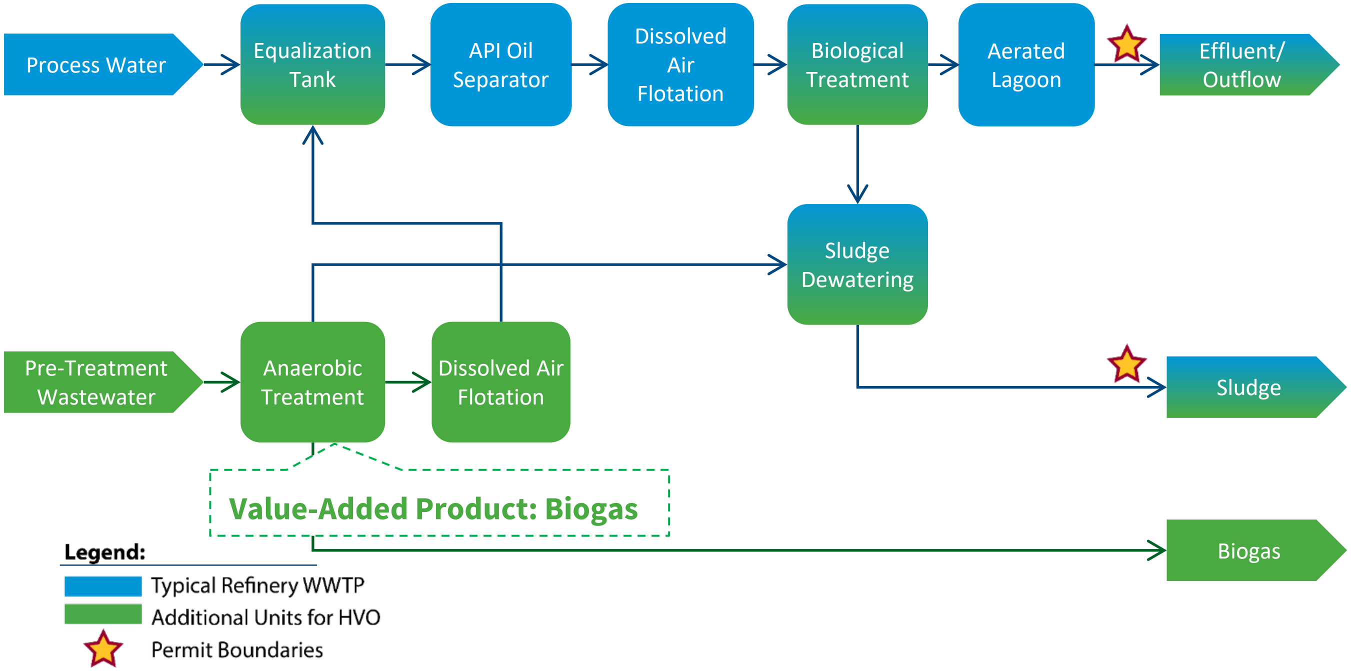
Typical Refinery WWTP

ABBREVIATION:

API : American Petroleum Institute

Case Study

Wastewater Treatment Plant Footprint



Additional Required Units:

- Anaerobic Treatment
- Dissolved Air Flotation (DAF)
- Odor Removal Unit (optional)

Modified Units:

- Equalization Tank
- Biological Treatment
  - Additional Nitrogen and Phosphorus Removal (subject to permit discussion)
- Sludge Dewatering

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RECAP: HVO Water and Wastewater

- Consider increasing market demand in Co-processing
- Diligent approach to Process Technology Selection and full integration **There are some “special “ aspects that can create some unexpected surprises !!!**
- Foresee the implications on utilities plus impacts **Cannot be fixed in the process, should be taken care of in the downstream units**
- Be conscious on Wastewater Treatment and permits. **Trouble in permitting might also impact process and production**

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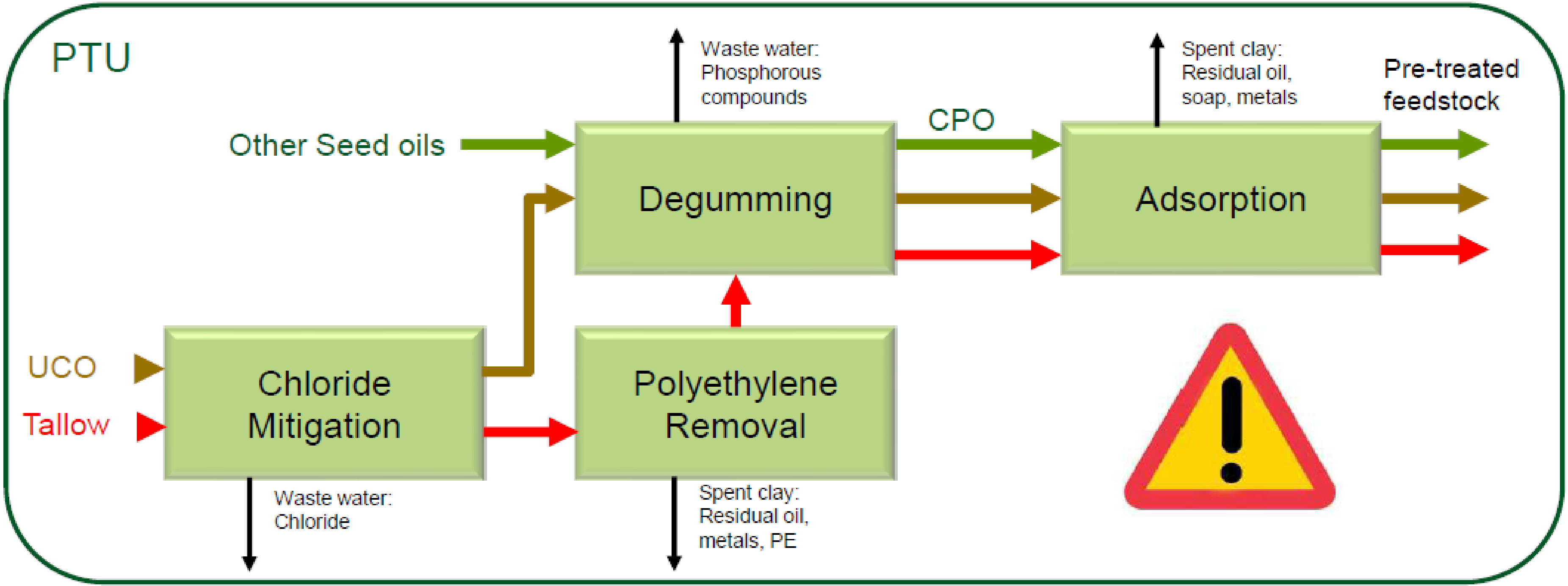
Bio feedstock



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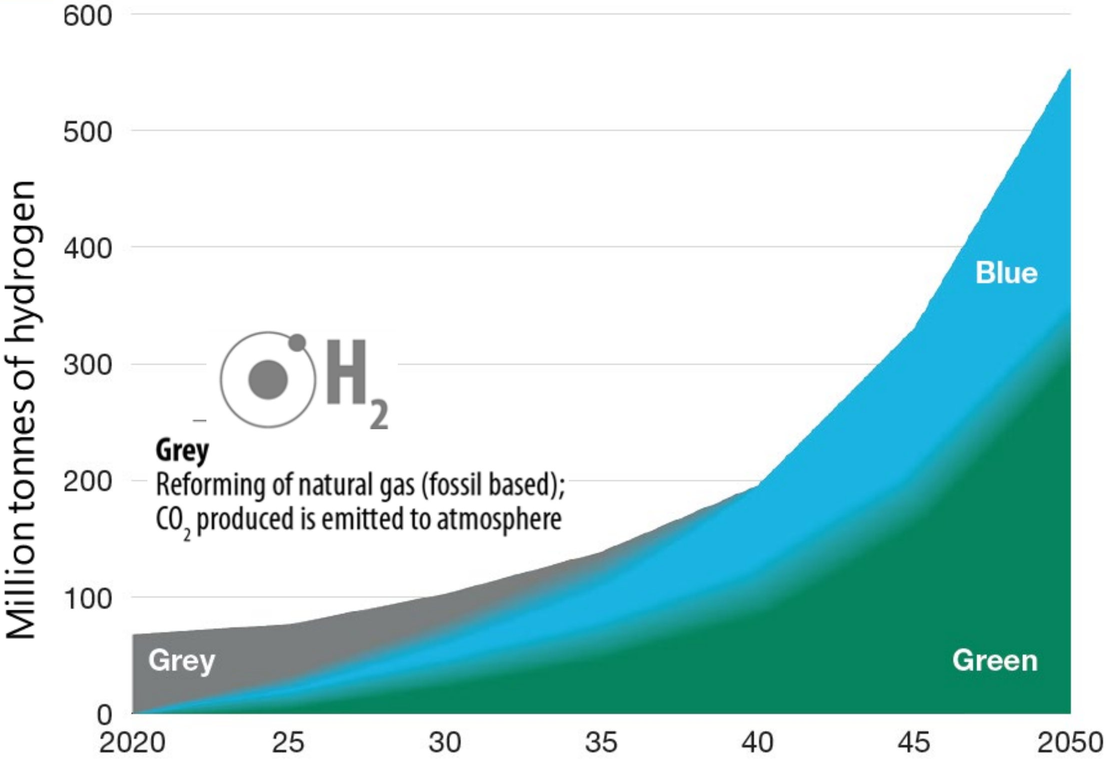
The Trending Green Hydrogen Global Production



Blue
Reforming of natural gas (fossil based);
CO_2 produced is captured and stored

Green
Electrolysis of water; electricity only from renewable sources (no CO_2 production)

Image Credit: Hydrogen Council, Hydrogen Decarbonization Pathways

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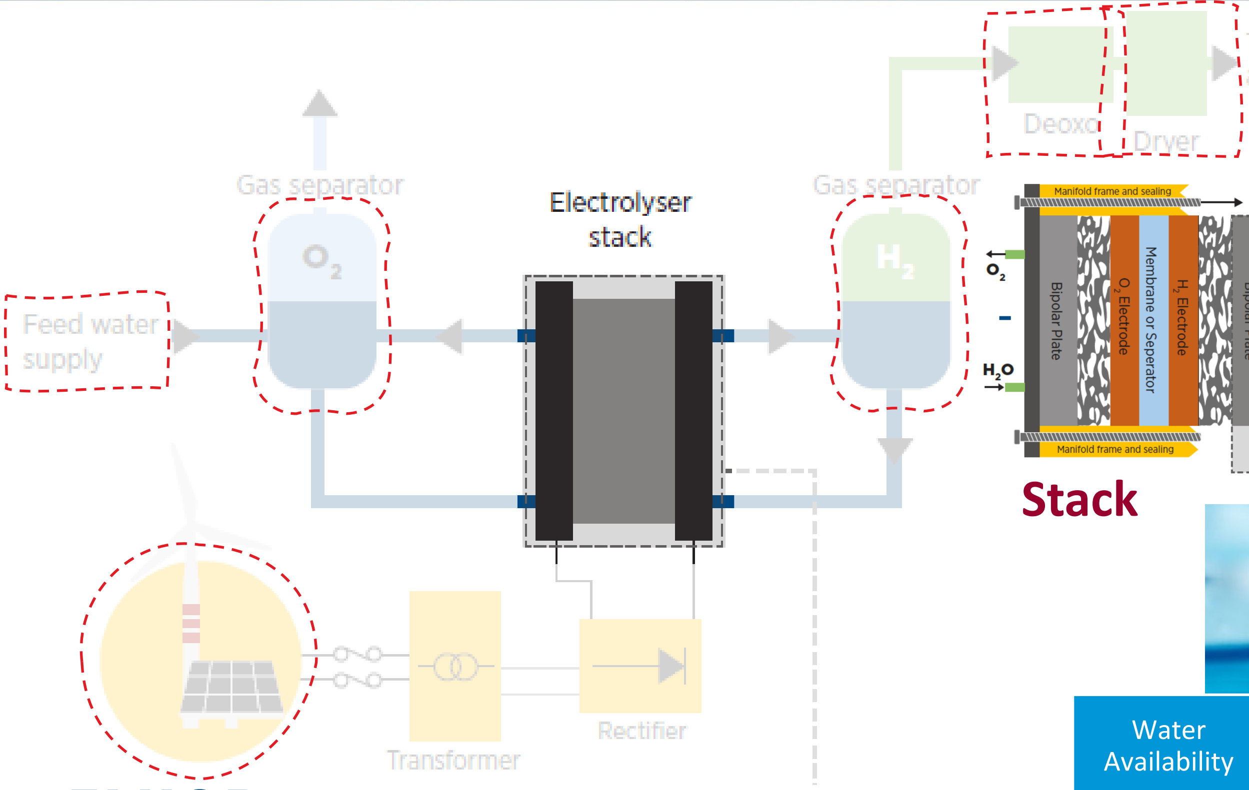
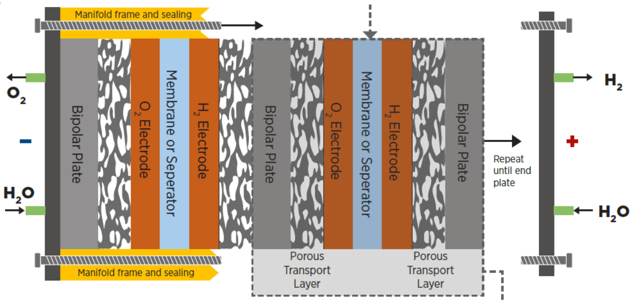
Electrolysis Technology Working Principle





Stack

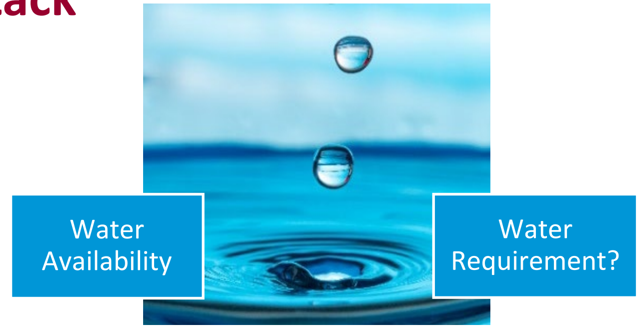
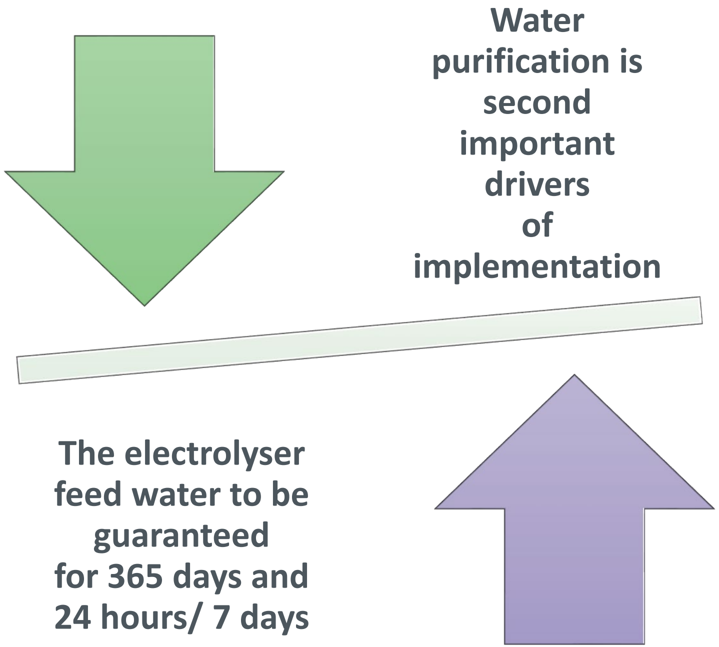


Image Credits: IRENA, Green Hydrogen Cost Reduction

Green Hydrogen

- Potential locations, hydrogen demand and plot sizes for these facilities
- System integration regarding infrastructure connections
- Availability of water and co-siting opportunities



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GW Scale Green Hydrogen Facilities

Proposed GW Locations | **Water Infrastructure** | **WW Treatment**

- 5 industrial clusters
- A total of 22 locations are identified and available space and infrastructure have been evaluated.

All locations across the five regions;

- No existing nor any projected facility that can provide the demin water demand of around 200m3/h and quality required for the GW electrolyser

https://rhk.maps.arcgis.com/apps/webappviewer/index.html?id=d94d70425c6b4c6f88a8143eda028d11

Source: Hydrohub: Integration of Hydrohub GigaWatt Electrolysis Facilities in Five Industrial Clusters in The Netherlands

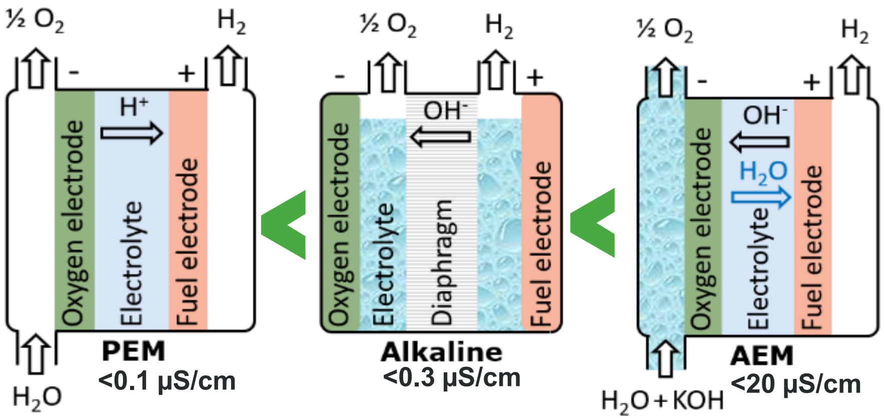
Feed Water Requirement in Electrolysis

Water

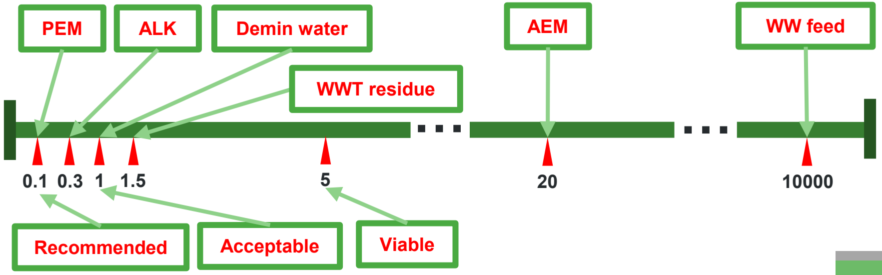
- **Low conductivity: <1 µS/cm is acceptable, although <0.1 µS/cm is recommended. Up to 5 µS/cm may be viable.** At these low cond., individual component specs are less important.
- Residuals from the water treatment process is starting point. Treat WW*: **1~1.5 µS/cm**.
- Extensive demineralization required. Demin water: **<1 µS/cm**.
- The PEM water supply requires lower cond. (**<0.1 µS/cm**) than alkaline process water (**<0.2 or <0.3-5 µS/cm**); AEM licensor indicates up to **20 µS/cm**.

* PO/TBA/POSM facility WWT unit effluent

Water (cond.) requirements for PEM, Alkaline, AEM:



Water (cond.) requirements overview



PEM: Proton Exchange Membrane
AEM: Anion exchange membrane

Industrial Water Grade System

Water Type Specifications as defined by ASTM D1193-91	Type I	Type II	Type III	Type IV
Electrical conductivity, max., µ8/cm at 298 K (25°C)	0.056	1.0	0.25	5.0
Electrical resistivity, min., MV cm at 298 K (25°C)	18	1.0	4.0	0.2
pH at 298 K (25°C)	*	*	*	5.0 to 8.0
Total organic carbon (TOC), max, µg/L	50	50	200	No limit
Sodium, max, µg/L	1	5	10	50
Chlorides, max, µg/L	1	5	10	50
Total silica, max, µg/L	3	3	500	No limit
Microbiological contamination – When bacterial levels need to be controlled, reagent grade types should be further classified as follows:		**Type A**	**Type B**	**Type C**
Maximum heterotrophic bacteria count		10/1000 mL	10/100 mL	100/10 mL
Endotoxin, EU/ml		<0.03	0.25	N/A

* *The measurement of pH in Type I, II, and III reagent waters has been eliminated from this specification because these grades water do not contain consistent in sufficient quality to significantly after the pH.*

Type I

- Ultrapure with a resistivity of >18 MΩ cm
- Required for analytical labs
- Applications include HPLC, gas chromatography, cell culturing, tissue culturing, mass spectrometry and any endeavor involving trace elemental laboratory instruments

Type II

- Resistivity of > 1 MΩ cm
- Cleaner than Type III but not ultrapure
- Applications include electrochemistry, sample dilution, radioimmunoassay and media preparation

Type III

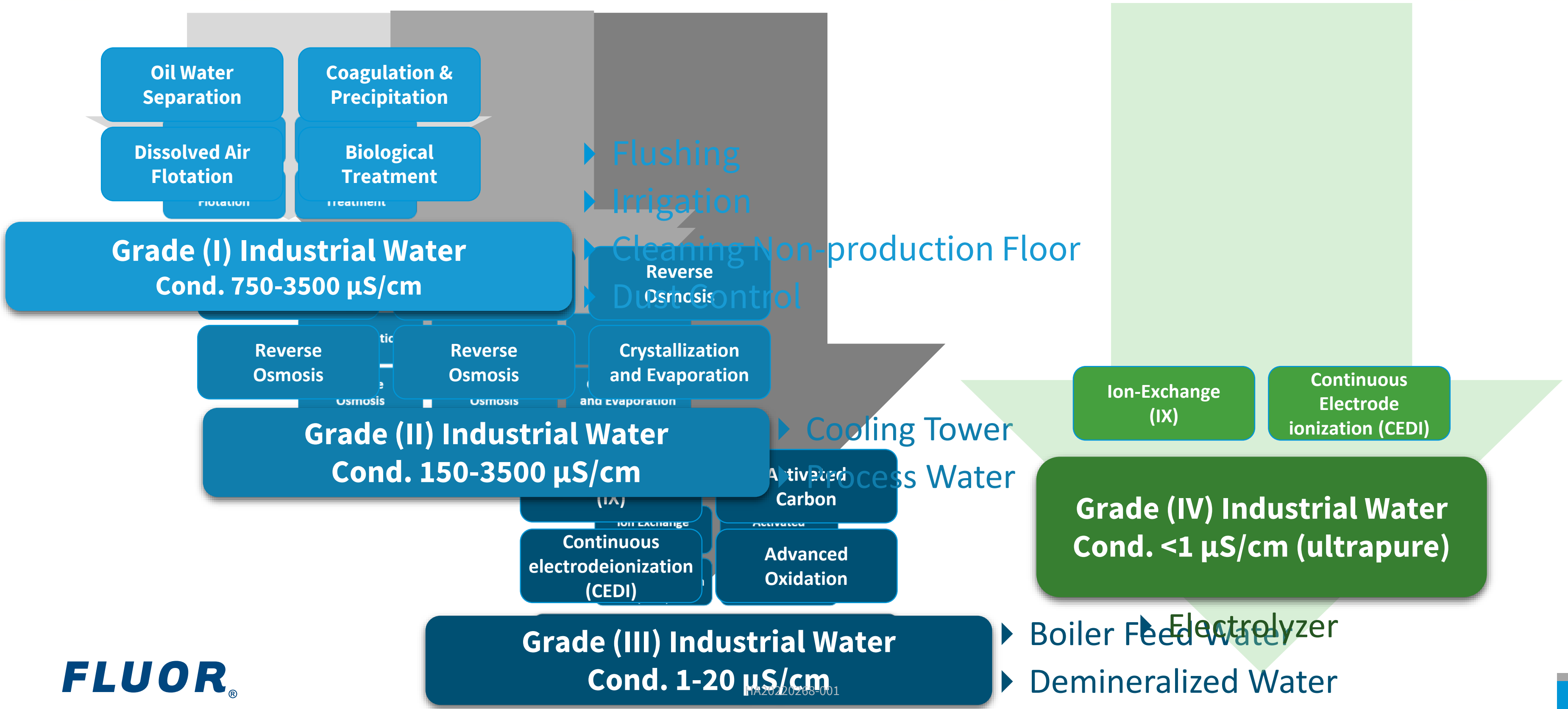
- Resistivity of >4 MΩ cm
- Produced using Reverse Osmosis (RO) and removes 90-99% of contaminants
- Applications include glassware rinsing, media preparation, feedwater use and other non-critical laboratory applications

Type IV

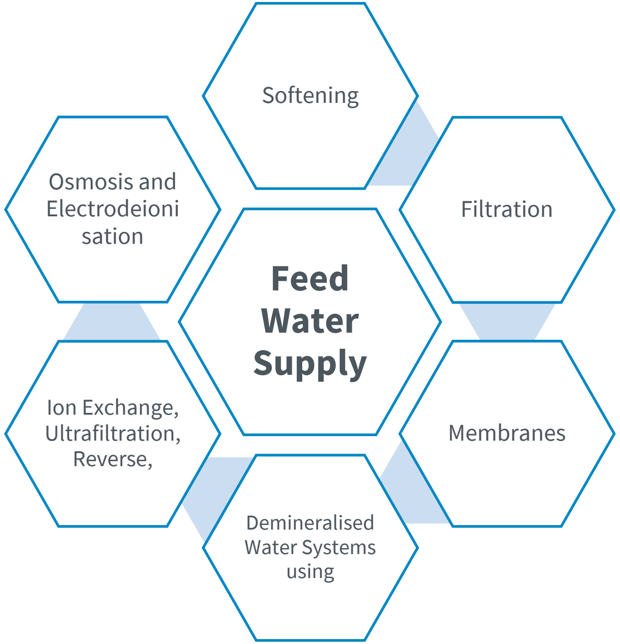
- Resistivity of 200KΩ
- Generally produced by RO
- Typically used as feedwater to a Type I or Type II deionized (DI) system

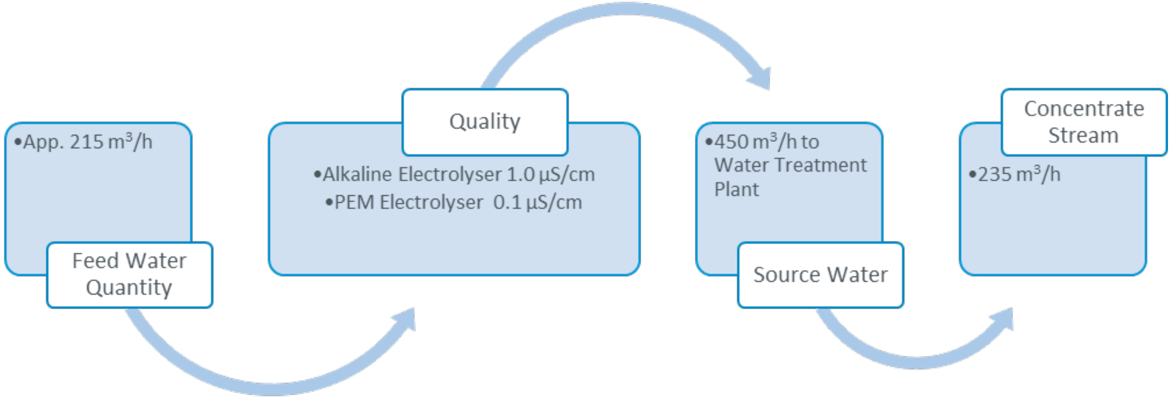
Water Quality Standard ASTM Type II
ISO3696 Standard Grade II:ISO 3696:1987 Water for analytical laboratory use
https://www.labconco.com/articles/water-type-difference#:~:text=Type%20I%20%2D%20Ultrapure%2C%20Type%20I,Total%20Organic%20Carbons%20(TOC).

Industrial Water Grade System



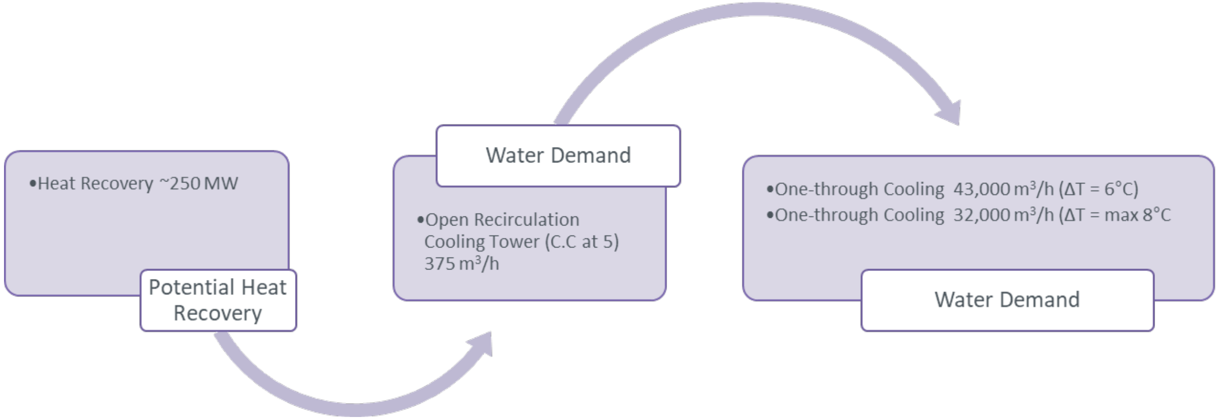
Feed Water Supply





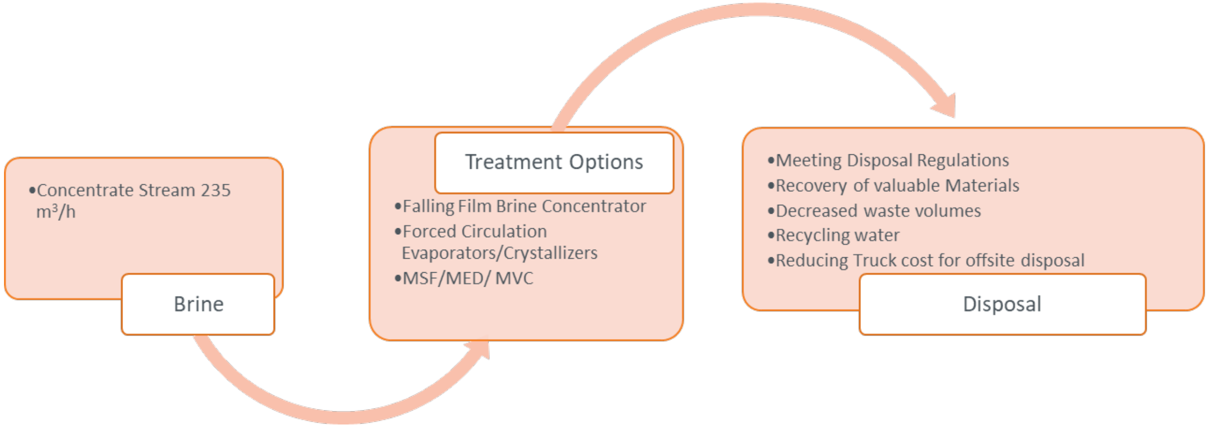
Source: ISPT, 2021

Cooling Water Systems



Source: ISPT, 2021

Wastewater Treatment and Reuse



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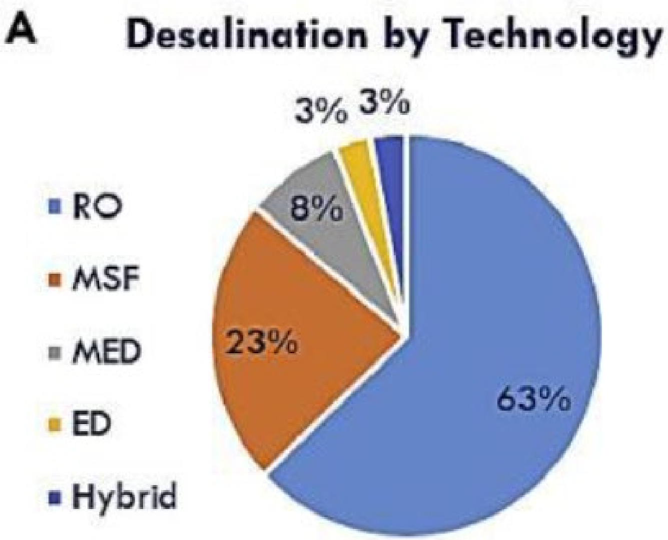
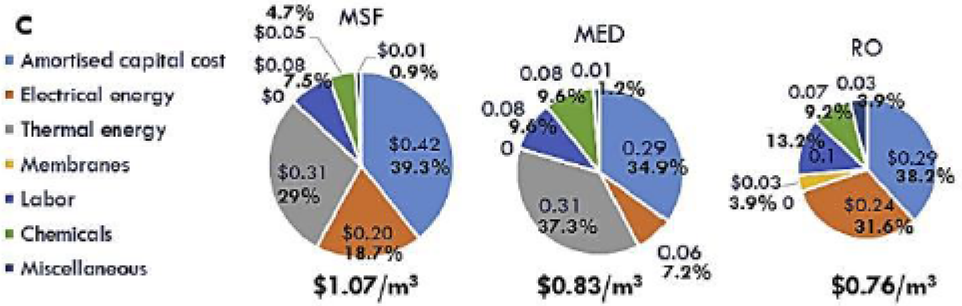
Technology Map

	Technology	ABBR	Type of Technology	Scale	Water Input	TRL Level (Current)	Output Water Quality [PPM]	Average Capacity [10^3 m^3/day]
1	Multi-Effect Distillation	MED	Evaporation and Condensation	Commercial	SW	9	10	0.6 - 30
2	Multi-Stages Flash	MSF	Evaporation and Condensation	Commercial	SW	9	10	50 to 70
3	Thermal Vapour Compression	TVC	Evaporation and Condensation	Commercial	SW	9	10	10 to 35
4	Mechanical Vapour Compression	MVC	Evaporation and Condensation	Commercial	SW	9	10	0.1 - 3
5	Saltwater Reverse Osmosis	SWRO	Filtration	Commercial	SW	9	400-500	1 - 627
6	Brackish Water Reverse Osmosis	BWRO	Filtration	Commercial	BW	9	200-500	Up to 98
7	Forward Osmosis	FO	Filtration	In development special application (hydration bags)	SW. BW	4		0.01 - 10
8	Nanofiltration	NF	Filtration	In development at dual stage unit	BW, SW Development	6		26.4 (ger)

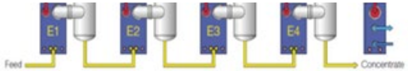
Technology Selection





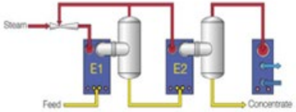
- Energy Recovery Device (ERD)

Steam or waste heat (hot water 90-95°C)



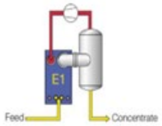
- TVR Thermo Vapour Recompression

Steam > 3-4 barg



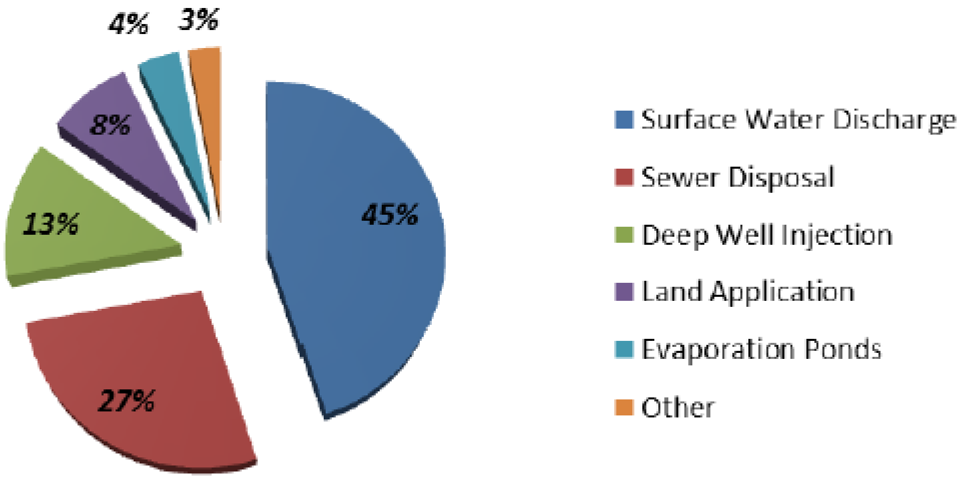
- MVR Mechanical Vapour Recompression

No steam required



Source: Lenntech, 2018

Brine Treatment



Source: Lenntech, 2018

- Bench scale test
  - Physical properties
  - Boiling point elevation
  - Crystallization, fouling, concentration limits

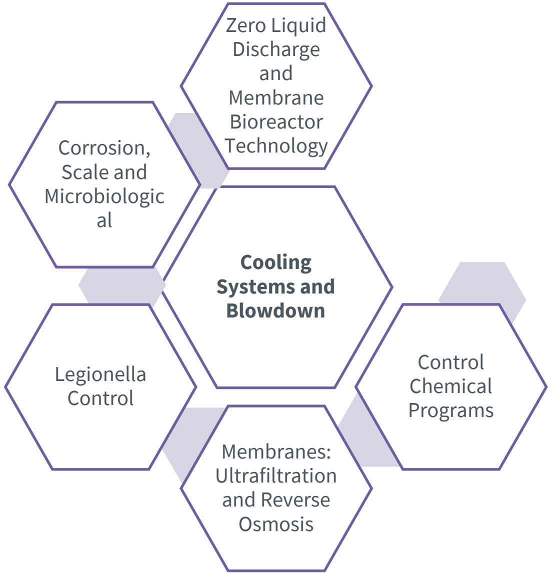
MLD – Minimum Liquid Discharge

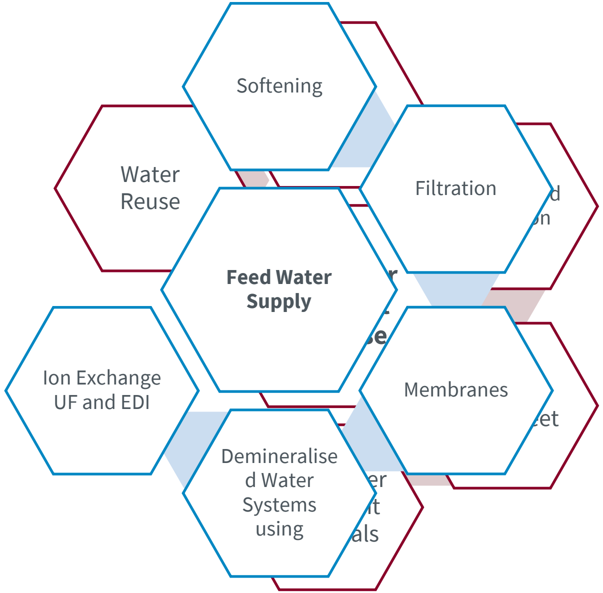
- Evaporator Only
- Effluent (residual waste) is Liquid
- < 40 wt% Total Solids (disolved + crystals)
- Limit solids content to avoid plugging

ZLD – Zero Liquid Discharge

- Evaporator + Solids Dewatering (decanter centrifuge)
- Effluent (residual waste) is Solid
- Cake Dryness up to 85 wt% (no liquid water dripping)

An Integrated Water Management





RECAP: Water for Green Hydrogen

- Global trends show that production of green hydrogen is replacing grey hydrogen.
- Electrolysis requires large amounts of water with stringent quality requirement i.e., in conductivity.
- Treated Effluent maybe be the starting point of electrolysis, with 1 uS/cm preferably.
- Alkaline electrolyser can handle water with higher conductivity values up to 5 uS/cm compared to PEM
- Integrated Water Management is crucial

RECAP

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Summary & Conclusion

Water is an integral part of energy transition

- Energy Transition Technologies gain great momentum and strong link with water.
- Definition of a higher grade of industrial water
- Product Recovery becoming important due to stringent water requirements
- Various wastewater treatment steps to recover different pollutants are required
- An integrated Water System is becoming more and more unavoidable
- Integrated Water Systems: Utilities system and wastewater system to be handled as one.

Design Approach

FLUOR INTEGRATED WATER SOLUTIONS

HA20200239-005

MINIMIZE AT SOURCE	*REUSE*	*PRODUCE*
Optimisation of production processes	Water Pinch Analysis	Biorefinery Focus
Increase of efficiency	Lean Water Investment	Valorisation of Wastewater
Not creating needless waste		

Questions?

Contact Details

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Thank You!

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