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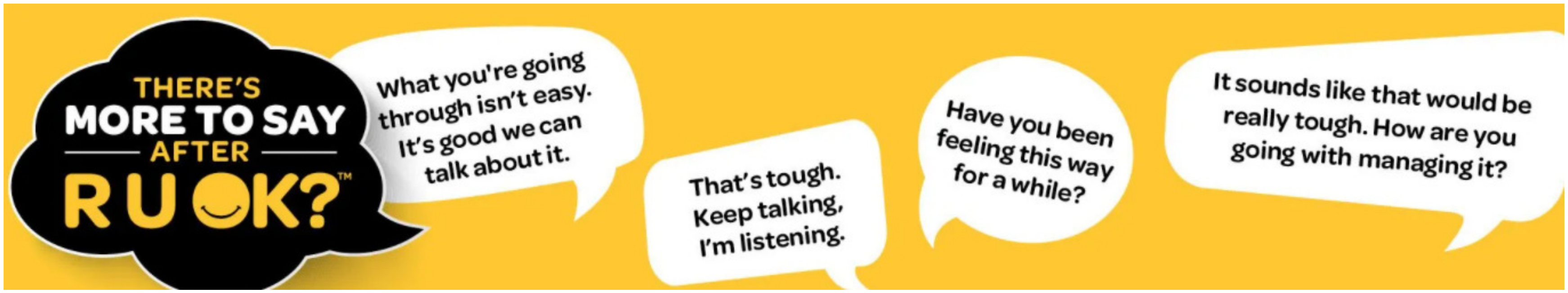
Hydrogen – A New Energy Solution for the Water Industry

In the kNOW Webinar Series

Oct. 26-27, 2020

R U Ok? How to talk about mental health



https://www.ruok.org.au/how-to-ask

- Be ready with time, a private setting and a genuine willingness to listen
- Be prepared to understand that you can't fix someone's problems, but you can listen without judgement

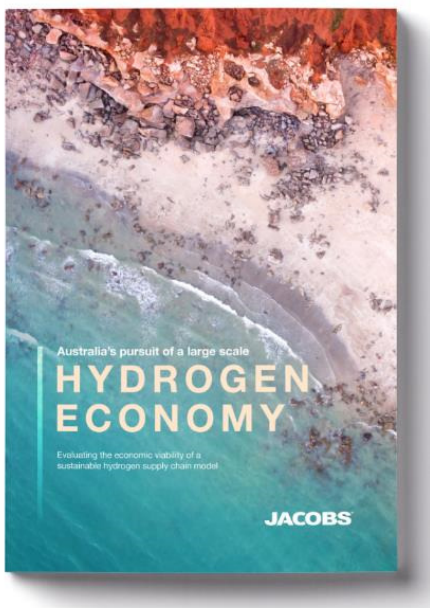
ASK – in a friendly way
LISTEN with an OPEN MIND – don't judge or rush to help, let them talk and seek to understand
ENCOURAGE ACTION - guide to draw on supports, including professional help
CHECK IN - Stay in touch

Hydrogen: what is it and why important?

- A form of energy **storage** - important for maximising renewable energy
- Can be produced in a number of ways – 'sustainable' hydrogen accounts for the water input
- Potential to decarbonise our most emissions-intensive industries (including transport)
- Cost-competitiveness?

1st hydrogen paper (2019)

Can hydrogen live up to its potential for economic growth without compromising broader sustainability goals, including emissions reduction and water security?



2nd hydrogen paper (2020)

Explores the pivotal role of water utilities in defining a cost-effective and environmentally-friendly role for recycled water in hydrogen production

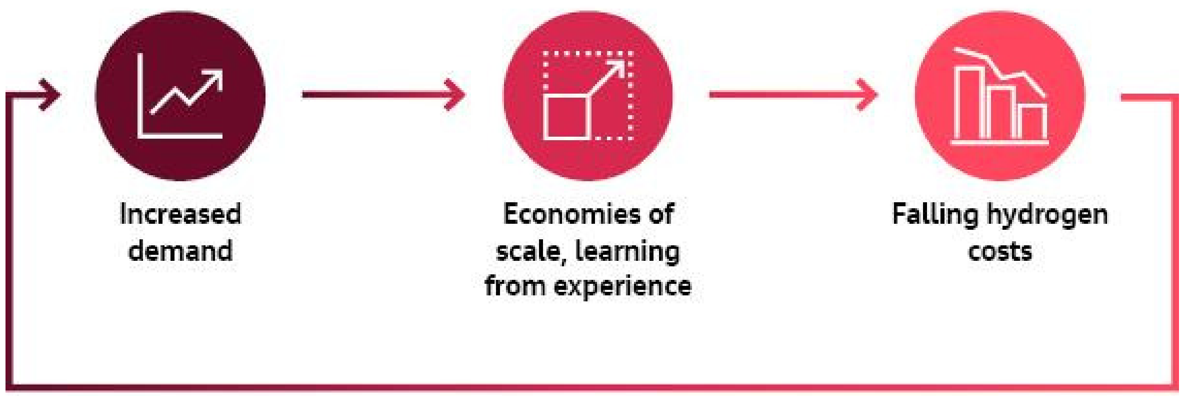
Agenda

- **David Middleton**, Executive Director, Water, Asia Pacific will share the role of Wastewater Treatment Facilities in the Development of Australia's Hydrogen Industry
- **Pat McCafferty**, Managing Director of Yarra Valley Water will discuss the case study for the Yarra Valley Water's Aurora Wastewater Treatment Plant
- **Tom Johnson,** Jacobs Global Technology Leader for Wastewater Process Simulation will share the case study for typical US wastewater treatment facilities
- **Sarah Dorminy,** Jacobs Systems Engineer will discuss renewable energy's role in hydrogen production
- **Q&A**

The context

Hydrogen in Australia: current status

- Sustainable hydrogen holds potential for decarbonisation and international trade
- Cost remains a barrier to widespread adoption
- A price range of $2-6/kg would allow hydrogen to compete with alternatives



Source: Adapted from Figure 2.4 from 'Australia's National Hydrogen Strategy', COAG Energy Council (2019).

The opportunity

‘What if’ the growth of Australia’s domestic hydrogen market could be supported by co-locating hydrogen production at Wastewater Treatment Plants?

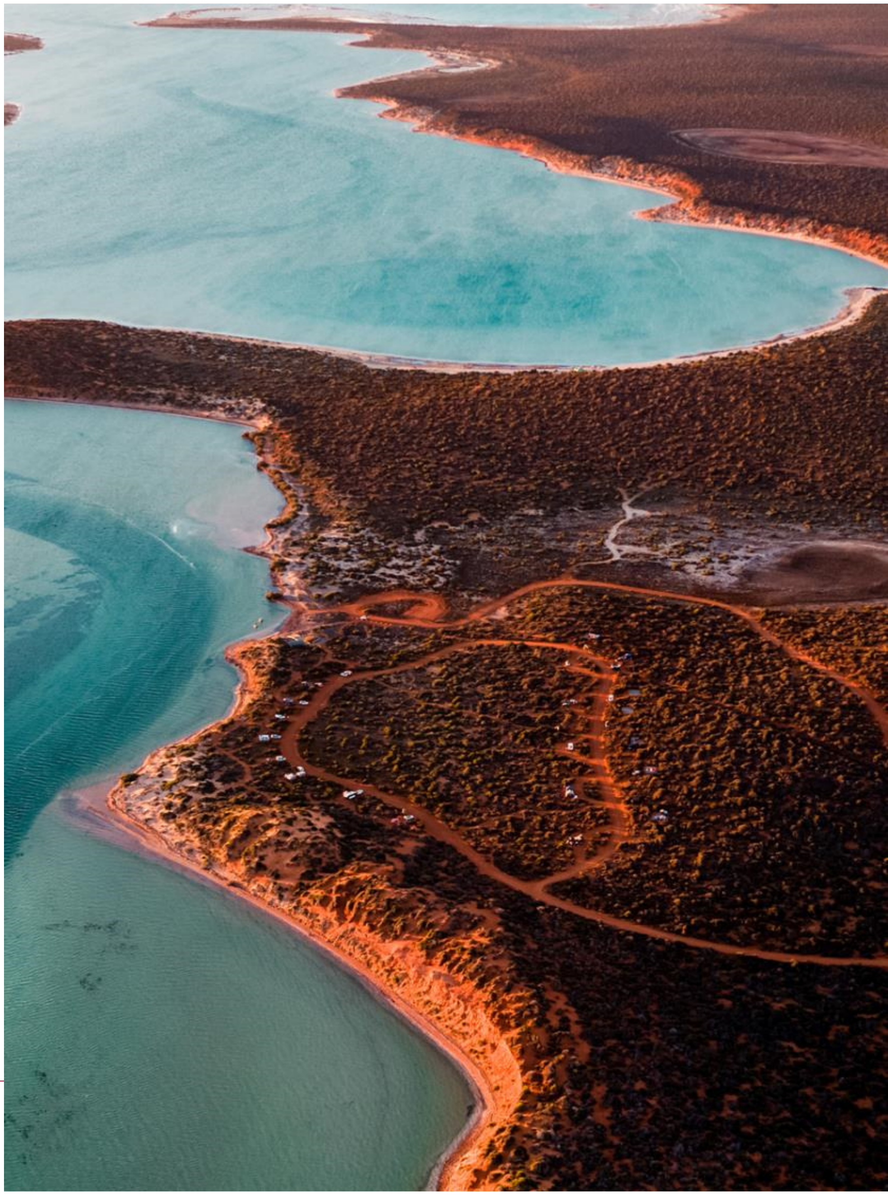
A demand for pure oxygen

- Electrolysis using renewable energy and recycled water produces two products – sustainable hydrogen and pure oxygen
- Pure oxygen can increase the efficiency of energy-intensive aerobic treatment processes
- If CAPEX and OPEX savings are substantial, this represents a unique opportunity to partially subsidise hydrogen production with the sale of oxygen and increase its commercial viability.

Results & Significance

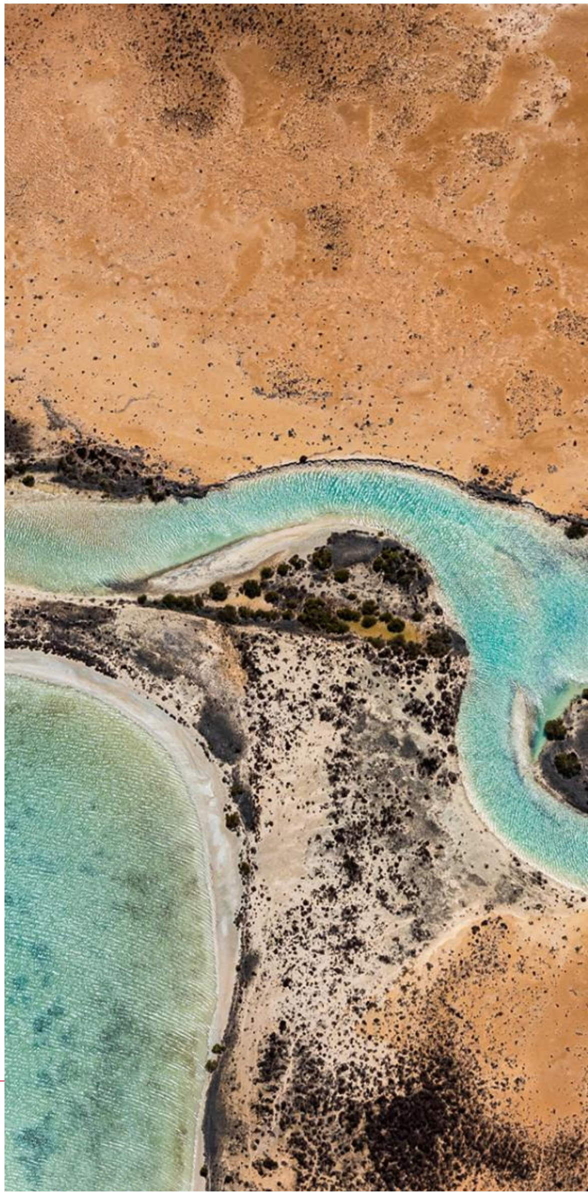
Overview of findings

- Implementing a type of oxygen-based treatment **delivered net capital and operating cost savings**
- At the same time, the guaranteed demand for oxygen was instrumental in enabling the co-located hydrogen facility to be commercially viable while selling hydrogen **within a competitive price range of $2-$6/kg.**



Significance for water utilities

1. Cost savings from oxygen-based treatment
2. Oxygen supply could be scaled for additional beneficial applications (odour and corrosion control)
3. Optimise use of water resources
4. New revenue streams from hydrogen and oxygen
5. Alignment with SDGs: Affordable and Clean Energy (7), Sustainable Cities and Communities (11), Climate Action (13), Partnerships (17)
6. Potential for enhanced community wellbeing



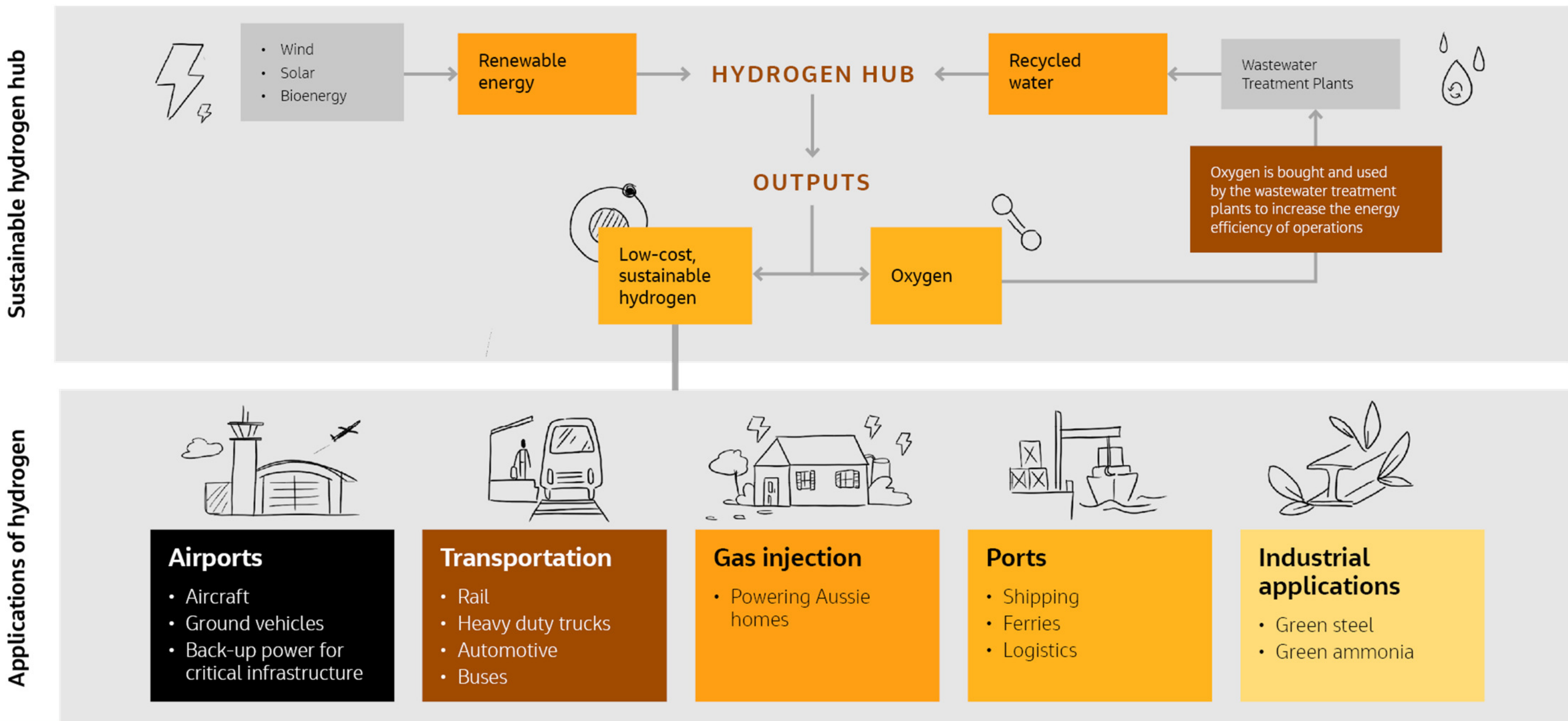
Aligns with Australia’s hydrogen objectives

1. A guaranteed demand for the oxygen could increase the commercial viability of co-located hydrogen production.
2. WWTP-based hydrogen hubs might improve the financial viability for early entrants.
3. Australian Governments’ ‘H2 under 2’ goal

Key message

- Water utilities could have **a pivotal role to play** in accelerating the development Australia's hydrogen industry.
- Co-locating hydrogen production at suitable WWTPs could help cut hydrogen prices by creating a second revenue stream from the oxygen.
- Whenever a WWTP is due for a substantially-sized upgrade, we recommend that the benefits of **transitioning to oxygen-based treatment** be considered alongside an assessment of whether an **on-site hydrogen facility** would be commercially viable.
- Next step is securing hydrogen offtake agreements with nearby businesses that could be mutually beneficial.

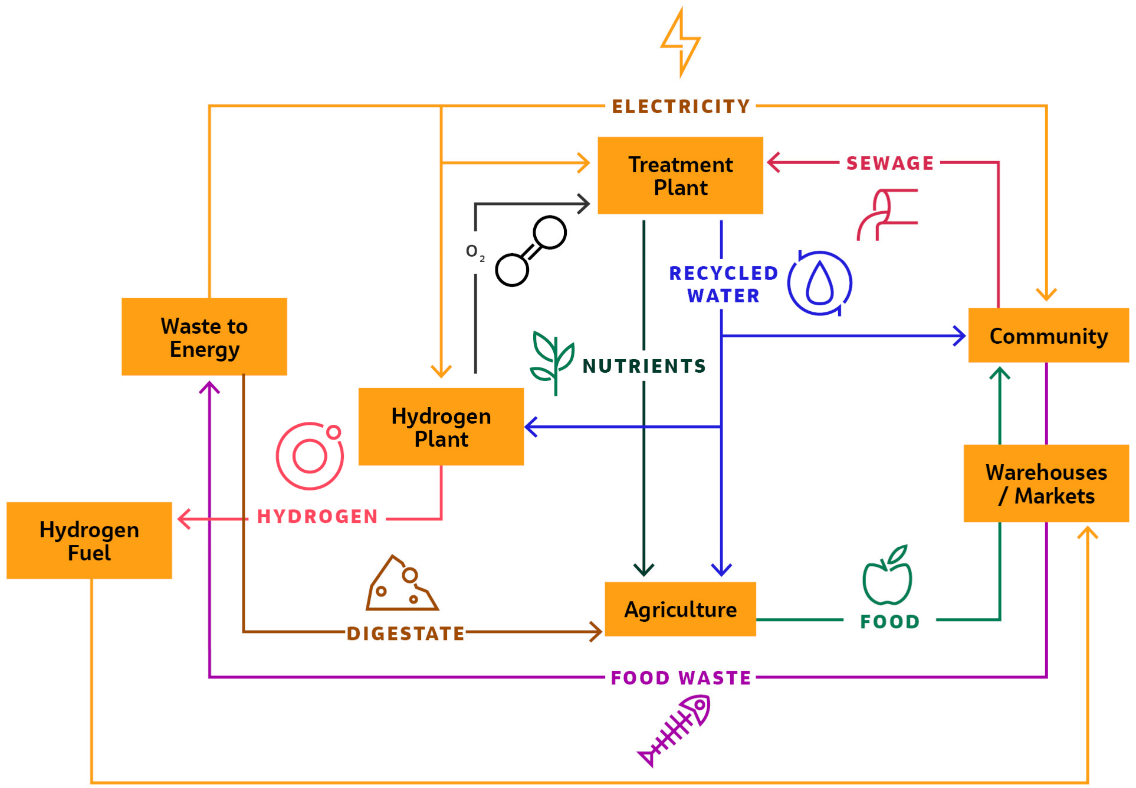
WWTP-based Hydrogen Hubs



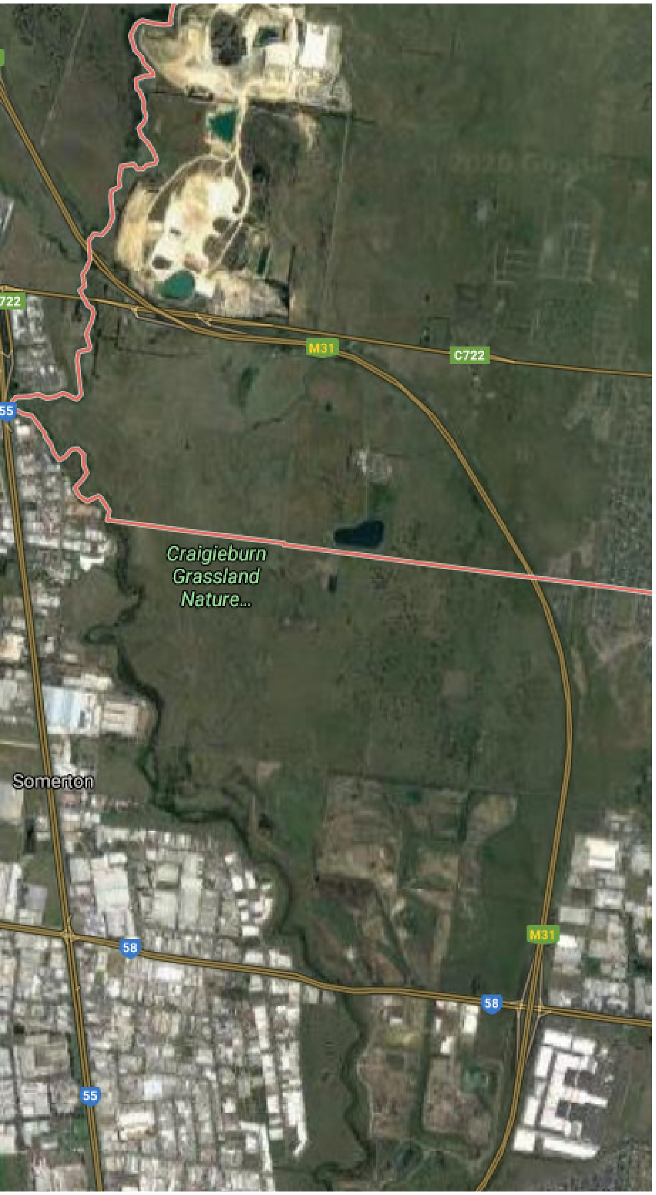
A case study:
Yarra Valley Water

Why we're interested: Suitability of WWTPs sites for hydrogen production

- Many WWTPs meet the recommended site conditions outlined for hydrogen hubs
- Access to primary inputs for sustainable hydrogen
  - Renewable energy
  - Recycled water
- Unutilised land in proximity of regional centres and potential off-takers



Resource	How it's currently used	How it could be used
Food waste from the community	Landfilled	As an input to waste-to-energy plants
Excess renewable energy from waste-to-energy plant	A proportion is unutilised due to infrastructure constraints.	As a source of renewable energy for hydrogen production
Recycled water	Dispatched into local waterways	As a sustainable water source for hydrogen production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C722
722
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Craigieburn Grassland Nature...
Somerton
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M31
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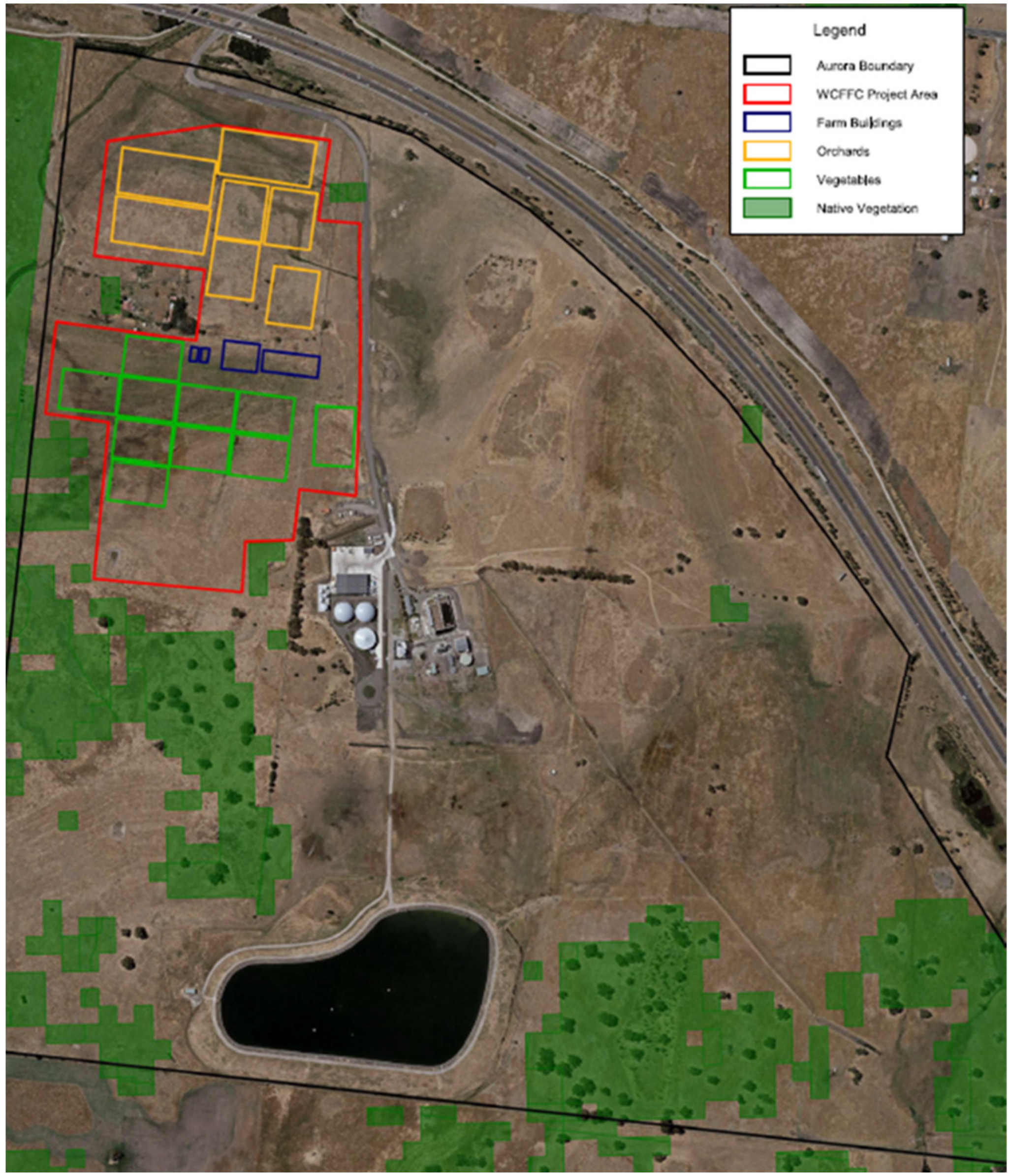
Legend
Aurora Boundary
WCFFC Project Area
Farm Buildings
Orchards
Vegetables
Native Vegetation

What's next for Yarra Valley Water

- Investigating hydrogen demand:
  - Gas network injection
  - Power generation
  - Mobility options (council garbage trucks, buses, forklifts in local industries)

Download the paper

- https://www.jacobs.com/newsroom/news/new-downloadable-thought-leadership-paper-toward-zero-carbon-future

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Using High Purity Oxygen Efficiently in WRFs

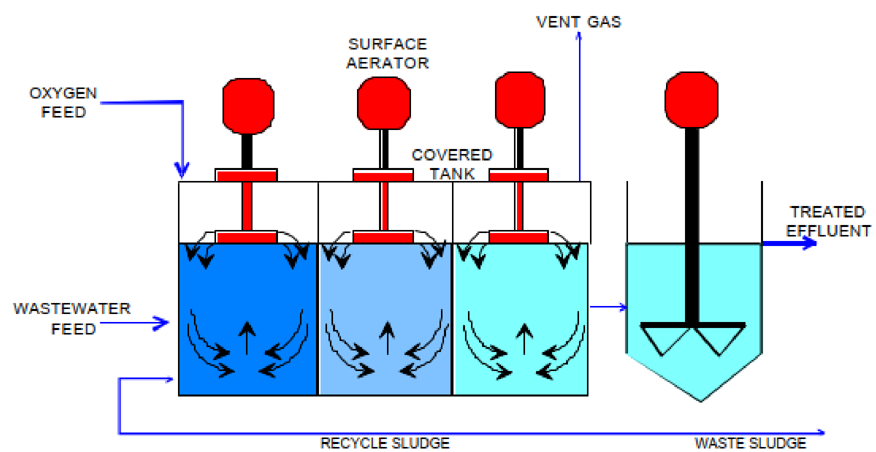
Tom Johnson, PE
Global Technology Leader in Wastewater Process Simulation

Hydrogen, Oxygen and Water Reclamation Facilities (WRFs)

- Oxygen is a valuable resource at WRFs
  - Biological treatment at WRFs primarily uses aerobic treatment for pollution degradation
  - Typically, air (~21% O_2) is compressed and injected/diffused into the liquid to dissolve oxygen for the microbiology to use for oxidation
  - High Purity Oxygen (HPO) is also an option for biological treatment
- Hydrogen is produced using electrolysis with water with pure oxygen (O_2) as a byproduct
- Thus WRFs would be an excellent customer to co-locate with hydrogen production facilities

How do we currently use High Purity Oxygen (HPO) in municipalities?

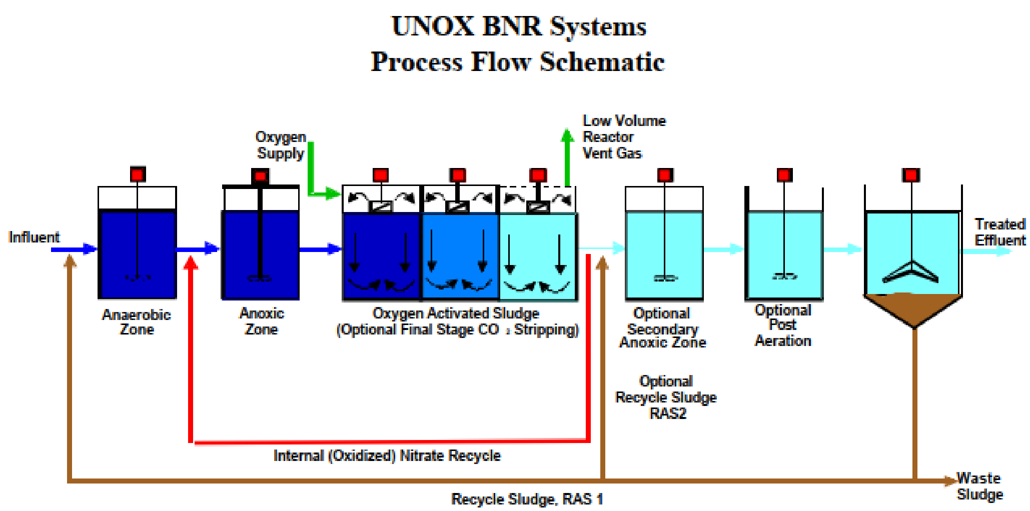
- HPO Activated Sludge (HPOAS) Process commercialized by Union Carbide (UNOX™) in early 1970s
  - Frequently used for larger municipalities (LA, NYC, Philadelphia, Detroit, etc.)
- At least 3 stages in series with HPO fed to the enclosed headspace with mechanical aerators providing mixing/aerating
  - HPO: 92-98% O_2 vs Air: 21% O_2
  - Can achieve >90% O_2 utilization
  - Can operate at ~2x biomass
  - Allows for higher dissolved oxygen concentrations



Morin, A. and Gilligan, T. (WEF 1999)

How do we currently use High Purity Oxygen (HPO) in municipalities?

- Biological Nutrient Removal (BNR) with HPO plants
  - Most designs are ‘high rate’ – removing carbon only
  - Nutrient removal requires additional facilities or treatment steps
    - Separate second stage (using air)
    - Additional zones in single-stage systems
  - Must reduce/control O_2 in recycles
- Innovative technologies such as MABRs provide opportunity to improve using HPO efficiently in nutrient removal



Morin, A. and Gilligan, T. (WEF 1999)

Membrane Aerated Biofilm Reactor (MABR) – What is it?

- Not a Membrane Bioreactor (MBR)!
- Bundles of hollow fiber gas permeable membranes through which air (or oxygen) is passed
- Technology that can be easily installed in existing activated sludge bioreactors to:
  - Improve oxygen transfer efficiency and reduce energy
  - Increase secondary treatment capacity
  - Improve biological treatment performance (e.g. ammonia-N and TN removal)

Courtesy of Oxymem

Courtesy of Suez Water Technologies and Solutions

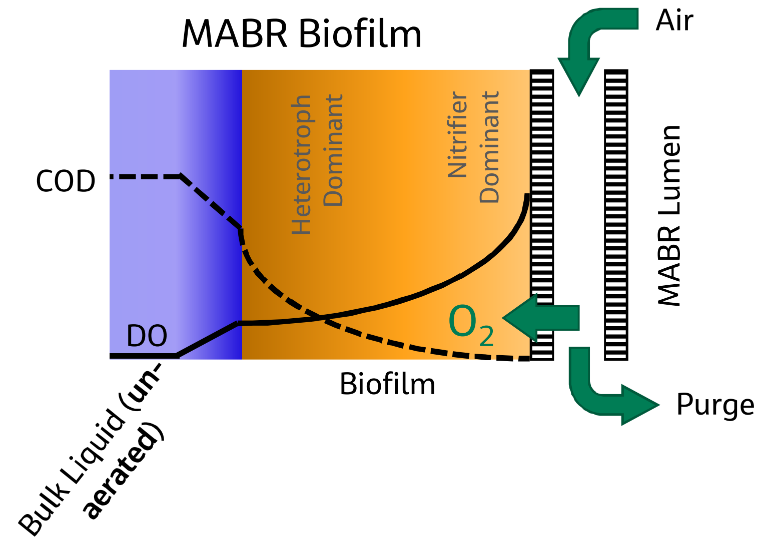
How does MABR reduce aeration energy?

- Let's look at the efficiency of conventional aeration
  - Oxygen transfer efficiency (OTE) only 10 – 15%
  - Most O_2 un-utilized
  - Delivery point is at the bottom of tank (relatively high pressure = high energy)
  - Significant Energy Demands
  - 50-90% of WRFs total energy costs is from aeration!

Typically 50% of energy costs!

MABR: Oxygen transfer into a biofilm

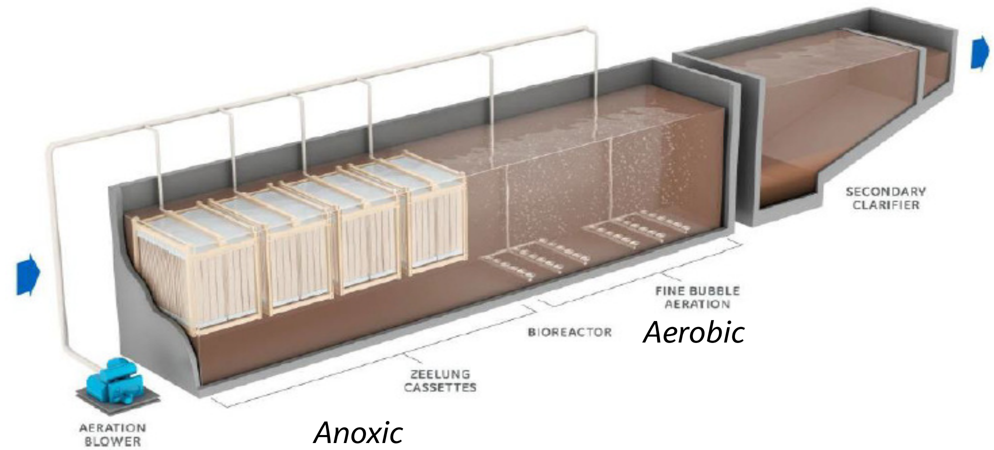
- High specific surface area
- Theoretically up to 100% OTE
- In practice, up to ~40 -50% OTE (needs purge)
- "On demand" O_2 supply
- Low energy consumption
  - Backpressure is low (<8 psi): ***Independent of tank depth***
  - The air never sees "water"
  - High O_2 transfer per unit Energy

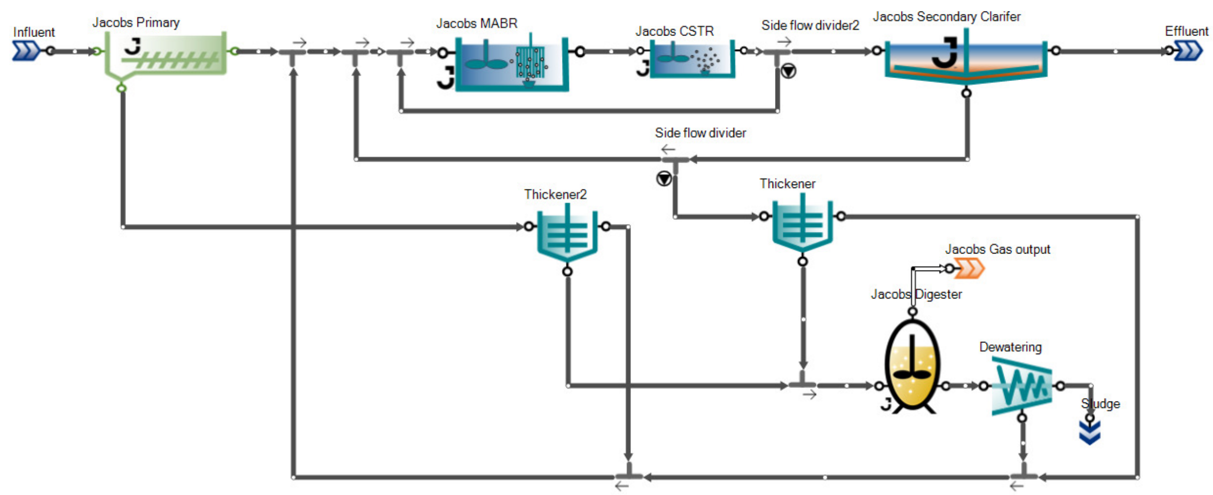


Theoretical Case Study

- Three treatment plants of varying size
  - 40,000 – 1.0M p.e.
- Example WRF
  - Primary Treatment + Activated Sludge
  - Sludge Thickening, Anaerobic Digestion, and Dewatering
  - High strength recycle
- Bioreactor Configuration
  - Conventional vs MABR
  - Nitrogen Removal (MLE)
  - MABR located in Anoxic Zone
  - Fine bubble diffusers in aerobic zone

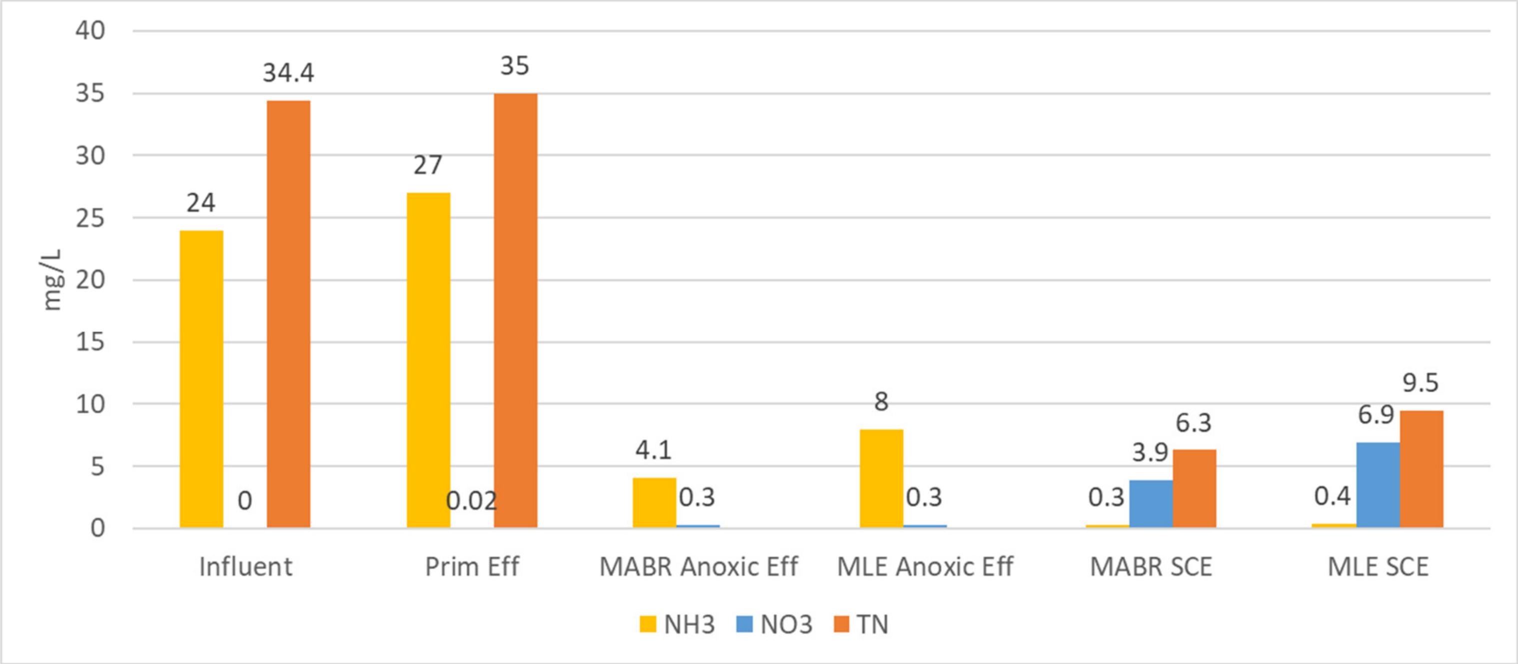
Courtesy of Suez Water Technologies and Solutions



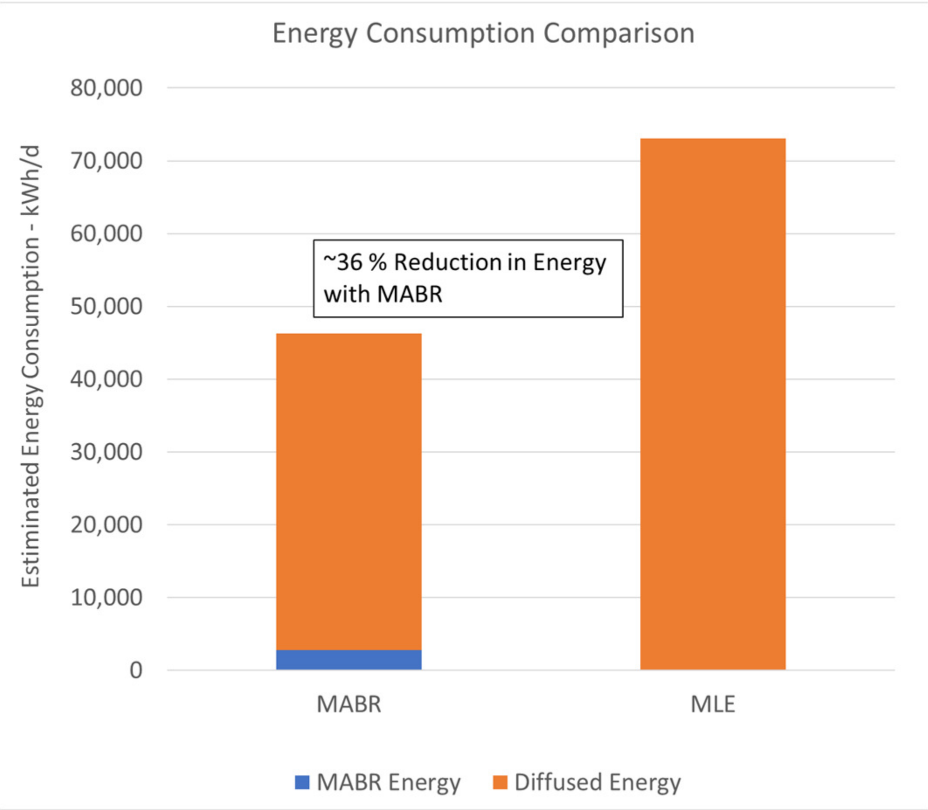


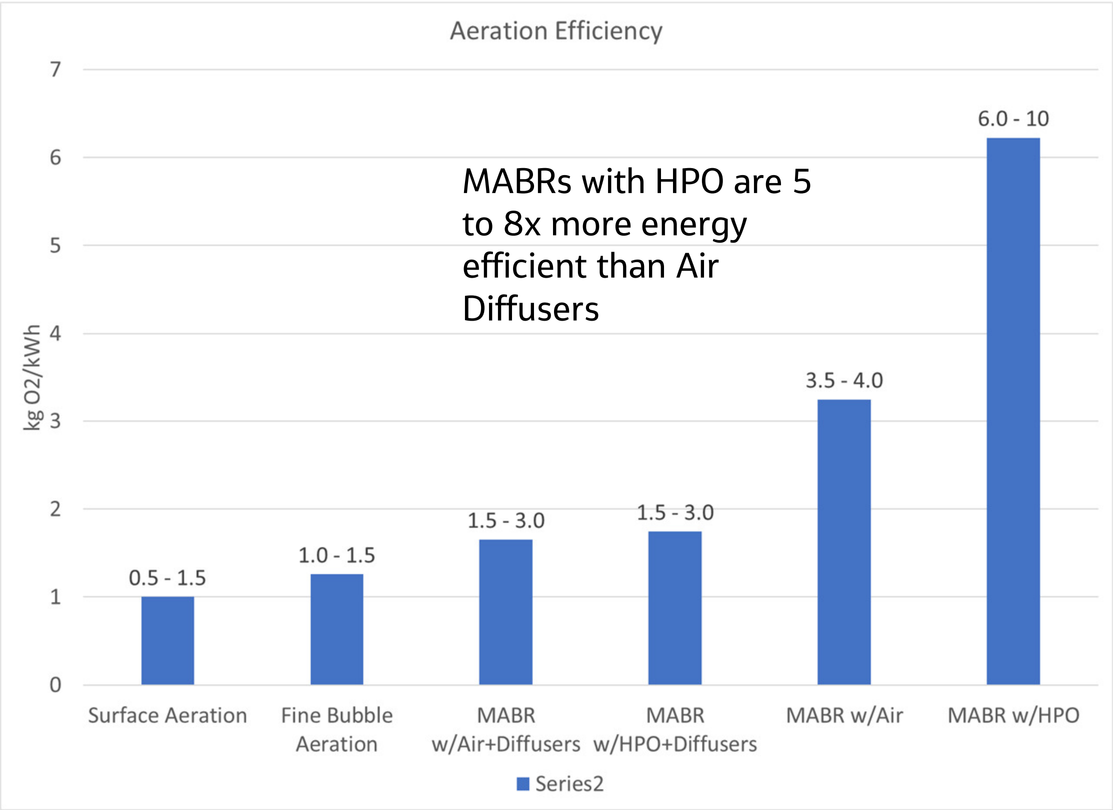
MABR Outperforms Conventional Configuration

- Bioreactor Performance Comparison
  - Similar Nitrate (NO_3-N) removal in the Anoxic Zone and overall Ammonia (NH_3-N) removal in the same bioreactor volumes
  - Anoxic Zone with MABR removes ~2x as much NH_3-N
  - MABR Total Nitrogen (TN) removal is 33% better



MABR Outperforms Conventional Configuration





Summary Thoughts

- Conventional aerobic treatment technologies are energy inefficient
- MABRs with HPO are the next generation of energy optimized treatment
  - Increased nitrogen removal in smaller volumes
  - Significantly lower energy consumption
  - Potential for additional optimizations
- Synergies between ‘Green’ Hydrogen production plants and WRFs using O_2 byproduct justify colocation

Courtesy of European Commission

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Renewable Energy's Role in Hydrogen Production

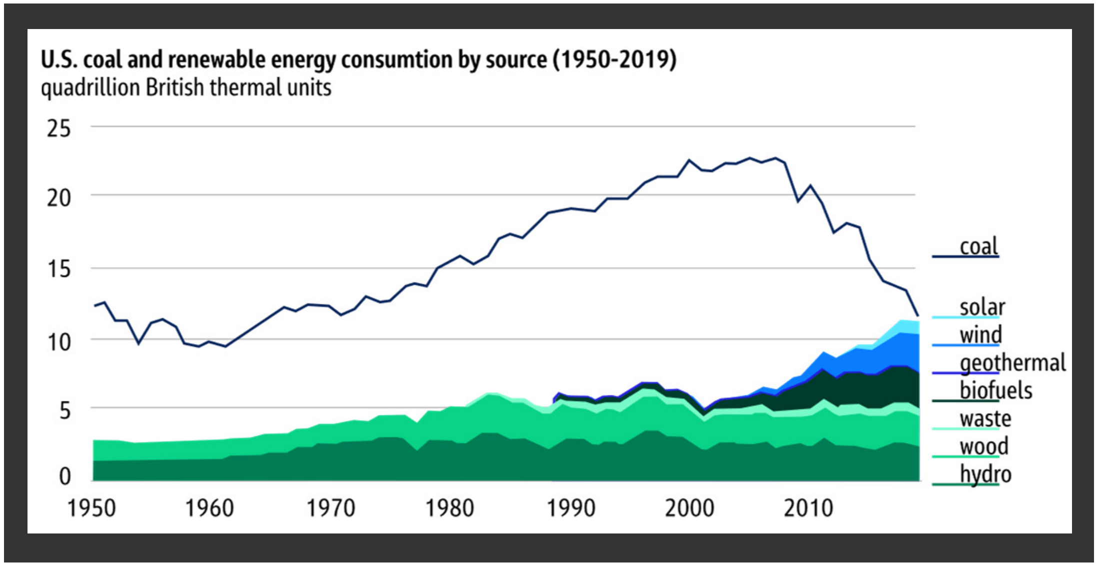
Sarah Dorminy
Jacobs Systems Engineer

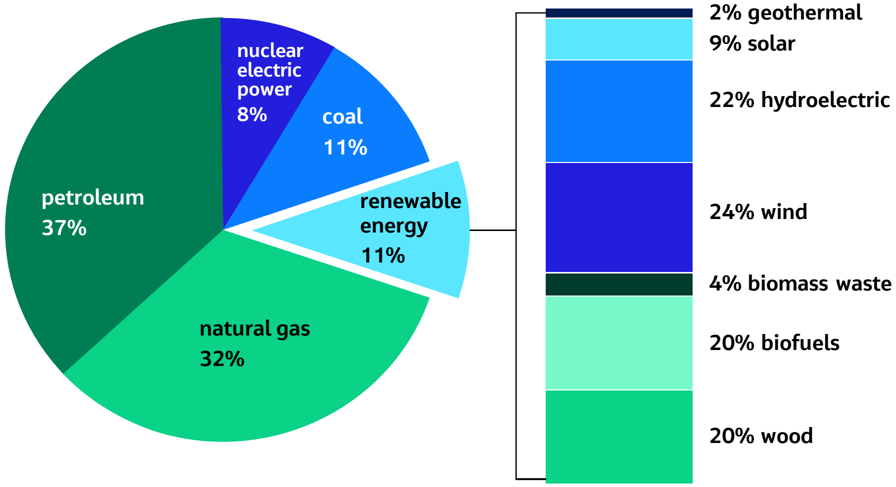
What is green hydrogen?

- Hydrogen is not a renewable energy source, but an energy storage solution
- Electrolysis/steam reformation requires significant energy input and has inefficiencies
- Virtually any primary energy source can be turned into hydrogen
  - Brown hydrogen
  - Blue hydrogen
  - Green hydrogen

2020: the Renewable Energy Decade

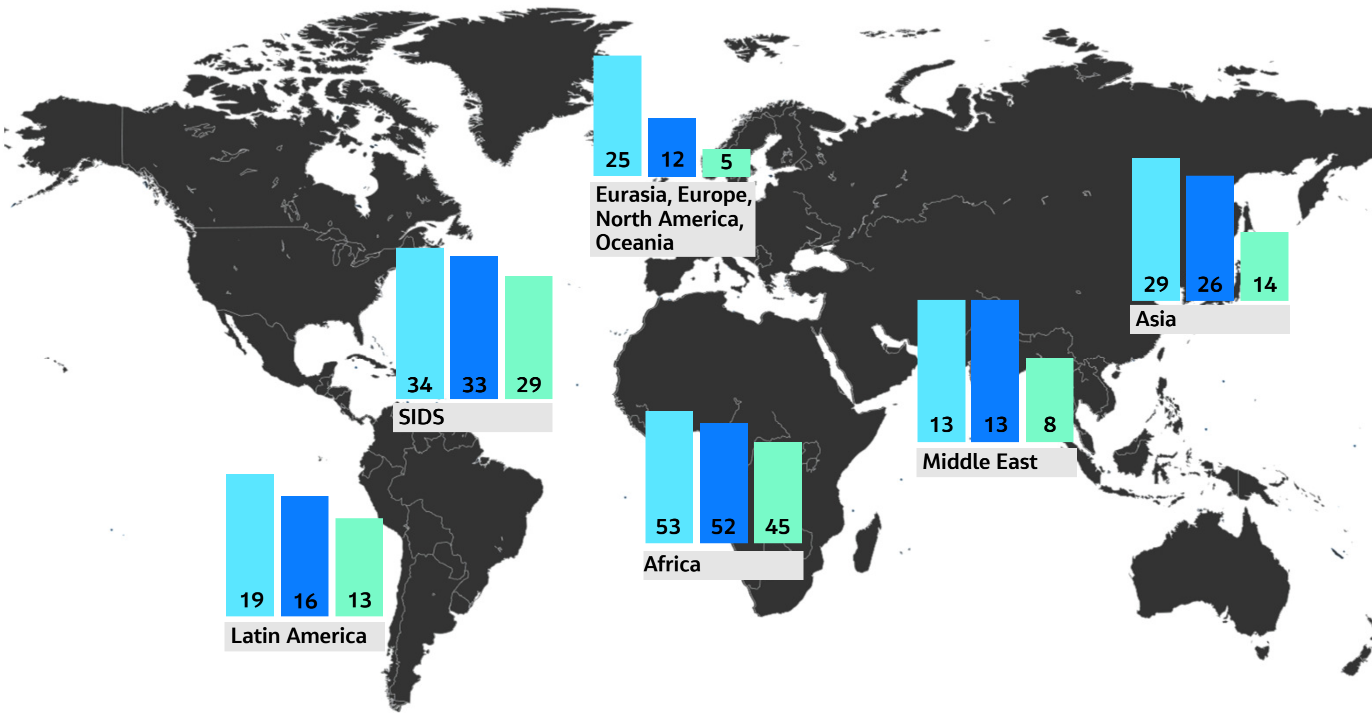
In April 2020, renewable energy surpassed coal consumption in the United States, for the first time.





Global Renewable Energy Targets

Number of countries with renewable energy policies tripled from 2004 to 2020



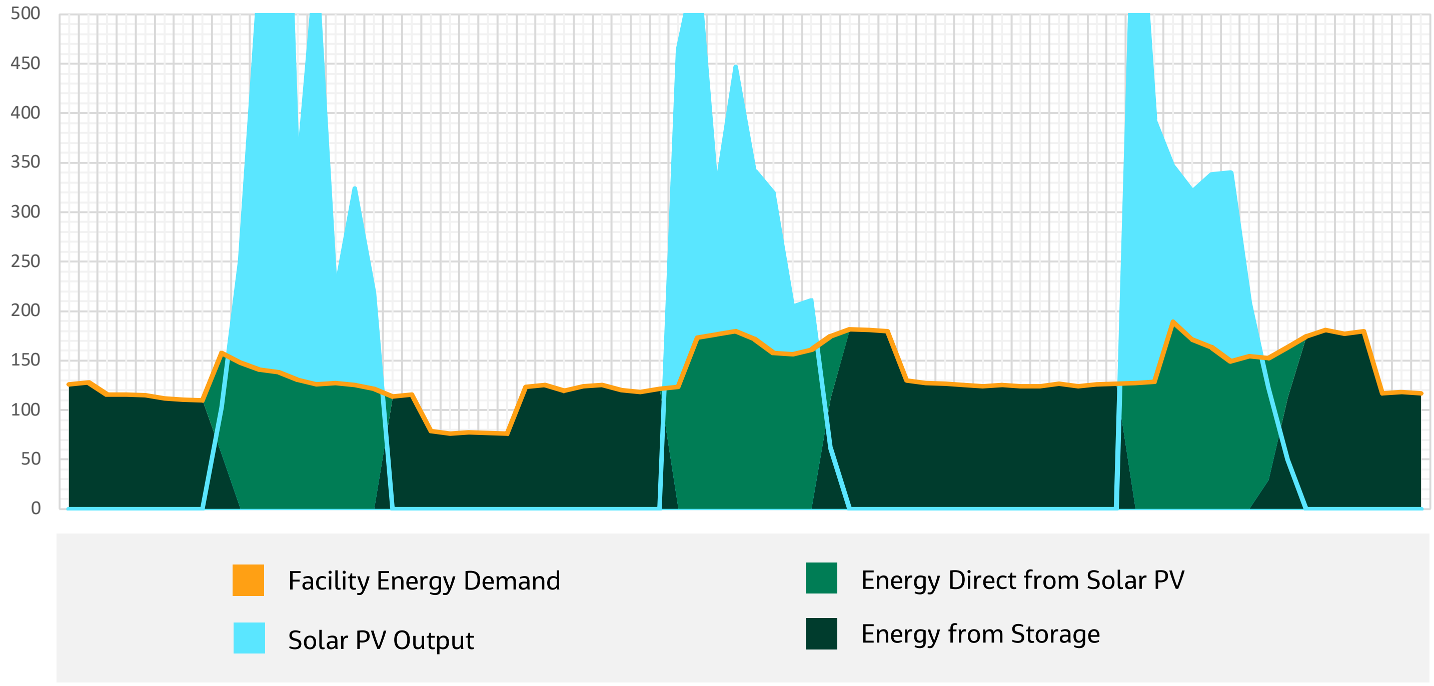
- 192 countries have submitted NDCs under the Paris Agreement, making up 96% of global greenhouse gas emissions.
- Renewable energy generation and energy storage address key energy action plan objectives:
  - Energy security
  - Environmental stewardship
  - Economic competitiveness

Countries with NDCs

Countries mentioning renewables in their NDCs

Countries with quantified renewable energy target in their NDCs

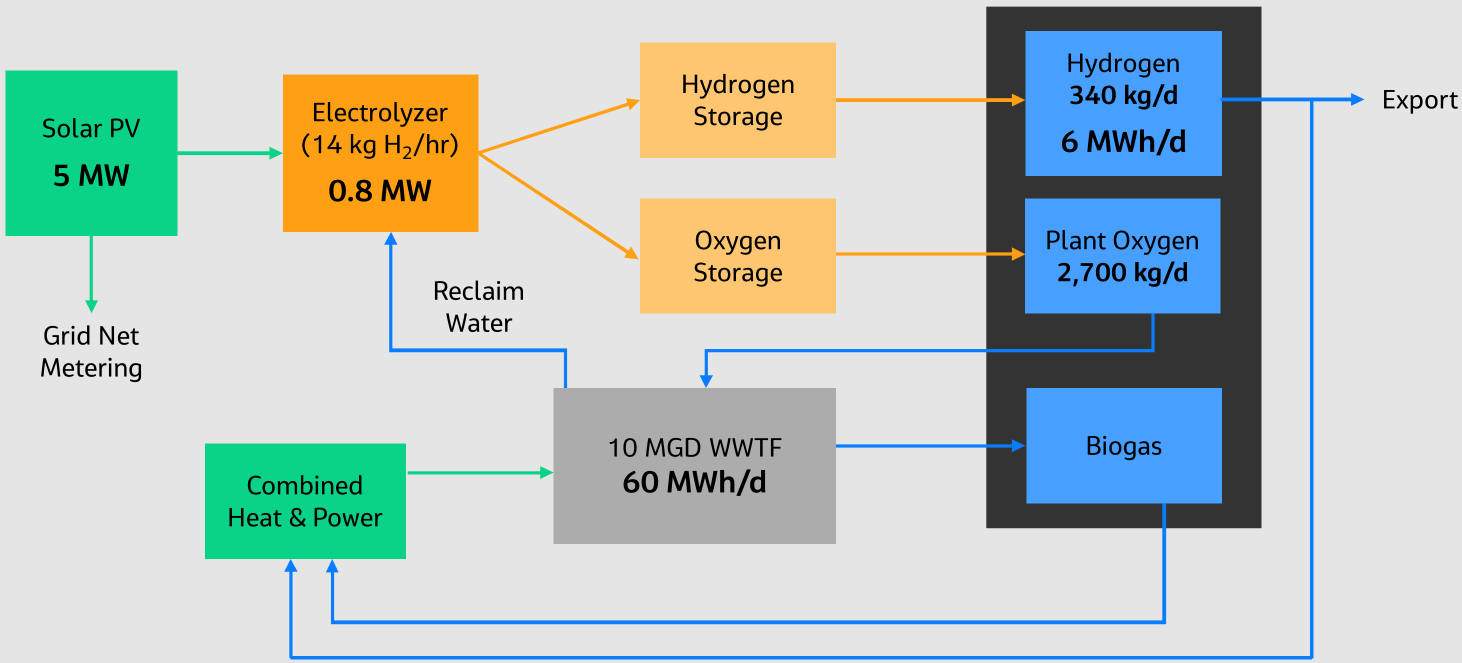
Pairing Renewable Energy with Energy Storage



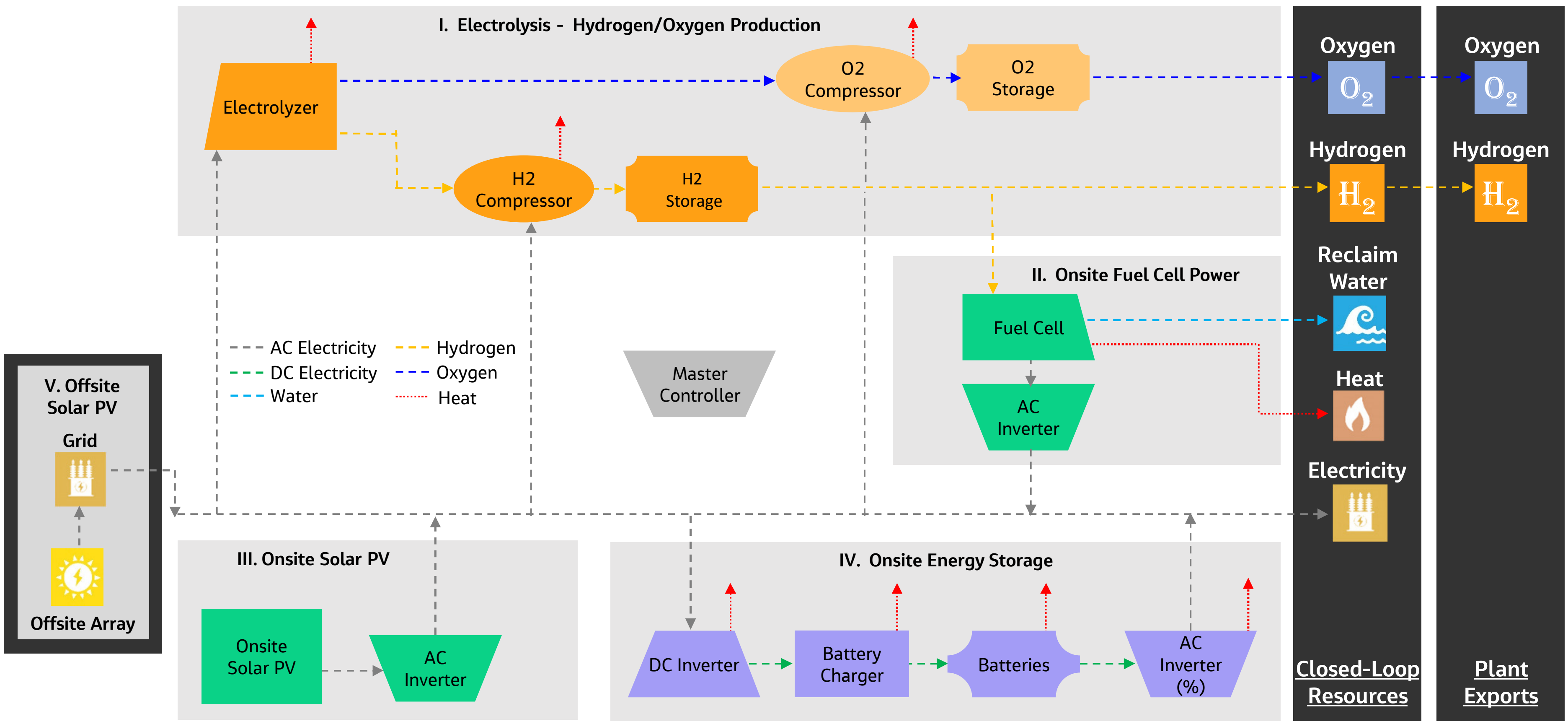
Storing energy during periods of oversupply:

- mitigates curtailment of renewable energy at the facility and/or grid scale
- balances demand response to reduce overburdening of grid infrastructure
- allows for shifting of grid energy consumption away from peak power rate periods

Facility Energy and Mass Balance



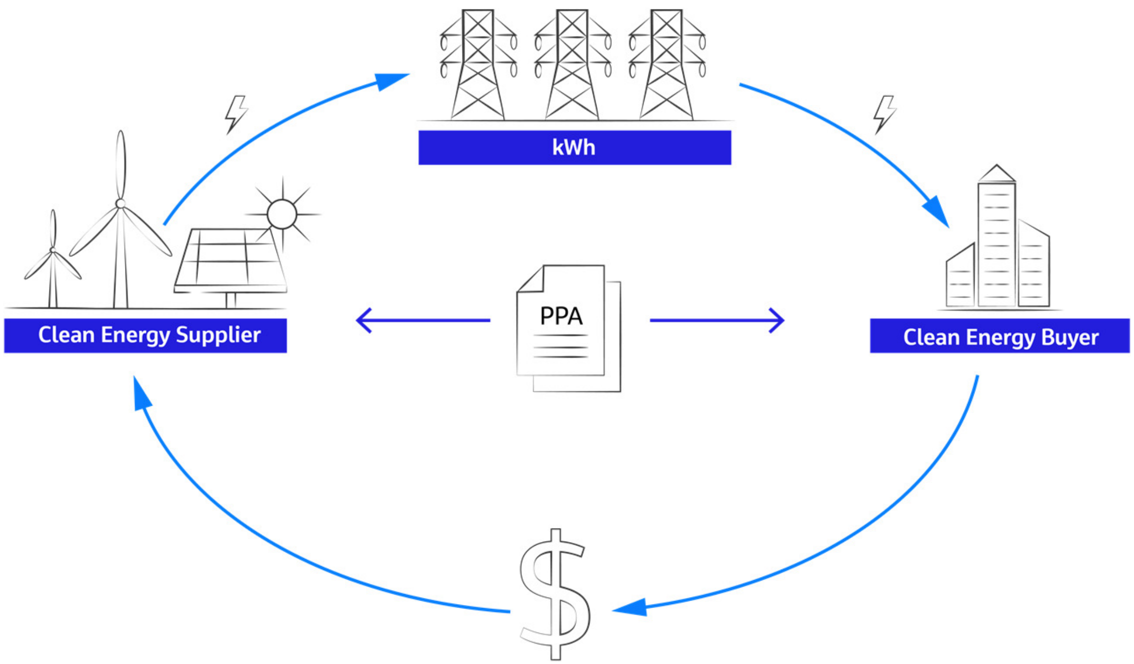
Facility Dynamic Energy Modeling



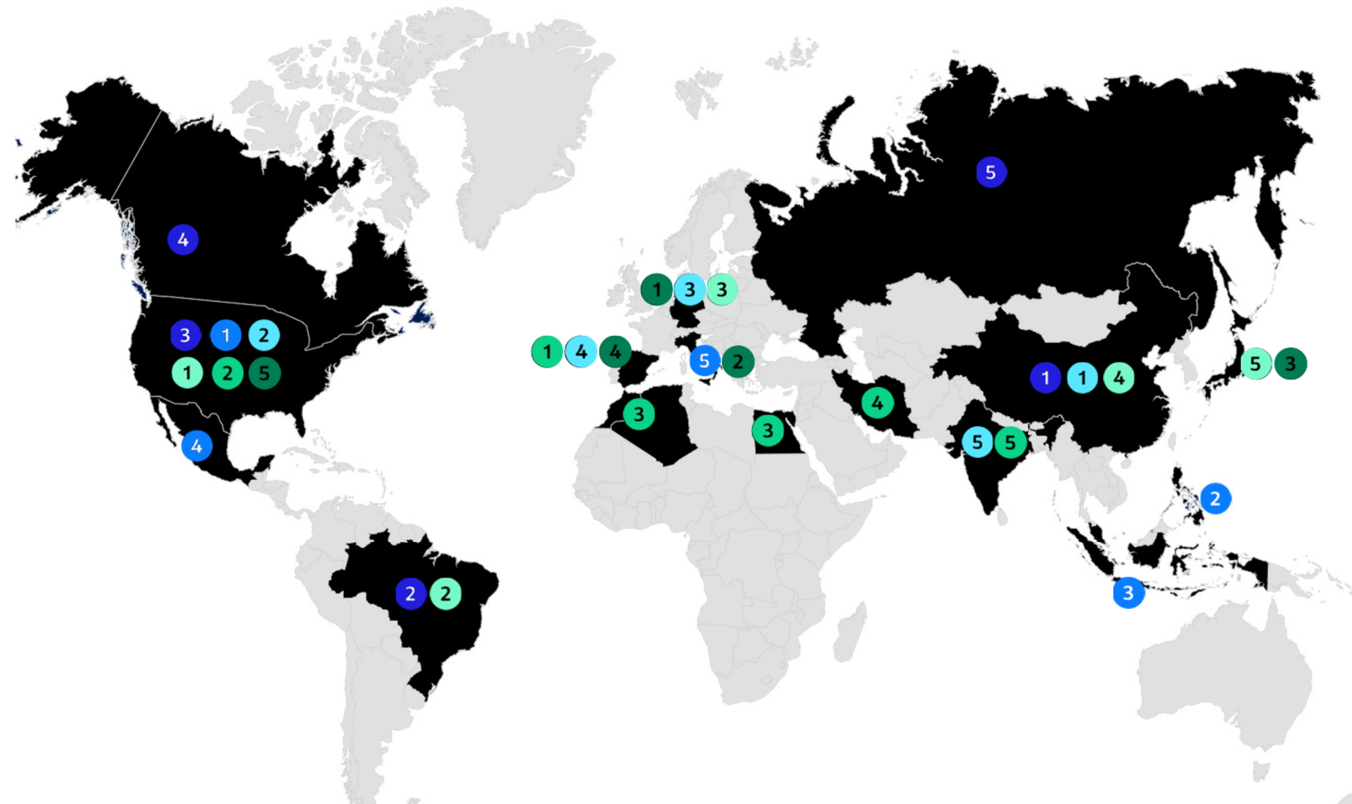
Renewable Energy Pathways

1. Onsite Solar PV

2. Offsite Power Purchase Agreement



Solutions are Location-Specific



Top Countries with Installed Renewable Electricity by Technology (2011)

Hydro
1. China
2. Brazil
3. United States
4. Canada
5. Russian Federation

Geothermal
1. United States
2. Philippines
3. Indonesia
4. Mexico
5. Italy

Wind
1. China
2. United States
3. Germany
4. Spain
5. India

Solar PV
1. Germany
2. Italy
3. Japan
4. Spain
5. United States

STEG
1. Spain
2. United States
3. Algeria/Egypt/Morocco
4. Iran
5. India

Biomass
1. United States
2. Brazil
3. Germany
4. China
5. Japan

Key Message

- Hydrogen is not green, unless its energy source is green.
- Renewable energy generation addresses global climate, resiliency, and sustainability issues. Pairing it with energy storage mitigates curtailment/waste of green energy potential.
- Facility energy modeling can build a solution around optimizing cost and resource efficiency.
- Solutions are location-dependent, but most facilities will require a mix of onsite and offsite renewable energy supply.

Thank you!

Questions & Answers

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